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Biological Services Program

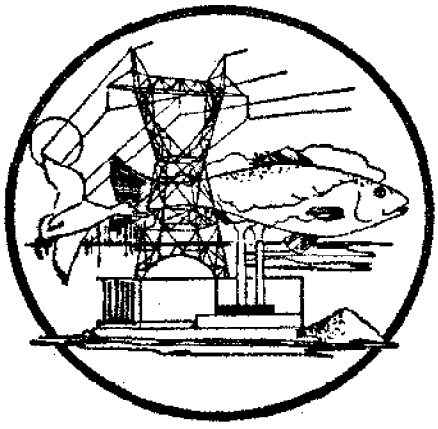
DEVELOPMENT OF FISHES OF THE MID-ATLANTIC BIGHT

AN ATLAS OF EGG, LARVAL AND JUVENILE STAGES

VOLUME

V

CHAETODONTIDAE THROUGH OPHIDIIDAE



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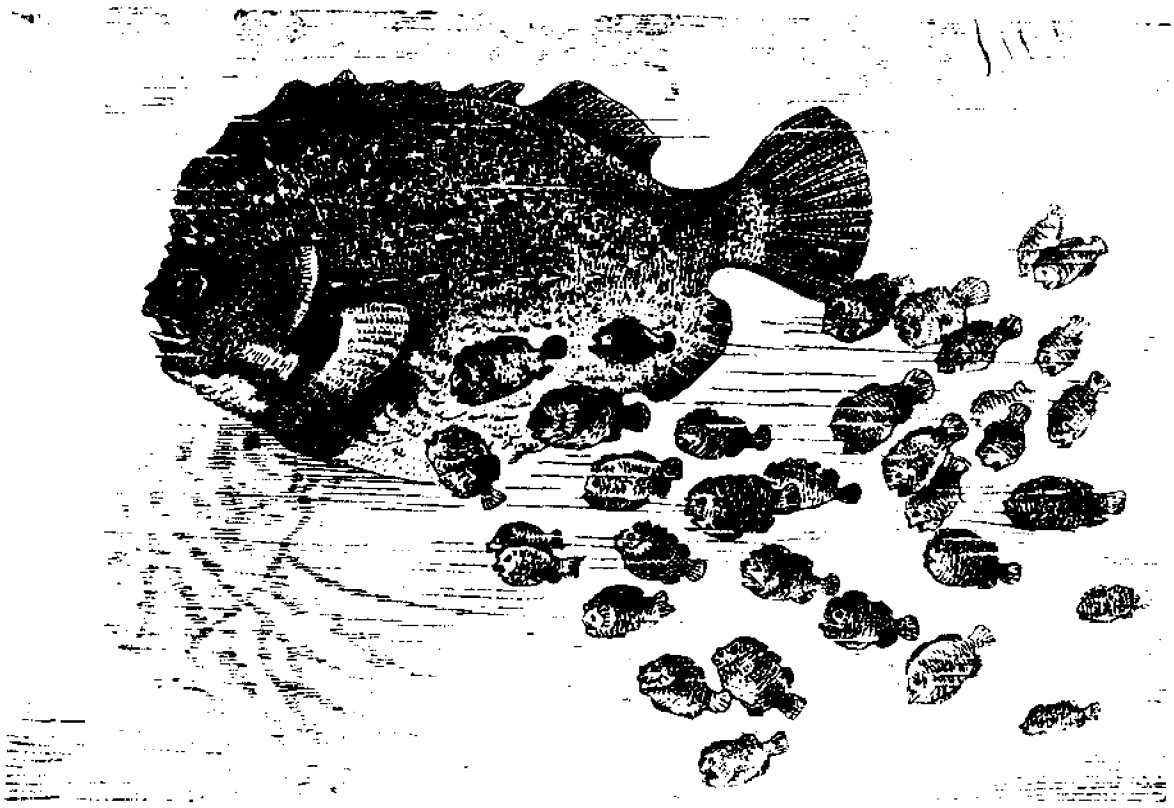

Frontispiece: Adult *Cyclopterus lumpus* L. herding its young (*Tretiakov, D. K., 1949, Ryby i kruglorotye. Akademia Nauk SSR, Moscow, 416 pp.*). In reality, this is a highly improbable situation.

Biological Services Program

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January 1978

DEVELOPMENT OF FISHES OF THE MID-ATLANTIC BIGHT

AN ATLAS OF EGG, LARVAL AND JUVENILE STAGES

VOLUME V

CHAETODONTIDAE THROUGH OPHIDIIDAE

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

Fish and Wildlife Service

U.S. Department of the Interior

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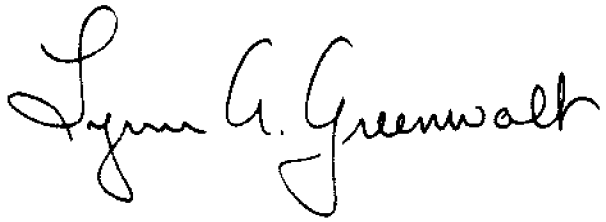
FOREWORD

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.



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.

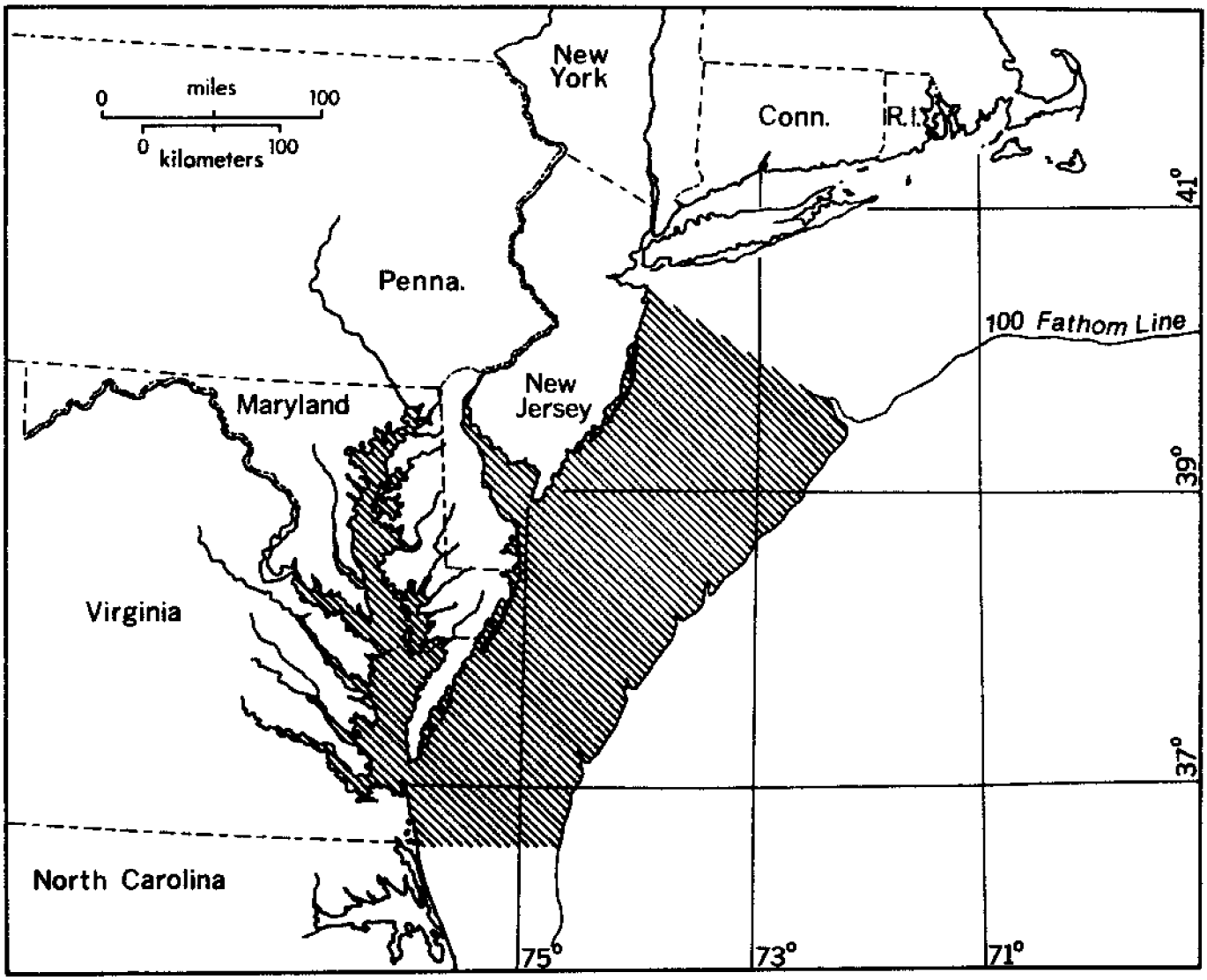

Fig. 1. Map of the Chesapeake Bay and adjacent Mid-Atlantic Bight. Hatching indicates the area considered in this series.

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.

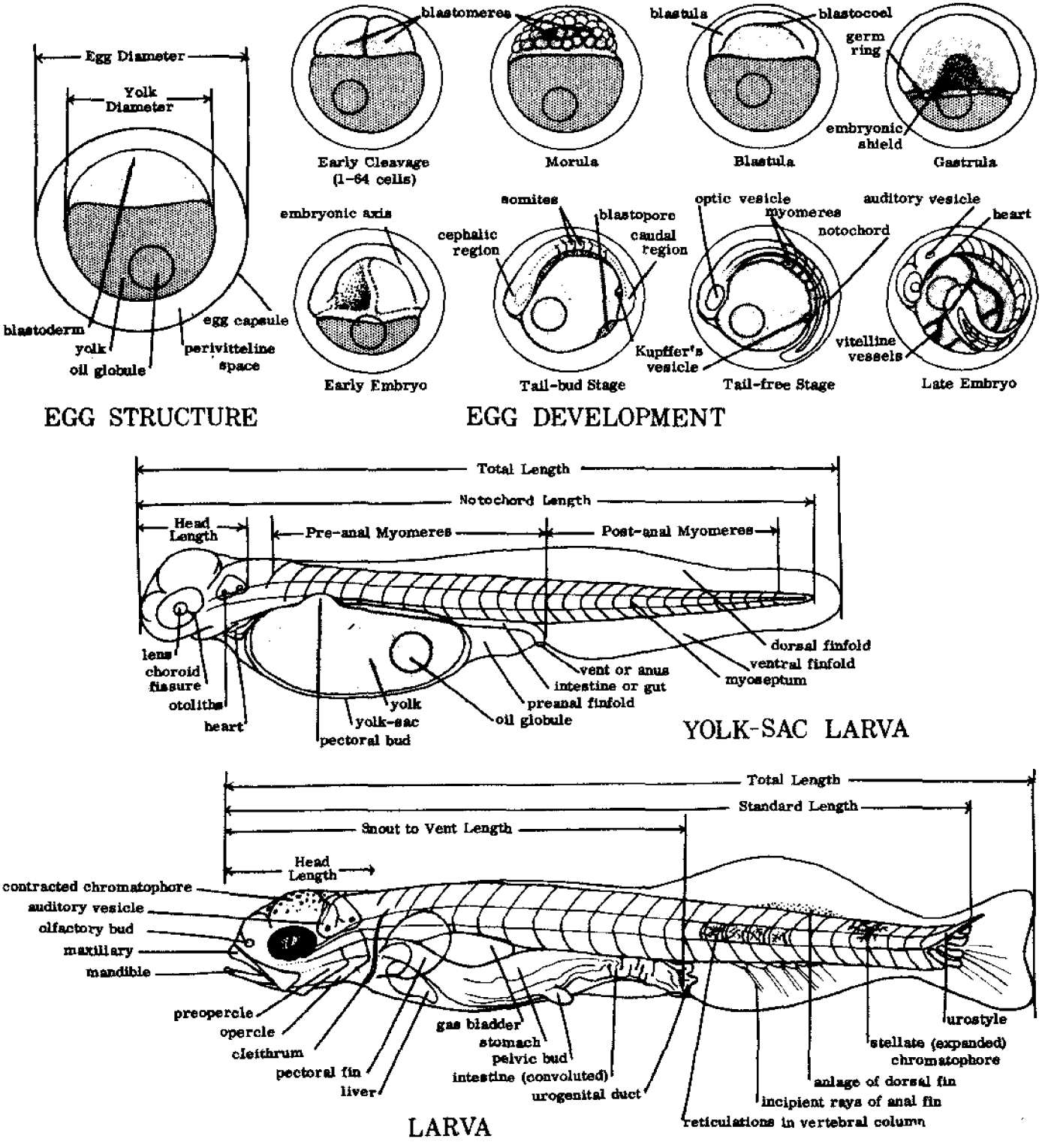

Fig. 2. Diagrammatic representation of morphology and development of egg and larval stages of a typical teleost.

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 V DEDICATION

This volume is dedicated to my wife, Edith, and my son, Karl, for their support and comfort during the period of my involvement with this project.

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INTRODUCTION TO VOLUME V

This fifth volume of the *Development of Fishes of the Mid-Atlantic Bight* includes accounts on fifty-two teleostean fishes (families Chaetodontidae–Ophidiidae). Although the original design called for accounts for every species reported as occurring in the area of coverage, this has not been possible. The following species were brought to my attention too late for inclusion in this volume: *Chaetodon striatus* Linnaeus, *Chaetodon capistratus* Linnaeus, *Pomacanthus arcuatus* (Linnaeus), *Nicholsina usta* (Valenciennes), *Eupomacentrus leucostictus* (Müller and Troschel), *Ruvettus pretiosus* Cocco, *Dormitator maculatus* (Bloch), *Lumpenus lumpetraeformis* (Walbaum), *Pholis gunnellus* (Linnaeus), *Anarhichas lupus* Linnaeus, *Cryptacanthodes maculatus* Storer, *Sebastes marinus* (Linnaeus), *Pontinus rathbuni* Goode and Bean, *Scorpaena brasiliensis* Cuvier, *Helicolenus dactylopterus* (De la Roche), *Neomerinthe hemingwayi* Fowler, *Trachyscorpia cristulata* (Goode and Bean), and *Aspidophoroides monopterygius* (Bloch). There are undoubtedly more species to be included and these gaps may be filled in future editions.

Original unpublished contributions are indicated by the initials of the contributor as follows:

EBB Edward B. Brothers, Cornell University, Ithaca, New York.
DJF Daniel J. Faber, National Museum of Natural History, Ottawa, Canada.
RAF Ronald A. Fritzsche, Chesapeake Biological Laboratory, Solomons, Maryland.
AWK Arthur W. Kendall, Jr., Northeast Fisheries Center, Highlands, New Jersey.
FDM F. Douglas Martin, Chesapeake Biological Laboratory, Solomons, Maryland.
WJR William J. Richards, Southeast Fisheries Center, Miami, Florida.
VGS Victor G. Springer, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

I would like to thank the following persons for reviewing manuscripts:

G. David Johnson, of the Chesapeake Biological Laboratory, for reviewing the Chaetodontidae and Cephalacanthidae; Douglas Diener, of Marine Ecological Consultants, for reviewing the Scaridae and Labridae; F. Douglas Martin, of the Chesapeake Biological Laboratory, for reviewing the Pomacentridae; William J. Richards, of the National Marine Fisheries Service, for reviewing the Scombridae, Istiophoridae, Xiphiidae, and Triglidae; John E. Fitch, of the California Department of Fish and Game, for reviewing the Trichiuridae; Edward B. Brothers, of Cornell University, for reviewing the Gobiidae; Daniel J. Faber, of the National Museum of Natural History, Canada, for reviewing the Cottidae; Kenneth W. Able, of McGill University, for reviewing the Cyclopteridae; Arthur W. Kendall, of the National Marine Fisheries Service, for reviewing the Ammodytidae; Frederick H. Berry, of the National Marine Fisheries Service, for reviewing the Uranoscopidae; Victor G. Springer, of the National Museum of Natural History, for reviewing the Blenniidae; Hugh DeWitt, of the University of Maine, for reviewing the Zoarcidae; and Robert N. Lea, of the California Department of Fish and Game, for reviewing the Ophidiidae. I also wish to thank those who gave permission to use their unpublished and/or copyrighted figures. The personnel associated with this project all provided much help and encouragement. Jerry D. Hardy, Jr. obtained the grant and provided the impetus for the work. George Drewry and F. Douglas Martin provided photographic support as well as much useful information. G. David Johnson gave willingly of his time and knowledge of fish morphology. Cindy Simmonds and L. Diane Haft typed the

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Chaetodon ocellatus

butterflyfishes
Chaetodontidae

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FAMILY CHAETODONTIDAE

The butterflyfishes are a circumtropical group of brightly colored reef fishes that are usually small, compressed, and oval-shaped. There are perhaps 150 species in the family, with only one species included here. Although members of this family may be locally abundant, the eggs and larvae of most species have not been described. However, the eggs are known to be pelagic.

The most outstanding feature of the life history of chaetodontids is their peculiar prejuvenile—the so-called *Tholichthys*. Jordan (1905: fig. 106) has figured the *Tholichthys*-stage for the western Atlantic *Chaetodon sedentarius* (Poey). *Chaetodon ocellatus*, the only member of the family included in this account, has had its *Tholichthys*-stage figured by Fowler (1945: fig. 288), however, the *Tholichthys*-stage of this species has no written description.

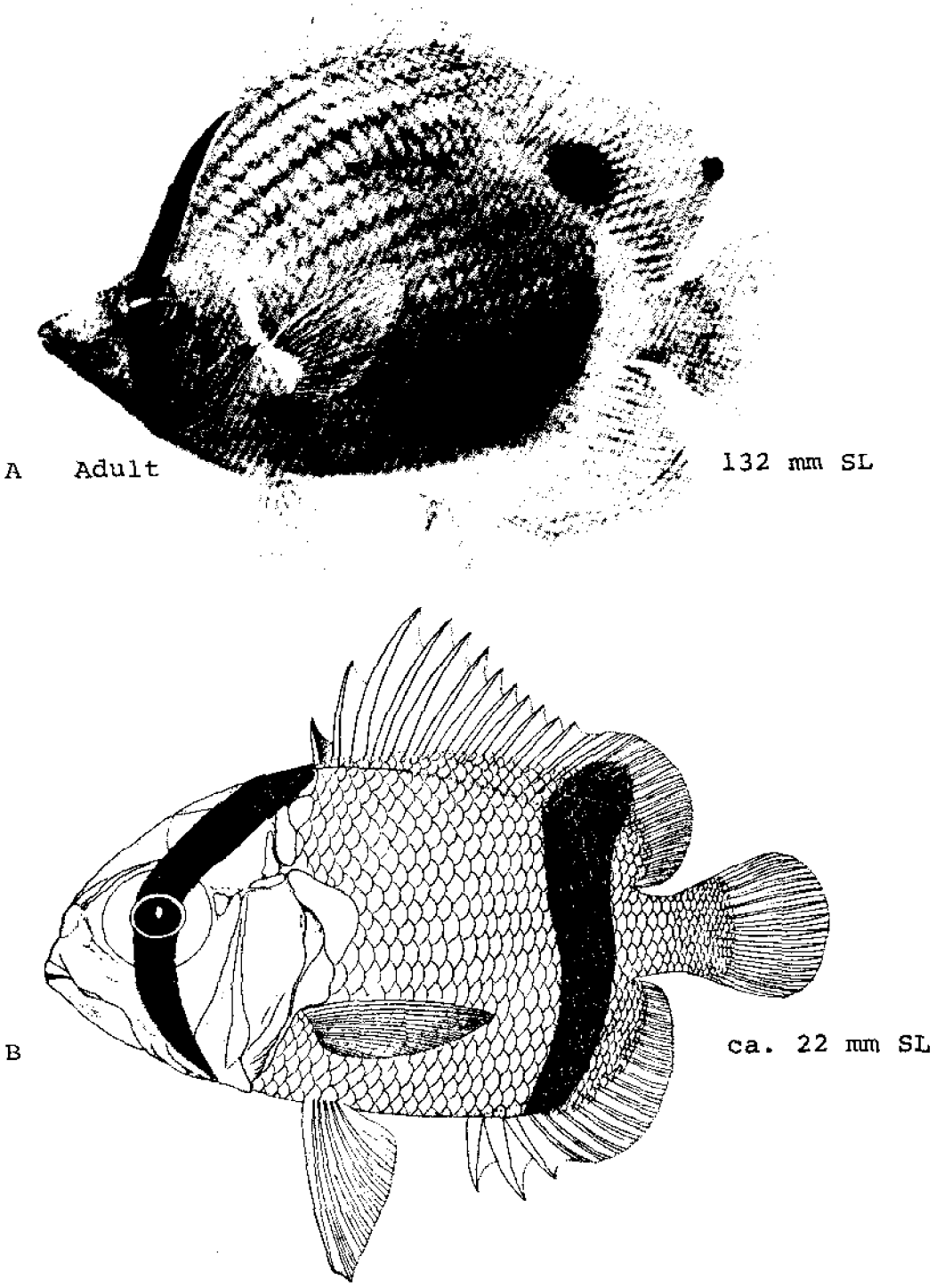

Fig. 3. *Chaetodon ocellatus*, Spotfin butterflyfish. A. Adult, 132 mm SL. B. *"Tholichthys"* prejuvenile, ca. 22 mm SL. (*A, Böhlke, J. E., and C. C. G. Chaplin, 1968: 421. © Academy of Natural Sciences of Philadelphia. Used with permission of authors and publisher. B, Fowler, H. W., 1945: fig. 288.*)

Chaetodon ocellatus Bloch, Spotfin butterflyfish

ADULTS

D. XII [3,6] to XIII,[6] 19–21; [8] A. III,[3,6] 16–18; [8,9] C. 3+9+8+3; [10] P. 16 (RAF) V. I, 5; scales 33 [8]–34; [6,8] vertebrae 10+14=24; [10] 12 gill rakers on lower limb of first arch (RAF); teeth in jaws fine, flexible, in band,[9] absent from vomer and palatines.[11]

Body proportions as times into SL or HL: head 2.55 [3]–3.0 in SL,[6] depth 1.25–1.6 [8] in SL; snout 2.95 in HL, orbit 2.3 in HL, interorbit 2.9 in HL, pectoral 1.3 in HL.[3]

Body very deep, strongly compressed,[3] anterior profile concave; [3,6] snout pointed,[8] produced; [6] mouth small, terminal. Scales ctenoid, large on sides, smaller on head and caudal peduncle.[3] Lateral line high, ending under posterior part of dorsal fin.[5,4,6] Dorsal fin scaled, spines strong,[3] soft part angulated behind; [8] anal fin scaled, soft portion similar in shape to dorsal; caudal fin nearly straight; pectoral fins broad based; pelvic fins under base of pectorals.[6]

Pigmentation: Body white; [8] median fins, pelvic fins and caudal peduncle bright yellow; [7,8] a black bar on head through eye margined with yellow; [7] large blackish spot basally on soft dorsal fin [8] and a smaller black mark distally; [7,8] narrow yellow bar from gill opening to pectoral fin base.[8]

Maximum length: To about 190 mm.[7,8]

DISTRIBUTION AND ECOLOGY

Range: Massachusetts to Brazil [8] including the Gulf of Mexico [7] and Bermuda,[9] common in the West Indies.[4,6]

Area distribution: Mobjack Bay [1] and Cape Charles, Va.; [3] Delaware River; [5] Beesleys Point, N.J.[2]

Habitat and movements: Adults—common among coral and rocky reefs in Puerto Rico (FDM).

Larvae—no information.

Juveniles—most common in *Thalassia* beds in Puerto Rico (FDM).

SPAWNING

No information.

EGGS

No information.

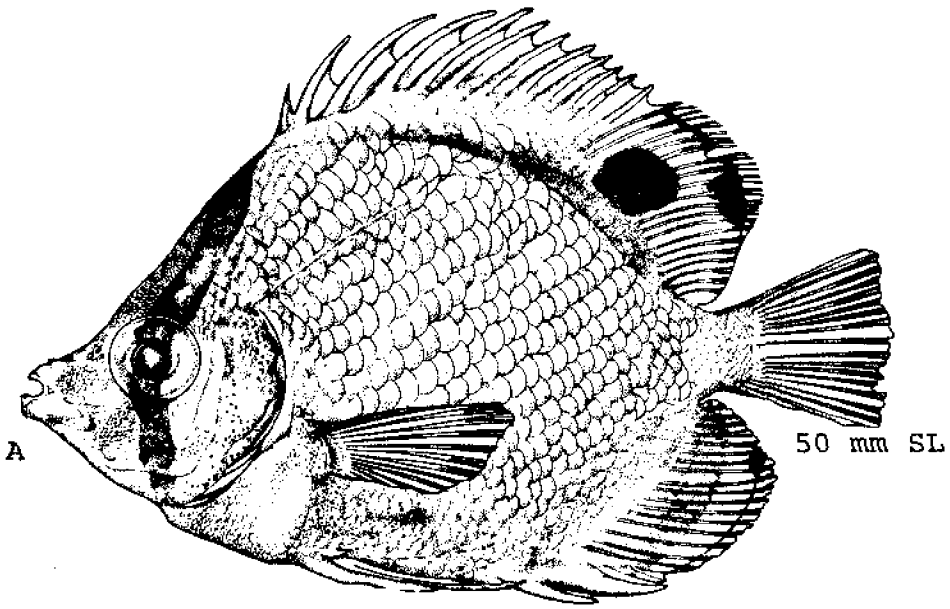

Fig. 4. ***Chaetodon ocellatus*, Spotfin butterflyfish.** A. Juvenile, 50 mm SL. *(A, Original drawing Elizabeth Ray Peters.)*

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

PREJUVENILES (*THOLICHTHYS* STAGE)

No information.

JUVENILES

To at least 27 mm SL.[7]

Pigmentation: Color grayish to yellowish; a jet black bar about two-thirds width of eye, extending from dorsal fin origin through eye to lower margin of preopercle; a second indefinite bar running from middle of anal to middle of soft dorsal; fins all more or less orange; middle part of soft dorsal with large black blotch.[8]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Abudefduf saxatilis

damselfishes
Pomacentridae

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FAMILY POMACENTRIDAE

The Pomacentridae, or damselfishes, are a group of small, often brightly colored fishes, inhabiting inshore habitats throughout the world's tropical and subtropical seas.

The damselfishes are characterized by having a split lateral line, a single nostril on each side of the head, two anal fin spines, a continuous dorsal fin, and a pelvic axillary process.

Typically, damselfish lay elliptical eggs in nests that are prepared and guarded by the male. These eggs are generally attached to the substrate by adhesive threads. The larvae are generally deep-bodied with a short gut at smaller sizes.

Abudefduf saxatilis (Linnaeus), Sergeant major

ADULTS

D. XIII,[4,9,10] 11[9]–13[4,9,10] (usually 12[9]–13[4]); A. II,[4,9,10] 10[4]–13[3] (rarely 10[4] or 11[9]); C. 6+8+7+5–6;[10] P. 16–20[15] (usually 19[4,9]); V. I, 5;[9] lateral line scales 21–23+7–10;[12] vertebrae 11+15=26; gill rakers long and slender,[9] 7–10+17–18=24–28;[12] teeth in one row in jaws, close-set, rigid and incisiform, with prominent notch at tip;[4] branchiostegals 5–6; pyloric caeca 3.[5]

Depth 1.6[4]–2,[13] head 2.8[9]–3.3 in SL. Snout 3.25–3.75, eye 3–3.3, maxillary 2.8–3.5, interorbital 2.75–3,[13] pectoral 0.9 in head.

Body deep, compressed;[5] mouth terminal, oblique;[4] maxillary extends little behind nostril;[13] scales large, ctenoid;[5] third and fourth dorsal spines longest, about equal in length to twelfth dorsal spine; soft dorsal and anal fins pointed; caudal fin lobes angular; first pelvic fin ray filamentous;[9,16] lower margin of suborbital free; preorbital not deep;[4] interorbital slightly convex.[9]

Pigmentation: Bluish white, upper part of body yellow, with five blackish bars on body (fifth bar at front of caudal peduncle), narrower than interspaces and nearly uniform in width; faint sixth bar may be present posteriorly on caudal peduncle;[4] all bars may be indistinct in some dark individuals;[16] black spot at upper base of pectoral fin.[4] Either light or dark color phase depending on surroundings, light phase over pale sandy bottoms or when swimming high above reef and in dark phase when down among crevices in reef. In light phase, lower two-thirds of body and entire head gray, often with greenish tinge; upper third of body yellow; soft dorsal, caudal and anal fins dusky. In dark phase, body dark gray or bluish, bars black.[3]

Maximum size: To 229 mm.[8]

DISTRIBUTION AND ECOLOGY

Range: Circumtropical;[3,4] in western Atlantic from Rhode Island[4] and Bermuda[3] to Uruguay,[3,4] including Gulf of Mexico.[3]

Area distribution: Recorded from Brigantine, New Jersey and Chincoteague Bay, Virginia.[2]

Habitat and movements: Adults—encountered everywhere, tide pools, grass beds, coral heads, rocks; sandy bottoms, and around wharves and pilings,[8,15] uncommon on grass beds or open sandy areas unless pilings, rocks or isolated coral heads available (FDM); aggregate when not breeding. In early daylight widely scattered groups extend from bottom to surface while actively feeding; during remainder of daylight, become less active, more cryptic and form close aggregations close to bottom. Found down to 8 m depth, most abundant from 1–3 m.

Larvae—pelagic.[15]

Juveniles—in small dense schools, in vicinity of adults but in much shallower water,[15] more common in tide pools than adults (FDM); sometimes found adrift in small patches of *Sargassum*, up to 37 km from shore.[15] Collected in New Jersey at 29 ppt and 19–26 C.[1]

SPAWNING

Location: In nests prepared and guarded by male; prepared on rocks, shipwrecks, pilings, reef outcroppings, retaining walls, and a variety of bottom debris.[15]

Season: From April–August at Eilat, Red Sea;[6] June–August at Bimini, Bahamas;[7] April–November (max. in April and September) in Jamaica.[14]

Temperatures: Between 18.5 and 30.5 C at Bimini.[15]

Fecundity: Females of 112 mm produce 18,051–21,109 eggs.[15]

EGGS

Unfertilized eggs: Deep red, pink, or salmon colored; ovoid, 0.5–0.94 mm (mode 0.57 mm) diameter.[15]

Fertilized eggs: Elliptical;[7,15] red, salmon, pink, or orange becoming iridescent green at 96 hours due to presence of retinal pigment; 0.80–0.96 mm ($\bar{x}$=0.89 mm, n=500) diameter;[15] adhesive filament attaches egg to substrate;[3,15] yolk deep red to amethyst; oil droplet large surrounded by smaller ones at vegetal pole; perivitelline space 1.2 mm.[7]

EGG DEVELOPMENT

Fertilized egg, 60 minutes—the high blastodisc can be seen at the proximal end of the egg.

Two-celled egg, 75–80 minutes—first sign of cleavage in this (and subsequent cleavages) occurs when the blastodisc exhibits irregularity. The blastodisc divides into two blastomeres.

Four-celled egg, 105 minutes—second cleavage furrow at right angles to the first, forming four blastomeres.

Eight-celled egg, 130 minutes—third cleavage furrow, double and parallel to the first, divides the four blastomeres into a plate of eight cells.

Sixteen-celled egg, 155 minutes—fourth cleavage furrow, double and parallel to the second, results in the formation of a plate of sixteen cells, four rows containing four cells each.

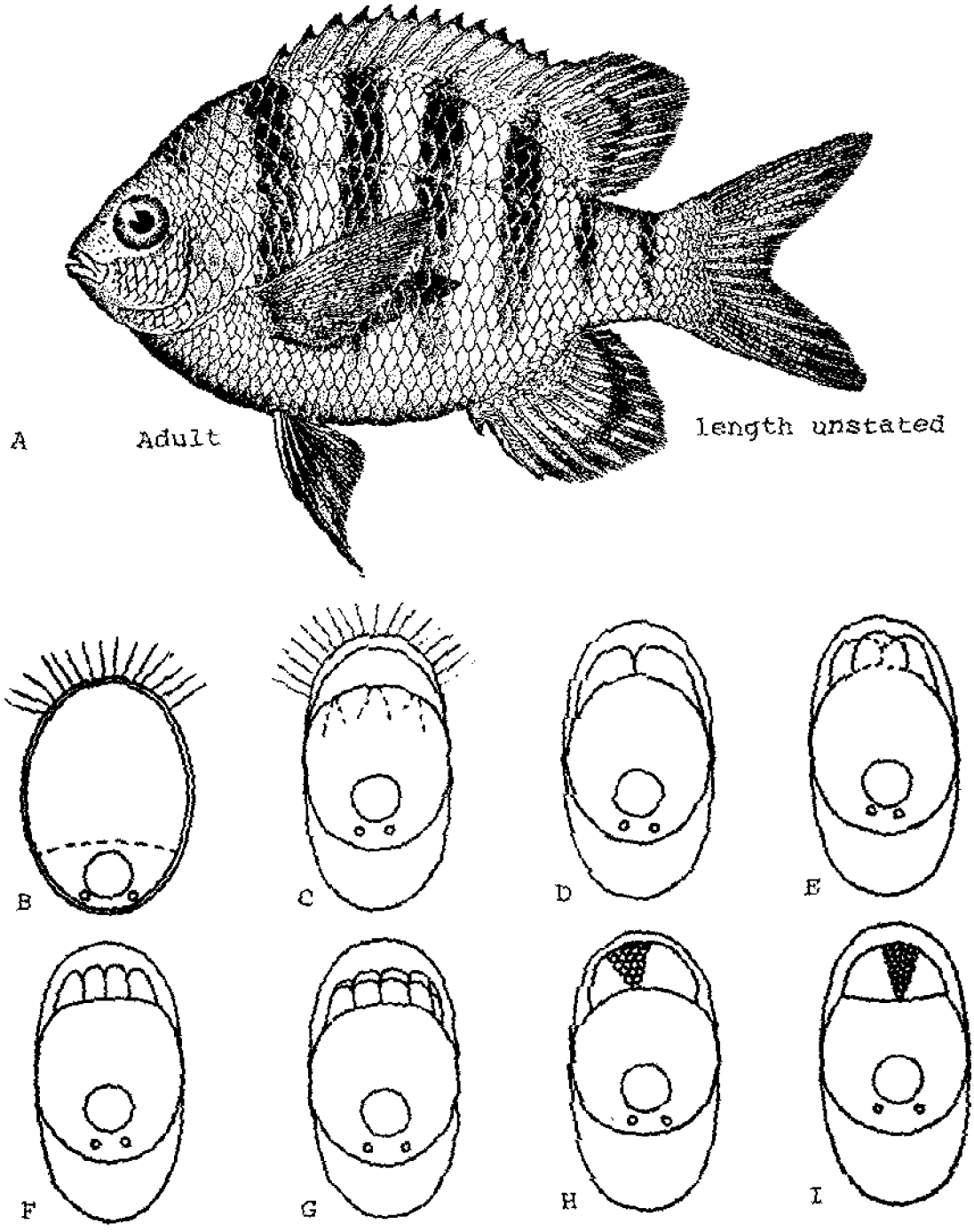

Fig. 5. *Abudefduf saxatilis*, Sergeant major. A. Adult, length unstated. *B. Unfertilized* egg. C. Fertilized egg, 60 minutes after fertilization. D. Two-celled egg, 75–80 minutes. E. Four-celled egg, 105 min. F. Eight-celled egg, 130 minutes. G. Sixteen-celled egg, 155 minutes. H. Early blastula, 5 hours. I. Late blastula, 8 hours. (A, Evermann, B. W., and M. C. Marsh, 1902: fig. 64. B-I, Shaw, E. S., 1955: figs. 1–8.)

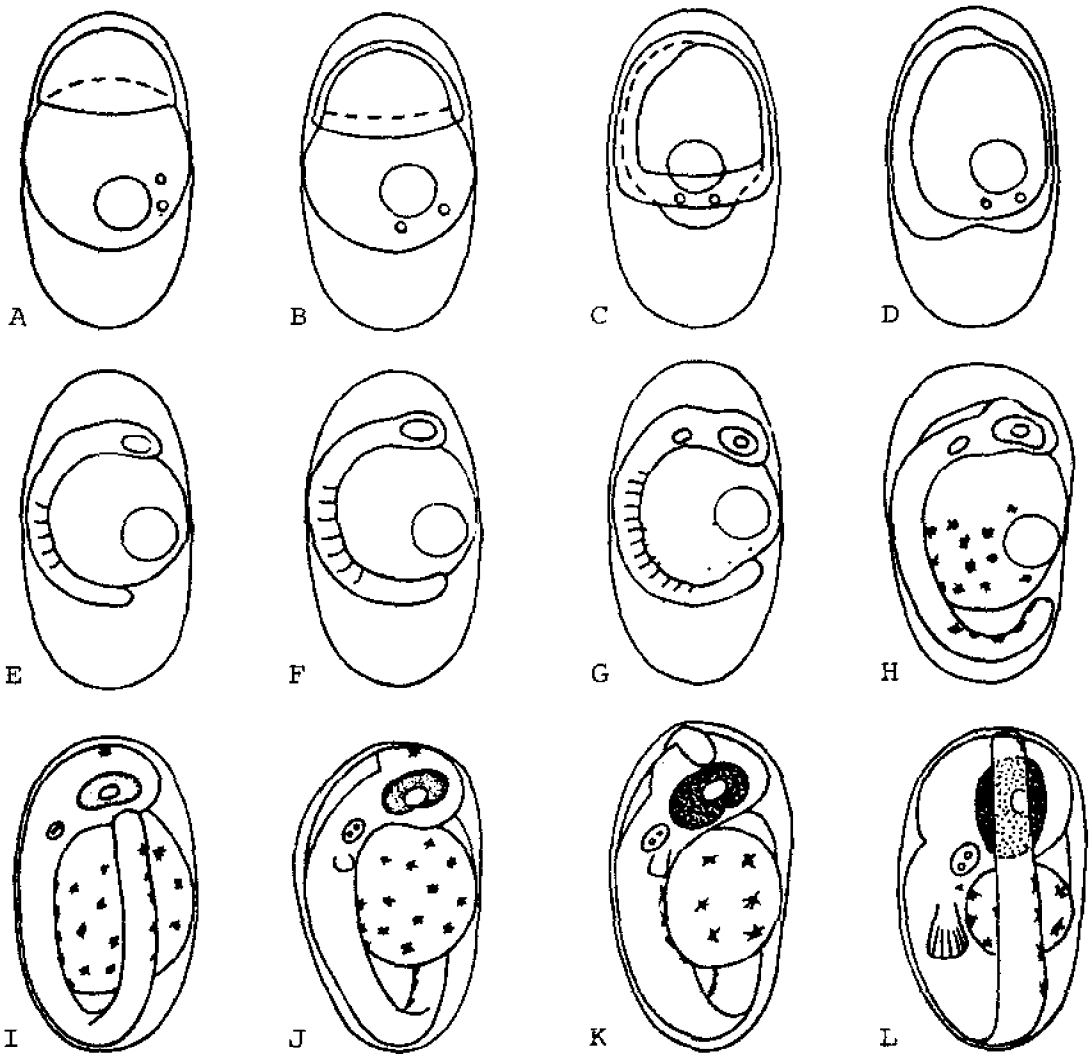

Fig. 6. *Abudefduf saxatilis*, Sergeant major. A. Early gastrula, 10 hours. B. Late gastrula, 14 hours. C. Yolk plug, 20 hours. D. Neurula, 22 hours. E. Optic vesicles, 25 hours. F. Brain constriction, 28 hours. G. Pigmentation, 35 hours. H. Motility, 44 hours. I. Retinal pigment, 60 hours. J. Iridiophores, 66 hours. K. Eyes mobile, 96 hours. L. Jaws mobile, 120 hours. (*A-L, Shaw, E. S., 1955: figs. 9–20.*)

Early blastula, 5 hours—the blastula, resulting from horizontal and vertical cleavages, is approximately five cells in depth.

Late blastula, 8 hours—the blastula, now about 10 cells deep, forms a lenticular cap over the yolk. The entire ovum has become more spherical.

Early gastrula, 10 hours—a peripheral band of cells, the germ ring, begins to migrate down over the yolk. This migration is equal at all points and there is no evidence of the accumulation of cells at any one point.

Gastrula, 14 hours—the thickened lips of the germ ring have advanced over one-half of the yolk, constricting it; shield formation is indicated by a localized accumulation of cells.

Yolk plug, 20 hours—advancing germ ring enclosing almost the entire yolk, leaving a small yolk plug extruding through the open blastopore; the embryonic shield is expanding anteriorly.

*Neurula, 22 hours—entire yolk enclosed in the extra-*embryonic membrane. The shield, a conspicuous thickened mass, contains the neural keel.

Optic vesicles, 25 hours—a small head-fold lifts the cephalic end of the embryo from the yolk, and a pair of optic vesicles are seen. Three or four somites visible in the mid-body region; a thickening present.

Brain constrictions, 28 hours—five or six somites present when the three primary regions of the brain become apparent.

Pigmentation, 35 hours—small, dot-like melanophores on the yolk sac epithelium, occasionally a few may be seen on the ventrolateral edge of the trunk. A lens has formed in the eye; the auditory vesicle is present and the mesencephalon has deepened. Twelve to thirteen somites and a small tail bud are visible. The embryo has moved away from the proximal end of the chorion and is found in the center, equidistant from both poles.

Motility, 44 hours—the somites have become myotomes and slow, twitching movements of the tail are visible; heart-beat discernible beneath the left side of the head. Two stellate melanophores, characteristic in all the *A. saxatilis* embryos, can be seen on the mesencephalon, and stellate melanophores are oriented along the ventrolateral edge of the tail. The embryo is 1.3 mm long.

Retinal pigment, 60 hours—the embryo has increased considerably in length, measuring 2.5 mm. The head has deepened and enlarged and the embryo fills the entire chorion. Pigment cells are more numerous over the yolk sac; light retinal pigment can be seen in the eye. Otoliths have appeared in the auditory vesicle. The embryo is able to rotate itself, and in many embryos the head is visible at the distal end of the chorion.

Iridiophores, 66 hours—blood corpuscles are clearly visible throughout the body and in the duct of Cuvier. Eye pigment has become more dense and iridiophores appear on the trunk between the auditory vesicle and the anal region. A small pair of pectoral fin buds present and the caudal fin anlage, a narrow membrane, is visible. The embryo is 2.9 mm in length.

Eyes mobile, 96 hours—eyes capable of turning in several directions and the retinal pigment has become concentrated and opaque. Melanophores on the yolk sac are dendritic rather than stellate. The head is steadily enlarging and the yolk sac is decreasing. The mouth is a thin ventromedial slit. The embryo is 3.1 mm long.

Jaws mobile, 120 hours—the head of the embryo has shown a marked increase in growth while the total length still remains 3.1 mm; jaws mobile and mouth irregularly opens and closes. The embryo is still able to rotate in the chorion.

Hatching, 155–160 hours—the chorion softens gradually when the time of hatching approaches. The embryos are quiescent in the narrow confines of the chorion. A break appears at the distal end of the chorion and the head of the embryo emerges.[7]

Hatching occurs in 155–160 hours at 24 C.[7]

YOLK-SAC LARVAE

Specimens described about 2.4 mm at 36 hours after hatching.

Caudal and pectoral rays visible; lips prominent; jaw bones well developed.[15]

Pigmentation: Large stellate melanophore on each side of occiput; about 10 melanophores on each side in vicinity of yolk sac.[15]

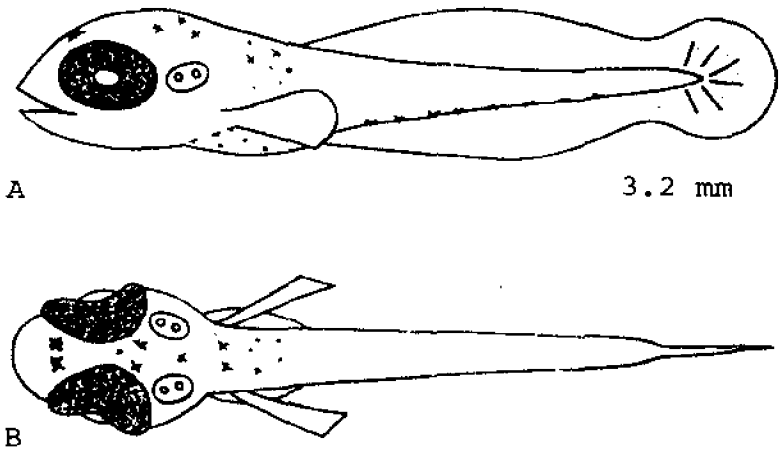

Fig. 7. *Abudefduf saxatilis*, Sergeant major. A. Yolk-sac larva at hatching, 155–160 hours, 3.2 mm. B. Dorsal view. (*A-B, Shaw, E. S., 1955: fig. 21.*)

LARVAE

No information.

JUVENILES

Maxillary reaches to eye.[13]

Pigmentation: Color pattern essentially as in adults in *specimens 18 mm SL and larger; occasional specimens* solid black, these never larger than 20 mm SL (FDM). Bars on sides may be indistinct "in the very young," fins colorless.[16]

GROWTH

Probably reach 100 mm in one year in captivity.[15]

AGE AND SIZE AT MATURITY

Males mature at about 100 mm; females at 83–127 mm.[15]

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Tautoga onitis
Tautogolabrus adspersus

wrasses
Labridae

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FAMILY LABRIDAE

The wrasses represent one of the largest families of fishes common to tropical and temperate seas. They are diverse in body form and size. Sequential hermaphoditism and numerous color patterns are typical of many species.

Labrid eggs and yolk-sac larvae are generally characterized by a large pigmented oil globule in the yolk. The yolk sac and the oil globule typically project anterior to the head in yolk-sac larvae (Orton, 1953), however, the two labrids, *Tautoga onitis* and *Tautogolabrus adspersus,* covered in this account, are unusual in not having an oil globule.

The eggs of *Tautoga* and *Tautogolabrus* are easily confused with those of *Pseudopleuronectes americanus* (Agassiz and Whitman, 1885). The eggs of *Pseudopleuronectes* are demersal, typically found in aggregates rather than singly, and they are usually slightly smaller than *Tautogolabrus* and *Tautoga* eggs. Further data are given in the account of *Pseudopleuronectes americanus* in Volume VI of this series.

Identification of labrid eggs is complicated by the fact that the eggs of both included species decrease in diameter during the spawning season (Williams, 1967). However, the decrease in size is parallel between the two species with the smaller eggs those of *Tautogolabrus.*

Key to the Eggs of Labridae.

1a. Egg diameter 0.84–1.0 mm; embryos with compact melanophores present on head and terminal part of tail ..... *Tautogolabrus*
1b. Egg diameter 1.0–1.2 mm; embryos with dendritic melanophores present on head and terminal part of tail ..... *Tautoga*

Key to the Larvae and Juveniles of the Labridae.

1a. Specimens shorter than 25 mm SL 2a
1b. Specimens longer than 25 mm SL 3a

2a. Posterior caudal region free of pigment; body covered with dendritic melanophores ..... *Tautoga onitis*
2b. Posterior caudal region with ventral pigment spot; definite band of pigment over gut; single large melanophore on back of head; a dorsoventral pair of large melanophores half-way between anus and tail-tip ..... *Tautogolabrus adspersus*

3a. Dorsal XVI–XVII, 10; brown or greenish more or less mottled with darker or with dark connected crossbands ..... *Tautoga onitis*
3b. Dorsal XVIII, 9–10; eight dark crossbands on side of body until adult color pattern is assumed at 150 mm SL ..... *Tautogolabrus adspersus*

Tautoga onitis (Linnaeus), Tautog

ADULTS

XVI [2,10] to XVII,[4] 10; [2,4,10] A. III, 7 [4]–8; [2,10] C. 8+7; [10] *P. 16*; [17] *V.* I, 5; *scales 60* [10] in lateral series; vertebrae 17+18; [10] gill rakers short,[2,4] blunt,[2] 9 on lower limb of first arch; [4] 2 or 3 large canine teeth in each jaw, teeth gradually decrease in size posteriorly.[2]

Head 3.25 [2,4,10]–3.56,[4] depth 2.55 [4]–3 [2,10] in SL; eye 3.05–6.0, snout 3.25–3.56,[4] pectoral fin length 1.67, pelvic fin length 2,[2] interorbital 3.85–5.1,[4] maxillary 3–3.55,[4] highest dorsal spine 3, highest dorsal ray 1.8, third anal spine 3, highest anal ray 1.8 [2] in head.

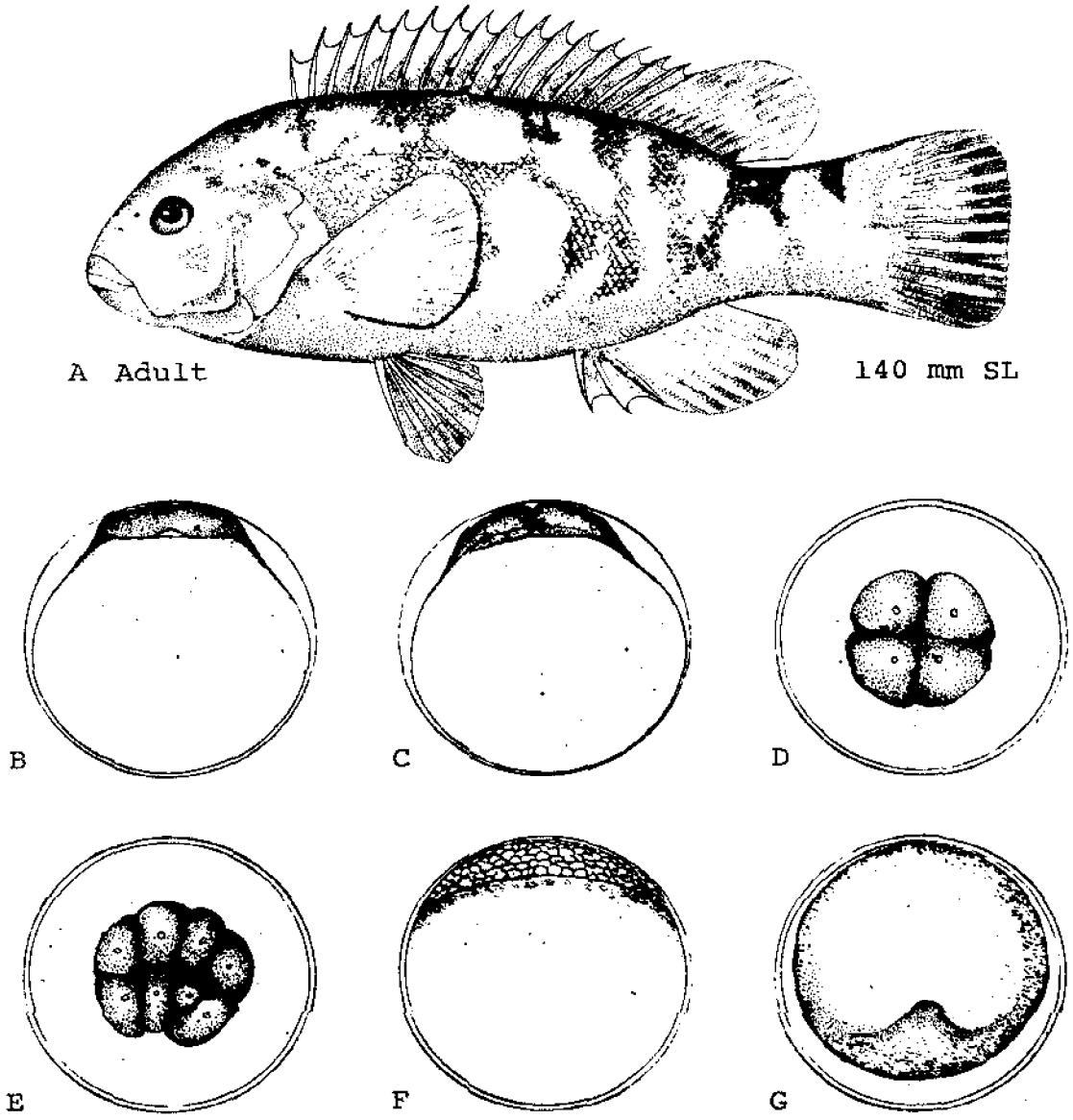


Fig. 8. *Tautoga onitis*, Tautog. A. Adult, 140 mm SL. B. Fertilized egg with fully developed blastodisc. C. Egg with blastoderm of 2 cells. D. Egg with blastoderm of 4 cells. E. Egg with blastoderm of 8 cells. F. Egg with blastoderm in late cleavage stage. G. Egg with blastoderm showing germ ring fully differentiated and an early stage in the differentiation of the embryonic shield. (*A, Goode, G. B., 1884: pl. 85. B-G, Kuntz, A., and L. Radcliffe, 1917: figs. 1–6.*)

Body deep, compressed;[2,4] head rather short, snout blunt,[4] profile steep, rounded;[2] mouth moderate, slightly subinferior; gape to anterior margin of orbit in young,[4] to anterior nostril in adults.[2] Scales small, thin, cycloid, reduced in size on belly and chest,[4] 5–6 series behind eye extending onto cheek, head and opercles otherwise naked.[2] Lateral line complete and continuous.[4] Dorsal soft rays somewhat higher than spines; anal fin with 3rd spine longest; caudal fin broad,[10] truncate or slightly rounded; pectoral fins broad, rounded.[2]

Pigmentation: Color blackish to greenish [2,4,10] or blackish blue;[10] fins plain, mostly color of body. Two color patterns—one plain blackish and the other having irregular blackish or brownish bars on pale background.[4]

Maximum size: To about 900 mm [2,3,4,10] and to weights of 10.2 kg.[3,4]

DISTRIBUTION AND ECOLOGY

Range: Western Atlantic coast from St. John, New Brunswick[9] to Charleston, South Carolina,[2,9] most abundant between Cape Cod and the Delaware Cape.[9]

Area distribution: Throughout the Chesapeake Bight.[9] Recorded in Chesapeake Bay from Chesapeake Beach and Solomons, Maryland; Tangier Island, Lewisetta, Lower York River, Cape Charles, Old Point Comfort, Buckroe Beach, and Ocean View, Virginia;[4] also recorded from Townsends Inlet, Delaware River and Indian River Bay.[16]

Habitat and movements: Adults—an inshore fish of rocky reefs,[15] mussel beds,[5] occasionally enter brackish water;[23] thought to spend winter in deeper water offshore [9,11] and move into estuarine embayments in the spring for spawning;[9] common in water less than 20 m [5] but to depths of about 25–55 m in the winter;[9] usually within 1.8–2.4 km from land north of Cape Cod and 6.0–7.2 km offshore south of Cape Cod.[8,23]

Larvae—collected in surface plankton nets.[7]

Juveniles—live chiefly in eelgrass and algae along the coast, and in coves and channels at depths of 2–5 m;[11] appear relatively inactive during the winter.[9]

SPAWNING

Location: Occurs inshore during June in the north and somewhat earlier further south.[14]

Season: From mid-May to mid-August in Long Island Sound,[5] most intense during first two weeks of June in Rhode Island.[8]

Temperature and salinity: Spawning occurs at temperatures between 10 and 26 C in Long Island Sound,[18] and between 13 and 14 C in Rhode Island;[8] and at salinities between 26–29 ppt in Long Island Sound.[18] A delay of 10 days in collectable eggs was thought to be result of heavy precipitation.[5]

Fecundity: The number of eggs in the ovaries reaches maximum in 7–9 year old fish and declines in fishes greater than 16 years old; a 3 year old fish had 5,000 eggs; a 4 year old had 34,000; a 6 year old had 104,000; a 13 year old had 457,000; a 14 year old had 235,000; and a 20 year old had 150,000.[8]

EGGS

Location: Buoyant,[3,4,11] concentrated in upper 5 m in Long Island Sound.[24]

Ovarian eggs: 1.0 mm.[15]

Fertilized eggs: Spherical, transparent; egg membrane thin and horny; diameter 0.89 [6]–1.15 [5,6] mm, largest in cooler months (May), decreasing in size with increasing temperatures (August);[19] nonadhesive;[3] yolk homogeneous [13] without an oil globule;[1,4,11] perivitelline space of moderate dimensions,[13] appears after fertilization.[1]

EGG DEVELOPMENT

Protoplasm concentrates at one pole of yolk sphere into a lenticular mass, the blastodisc. First cleavage occurs less than one hour after fertilization. Blastoderms observed four hours after fertilization. At 4-cell stage two axes of blastoderm about equal. Early blastoderms of more than four cells are markedly asymmetrical; viewing the blastoderm from above, a roughly triangular area appears at the posterior pole which marks an early stage in the differentiation of the embryonic shield; soon a linear thickening appears along the anteroposterior axis of the embryonic shield marking the axis of the embryo. The embryo develops sequentially from posterior end. Once the embryo is well formed the blastoderm covers about three-fourths of the surface of the yolk; the blastopore closes 18 hours after fertilization. Pigmentation is observed in embryos with 15–20 myomeres and appears as small, round, black dots scattered over the dorsal surface of the embryo, however, the embryo remains transparent.[1] From above, the dots appear to be arranged in two lateral lines; the largest dots .005 mm in diameter.[12]

Incubation period 42–45 hours [1,4] at 22 C.[1]

YOLK-SAC LARVAE

Hatch at 2.2 [1,4]–3.05 mm.

Pectoral fins scarcely developed and pelvic fins not developed.[13] Distance from posterior margin of yolk-sac to vent contained 5.5 times in TL; yolk-sac large, ovate elliptical [1] and without pigment,[1,12] greatly reduced at 2.8–3 mm (1 day) [1] and absorbed at 3.2–3.5 mm (4 days).[1,4]

Pectoral fins double in length second day after hatching; [12] finfold depth less than depth of body just posterior to vent; [1] anus open at hatching,[13] at margin of finfold one half distance from snout to tail tip.[1,6]

Pigmentation: Eye scarcely pigmented at hatching; [13] a little green pigment second day after hatching. Melanophores on newly hatched confined to dorsal and dorsolateral aspects of body; [6] tail left free of pigment with growth; [6,12] two lines of pigment around head diagnostic; one day after hatching melanophores expand, assume dendritic form so that fish appears quite dark.[12]

LARVAE

Yolk absorbed by 3.3 mm and metamorphosis completed by 10 mm.

Mouth fully formed by 3.3 mm.[4] Fish of 5 mm marked by increase in depth and thickness of body rather than increase in length. At 10 mm dorsal, anal and caudal fins are becoming well differentiated.

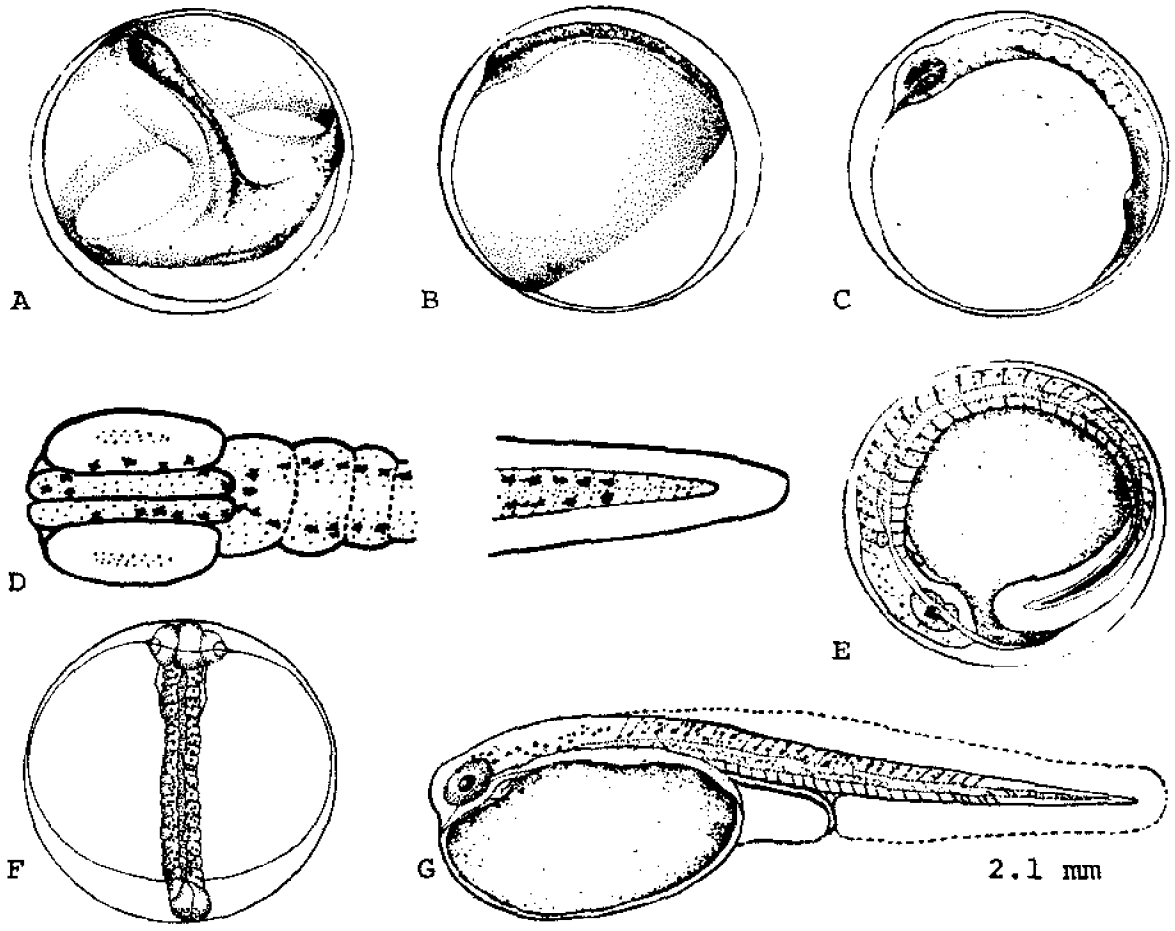
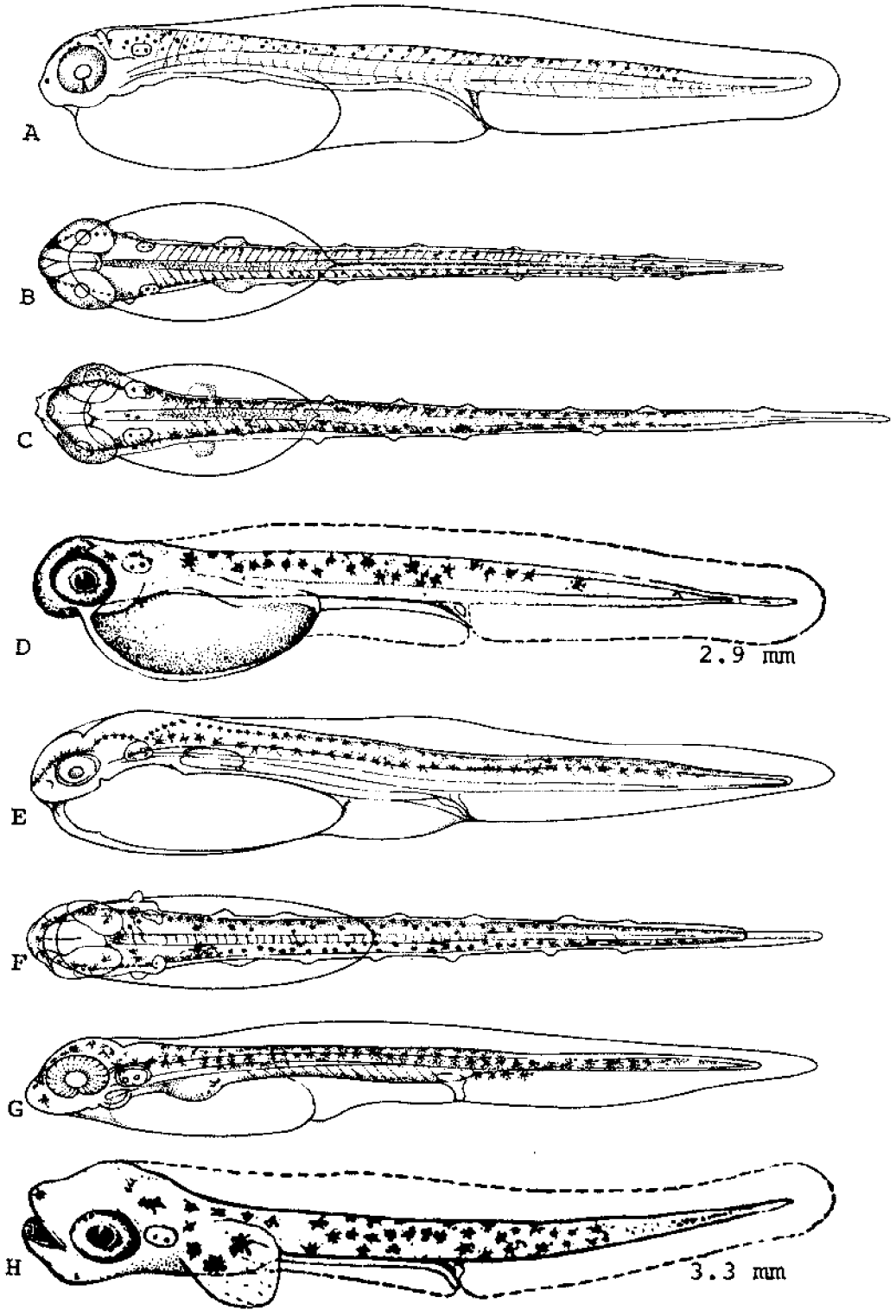


Fig. 9. *Tautoga onitis*, Tautog. A. Egg showing advanced stage in differentiation of embryonic axis. B. Same as A, lateral view. C. Egg with advanced embryo. D. Anterior and posterior end of embryo. E. Egg with advanced embryo, shortly before hatching. F. Egg shortly before the closing of the blastopore. G. Newly hatched fish, 2.1 mm. *(A-C, E, G, Kuntz, A., and L. Radcliffe, 1917: figs. 7–11. D, Williams, G. C., 1967: fig. 2. F, Agassiz, A., and C. O. Whitman, 1885: pl. 10, fig. 1, redrawn by Elizabeth Ray Peters.)*

Fig. 10. *Tautoga onitis*, Tautog. A. Profile view at time of hatching. B. Dorsal view of A. C. Dorsal view twenty-four hours after hatching. D. Yolk-sac larva one day after hatching, 2.9 mm. E. Profile of a one to two day old yolk-sac larva. F. Dorsal view of E. G. Yolk-sac larva two days old. H. Larva four days after hatching, 3.3 mm. *(A-C, E-G, Agassiz, A., and C. O. Whitman, 1885: pl. 10, figs. 4, 6, 7; pl. 11, figs. 8–10, redrawn by Elizabeth Ray Peters. D, H, Kuntz, A., and L. Radcliffe, 1917: figs. 12–13.)*


A
B
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2.9 mm
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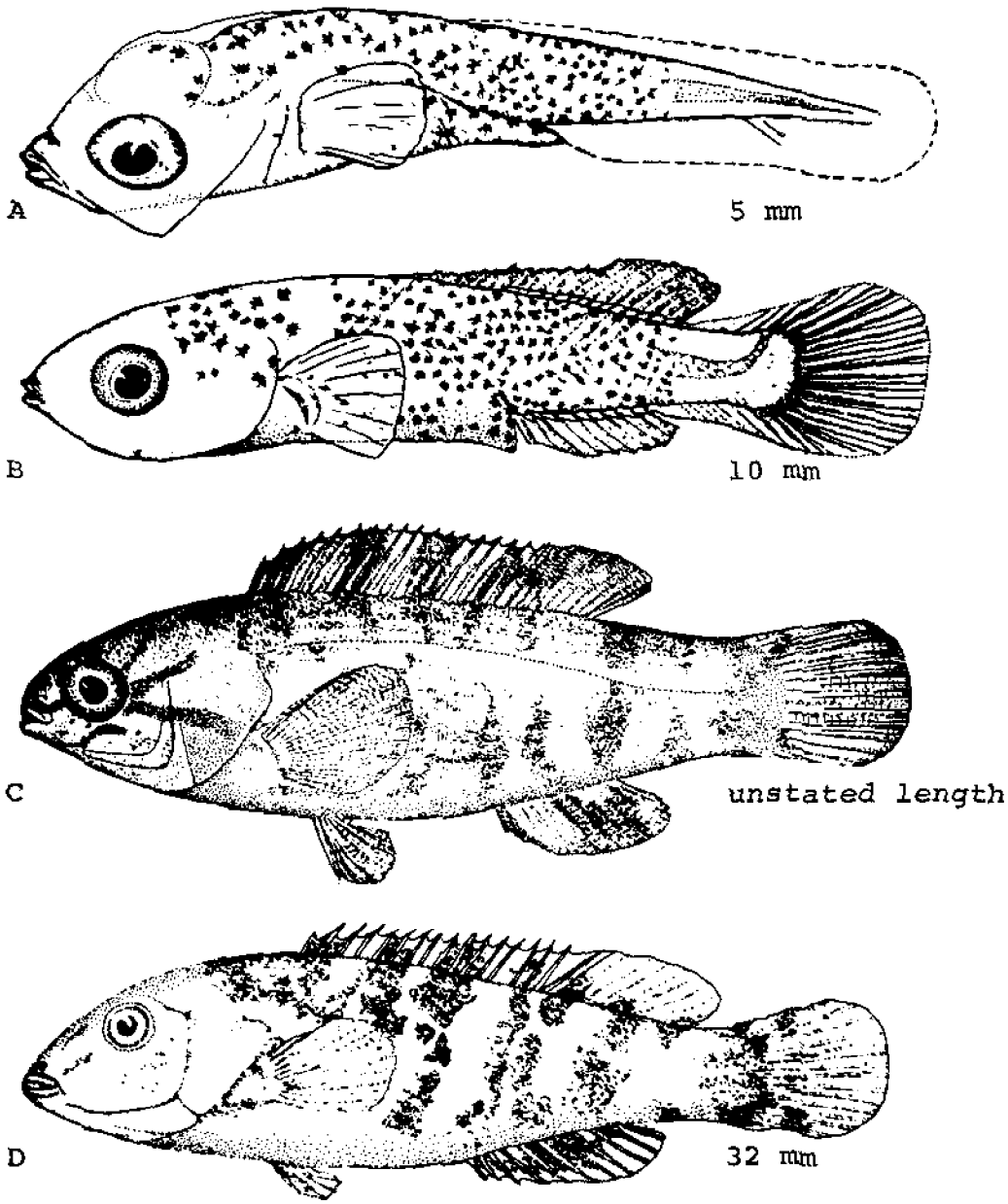

Fig. 11. *Tautoga onitis*, Tautog. A. Larva, 5 mm. B. Larva, 10 mm. C. Juvenile, unstated length. D. Juvenile, 32 mm. *(A, B, D, Kuntz, A., and L. Radcliffe, 1917: figs. 14–16. C, Bean, T. H., 1888: pl. 3, fig. 3.)*

Pigmentation: Posterior caudal region remains free of pigment; both at 5 mm and 10 mm chromatophores are larger and have increased in number.[1]

JUVENILES

Specimens described 30 mm [1] to 125 mm [20] in length.

At 30 mm depth of body is rapidly increasing and back is becoming arched.[1]

Pigmentation: Ground color greenish,[1,10,20] or brown, more or less mottled with darker or with dark connected crossbands.[10]

GROWTH

72 [4]–288 [11] (questioned, RAF) mm after one year.

AGE AND SIZE AT MATURITY

Maturity reached at beginning of 3rd year for males and at 4 years for females.[8]

Maximum age for males 34 years, females 22 years.[9]

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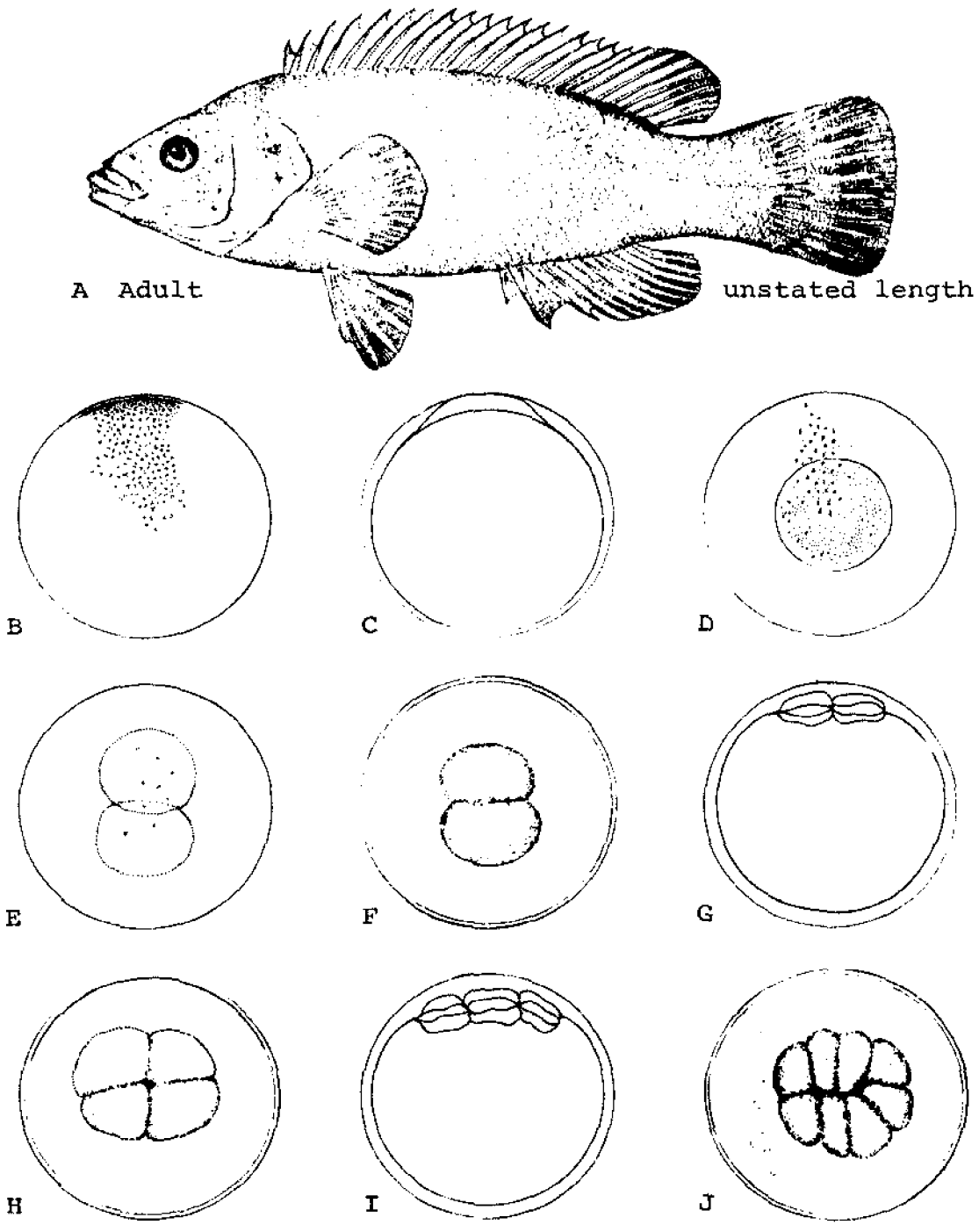

Fig. 12. *Tautogolabrus adspersus*, Cunner. A. Adult, unstated length. B. Unfertilized egg. C. Fertilized egg with blastodisc. D. Dorsal view of C. E. Egg with blastoderm of 2 cells. F. Egg with blastoderm of 2 cells. G. Egg with blastoderm of four cells. H. Egg with blastoderm of four cells. I. Egg with blastoderm of 8 cells. J. Egg with blastoderm of 8 cells. (*A, F, H, J, Kuntz, A., and L. Radcliffe, 1917: figs. 18–20, 29. B-E, G, I, Agassiz, A., and C. O. Whitman, 1885: pl. 7, figs. 1–6 redrawn by Elizabeth Ray Peters.*)

Tautogolabrus adspersus (Walbaum), Cunner

ADULTS

D. XVIII,[2,4,10] 9[4,10]–10;[2,10] A. III, 8[4]–9;[2,10] C. 8+7 (RAF); V. I, 5; scales 41[4]–46 in a lateral series; vertebrae 17+19; gill rakers short, 6+11; 5 canine teeth in front of upper jaw, about 4 in lower, teeth on sides of jaw enlarged anteriorly,[2] with bands of small concave teeth behind canines.[2,4]

Head 3.45[4]–3.5, depth 3[2]–3.45 in SL. Eye 2.8[4]–4.5,[2] interorbital 4.7, maxillary 3.5, pectoral fin 1.45[4]–2, highest dorsal spine 2.67, highest dorsal ray 2, third anal spine 2.5[2] in head.

Body rather robust,[2] moderately deep, compressed;[4,9] caudal peduncle deep;[4,9] head low, moderately long;[4] snout pointed;[2,4,10] mouth moderate,[2,4] terminal,[4] maxilla reaching anterior margin of orbit.[2,4] Scales cycloid, thin, with smooth membranous edges, reduced on chest,[4] absent on top of head, preorbital and opercle, about 5 rows of small scales on preopercle, preorbital and upper opercle with 4 or 5 rows of larger ones; fins naked.[10] Lateral line complete and continuous; running high anteriorly but becoming median on caudal peduncle. Dorsal fin long, continuous,[4] the soft rays about one-third as long as spines;[10] anal fin similar to dorsal in outline;[4,10] *caudal fin round,*[4] *or slightly convex with* rounded corners; pectoral fin rounded,[10] moderately broad; pelvic fin moderate. Gill membranes free from isthmus, united. Preopercular margin serrate.[4]

Pigmentation: Color varies with habitat;[10] breeding females brown; breeding males blue; non-breeding adults black; fins generally reddish, except the whitish or bluish anal and pelvic fins;[15] head and back sometimes brassy with spots.[2]

Maximum *size: 430 mm in the northern part of* range[3,4,10,15] and usually under 305 mm in the southern part;[2,3] and to a weight of 1.1 kg.[3]

DISTRIBUTION AND ECOLOGY

Range: Conception Bay, east coast of Newfoundland, and western end of southern parts of Gulf of St. Lawrence[4,10] southward in abundance to New Jersey[10] and Virginia.[4]

Area distribution: Known from Delaware Bay;[13] Ocean City, Maryland;[18] Cape Charles, Virginia;[4] and occasionally to mouth of Chesapeake Bay.[10]

Habitat and movements: Adults—frequent wharves, pilings,[2,3,4] rocky bottoms,[2,3,4] and eelgrass;[5] retreat to deeper, colder water during the winter;[10,15] common in water less than 20 m;[5] majority within 3–3.6 km of the shore.[10]

Larvae—closely confined to the coast,[10] in eelgrass and seaweed;[9] *9–10* mm specimens taken with nets fished along the bottom in Long Island Sound;[7] collected at temperatures between 19.1 and 22.8 C and salinities of 27–30 ppt.[5]

Juveniles—*common in shallow water around rocks and* wharves,[9] sandy bottoms near river mouths,[5] among eelgrass and in rock pools.[10]

SPAWNING

Location: Occurs inshore.[5]

Season: From June[3,4] to August[4,6] and occasionally to mid-October.[5]

Time: Between *1200* and *1700* hours at Shrewsbury Rocks (40° 20.5′ N, 73° 57.5′ W).[7]

Temperature and salinity: Eggs have been collected when the water temperature is between 10[5,16] and 26 C and at salinities between 26[16] and 29 ppt.[10,19]

Notes on spawning: 75–125 mm fish participate in group spawning in the water column.[7]

EGGS

Buoyant;[3,4,10] concentrated in upper 5 m in Long Island Sound;[19] 0.75[1,4,5]–1.03 mm[5] diameter, mean 0.85 mm in diameter;[12] egg size larger in cooler-water months (May) becoming smaller as summer progresses (August);[16] non-adhesive;[3] no oil globule.[1,4,10]

EGG DEVELOPMENT

Pigmentation first observed in embryos with 10–15 myomeres; early chromatophores appear as minute black dots distributed over dorsum;[1] pigment spots increase in size but not number up to moment of hatching.[17]

Incubation period 40 hours[1,3,10] at 21–22 C,[3,10] 2–6 days depending on temperature.[15,17,20]

YOLK-SAC LARVAE

Hatch at 2[1,4,10]–3.43 mm, mean of 2.9[12] mm.

Caudal and pectoral rays appear second day after hatching.[15] Distance between posterior margin of yolk sac and anus 11% TL.[8] Head slightly deflected at hatching[1] and increases in size by second day.[15] Yolk sac large at hatching and absorbed in fish 2.8–3 mm (3 days).[1] Mouth appears second day after hatching.[15] Finfold depth

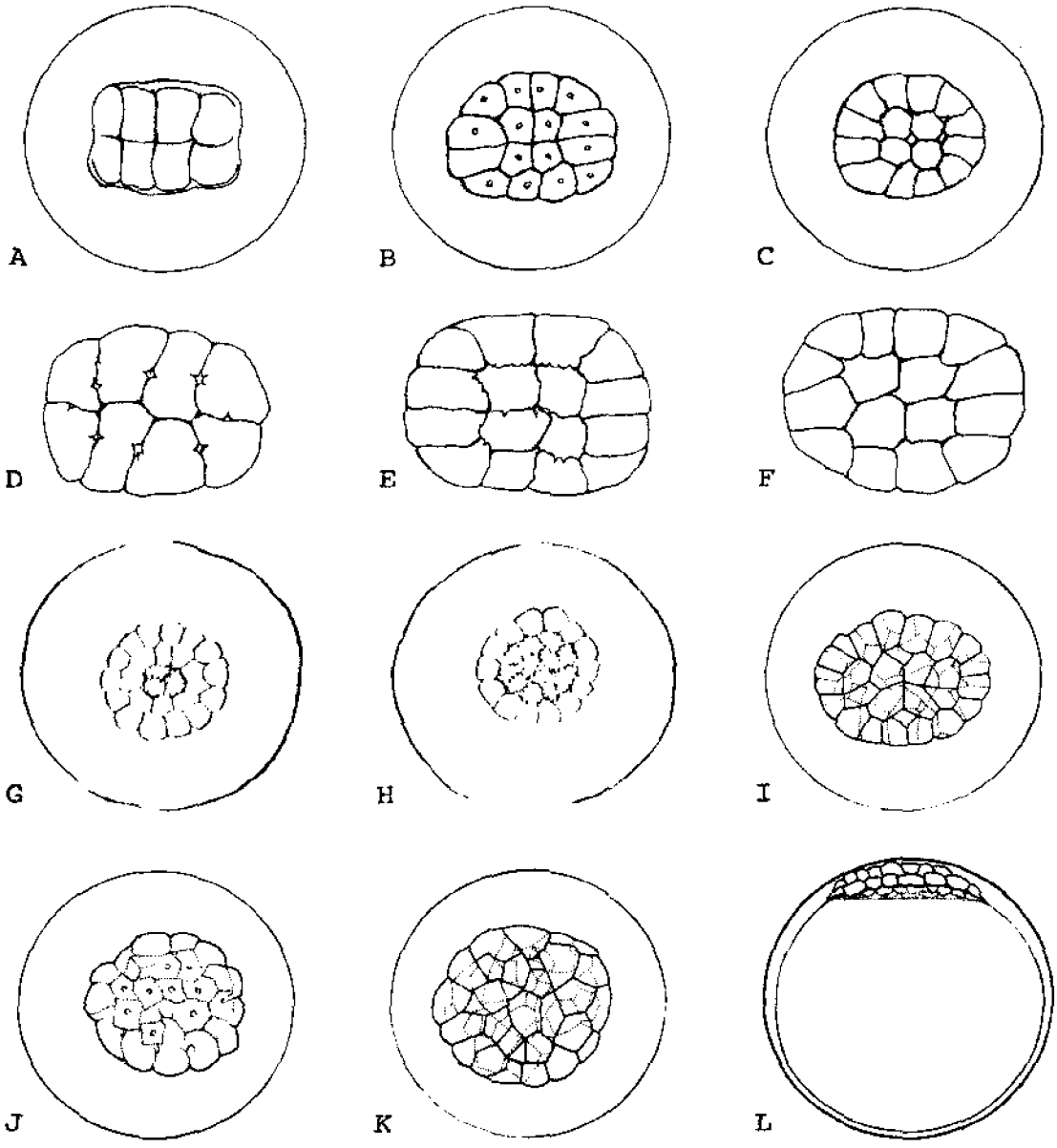

Fig. 13. *Tautogolabrus adspersus*, Cunner. A. Egg with blastoderm of 8 cells. B. Egg with blastoderm of 16 cells. C. Same as B after disappearance of the nuclei. D. 8-cell stage in process of dividing. E, F. Two examples of 16-cell stage. G, H. Two stages in the disintegration of the early blastoderm. I. 32- to 64-cell stage. J. Same as I, showing many of the marginal cells in a state of division. K. Slightly older stage. L. Same as K, from the side. *(A-F, I-L, Agassiz, A., and C. O. Whitman, 1885: pls. 7–8, figs. 7–16; I-L redrawn by Elizabeth Ray Peters. G, H, Hyman, L. H., 1921: pl. 1, figs. 1–2.)*

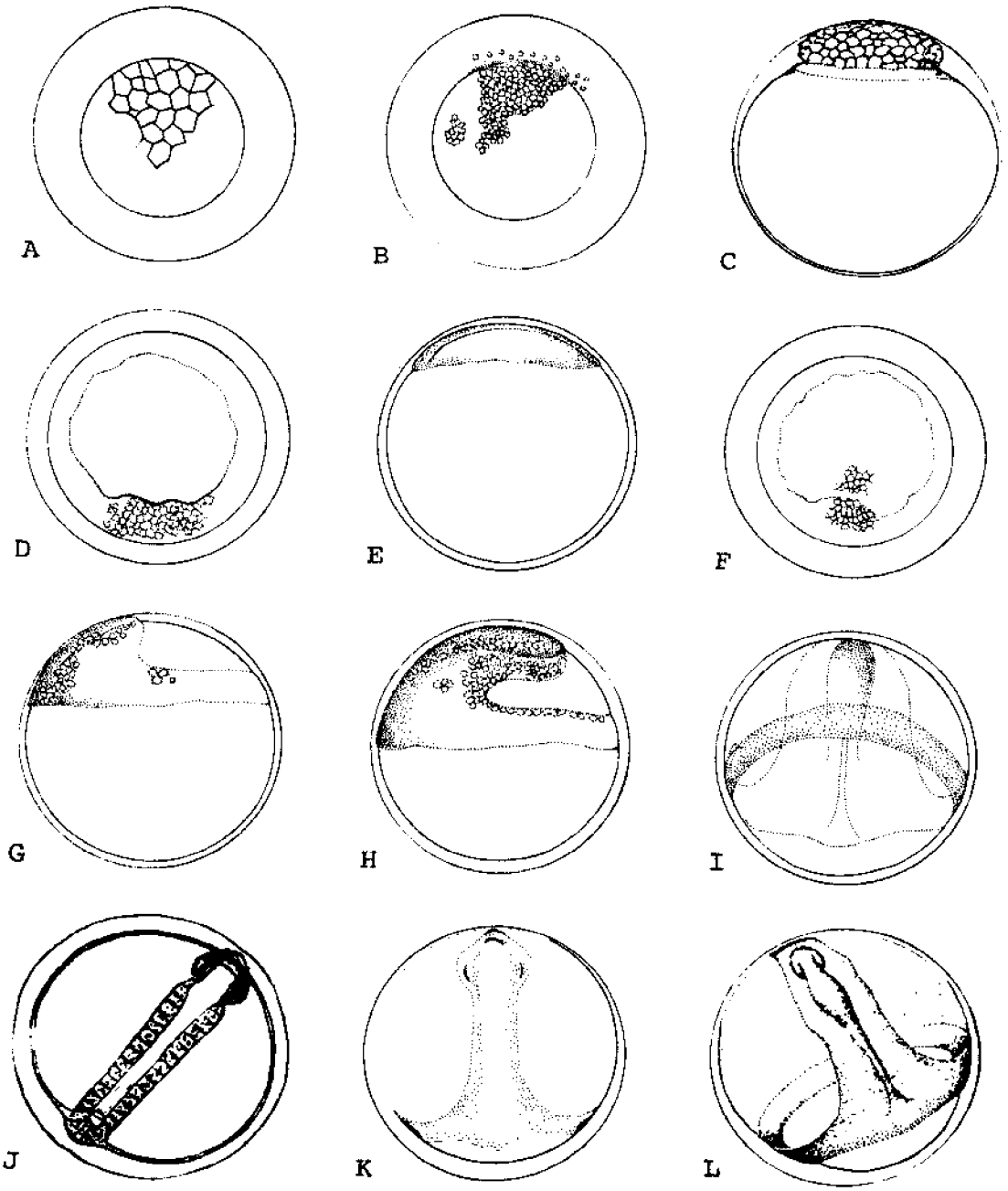

Fig. 14. *Tautogolabrus adspersus*, Cunner. A. A still more advanced stage of cleavage. B. The blastodisc is split up into very small cells, with a wreath of periblastic nuclei around it. C. Egg with blastoderm in advanced stage of cleavage and periblast differentiated. D. An early stage of the embryonic ring. E. Profile view of the disc at the time the ring begins to form. F. The axial plate appears at one point of the ring. G. The ring has now attained its full width, and the embryonic shield is much larger. H. Embryonic shield still longer, and the ring advanced to any equatorial position. I. The embryonic shield seen from above, just after the ring has passed the equator of the egg. J. Ventral view of embryo. K. Embryonic ring well advanced; optic vesicles forming. L. Egg showing moderately advanced stage in the differentiation of the embryo. (*A-B, D-I, K, Agassiz, A., and C. O. Whitman, 1885: pls. 8–9, figs. 17–25; A-B and D-I redrawn by Elizabeth Ray Peters. C, L, Kuntz, A., and L. Radcliffe, 1917: figs. 21–22. J, Johansen, F., 1925: fig. 1.*)

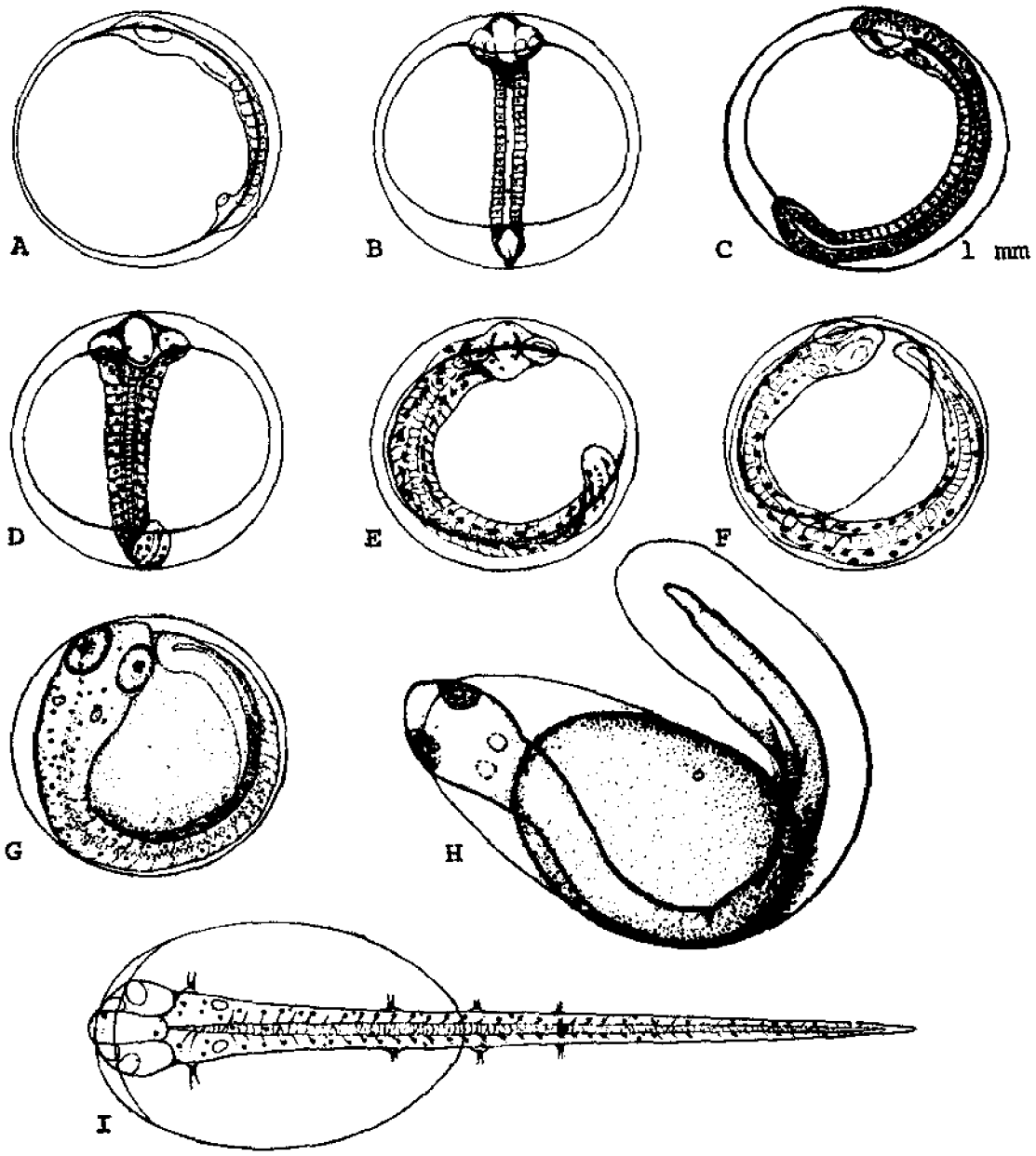

Fig. 15. *Tautogolabrus adspersus*, Cunner. A. Profile view just after closure of the blastopore; Kupffer's vesicle still prominent. B. Caudal end well formed; black pigment spots appear. C. Lateral view of embryo, 1 mm diameter. D. Later stage. E. Still more advanced embryo. F. Just prior to hatching; yolk sac reduced. G. Advanced embryo. H. Embryo at moment of hatching. I. Embryo seen from above at time of hatching. (*A-E, D-F, I, Agassiz, A., and C. O. Whitman, 1885: pl. 9, figs. 26–31. C, Johansen, F., 1925: fig. 2. G, Kuntz, A., and L. Radcliffe, 1917: fig. 23. H, Tracy, H. C., 1926: fig. 9.*)

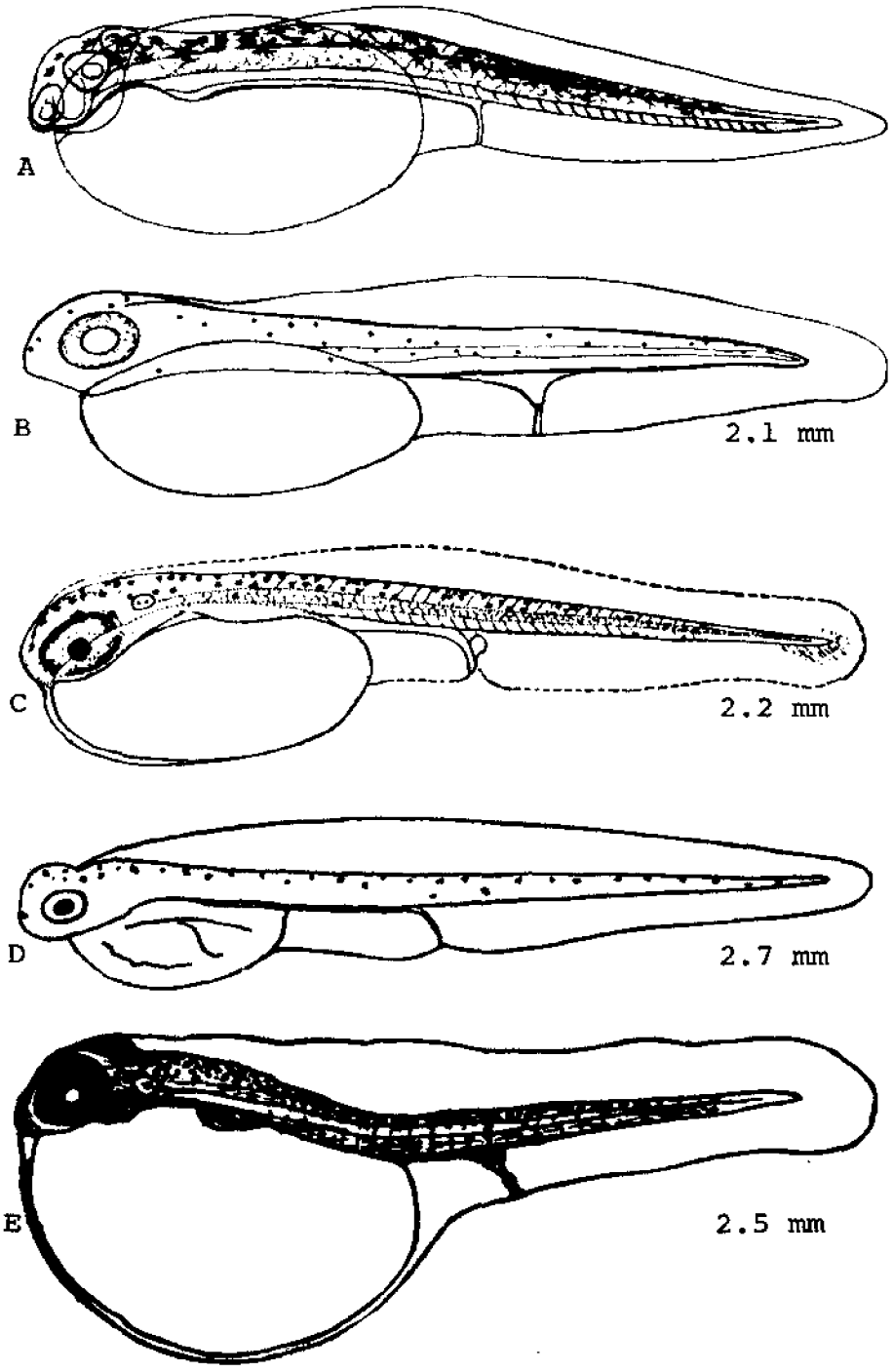

Fig. 16. *Tautogolabrus adspersus*, Cunner. A. Yolk-sac larva several hours after hatching. B. Yolk-sac larva, just hatched, 2.1 mm. C. Yolk-sac larva, just hatched, 2.2 mm. D. Yolk-sac larva, just hatched, 2.7 mm. E. Yolk-sac larva, just hatched, 2.5 mm. (*A, Agassiz, A., and C. O. Whitman, 1885: pl. 9, fig. 32. B, Tracy, H. C., 1926: fig. 7. C, Kuntz, A., and L. Radcliffe, 1917: fig. 24. D, Miller, D., 1958: [13]. E, Johansen, F., 1925: fig. 3.*)

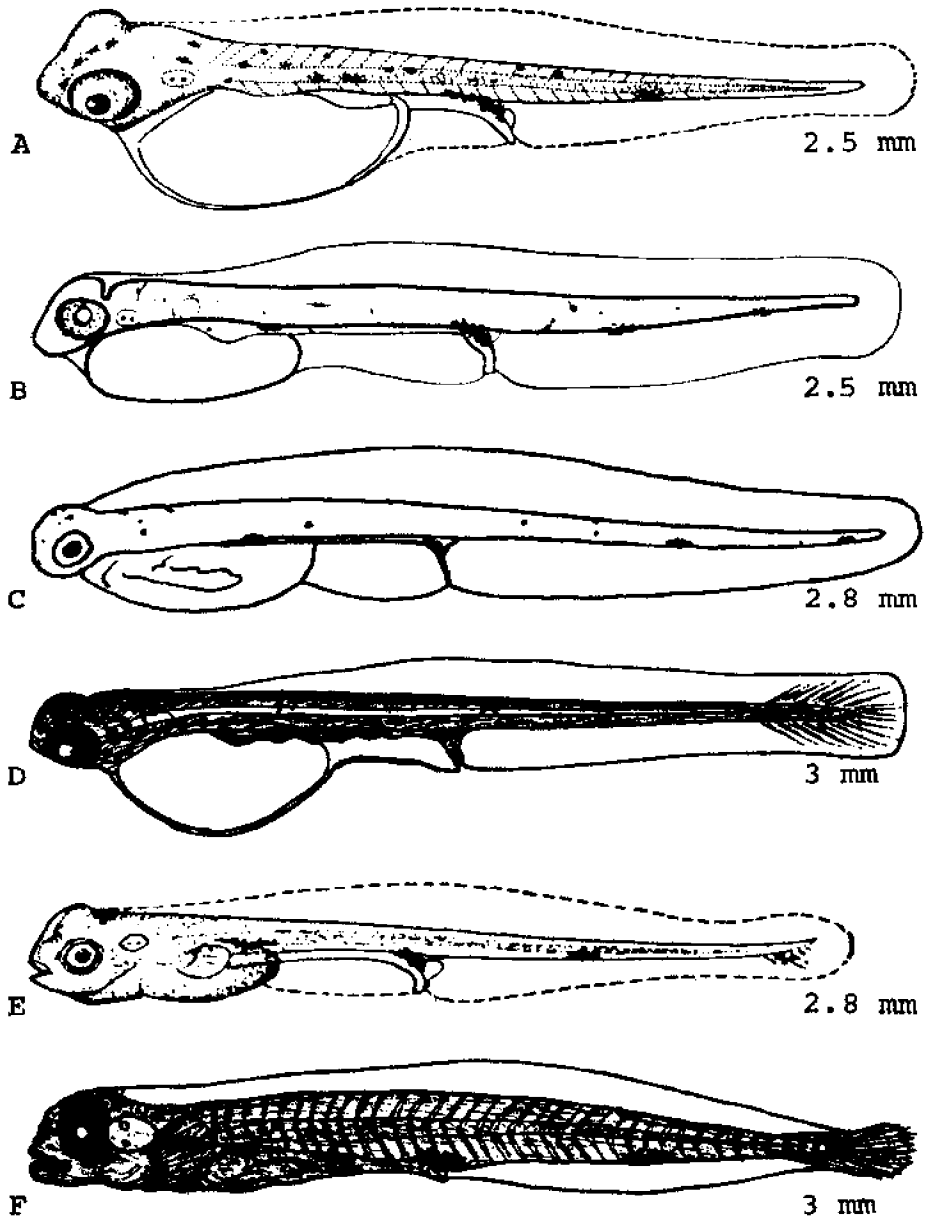

Fig. 17. *Tautogolabrus adspersus*, Cunner. A. Yolk-sac larva, one day after hatching, 2.5 mm. B. Yolk-sac larva, one day after hatching, 2.5 mm. C. Yolk-sac larva, 30 hours after hatching, 2.8 mm. D. Yolk-sac larva, 1–2 days old, 3 mm. E. Yolk-sac larva, 3 days after hatching, 2.8 mm. F. Larva, one-half week old, 3 mm. (*A, E, Kuntz, A., and L. Radcliffe, 1917: figs. 25–26. B, Tracy, H. C., 1926: fig. 8. C, Miller, D., 1958: [14]. D, F, Johansen, F., 1925: figs. 4–5.*

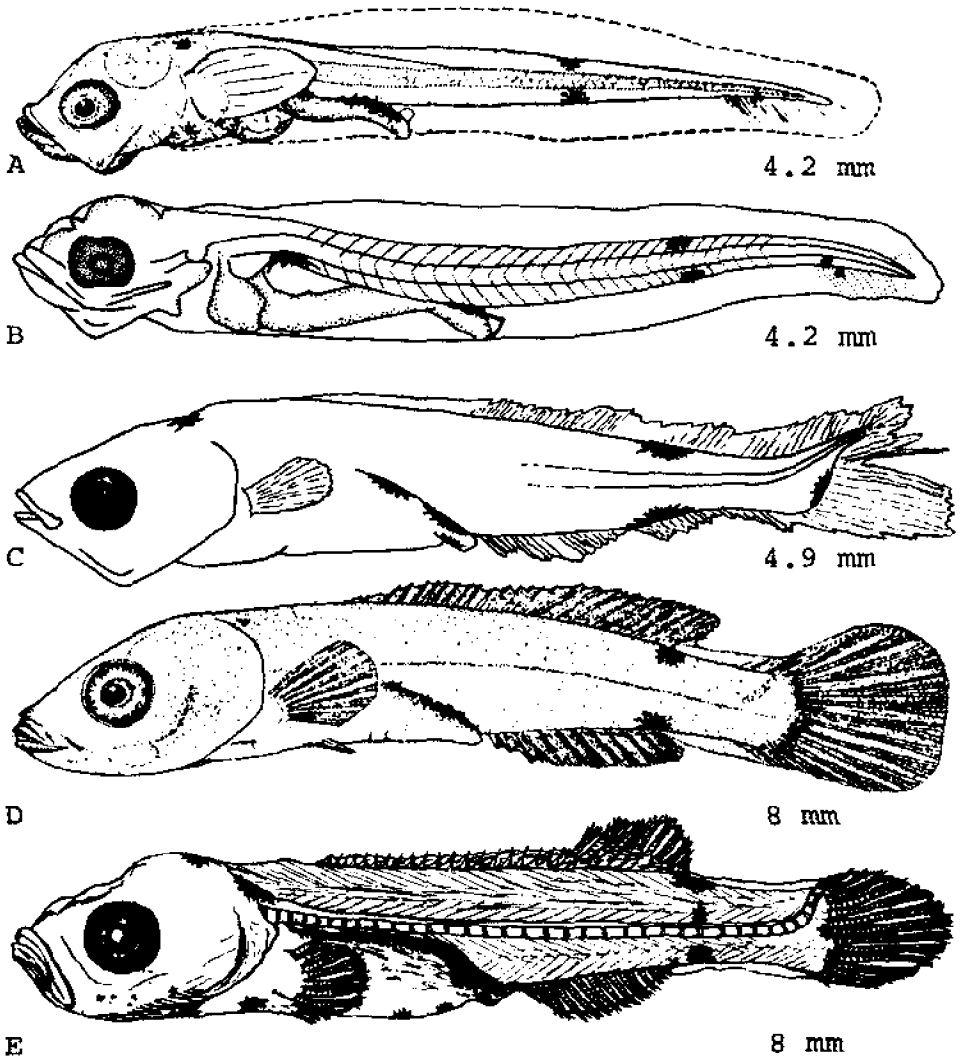

Fig. 18. *Tautogolabrus adspersus*, Cunner. A. Larva, 4.2 mm. B. Larva, 4.2 mm. C. Larva, 4.9 mm. D. Juvenile, 8 mm. E. Juvenile, 8 mm. *(A, D, Kuntz, A., and L. Radcliffe, 1917: figs. 27–28. B, Dannevig, A., 1918: fig. 1 reversed, redrawn by Daniel M. Carver. C, Miller, D., 1958: [15]. E, Johansen, F., 1925: figs. 6–7.)*

greater than depth of body posterior to anus.[1] Anus opens at margin of finfold, midway between head and tail.[1,6]

Pigmentation: Melanophores of newly hatched small, limited to dorsal and dorsolateral aspects of body and extend to tail;[1,6] soon after hatching (1 day) some melanophores aggregate into spots, one at turn in gut, second ventrally half-way between anus and tip of tail, and third near tip of tail.[1,6,12]

LARVAE

Yolk absorbed by third day after hatching[15] at 3.2–3.5 mm[1,6,12] and metamorphosis complete by 10 mm.[12]

Caudal and pectoral fins distinct at sizes greater than 3 mm; spinous and soft portions of dorsal fin begin differentiation at 7–8 mm; caudal fin begins separation at 6–7 mm; pelvic fins plainly seen at 7–8 mm.[15]

Pigmentation: A definite band of pigment over gut, a single large melanophore on back of head, a dorsoventral pair of large melanophores half-way between anus and tip of tail, and an aggregate of melanophores on ventral side of tip of tail.[6,12]

JUVENILES

Specimens described 8 mm[1,6]–25 mm[10] in length.

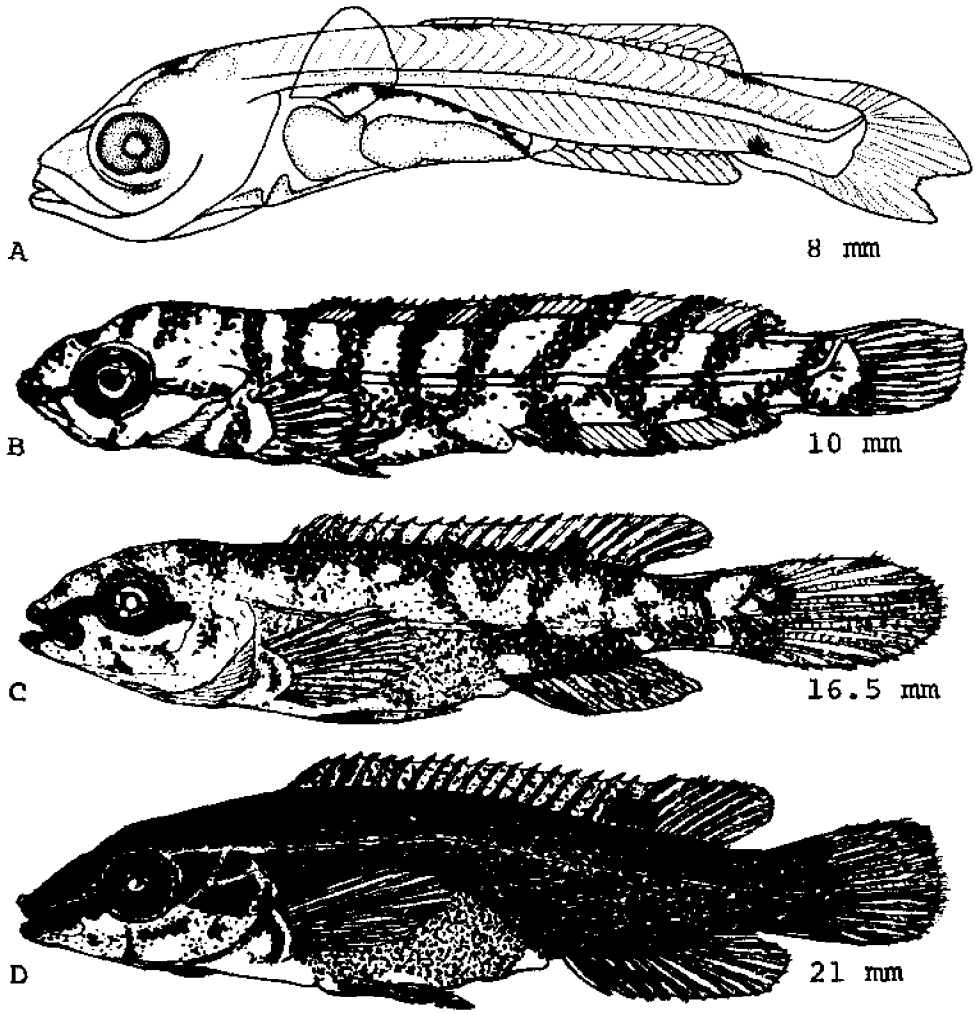

Fig. 19. *Tautogolabrus adspersus*, Cunner. A. Juvenile, 8 mm. B. Juvenile, 10 mm. C. Juvenile, 16.5 mm. D. Juvenile, 21 mm. (*A, Dannevig, A., 1918: fig. 2 reversed, redrawn by Daniel M. Carver. B-D, Johansen, F., 1925: figs. 8–10.*)

All fins well differentiated by 8 mm except spinous portion of dorsal not as well developed as soft portion.[15]

Pigmentation: Larval pigmentation persists to 10–20 mm,[1,10] by 25 mm colored as adults.[10] Specimens 8 mm orange-yellowish particularly ventrally and on gill cover below eye. By 9–10 mm pigmentation more elaborate and extensive in the form of eight crossbands on side of body and tail and continued out into dorsal and anal fins; a cross arrangement of dark bars on side of head, one of which is from maxilla through eye to corner of opercle and one from eye to isthmus; some pigment on jaws, branchiostegal membrane and on pelvic and pectoral fins. By 10 mm, fish are moving to bottom. By 15 mm the eight dark crossbands become somewhat dissolved laterally and begin to amalgamate, first ventrally.[15]

GROWTH

Juveniles reach 40–54 mm by autumn.[5] In the Gulf of Maine reach 76–102 mm by 2 years; 102–127 mm by 2–3 years; 127–152 mm by 3 years; 152–178 mm by 4–5 years; 203–229 mm by 5–6 years; 229–254 mm by 6 years; 254–280 mm by 6–7 years.[10]

AGE AND SIZE AT MATURITY

Maturity reached in two years[15] when fish are 76 mm+.[10]

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Scarus coeruleus

parrotfishes
Scaridae

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FAMILY SCARIDAE

The parrotfishes are medium-to-large often colorful fishes of coral reefs. As sequential hermaphrodites, they have complicated life histories. Juveniles and each adult sex may have different color patterns, consequently several names are usually applied to one species.

The early life histories of scarids are very poorly known. It is known that the eggs are pelagic. The genus *Sparisoma* has spindle-shaped eggs, 0.6–1.1 mm long, and *Scarus* has spherical eggs, 2.4–3.1 mm in diameter. The larvae generally have an anteriorly produced yolk sac which contains an oil globule at its anterior end, as in most labrids.

Scarus coeruleus (Bloch), Blue parrotfish

ADULTS

D. IX, 10; A. III, 9; C. 7+6 (RAF); P. 14 or 15; [3] *V. I, 5*; scales 24–26 oblique rows; [2,4] gill rakers 31–50 outer, 44–52 inner; teeth fully coalesced, forming plates,[1] no free canines; [2,2,3] gill membranes connected.[2]

Head 3.15–3.6,[1] depth 2.8–3.2 [1,4] in SL. Snout 2.35 [1,4]–3.25; [4] eye 5.15–6.4; [1] interorbital 3.1; [4] pectoral fin 1.3–1.55 [1] in head.

Body elongate,[1,2] moderately compressed,[1] becoming deeper with age; [2] head not much longer than deep, snout very blunt; [1] well developed fleshy pad on forehead of larger adults; [1,3] mouth small, reaching about halfway to eye. Scales cycloid, large, not reduced on chest; most of head scaled; [1] cheek with two rows of scales, uppermost row larger scales; [1,2] six predorsal scales.[2] Lateral line interrupted under posterior rays of dorsal,[1] pores simple tubes [4] to more or less branched. Dorsal spines flexible, each with fleshy tip; anal fin with three flexible spines, first short; [1] caudal fin truncate, with lobes slightly produced, becoming more so in larger adults; [2,3] pectoral fins not reaching past pelvic fins; [2] pelvic fins shorter than pectoral fins.[1]

Pigmentation: Ultramarine blue [2,3] to dark green or slightly grayish green [1,3] above; dark gray region on cheek and postorbital; [6] teeth pale; [2] eyes deep blue-green; [1] a sky blue band from eye to, and across, each lip; a pale band below it on lower lip; dorsal fin edged with darker blue; pectoral base and upper ray blue, remainder of fin pale; anal fin deep blue, blackish at base; pelvic fins blue, the last rays paler; caudal fin deep blue, outer rays darker, posterior edge pale; [2] one phase has irregular zigzag bands separating blocks of brownish or reddish.[6]

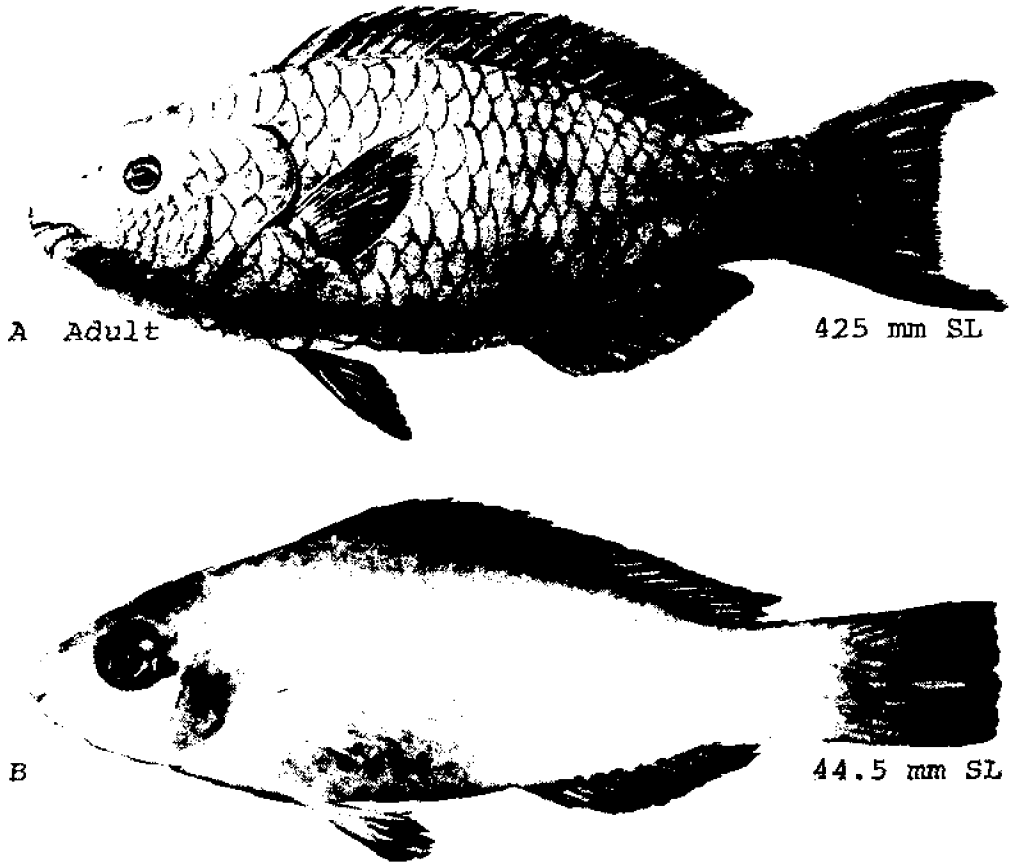

Fig. 20. *Scarus coeruleus*, Blue parrotfish. A. Adult, 425 mm SL. B. Juvenile, 44.5 mm SL. (*A, B, Böhlke, J. E., and C. C. G. Chaplin, 1968: 475, pl. 25. © Academy of Natural Sciences of Philadelphia. Used with permission of publisher and authors.*)

Maximum size: To about 91 cm in length.[4,5]

DISTRIBUTION AND ECOLOGY

Range: Bermuda [3] and Maryland [1,3,5] south to Rio de Janeiro.[3]

Area distribution: St. George Island, Maryland.[1]

Habitat and movements: Adults—on reefs, most frequently found deeper than 5 m (FDM).

Larvae—no information.

Juveniles—common on reefs [3] and on *Thalassia* beds, largest collections from *Thalassia* beds 2–10 m deep (FDM).

SPAWNING

No information.

EGGS

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Specimen described 102 mm in length.[2]

Pigmentation: Light livid blue-gray, tinged with brownish above, bluish below; [2] yellowish olive on top of head,[2,6] diminishing with growth; [6] jaws bright flesh red; snout bluish; teeth pale; dorsal edged with bright blue, orange below; caudal grayish, faintly banded with olive, upper and lower edges bright blue; anal flesh color, edged with bright blue; pelvic fins greenish blue; pectorals flesh color, axil light blue; [2] young stages pass through a striped phase.[6]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Trichiurus lepturus

cutlassfishes
Trichiuridae

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FAMILY TRICHIURIDAE

The cutlassfishes are primarily oceanic, but some are known to enter estuaries or shallow water to spawn. This family contains about 22 species of oceanic fishes with narrow, compressed bodies tapering to a very small tail or a point.

In the most recent review of the family (Tucker, 1956) the genus *Trichiurus* was considered to be composed of one worldwide species. Recent evidence (Fitch and Gotshall, 1972) has shown that the eastern Pacific form, *Trichiurus nitens*, is distinct from *T. lepturus*. This volume has followed Fitch and Gotshall in recognizing the distinctiveness of *T. nitens*.

The following account does not include the description of *Trichiurus* eggs given by Tang and Wu (1936). The eggs they describe are 0.66–0.84 mm in diameter rather than 1.7–1.9 mm as reported by all other investigators.

This volume does not include the description of *Trichiurus* eggs and larvae given by Delsman (1927). Delsman describes developmental series of several trichiurids. It is impossible to separate out information which pertains solely to *T. lepturus*.

Trichiurus lepturus Linnaeus, Atlantic cutlassfish

ADULTS

D. III,[10,12] 126–137; A. 105–108; [10] C. absent; [5] P. 11; [11] *V.* absent; scaleless; [5] vertebrae *39–40* [10,12] + *123–128* = 162–168; [10] gill rakers poorly developed and unequal in length, 5–15 more or less developed on lower limb of first arch; teeth strong, unequal, compressed, largest ones with distinct barbs on posterior edges.

Head 7.2 [8]–9.4,[10] depth 13 [8]–21 [10] in TL (extreme variation probably due to specimens with broken tails); snout 2.8–2.9,[8] eye 5.0 [10]–7.4, interorbital 7.0–7.8, maxillary 2.2–2.7, pectoral fin 3.3 in head.[8]

Body extremely elongate, strongly compressed; tail very slender, tapering to a point; head long, compressed;[8] snout long, pointed; [8,9] mouth large, lower jaw strongly

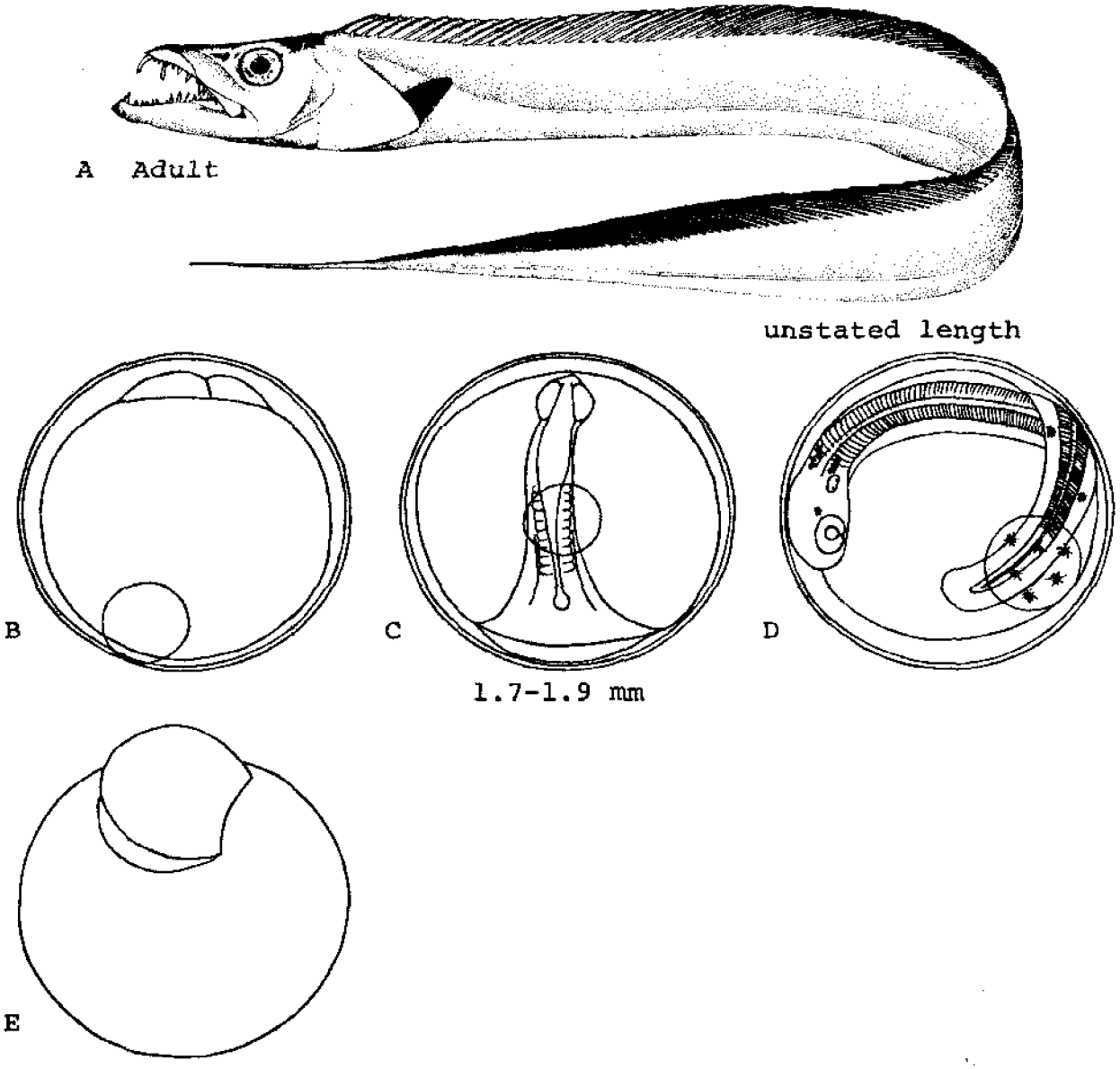

Fig. 21. *Trichiurus lepturus*, Atlantic cutlassfish. A. Adult, unstated length. B-D. Eggs, 1.7–1.9 mm in diameter. E. Egg capsule. (*A, Goode, G. B., 1884: pl. 114. B-E, Tsukahara, H., 1961: figs. A-D.*)

projecting;[8] maxillary reaching anterior margin of pupil, concealed by preorbital.[6,8] Lateral line beginning opposite upper margin of eye, dropping behind pectoral fin and continuing to tail near belly.[7] Dorsal fin extremely long, beginning over preopercular margin and occupying entire length of back; caudal and pelvic fins absent; anal fin consisting of very short spinous rays,[8] first 60 or so directed posteriorly, last 40 or so directed anteriorly;[10] pectoral fins small.[8]

Pigmentation: Uniformly bright[9] or glistening[7] silver; tips of jaws blackish; dorsal fin plain,[8] with dark margin,[7,8,10] pectoral fins plain, with dusky distal margins.[8]

Maximum size: To about 2337 mm.[18]

DISTRIBUTION AND ECOLOGY

Range: World-wide distribution,[10] except eastern Pacific,[16] in warm seas.[9] In western Atlantic north to Massachusetts, common from Chesapeake Bay south.[7]

Area distribution: Recorded from entire Chesapeake Bay[17] and specifically from Cape Charles City, Mobjack Bay, and Lynnhaven Roads, Virginia.[8]

Habitat and movements: Adults—benthopelagic; on continental shelf to 300–500 m;[19] enter estuaries during early winter in Australia;[6,18] modally abundant at 6.3–46 m off Louisiana in February–March, October–November, and May or June–July; migrate offshore in autumn.[13] Associated with salinities between 16 ppt and sea water.[17] During the day, it remains within bottom layers (80–140 m) while coming to the surface during the night.[20]

Larvae—pelagic.[2]

Juveniles—most abundant at depths from 27 to 46 m off Louisiana.[18] Reported to pass into bay nursery grounds during summer and to return to the Gulf of Mexico in the fall.[1]

SPAWNING

Location: Occurs offshore in the Gulf of Mexico at depths greater than 46 m.[13]

Season: Reported to spawn during summer months;[7] July–August in Japan;[2] May–October in northwest African waters;[20] April–August in East China Sea.[21]

Fecundity: Adult female carries 33,000–85,000 eggs.[9]

EGGS

Pelagic[8] "in middle layer of sea water"; 1.7–1.9 mm in diameter; egg membrane thin, transparent, colorless, without sculpturing; yolk slightly pink-yellow and transparent; one oil droplet 0.4 mm in diameter, copper-yellow; perivitelline space rather narrow.[2]

EGG DEVELOPMENT

After fertilization, protoplasmic part of egg passes to animal pole, and appears as rounded cap. First act of cleavage occurs at 1.5 hours after fertilization. Subsequent cell divisions form blastodermal cap and germ ring at 10–14 hours after fertilization. Embryonic shield appears at 36 hours after fertilization, and has advanced well beyond equatorial plane of the yolk. Notochord, optic vesicles, Kupffer's vesicle and 18–19 myomeres appear 48 hours after fertilization. Black pigment and 90 myomeres present 72 hours after fertilization; Kupffer's vesicle almost completely disappears; melanophores distributes irregularly on oil globule, head, and on dorsal and anal finfolds.[2]

YOLK-SAC LARVAE

Hatch at 5.5–6.5 mm and reach 7 mm in 3 days.

Total myomeres 106, 16 preanal, and 90 postanal; preanal part of body short; body slender; head rather small, with pointed snout; yolk mass relatively large at hatching, becoming reduced after 3 days;[2] oil globule in posterior part of yolk mass;[2,14,15] mouth not formed at hatching, large and functional after 3 days; pectoral fin evident at 7 mm (3 days); few short spines present in dorsal finfold at 7 mm (3 days); anus immediately behind yolk mass at hatching.[2]

Pigmentation: Transparent at hatching; dendritic melanophores of finfold concentrated at fin margins, one patch on center of dorsal finfold just posterior to midportion of body and another on ventral finfold slightly behind dorsal patch; melanophores on head and oil globule and in a series along lateral line.[2]

LARVAE

Specimens described 7.7 mm.

Body slender, compressed; head larger and organized; dorsal fin high, 3 spines present anteriorly, rays appearing in finfold; anal and pectoral fin rays appearing.

Pigmentation: Melanophores disappear except on head and the row along frontal part of dorsal side; silvery guanin begins to be deposited on body surface.[2]

JUVENILES

Specimens described 59–240 mm.

D. 128–141; A. 98–109; P. 10–11; vertebrae 39–42 + 124–133; 7–9 gill rakers on lower limb of first arch, becoming progressively shortened, embedded and indistinct with growth.

Head 6.1–7.9, depth 17.4–26.9, length to anal origin 2.0–3.3, dorsal base 1.2–1.4, anal base 1.7–1.9 in TL;

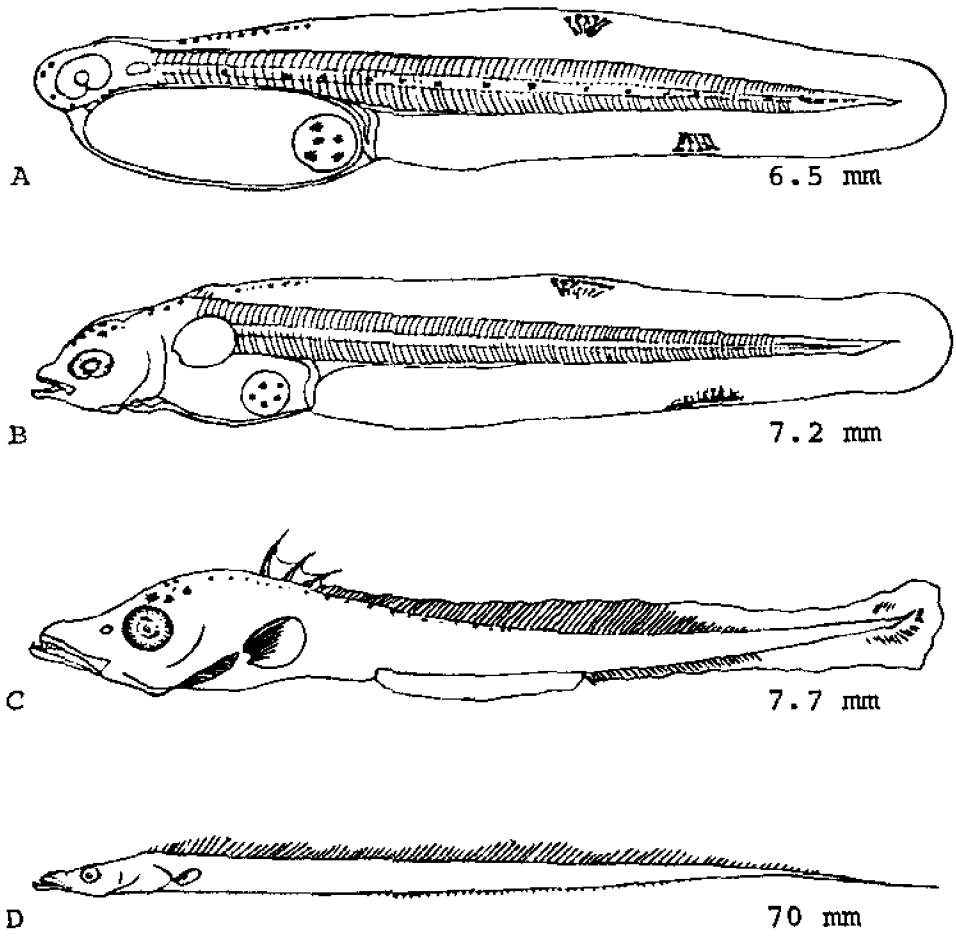

Fig. 22. *Trichiurus lepturus*, Atlantic cutlassfish. A. Newly hatched larva, 6.5 mm in length. B. Yolk-sac larva, 7.2 mm in length. C. Larva, 7.7 mm in length. D. Juvenile, 70 mm in length. (*A-D, Tsukahara, H., 1961: figs. E-H.*)

snout 3.0–4.0, eye 5–6.5, postorbital 1.7–2.2, interorbital 6.5–10.5, maxillary 3.0–4.3, longest dorsal ray 2.1–3.5 in head.[4]

Body band-like, tapering to pointed tail; head relatively small; mouth large, lower jaw projecting; teeth in each jaw, small teeth behind larger fang-like teeth; dorsal fin relatively high, first three spines degenerated and now shorter than following rays; anal fin reduced to series of short rays; caudal and pelvic fins never developed; pectoral fins small.[2]

Pigmentation: Body plain silvery;[2,11] black chromatophores present only on jaws.[11]

GROWTH

Reach a mean of 250 mm by end of first year; 400 mm by early in second year; and 700 mm by early in third year in the Gulf of Mexico.[13] Reported to reach 47 cm at 1 year; 84 cm at 2; 95 cm at 3; 105 cm at 4; 115 cm at 5; 120 cm at 6; 130 cm at 7; and 140 cm at 8 in northwest Africa.[20]

AGE AND SIZE AT MATURITY

Ten to 40% of population mature at 1 year, total population mature at 5 years.[21]

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Acanthocybium solanderi
Auxis sp.
Euthynnus alletteratus
Katsuwonus pelamis
Sarda sarda
Scomber japonicus
Scomber scombrus
Scomberomorus cavalla
Scomberomorus maculatus
Scomberomorus regalis
Thunnus alalunga
Thunnus albacares
Thunnus atlanticus
Thunnus obesus
Thunnus thynnus

mackerels and tunas
Scombridae

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FAMILY SCOMBRIDAE

The Scombridae include the fishes commonly called mackerels, bonitos, and tunas. These fishes range around the world in tropical and temperate seas, their distribution being regulated principally by the water temperature. The family contains about 14 genera and 42 species, with 15 species being found within the Mid-Atlantic Bight. Although descriptions of developmental stages are provided for all these species, only *Sarda*, *Scomber* and *Scomberomorus* are known to reproduce within this area.

The family is characterized by the body being streamlined and fusiform. The dorsal and anal fins are followed by a series of finlets. The scalation near the pectoral region is often modified into a "corselet." The caudal peduncle bears keels just in front of the caudal fin. The number of vertebrae is high for perciforms, with *Thunnus* having 39, *Katsuwonus* 41, and *Scomberomorus* 42–53.

The frigate or bullet mackerels, genus *Auxis*, are in a very confused state taxonomically. There are two commonly recognized species, namely *A. thazard* and *A. rochei*, however, current opinion is divided as to whether these are two separate or just one variable species. Also, it is not known for certain whether the Atlantic and Pacific *Auxis* are conspecific. Therefore, data are only included on Atlantic *Auxis*. There are two different types of larvae, however, and recent usage in designating these type I and type II has been followed.

The available literature on development of scombrids is far from complete even considering the commercial importance of such species as the skipjack and yellowfin tunas. The literature on the eggs and young of scombrids from 1880–1970 has been compiled in an excellent bibliography by Richards and Klawe (1972). Also, synopses of biological data on most scombrid species have been compiled and published by the Food and Agriculture Organization of the United Nations as a result of the World Scientific Meeting on the Biology of Tunas and Related Species held in La Jolla, California, from 2–14 July 1962.

Although the early stages of the tunas, genus *Thunnus*, have been described a number of times, the exact identity of the specimens has, until now, not been adequately determined. The recent paper by Matsumoto, *et al.* (1972) reviewed the literature and determined those larval descriptions that can be confirmed as being correct. Matsumoto, *et al.* (1972) and Richards and Potthoff (1974) have summarized the important characters used in identifying tuna larvae. These papers have pointed out that the position of red chromatophores (erythrophores), often used in the identification of tuna larvae, cannot be used in day-caught specimens because of the dispersed nature of these chromatophores.

Elbert H. Ahlstrom (pers. comm.) has provided the following characters for scombrid larvae:

1. Big headed and deep bodied.
2. Snout accentuated and may be prolonged (e.g., *Acanthocybium*).
3. Large jaws (WJR).
4. Pronounced preopercular spines in all but *Scomber*.
5. Usually a marked space between the anus and origin of anal fin.
6. Triangular-shaped gut on most except *Scomber* and *Acanthocybium* (WJR).

Fin formation is characteristic for scombrid larvae.

1. Caudal fin always first to form and has 9+8 principal rays.
2. Pelvic fin always I, 5. Time of formation depends upon formation of first dorsal. If first dorsal forms before second then pelvics form at same time. *Acanthocybium* has delayed formation of pelvic fins.
3. Pectoral fin forms rays fairly early (e.g., *Scomber*), but lags in those with first dorsal forming early (e.g., *Thunnus*). The number of pectoral rays is an important character since *Scomber* has 19–21, *Acanthocybium* has 23, *Auxis* has 23–25, and *Euthynnus* has 21–28.
4. Primitive condition is for second dorsal fin to form before first. Posteriormost spines in the first dorsal may be short and hard to see.
5. First dorsal forms before second in all but *Scomber* and *Rastrelliger* (WJR) and Richards and Potthoff (1974).

Tables 1–3 are adapted from Matsumoto, *et al.* (1972) and Potthoff (1974) and are provided as an aid for determining the identity of *Thunnus* larvae.

TABLE 1.—Characters to separate larvae of *Thunnus albacares* and *Thunnus alalunga* at sizes greater than 10 mm SL (adapted from Matsumoto, *et al.*, 1972).

Characters	*T. albacares*	*T. alalunga*
Array of [1]D_2 pterygiophores between two adjacent neural spines	1, 2, 2, 2, 3, 2, 1, 1	1, 1, 2, 2, 2, 3, 2, 1
Position of first haemal arch (vertebra number)	11th	10th

[1] D_2 refers to second dorsal fin.

TABLE 2.—Comparison of diagnostic characters for the juvenile *Thunnus* species. Parentheses indicate rare occurrence (adapted from Potthoff, 1974).

Character	*T. thynnus*	No.	%	*T. alalunga*	No.	%	*T. atlanticus*	No.	%	*Thunnus* spp.	No.	%
Number of vertebrae, precaudal and caudal	18 + 21 = 39	149	95	18 + 21 = 39	114	97	19 + 20 = 39	105	98	18 + 21 = 39	35	85
	16–19 + 20–22 = 36–40	8	5	19 + 20 = 39	4	3	18, 19 + 19, 21 = 38, 39	2	2	17, 19 + 21, 22 = 39, 40	6	15
First haemal arch on vertebra number	10	137	88	10	115	99	11	101	94	11	38	93
	11, (9)	19	12	(9)	1	1	12, (10)	6	6	10, 12	3	7
Pattern of single second dorsal fin pterygiophores for interneural spaces [1]	1,1, — — — — — 1,1	140	95	1.1.1.— — — — — 1	116	100	1.1.1.— — — — — 1	42	46	1,1 — — — — — 1,1	40	98
	1,1, — — — — — — 1	8	5				1,1 — — — — — 1	32	35	1.1.1.— — — — — 1	1	2
							1,1 — — — — — 1,1	18	19			
Pattern of single anal fin pterygiophores for interneural spaces	— — — — — 1,1	116	84	— — — — — 1,1	74	66	— — — — — 1	55	61	— — — — 1,1,1	31	78
	— — 1 — — 1,1 — — — — 1,1,1	23	16	— — 1 — — 1,1	38	34	— — — — 1,1	34	38	— — — — — 1,1	9	22
Gill raker number over ceratobranchial bone	17,18,(19,20)	102		14,15,(16)	81		11,12,(13)	92		14,15,16	27	

[1] The pattern of 2nd dorsal fin pterygiophores for interneural spaces differs from that expressed in Matsumoto *et al.* (1972) because a slightly different method of counting was used. For a description of the method consult Potthoff (1974). He positions the 2nd dorsal fin 1 interneural space anterior to that expressed by Matsumoto *et al.* (1972).

TABLE 3.—Characters to separate larvae of *Thunnus* in size range of 3–10 mm SL (adapted from Matsumoto *et al.*, 1972).

Characters:	*T. albacares*	*T. alalunga*	*T. thynnus* (Atlantic)	*T. thynnus* (Pacific)	*T. obesus*
Black pigmentation: (number of cells)					
Upper jaw	Appears at 5.8 mm SL, mostly after 6.0 mm SL	Appears at about 5 mm SL	No observation	Appears above 6 mm SL	Appears above 5 mm SL
Lower jaw	Appears at 4.5–6.0 mm SL	Appears at 9–10 mm SL			
	At tip on inner edge; migrate to outer edge with further growth	At tip on outer edge	2 on inner edge	2 on inner edge above 4 mm SL	0–2 cells on inner edge below 4 mm SL
Dorsal edge trunk	None	None	1 or 2	1 or 2	None
Lateral line	None	None	0–2 near mid-trunk	None	None
Ventral edge trunk	None	None	1–4	2 or more	1 or more
Red pigmentation (number of cells)					
Dorsal edge trunk	0, 1, 2, (3) [mean = 0.6] near caudal peduncle	2, 3, (4) [mean = 2.6] from caudal peduncle to mid-second dorsal fin base	Streak on caudal peduncle [1]	1–5, mostly 33	0, 1, (2)
Lateral line	(0), 1, 2, 3, 4, (5) [mean = 2.4]	(2), 3, 4, (5) [mean = 3.5]	Indistinct [1]	Number not available	0, 1, 2, 3, 4
Ventral edge trunk	3–12 [mean = 7.0]	5–12 [mean = 8.0]	Streak anus to caudal peduncle [1]	Number not available	1–8 mean = 5.3
Lower jaw ventral view	No observation	No observation	Streak along margin anterior half of jaw and midline [1]	2 well spaced on anterior half	1 on each side near tip

[1] Only one larva taken in a day tow was examined.

Acanthocybium solandri (Cuvier), Wahoo

ADULTS

D. XVII, 12[1,3]–14[1]+9;[1,3] A. 12[1]–13+9;[1,3] C. 9+8 (RAF); P. 23; V. I, 5;[5] vertebrae 31–33+30–34=62–66;[1] gill rakers absent; teeth in jaws close-set, slightly serrated, increasing in size posteriorly, 40–45 in lower jaw, 45–50 in upper;[5] teeth present on vomer, palatines, and tongue.[4]

Head 4.0–4.3, depth 6.2–6.8, caudal fin 8.4–9.5 in SL. Eye 9.2–9.8, snout 1.9–2.1, pectoral fin 1.9–2.2, caudal fin 1.9–2.2 in head.[5]

Body elongate and cigar-shaped; head very long and slender; snout long, beak-like; maxillary extending below anterior edge of eye. Scales small, narrow, rhomboidal, elongated and lanceolate at bases of vertical fins.[5] Two distinct lateral lines, upper one begins at opercle and runs along dorsal half of body to caudal peduncle, lower one branches from upper below dorsal fin and descends sharply to run posteriorly to join upper lateral line.[4] First dorsal fin high, with well-developed, subequal spines; second dorsal fin small; pectoral fins originating little anterior to dorsal fin; pelvic fins small, thoracic; caudal fin short, lunate. Preopercular edge slightly serrated.[5]

Pigmentation: Steel-blue above; paler ventrally; sides with 25–30 faint vertical bars. Anterior dorsal fin similar to body in color, but paler; second dorsal, pectoral and caudal fins blackish; pelvic and anal fins dusky.[5]

Maximum size: To 211 cm and 60.6 kg.[9]

DISTRIBUTION AND ECOLOGY

Range: Circumtropical;[1,5,8,12] in western Atlantic from New Jersey and Bermuda to Columbia and throughout Gulf of Mexico.[11]

Area distribution: Throughout the Mid-Atlantic Bight.[11]

Habitat and movements: Adults—oceanic and pelagic;[5] abundant in Hawaii in summer,[1] southern Florida in winter, and Bermuda in September and October;[7] prefer shallow depths close to shore.[8]

Larvae—pelagic; between 30° N to 25° S and 175° E to 115° W in Pacific Ocean;[1] recorded in salinities from 36.0–38.5 ppt and 27–29.3 C in Florida straits; prefer waters less than 100 m.[6]

Juveniles—no information.

SPAWNING

Near Cuba, Straits of Yucatan and Florida, from May to October, peaking in June.[6]

Fecundity: Female of 131 cm with 6.1 million eggs.[8]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Specimens described 2.8–17.8 mm SL.[1]

D. (Atlantic) I, 4 at 6.9 mm; V, 16 at 9.4 mm; IX, 16 at 10.0 mm;[6] (Pacific) II, 4 at 6.8 mm; XXVIII by 13.2 mm; 23 rays at 17.8 mm.[1] A. (Atlantic) 2 at 5.9 mm, 8 at 6.9 mm, 14 at 9.4 mm. C. (Atlantic) 2+3 at 5.9 mm, 5+3 at 6.57 mm, 5+6 at 6.9 mm, 6+6 at 8.3 mm, 9+8 at 8.88 mm;[6] (Pacific) 0+3+3+0 at 5.8 mm, 9+9+8+9 at 17.8 mm. P. (Pacific) 4 at 6.6 mm, 19 by 17.8 mm. V. (Pacific) buds at 6.8–9.2 mm; I, 5 by 13.2 mm.[1] Total myomeres (Atlantic) 61–64;[6] (Pacific) 63–65, preanal 26–30, postanal 32–39.[1] Branchiostegals (Pacific) 1 at 5.2 mm increasing to 7 by 7.6–8.4 mm; (Atlantic) 1 by 5.9 mm, 7 by 6.9 mm. Preopercular spines 2 at 4.86 mm, 3 at 6.57 mm, 4 at 6.9 mm, 5 at 7.16 mm, 6 at 9.4 mm. Teeth on upper jaw (Atlantic) 5 at 4.54, 34 at 9.4 mm;[6] (Pacific) 7 at 4.5 mm, 28 at 17.8 mm.[1] Teeth in lower jaw (Atlantic) 4 at 4.54 mm, 32 at 9.4 mm;[6] (Pacific) 8 at 4.5 mm, 24 at 17.8 mm.[1]

Nostrils form at 10.7–13.2 mm. For sequence of ossification see Table 4. First dorsal fin base forming at 6.2 mm; first dorsal spines form anteriorly at 6.8 mm, all spines present by 13.2 mm; concavity in fin after 5–9 spines are formed. Second dorsal fin base appears at 5.8 mm; first rays form in middle of fin; last finlet formed after formation of all second dorsal fin rays. Anal fin ossification simultaneous with second dorsal. Caudal flexion in larvae less than 6.8 mm; principal rays form first from middle outwards; secondary rays appear at 8.4 mm and complete by 23.7 mm. Pectoral fins formed by 2.8 mm, membrane large and fan-shaped; rays develop from dorsal to ventral. Pelvic fins last to develop; buds at 6.8–9.0 mm. Vertebrae first appear as ossified neural spines at 6.7 mm, all spines and centra

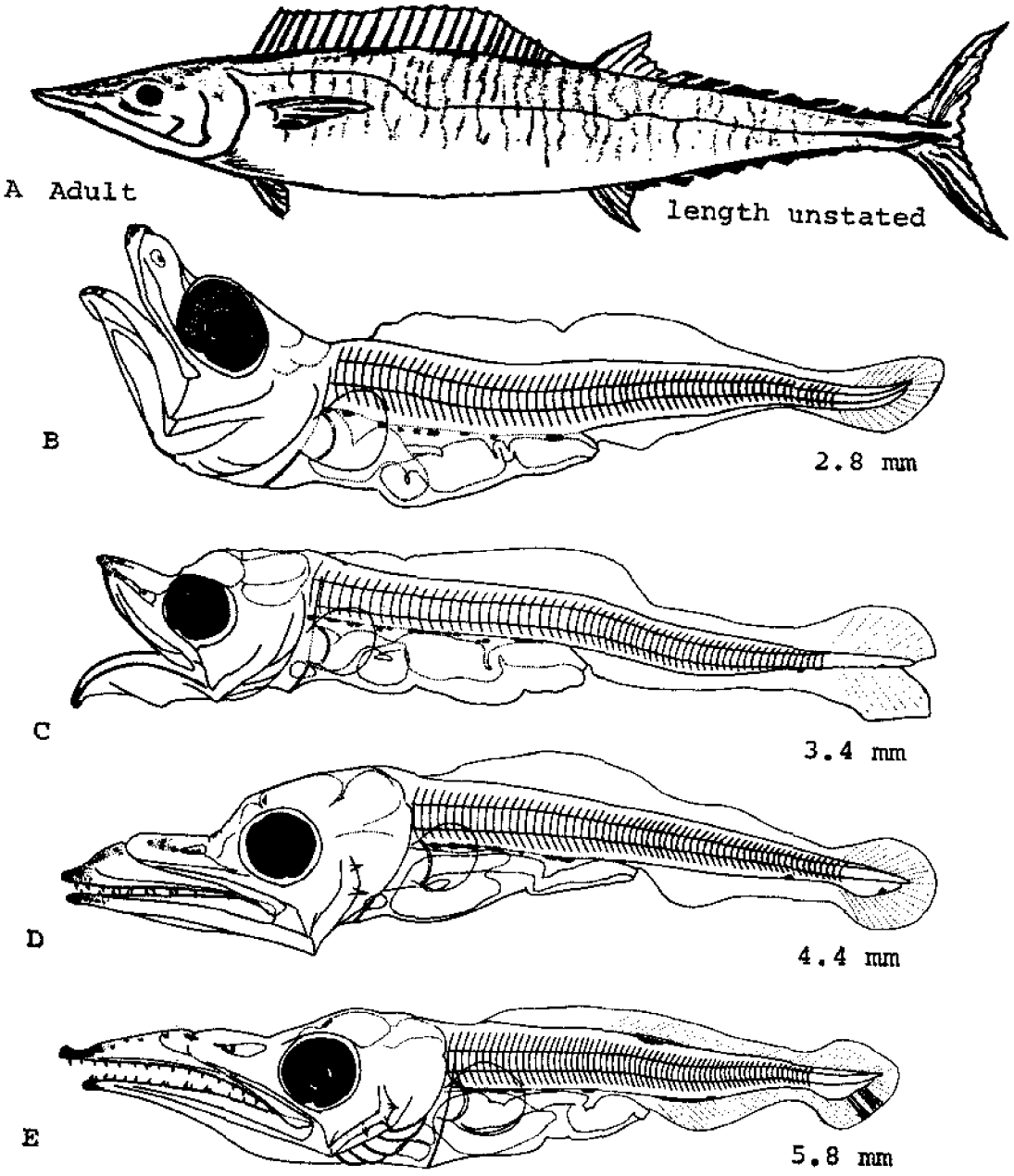

Fig. 23. *Acanthocybium solandri*, Wahoo. A. Adult, length unstated. B. Larva, 2.8 mm. C. Larva, 3.4 mm. D. Larva, 4.4 mm. E. Larva, 5.8 mm. (*A, Collette, B. B., and R. H. Gibbs, Jr., 1963: pl. 7. B-E, Matsumoto, W. M., 1968: fig. 2.*)

ossified by 17.5 mm, sequence of development from anterior to posterior. Urostyle first develops at about 8 mm and completely ossified by 13 mm. Anus situated between 26th and 29th myomeres, near origin of anal fin.[6]

Pigmentation: Atlantic—midbrain pigmentation appears at about 7 mm; chromatophores appear on cartilaginous pad at mandibular symphysis at about 4.8 mm; first dorsal fin pigmentation appears before 10 mm.[6]

Pacific—midbrain area remains unpigmented in larvae smaller than 4.4 mm. Single melanophore present on anterior portion of midbrain between 4.4–5.5 mm; six present at 10.7 mm; and about 27 in larvae up to 13.2 mm. Single melanophore on forebrain in larvae about 7.4 mm and number increases to only 4 or 5 in larvae up to 17.8 mm. Lateral pigmentation on posterior part of head lacking in larvae up to 13.2 mm but 50 small melanophores appear at about 17.8 mm. Snout pigmentation in two areas: near primordial nasal cavity and tip of lower jaw. Pigmentation in primordial nasal cavity develops slowly as nostrils form, few melanophores appear on surface between anterior and posterior nostrils, no more than 13–15 present in 13.2 mm larva. Number of melanophores increases slowly on anterior portion of upper jaw up to 4.3 mm; pigmentation increases rapidly so that by 6.8 mm 2–3 rows of 18–25 melanophores present, entire surface covered with melanophores at 13.2 mm and longer. Additional melanophores develop posteriorly on snout and by 17.8 mm all snout and jaw pigment merges into single large area. Tip of lower jaw has few melanophores at 2.8 mm, number increases to 7 or 8 by 8.4 mm. Lower jaw pigmentation confined to cartilaginous projection in larvae over 10.7 mm. Preanal trunk region free of dermal pigment until 10.7 mm. Internal pigment in dorsal part of abdominal cavity consisting of 7–10 large spots at 8.4 mm, spreading to ventral third of digestive track by 10.7 mm. Wide band of melanophores over lower half of body below pectoral fin at 17.8 mm. Postanal pigment confined to one melanophore at 4.4 mm, but some with 2–3 melanophores on ventral midline on caudal peduncle and small melanophore ventral to posterior end of notochord. Melanophore at caudal peduncle migrates to anal fin base by 5.8–6.2 mm. Anal fin with fine granules of pigment formed on base by 6.8 mm, replaced by series of evenly spaced melanophores by 10.7 mm. Fin pigmentation not extensive; pectoral, ventral, and caudal unpigmented; first dorsal with first five interspinous membranes pigmented at 13.2 mm, 8 by 17.8 mm. Finlets with basal pigmentation at 17.8 mm.[1]

JUVENILES

Specimens described 23.7 mm[2]–159 mm SL.[1]

D. XXVII, 24; A. 22; C. 17; P. 23; V. I, 5; branchiostegals 7; 28 teeth on each dentary and 25 on each premaxillary. Gill filaments J-shaped, not yet fused; anterior margins of preopercle bears short spine at angle and another on lower limb; posterior margin of preopercle with 2 short spines on upper limb, long spine at angle and 5 irregular spines on lower limb; pterotic with 2 small spines on posterior tip.[2]

Pigmentation: At 23.7 mm body dusted with tiny melanophores giving a uniform tan color, except dark brown pigment on dorsal part of snout.[2] At 27 mm, 20 transverse bands on body, those in precaudal region fade away near ventral median line.[9]

GROWTH

Increasing by 3–4 cm per month in individuals over 96–105 cm.[7]

AGE AND SIZE AT MATURITY

No information.

TABLE 4.—Sequence of ossification of bones of wahoo larvae.[1]

Body part	Fish length at start	Fish length at finish
	Mm	*Mm*
Cleithrum	2.8	3.1
Parasphenoid	2.8	3.1
Maxillary	3.1	3.1
Dentary	3.1	3.8
Gill arch	3.4	6.8
Premaxillary	3.8	4.5
Teeth—upper jaw	4.1	....
Preopercular spines	4.1	....
Teeth—lower jaw	4.2	....
Preopercle	4.3	....
Articular	4.3	4.5
Palatine	4.3	8.4
Vomer	4.5	8.4
Palatine teeth	4.6	13.2
Branchiostegal rays	5.2	8.4
Parietal	5.7	10.7
Frontal	5.7	17.8
Caudal fin (principal rays)	5.8	8.4
Pectoral fin	6.6	23.7
Second dorsal fin and finlets	6.6	10.2
Anal fin and finlets	6.6	13.2
Vertebrae	6.8	17.8
First dorsal fin	6.8	13.2
Vomerine teeth	8.4	....
Caudal fin (secondary rays)	8.4	<23.7
Pelvic fin	10.2	13.2
Opercle	<13.2	....
Supraoccipital crest	13.2	>23.7

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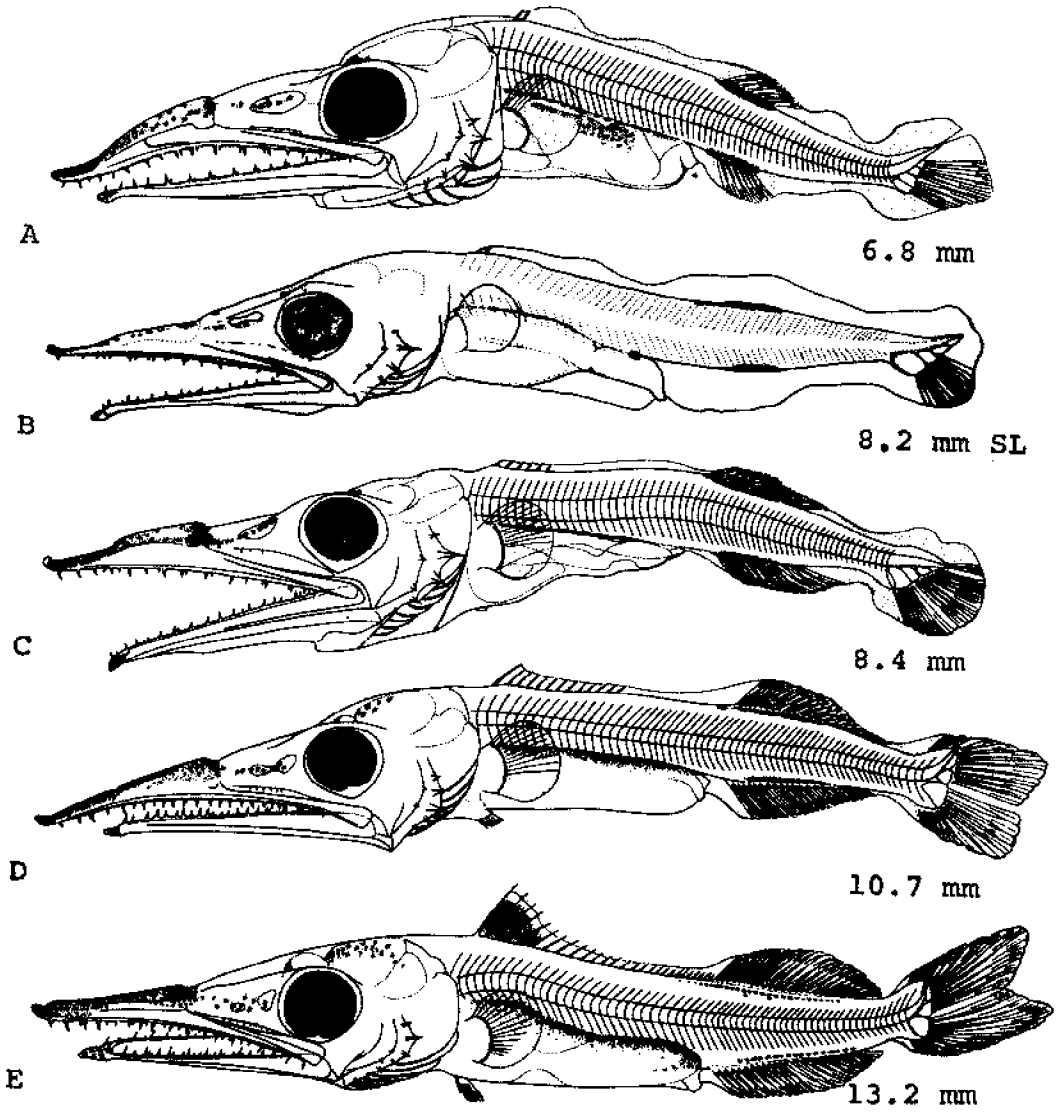

Fig. 24. *Acanthocybium solandri*, Wahoo. A. Larva, 6.8 mm. B. Larva, 8.2 mm SL. C. Larva, 8.4 mm. D. Larva, 10.7 mm. E. Larva, 13.2 mm. (*A, C-E, Matsumoto, W. M., 1968: fig. 3. B, Wollam, M. B., 1969: fig. 2.*)

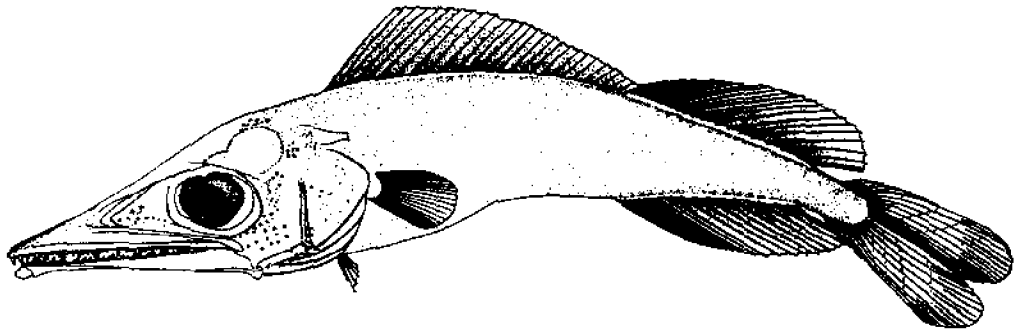

Fig. 25. *Acanthocybium solandri*, Wahoo. A. Juvenile, 23.7 mm SL. (*A, Strasburg, D. W., 1964: fig. 2.*)

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Auxis sp., Frigate or Bullet mackerel

ADULTS

D. IX [18] to XI,[5,9,22] 10 [5]–12 [5,9,22] + 8–9; A. 12 [5]–14 + 7–8; C. 13 + 9 + 8 + 11; [22] P. 20–30; [5] V. I, 5; [9] branchiostegals 7; [20] scales present only on anterior corselet, either up to 5 scales wide under second dorsal fin origin or 6–20; [16] vertebrae 20 + 19 = 39; [22] gill rakers finely lanceolate [17] 8–10 + 1 [2] + 29–36 [16] = 37 [1,10]–44; [2] teeth on jaws small, conical,[5] occasionally on vomer.[21]

Head 3.3–4, depth 4–4.5 in SL. Snout 4–4.3, eye 5.2–5.5, maxillary 3, interorbital 3.8–4 in HL.[17]

Body robust,[5,17] fusiform, moderately compressed; [17] head large; snout short, pointed,[5] conic; mouth moderate, lower jaw slightly protruding; maxillary reaching opposite center of eye.[17] Dorsal fins broadly separated; [1] spinous dorsal fin origin little behind pectorals, triangular; origin of anal fin posterior to second dorsal; pectoral

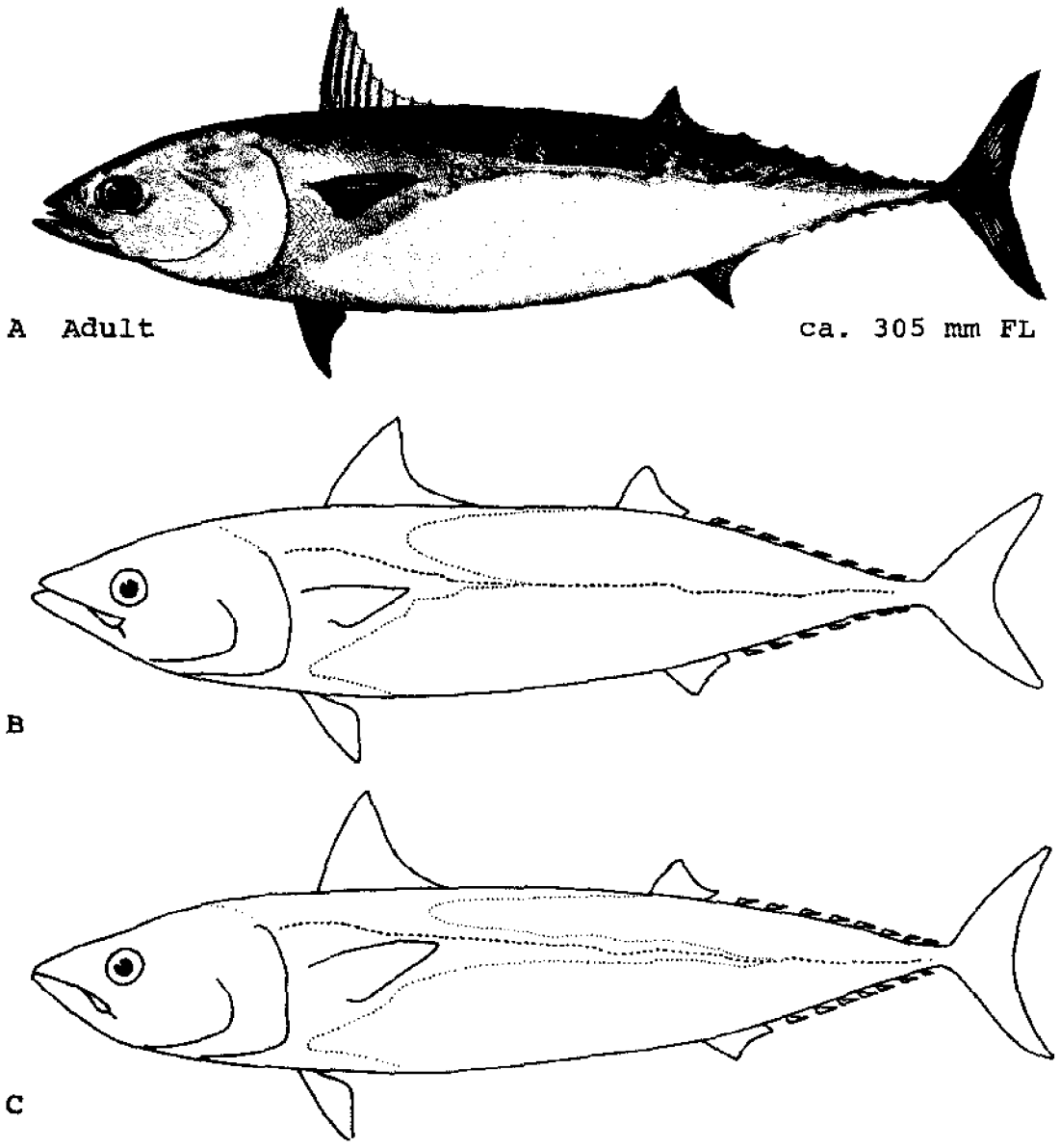

Fig. 28. *Auxis* sp., Frigate or Bullet mackerel. A. Adult, ca. 305 mm FL. B-C. Two forms of frigate mackerel showing difference in corselet. *(A, Goode, G. B., 1884: pl. 92. B-C, Matsumoto, W. M., 1959: fig. 18.)*

fins small,[5] pointed, ending posteriorly under scaleless area above corselet or not; [16] pelvic fins smaller than pectorals; [5] caudal fin small,[5,17] forked.[17] Interpelvic process single, long; [4] caudal peduncle short,[5,17] slender, depressed; [17] interorbital with median depression; [5,17] eye round.[5]

Pigmentation: Bluish above, very deep purple, almost black, *on upper part of head; oblique dark bars and* stripes on dorsum; silvery white below; several large, *regular dark blotches anteriorly; pectoral and pelvic fins* purple, black on inner side; pectoral is paler on outer side; white ventrally.[16]

Maximum size: To 50 cm.[9]

DISTRIBUTION AND ECOLOGY

Range: Cosmopolitan in tropical and subtropical waters of Atlantic and in Mediterranean and Black seas.[16] In western Atlantic from Barnstable, Massachusetts [24] to *Brazil* including Caribbean Sea, Bahamas and Gulf of Mexico,[16] occurrence along western Atlantic coasts very *erratic.*[23]

Area distribution: Entire Mid-Atlantic Bight; [16,24] specifically recorded from 3.7 km off of New Jersey shore.[19]

Habitat and movements: Adults—pelagic; [5,20] straying *near coasts;* [12] *highly migratory, with tendency to school,* often found in mixed schools with other small-sized tunas and tuna-like species; [16] (eastern Atlantic) 25.40–36.35 ppt and 14–22 C.[5]

Larvae—usually found offshore,[5,14] 19–167 km from land in eastern Pacific,[14] but also captured in middle of Atlantic; [2] 30 (New Jersey) [19]–35.35 ppt (Gulf of Guinea); [13] 17.5 (New Jersey) [19]–26 C (Gulf of Guinea).[13]

Juveniles—no information.

SPAWNING

Location: Restricted to coastal regions and gulfs,[12] 15–30 km east of Miami [11] and 2–10 km east of western edge of Florida Current; data suggest onshore movement of spawning population as season progresses.

Season: Females with ripe eggs found in eastern Atlantic during February–April, June, September–October and in western Atlantic during March–April; [6] eggs collected June–September near Greece,[9] and in Florida Current.[11]

Fecundity: Females 360–455 mm FL release 56,000–148,000 eggs.[9]

EGGS

Unfertilized eggs: Spherical 1.10 mm in diameter, transparent and yellowish.[15]

Fertilized eggs: Pelagic; spherical; transparent; [9] type I 0.82–0.88 mm ($\bar{x}$=0.85, n=8), type II 0.84–0.9 mm ($\bar{x}$=0.88, n=6) diameter [11] to 1.10 mm diameter; egg membrane either unsculptured [9] or with "special" sculpturing; [15] yolk homogeneous; [9,15] oil droplet single or with 1–5 smaller droplets, located at vegetative pole,[15] type I 0.24–0.25 mm ($\bar{x}$=0.24) and type II 0.24–0.29 mm ($\bar{x}$=0.26) diameter; [11] perivitelline space very small.[15]

EGG DEVELOPMENT

Type I—green chromatophores scattered over anterior portion of embryo; melanin occurs in 2 dorsolateral rows of spots on embryo and in 6–14 stellate or granular bodies on dorsal surface of oil globule.[11]

Type II—green chromatophores in more definite pattern; melanophore pigment identical with type I.[11]

Hatching occurs in 2 1/2 days; [15] between 1600–0300 hours at 27 C.[11]

YOLK-SAC LARVAE

About 2.0–2.5 mm at hatching, yolk absorbed by 4.2 mm.

Total myomeres 34–39; [11] teeth present with some straight and some recurved; [3] opercular spines 0–1.[11]

Snout-vent length 37–50% body length.[12]

Head slightly deflected; yolk mass large at hatching,[15] absorbed in 150 hours (4.2 mm); [11] oil globule posterior in yolk; mouth not open at hatching; eye and auditory vesicles well-developed at hatching; [15] caudal fin hypurals with some rays by 3 mm; [8] dorsal finfold originates at level of yolk sac.[15]

Pigmentation: Type I—at 3–6 hours after hatching, granular, yellow-green chromatophores along anterior dorsal third of dorsal finfold, on yolk, and on posterior surface of intestine; some individual variation in location and number of granules; however, posterior portion of trunk lacks chromatophores; chromatophore granules persist through yolk absorption; melanophores distinct along ventral midline of trunk; 8–25 ventral melanin spots and melanin present on yolk sac, oil globule, snout, and around optic cups.[11]

Type II—patches of green pigment above posterior portion of trunk in finfold; melanophore pattern identical to type I.[11]

LARVAE

Specimens described 4.2 mm [11]–12.77 mm FL.[14]

D. VII, 19 at 8.74 mm FL; VIII, VII, 12+8 at 10.53 mm FL. A. 18 at 8.74 mm FL; 13+8 at 10.53 mm FL; [14] 12+7 at 12 mm. P. I, 6 [8] (?, RAF). Total myomeres 37-

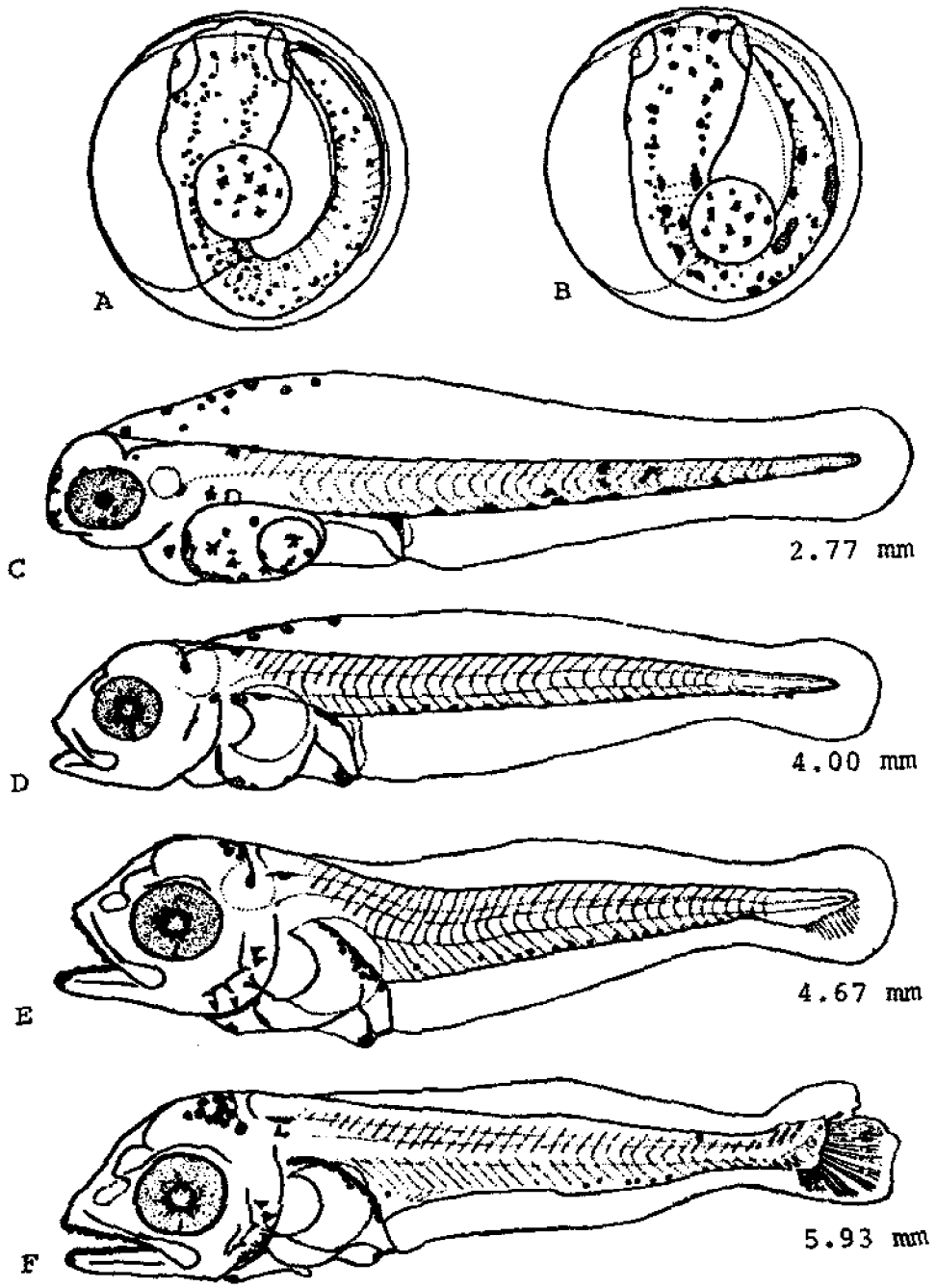

Fig. 27. *Auxis* sp., Frigate or Bullet mackerel. A. Egg type I, 0.85 mm diameter. B. Egg type II, 0.88 mm diameter. C. Yolk-sac larva type I, 2.77 mm. D. Yolk-sac larva type II, 4.00 mm. Spots indicate colored chromatophores. E. Larva type I, 4.67 mm. F. Larva type II, 5.93 mm. *(A-F, Mayo, C. A., 1973: figs. 2b-c, 6a-d, used with the permission of the author.)*

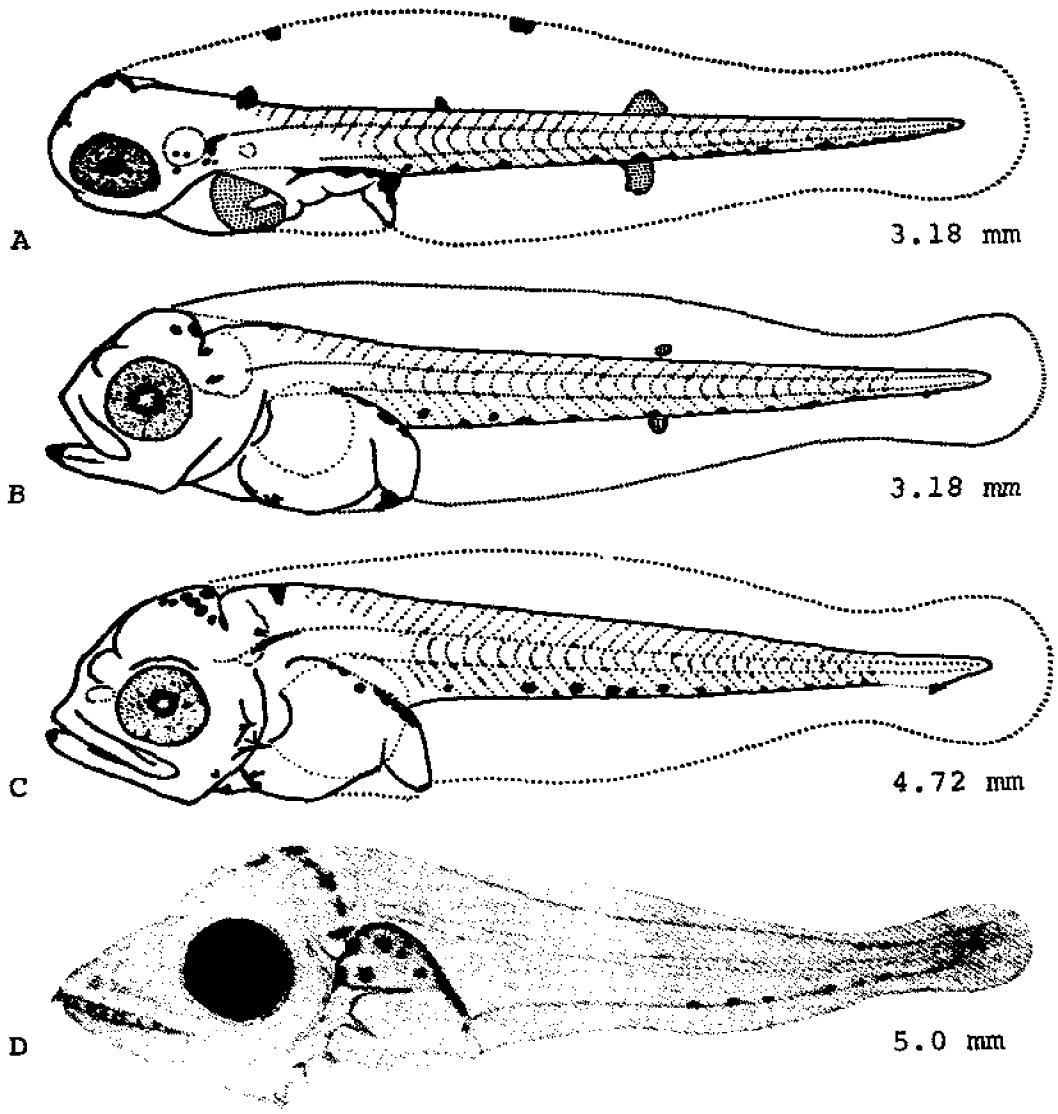

Fig. 28. *Auxis* sp., Frigate or Bullet mackerel. A. Yolk-sac larva type II, 3.18 mm. B. Yolk-sac larva type II, 3.18 mm. Spots indicate colored chromatophores. C. Larva type II, 4.72 mm. D. Larva type II, 5.0 mm. (*A-C, Mayo, C. A., 1973: fig. 7a-c, used with the permission of the author. D, Ehrenbaum, E., 1924: fig. 8g.*)

40.[11] *Preopercular spines* 7 at 8.74 mm FL;[14] 3 at 12 mm;[8] 10 at 17.5 mm.[10] Opercular spines 1–7.[11] Nuchal spines 2 at 8.74 mm FL.[14]

Snout-vent length 39–51% BL.[11]

Body generally elongate; head small; snout short, not prolonged into beak;[14] nostrils separated by 12 mm;[8] ray buds formed in dorsal, anal, and pelvic fins by 6.0 mm;[11] pelvic fins well formed at 8.74 mm FL;[14] notochord flexion begins at 4.5 mm and is complete at 6.4 mm.[11]

Pigmentation: Type I—at 4–8 mm, pigment cells on ventral margin decrease in number (from 15–25 to 5–15) and size; thereafter again proliferating and becoming larger and more stellate. Melanophores on dorsal margin of trunk first appear at 5.93 mm and thereafter proliferate. Caudal spot poorly defined and may be present or absent in specimens longer than 3.1 mm. Pigmentation of midbrain begins as lateral melanophore in commissure between mid- and hindbrain at 3.8 mm. At 4.3–6.5 mm, 1–20 melanophores situated only on posterior half of midbrain. Midbrain pigment proliferates and spreads forward from original melanophore on posterior portion of

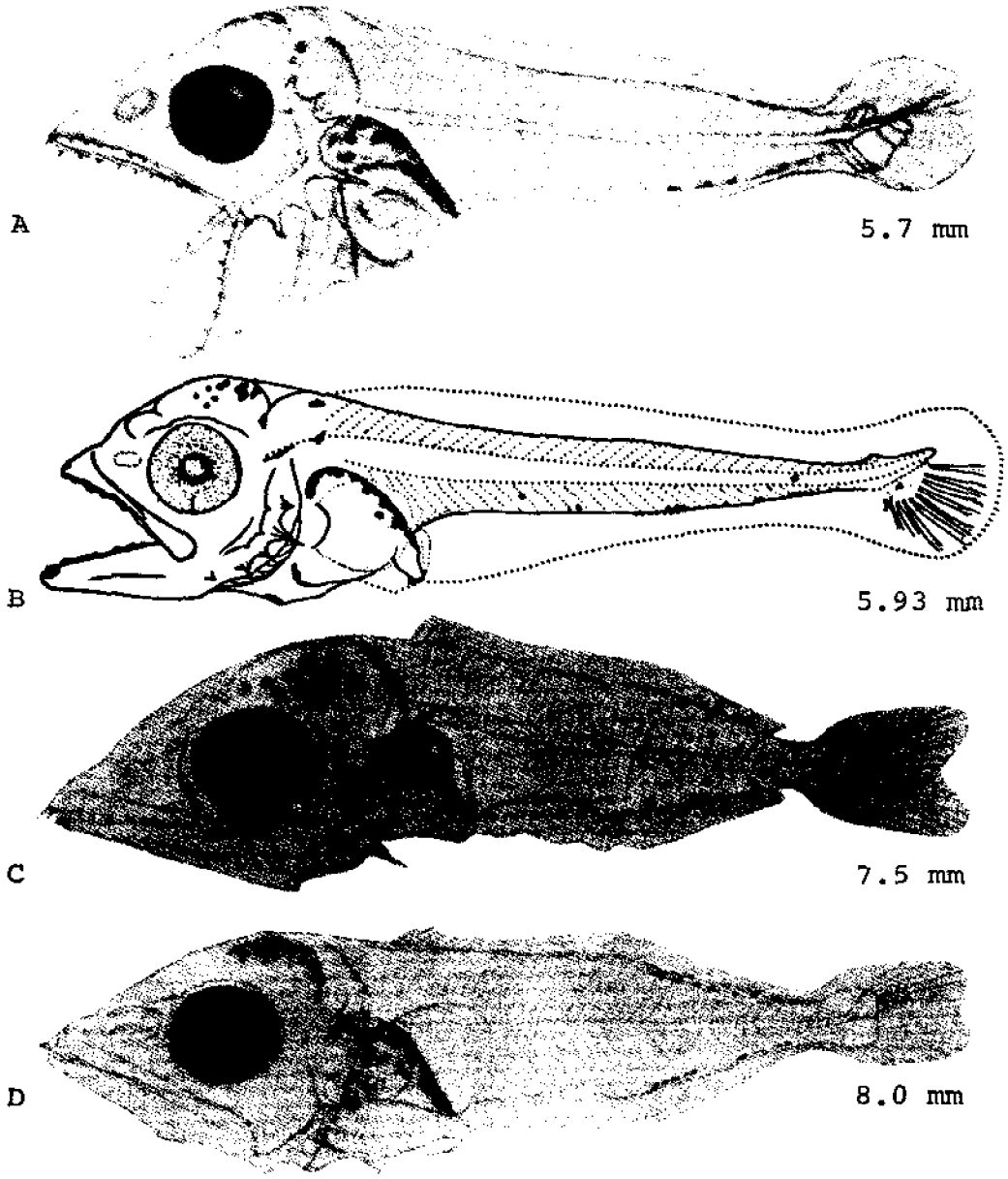

Fig. 29. *Auxis* sp., Frigate or Bullet mackerel. A. Larva type II, 5.7 mm. B. Larva type II, 5.93 mm. C. Larva, 7.5 mm. D. Larva, 8.0 mm. *(A, C-D, Ehrenbaum, E., 1924: figs. 8e (reversed)-f. B, Mayo, C. A., 1973: fig. 6d, used with the permission of the author.)*

midbrain. Hindbrain melanophore in specimens 3.8–6.0 mm arises from small granules on dorsal part of notochord and may be paired and laterally oriented, or single and on dorsal midline. Hindbrain pigment visible through nape tissues in specimens up to 8.9 mm. Tip of lower jaw pigmented by 4.5 mm and lower jaw at 5.5 mm. Increase in number of melanophores on upper and lower jaws first occurs at 7.5 mm. Melanin present on cleithral symphysis in specimens over 4.3 mm. Preanal finfold pigmented in specimens over 4.0 mm.

Type II—melanophore pattern identical to type I. However, 1 or 2 well-developed caudal melanophores present from 4.5–6.0 mm and lateral stellate melanophores present on trunk from 5.73–5.89.[11]

At 8.74 mm FL—2 chromatophores at tip of mandible; 5 behind eye; small group on opercle; and 1 at cleithral symphysis; 18 along dorsal fin base; 10 along anal base; 5 along median line below dorsal finlets and 3 at caudal fin base; dorsal part of visceral mass pigmented; few

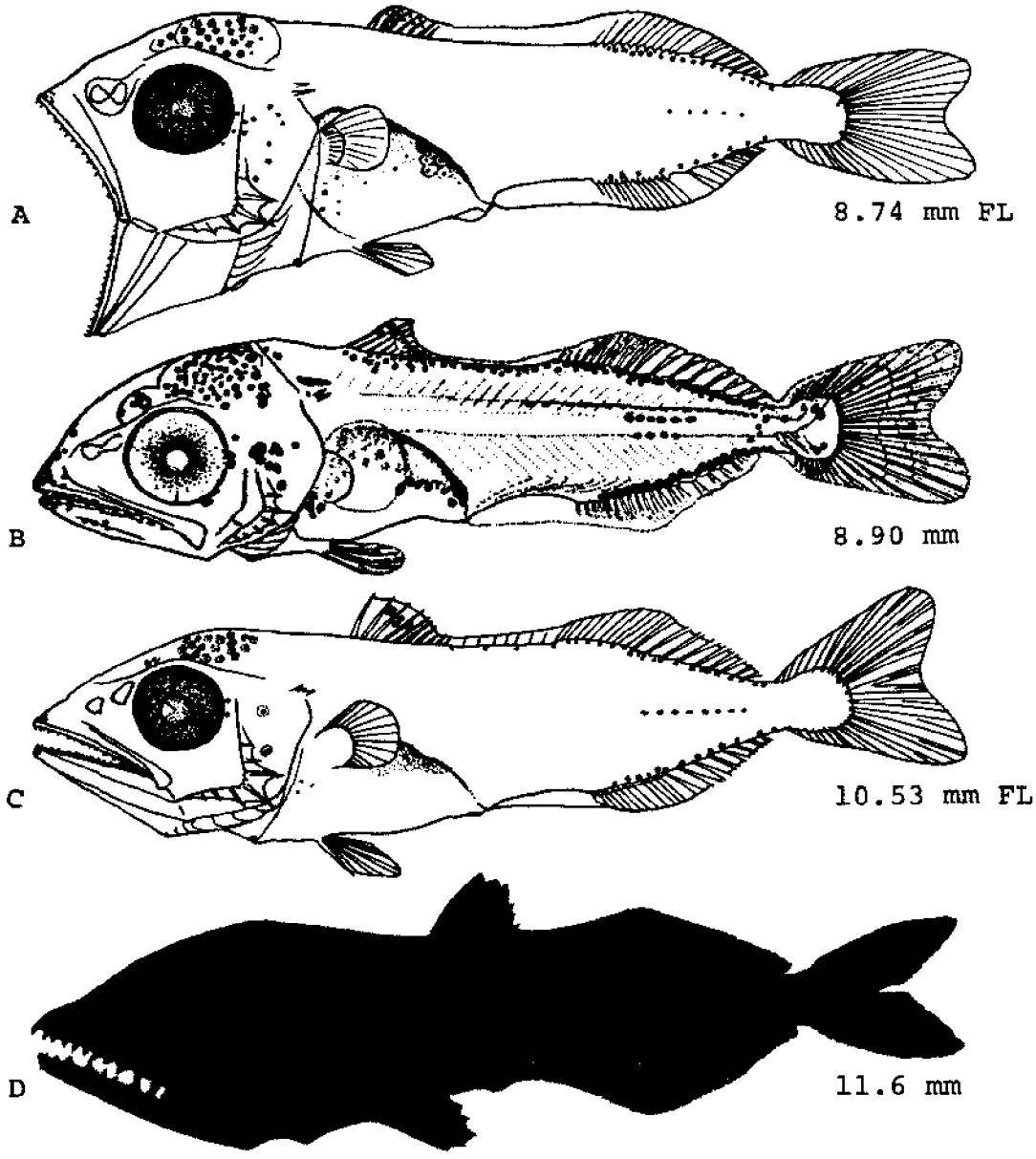

Fig. 30. *Auxis* sp., Frigate or Bullet mackerel. A. Larva, 8.74 mm FL. B. Larva, 8.90 mm. C. Larva, 10.53 mm FL. D. Larva, 11.6 mm. (*A, C, Marchal, E., 1963c: figs. 17–18. B, Mayo, C. A., 1973: fig. 8d, used with permission of the author. D, Ehrenbaum, E., 1924: fig. 8c.*)

pigment spots anterior in first dorsal fin.

At 12.77 mm FL—2 chromatophores on caudal peduncle; 22 along base of second dorsal fin; 15 between spinous and soft dorsal fins; 3 along base of spinous dorsal fin; 1 at caudal fin base; 3 on inferior caudal peduncle; 14 under anal fin and finlets; 7 along median line; 2 at cleithral symphysis; 12 on first dorsal fin between 2nd and 7th rays.[14]

JUVENILES

Specimens described 16.32–56.7 mm FL.

D. X to XI, VI, 13–14+8; A. 14+7; P. 24; gill rakers 10+1+33 at 56.7 mm FL,[14] full complement attained at about 40 mm; [7] preopercular spines 3 at 23.69 mm FL; nuchal spines remain visible.

Body generally elongate, becoming fusiform by 56.7 mm

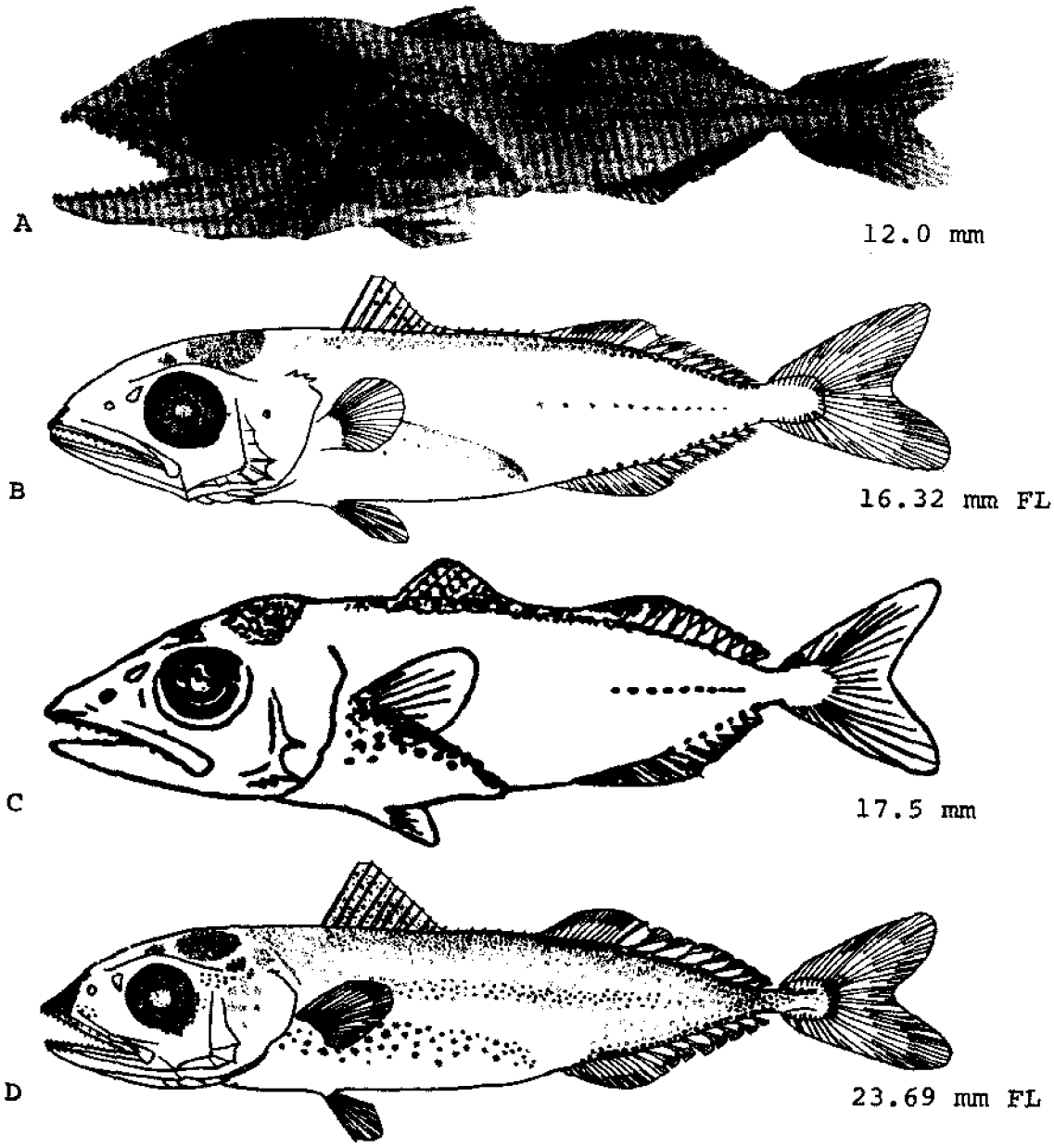

Fig. 31. *Auxis* sp., Frigate or Bullet mackerel. A. Larva, 12.0 mm. B. Juvenile, 16.32 mm FL. C. Juvenile, 17.5 mm. D. Juvenile, 23.69 mm FL. (*A, Ehrenbaum, E., 1924: fig. 8a (reversed). B, D, Marchal, E., 1963c: figs. 19–20. C, de Buen, F., 1932: fig. 26.*)

FL, head small; [14] space between spinous and soft dorsal fins with 6 short spines that ultimately become buried in skin.[2]

Pigmentation: At 16.32 mm FL—body pigment accentuated along dorsal profile from caudal peduncle to origin of first dorsal fin, along anal fin base behind 5th ray, and along lateral line posterior to second dorsal fin; 3 chromatophores at cleithral symphysis; 8 chromatophores between 2nd and 8th dorsal fin spines; most of jaws unpigmented.

At 23.69 mm FL—pigmentation accentuated on head, notably on snout and behind and below orbit; body pigment concentrated posteriorly; 1 chromatophore at cleithral symphysis; small chromatophores in first dorsal fin.

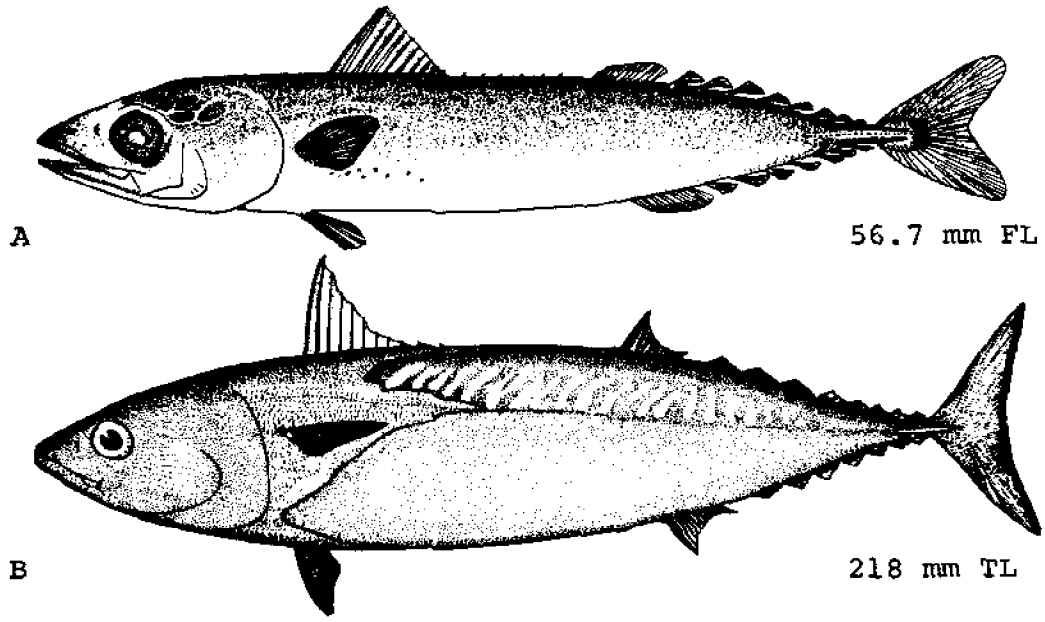

Fig. 32. *Auxis* sp., Frigate or Bullet mackerel. A. Juvenile, 56.7 mm FL. B. Juvenile, 218 mm TL. (*A, Marchal, E., 1963c: fig. 21. B, Suarez Caabro, J. A., and P. P. Duarte Bello, 1961: fig. 21.*)

At 44.4 mm FL—head only unpigmented just anterior to eye; body entirely pigmented except for ventral surface; pectoral fins with some pigment at bases of first rays.

At 56.7 mm FL—fin pigment discrete, few spots at bases of second dorsal rays and finlets, and on upper 5 pectoral rays; anal fin and finlets and pelvic fins unpigmented.[14]

GROWTH

Grow to about 4.5 mm in 160 hours, 5.5 mm in 13 days, and 9 mm in 20 days.[11]

AGE AND SIZE AT MATURITY

At about 290 mm FL; eastern Atlantic population may mature at smaller size than western.[6]

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Euthynnus alletteratus (Rafinesque), Little tunny

ADULTS

D. XV, 11–12+7; A. 12+7;[12,21] C. 9+8;[27] P. 26–27;[12,21,22] V. I, 5;[12,21] body naked behind anterior corselet;[22,23] soft dorsal fin, anal fins, pectoral fin base, and caudal fin base covered with minute scales;[23] vertebrae 19+20;[27] gill rakers 8^{23}–$12^{7}+24^{23}$–$30^{7}=37$–43;[22] vomerine teeth absent;[7,23] jaw teeth simple, conic, small, uniserial.[23]

Head 3.4–3.8, depth 3.8–4.2 in SL. Snout 3.3–3.7, eye 4.8–7.5, maxillary 2.5–2.8, interorbital 3.2–4.0, caudal peduncle depth 8.8–12 in HL.[23]

Body fusiform; head moderate, broadly convex above, well compressed; snout conic; mouth slightly curved, rounded, lower jaw slightly protruding; maxillary reaching past front part of pupil. Lateral line slightly undulate, with slight arch below spinous dorsal fin anterior, then straight to caudal keel. Spinous dorsal fin inserted about midway between tip of snout and origin of soft dorsal; soft dorsal fin inserted nearer spinous dorsal origin than caudal base; dorsal and anal finlets alike, decreasing in size posteriorly; caudal fin deeply lunate; pectoral fins moderate, pointed; pelvic fins inserted slightly behind pectoral fin origins. Caudal peduncle greatly

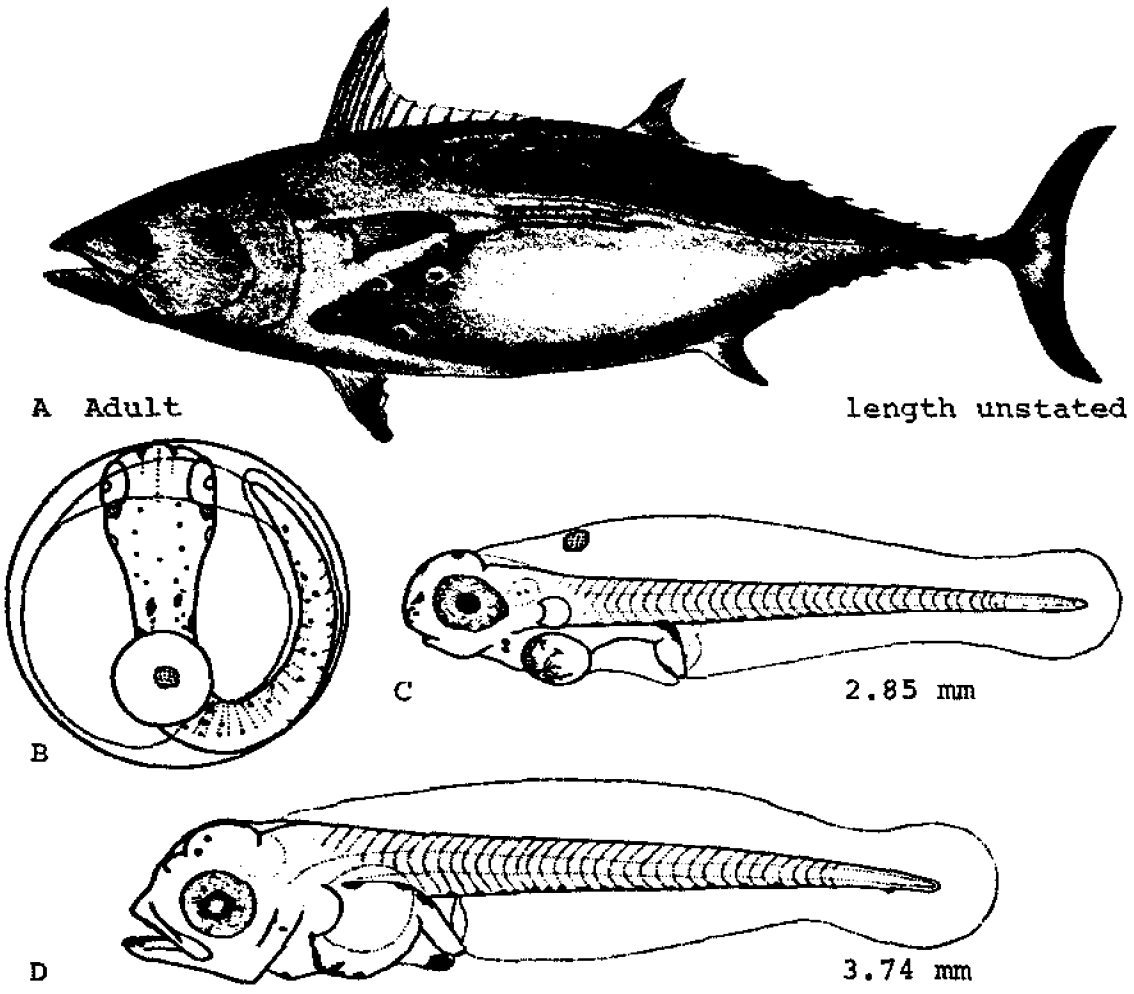

Fig. 83. *Euthynnus alletteratus*, Little tunny. A. Adult, length unstated. B. Egg, 0.89 mm diameter. C. Yolk-sac larva, 2.85 mm. D. Larva, 3.74 mm. (*A, Smitt, F. A., 1893: fig. 26. B-C, Mayo, C. A., 1973: figs. 2a, 4 a-b, used with the permission of the author.*)

depressed, slender, with wide keel on each side; adipose eyelids moderate; anterior nostril simple pore near last third of snout, posterior nostril close before eye as vertical slit; interorbital broad, depressed or slightly convex.[23]

Pigmentation: Dark blue [22] to steel-bluish above; sides and below silvery white [23] to silvery gray; several dark spots between pelvic and pectoral fins; [22] upper fins dusky, lower pale.[23]

Maximum size: To 122 cm.[7,23]

DISTRIBUTION AND ECOLOGY

Range: Subtropical and tropical waters of Atlantic Ocean [15,22] and Mediterranean; [22] in western Atlantic from Ilha Victoria, Brazil north to Bermuda and Gulf of Maine, and throughout Caribbean [3] and northern and eastern Gulf of Mexico.[5,28]

Area distribution: Throughout Mid-Atlantic Bight; [3] *early* summer and late fall in Chesapeake Bay.[8]

Habitat and movements: Adults—pelagic,[7] inshore,[3,15] over continental shelf [7] in turbid waters.[3] Most abundant off south Florida in summer; [18] arrive off Senegal in January–February and May–June, off Guinea July–December, Ivory Coast December–February, and Angola October–February or March; [7] arrive off Tunisia in spring and Morocco in May.[20] Salinity 12 (Chesapeake Bay) [8]–34.3 ppt (Saint Thomas); temperature 16 (Mediterranean)–24.9 C (Saint Thomas); [7] over water of 9–1080 m [3] and to 112–128 km offshore.[7]

Larvae—19–157 km offshore (West Africa), usually 56 km; [19] more often at surface during night. Salinities 32.7 [2]–36.6 [16] ppt; temperature 19.8 [16]–29.3 C; [2] depth 25 [15]–50 [16] m.

Juveniles—associate in compact schools offshore in Gulf of Mexico.[4]

SPAWNING

Location: Occurs outside continental shelf.[15]

Season: During summer in Straits of Florida,[10] peak in April–August,[3] June–August in Mediterranean,[7,26] and October–June off Ivory Coast.[7]

Temperature: Not less than 25 C.[15]

Fecundity: Female of 79 cm contained 1,750,000 eggs.[3,7]

EGGS

Intraovarian eggs: 0.6 mm diameter.[7]

Fertilized eggs: Pelagic,[12] spherical, transparent, 0.84–0.94 mm ($\bar{x}$=0.89, n=8) [18] to 1.08 mm in diameter; yolk rich in black pigment; oil droplet single,[26] light amber,[14] 0.28 mm in diameter.[10,26]

EGG DEVELOPMENT

Light yellow chromatophores form distinct pattern in late-stage eggs: (1) 1–3 on dorsal surface of oil globule; (2) 2 in tissues between oil globule and ventral surface of notochord; (3) 1 posterior to each optic cup; and (4) 2 lateral, block-like patches at anterior end of notochord. Melanin appears as small scattered granules on dorsolateral surface of notochord. Eight hours before hatching, melanophores become more distinct, and at 2 hours before hatching, are aligned in 2 rows on dorsal surface of notochord and lateral and ventral surfaces in caudal region. Oil globule lacks melanin.[10]

Hatching occurs at about 24 hours in Gulf Stream.[12]

YOLK-SAC LARVAE

Hatching at 3 mm and yolk absorbed at 3.2–3.4 mm (48 hours).[11]

Total myomeres as few as 34.[10]

Anus halfway back at hatching.[26]

Yolk mass large at hatching,[11] absorbed 48 [11,14] to 66 [10] hours after hatching; oil globule single, prominent; mouth functional at time of yolk absorption.

Pigmentation: Eyes unpigmented at hatching, pigment appears 48 hours later. Chromatophores on yolk, behind optic cups, and in dorsal finfold. Melanophores at most loci proliferate during early development. Shortly after hatching, melanophores develop into line of stellate bodies along ventral midline of trunk. Ventral melanophores may remain fixed or become slightly reduced in number. Small caudal spot present. Rapid proliferation of melanophores on surface of fore- and midbrain characteristic. First melanophores on lower jaws at 3.0 mm, about 60 hours after hatching. Melanophore proliferation occurs primarily along extent of gular region, while tip of upper jaw pigmented at hatching. Large dendritic melanophore in preanal finfold in 3.0 mm specimens.[10]

LARVAE

Specimens described 3.7 [16]–13.95 mm FL.[19]

D. VI, 13+8 at 8.24 mm, XIII, 11+8 at 10.15 mm, XVI, 13+8 at 13.95 mm; A. 12+6 at 8.24 mm, 12+7 at 10.15 mm, 14+7 at 12.93 mm; [19] total myomeres 40 at 3.7 mm,[16] 39 at 3.8 mm,[17] and 40 at 4.6 mm; [1] vertebrae 20+19 [1,5] by 8.5 mm; branchiostegals 6 at 8.5 mm; [9] preopercular spines 3 at 3.7 mm,[16] 4 at 4.0 mm,[19] 7 at 8.5 mm; [9] opercular spines 1 at 3.74 mm, 5 at 4.00 mm, 5 at 5.39 mm,[19] 6 at 8.7 mm.[17]

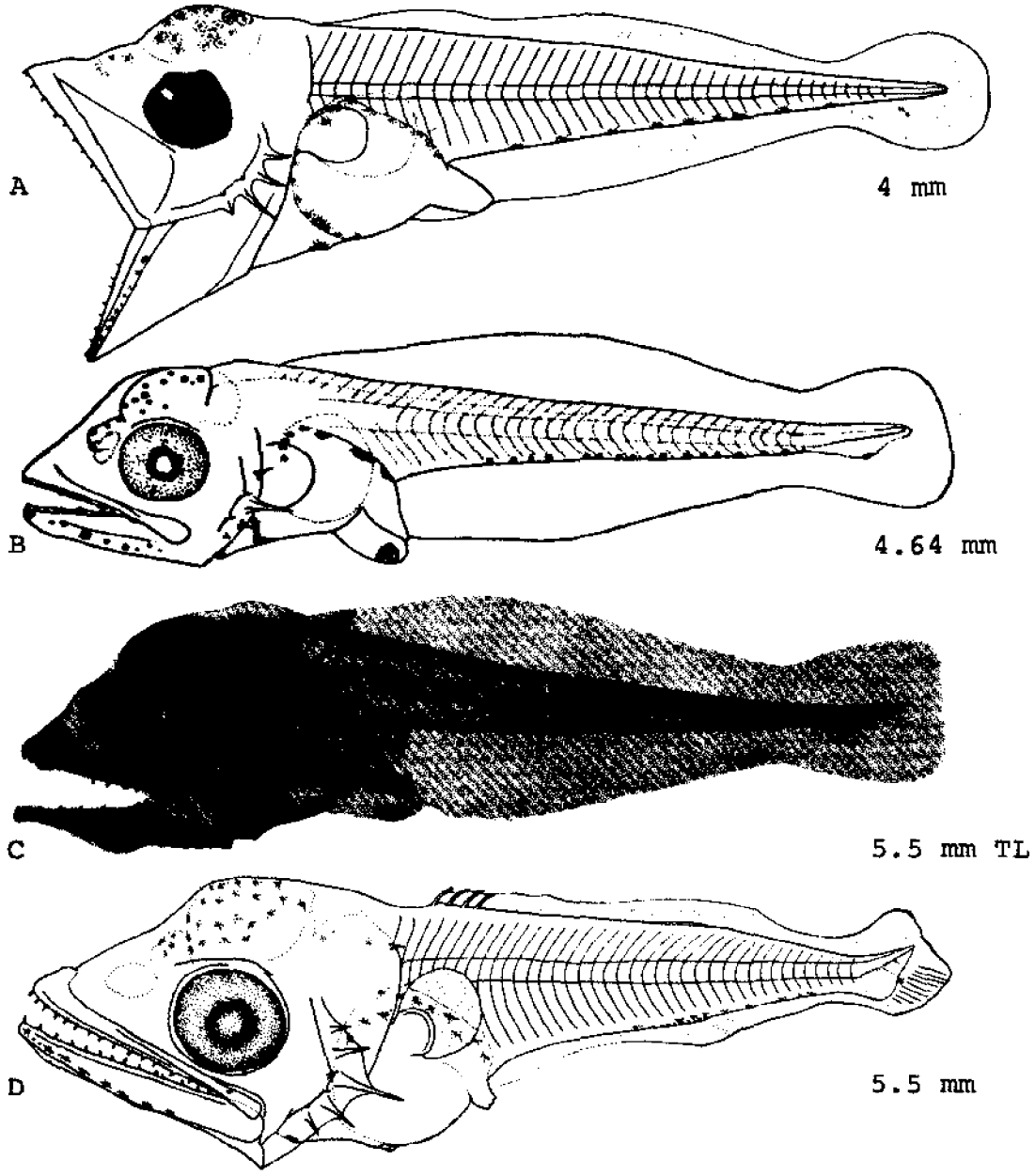

Fig. 34. *Euthynnus alletteratus*, Little tunny. A. Larva, 4 mm. B. Larva, 4.64 mm. C. Larva, 5.5 mm TL. D. Larva, 5.5 mm. (*A, Klawe, W., and B. M. Shimada, 1959: fig. 4a. B, Mayo, C. A., 1973: fig. 4c, used with the permission of the author. C, Weeks, A., 1970: fig. 26. D, Matsumoto, W. M., 1959: fig. 8.*)

At 8.5 mm, head 36% SL, predorsal length 40% SL, prepelvic length 40% SL, preanal length 62.5% SL, eye 40% HL.[9]

Head large, snout long at 10.15 mm FL.[19] Jaw teeth absent at 3.8 mm,[7] 7 on upper jaw at 3.9 mm,[16] 8 upper and 6 lower at 4.4 mm,[7] 12 upper and 10 lower at 8.24 mm,[19] 21–124 upper and 18–24 lower at 9–79 mm,[10] 21–22 upper and 23–24 lower by 11.5 mm,[1] 18 upper and 17 lower at 12.93 mm FL. Palatine teeth 4 at 12.93 mm.[18] Eye large at 8.5 mm; [9] nares united at 8.24 mm FL,[19] separated at 8.5 mm; [9] dorsal fin buds present at 4.92 mm,[10] 4 very short spines anteriorly at 5.5 mm, 9 very long spines and

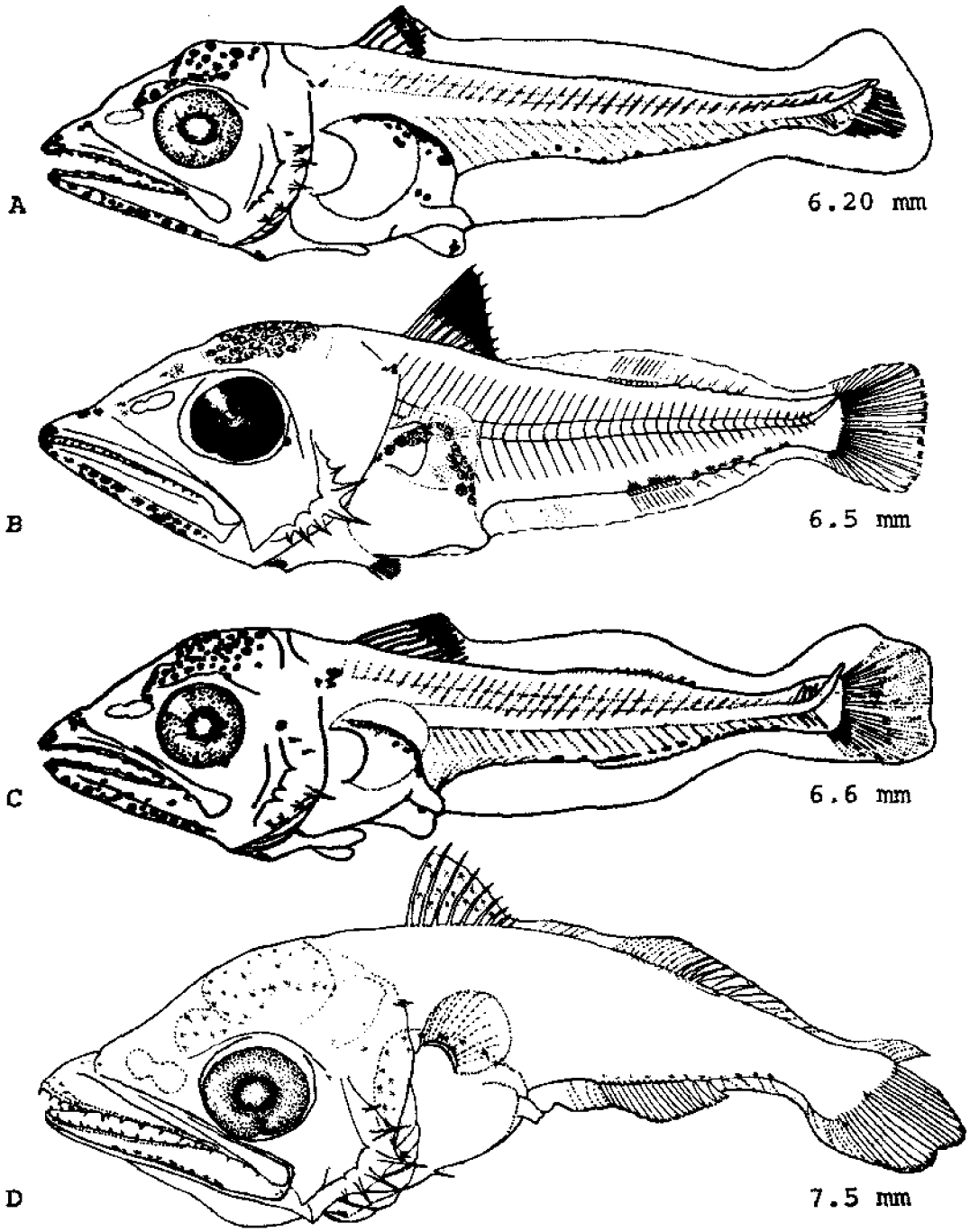

Fig. 35. *Euthynnus alletteratus*, Little tunny. A. Larva, 6.20 mm. B. Larva, 6.5 mm. C. Larva, 6.6 mm. D. Larva, 7.5 mm. (*A, C, Mayo, C. A., 1973: figs. 4d, 8a, used with the permission of the author. B, Klawe, W., and B. M. Shimada, 1959: fig. 4b. D, Matsumoto, W. M., 1959: fig. 9.*)

12–13 rays at 7.5 mm; anal fin beginning to develop at 5.5 mm; caudal fin beginning to develop at 5.5 mm,[1] slightly forked at 8.54 mm [19] and 9.3 mm; [1] pectoral fins large and reach anus at 8.2 mm; [5] pelvic fins present as buds at 5.39 mm [10]–5.5 mm, beginning to enlarge at 9.3 mm; [1] notochord beginning flexion at 4.6 [10]–5.5 mm,[1] hypural bones forming from 4.7–6.2 mm.[10]

Pigmentation: At 3.7 mm, 10 melanophores on each side above midbrain; pigment along lower jaw; solid pigment line stretching along 5–6 myomeres beginning at 21st myomere; one melanophore below urostyle.[16] Beginning at 4.5 mm, melanophores appear over forebrain; chromatophores appear on isthmus and directly ahead of anus; dotted line of chromatophores on posteroventral surface of body; chromatophores appear as dotted line on lateral surfaces of lower jaw; chromatophores on first dorsal fin.[24] At 5.5 mm, chromatophores along margin of lower jaw have increased in number and extend over anterior 2/3 of jaw length; 9 chromatophores on midventral line from anal fin origin to caudal peduncle. At 7.5 mm, marked increase in pigmentation of first dorsal fin; about 13 well scattered chromatophores present on outer 2/3 of fin between first and seventh spines; chromatophores along lower jaw increased in number and now appear closer together; 7 chromatophores present over forebrain and 25 over midbrain; row of pigmentation along midventral edge of body consists of about 11–15 regularly spaced chromatophores; several small chromatophores

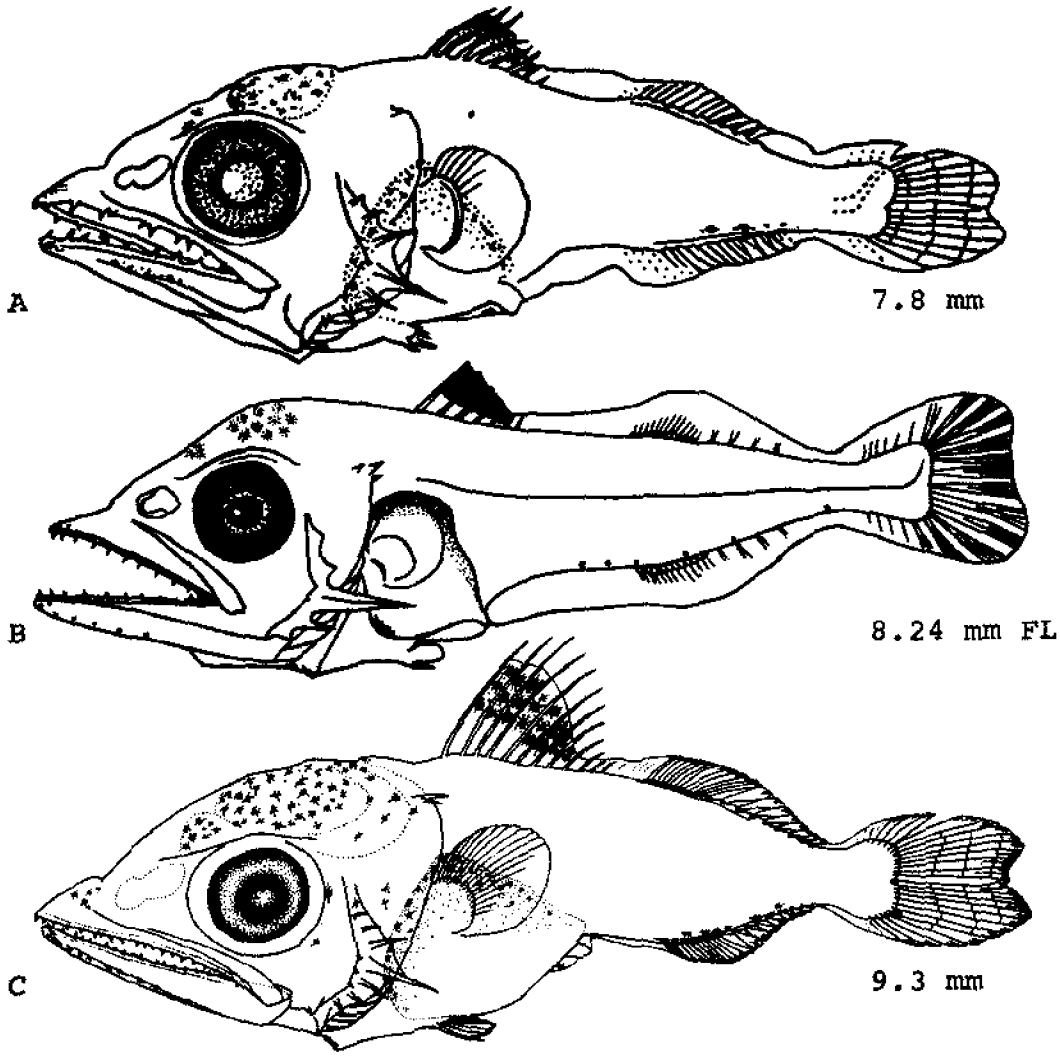

Fig. 36. *Euthynnus alletteratus*, Little tunny. A. Larva, 7.8 mm. B. Larva, 8.24 mm FL. C. Larva, 9.3 mm. (*A, Ueyanagi, S., and H. Watanabe, 1964: fig. 5. B, Marchal, E., 1963b: fig. 7. C, Matsumoto, W. M., 1959: fig. 10.*)

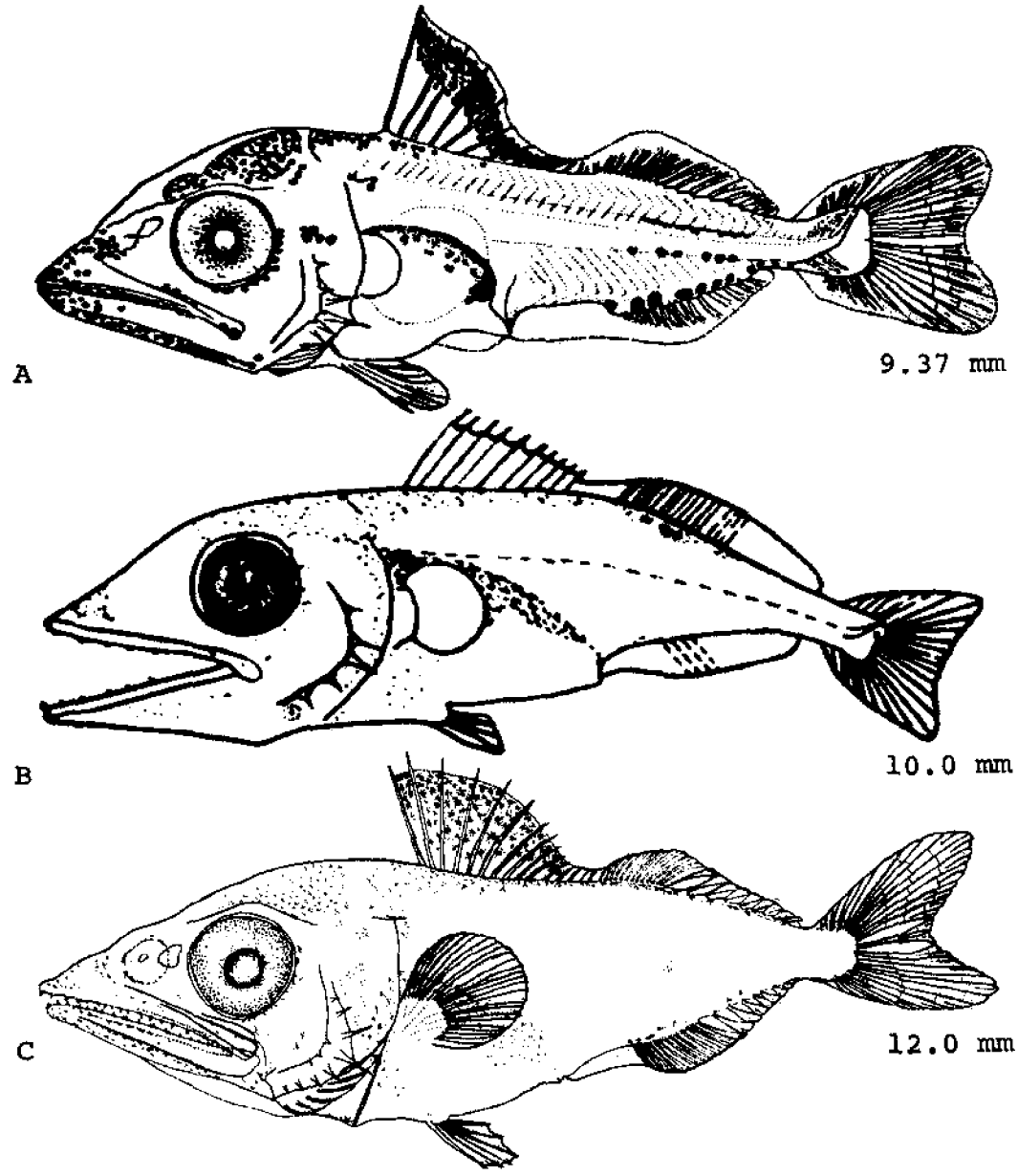

Fig. 37. *Euthynnus alletteratus*, Little tunny. A. Larva, 9.37 mm. B. Larva, 10.0 mm. C. Larva, 12.0 mm. (*A, Mayo, C. A., 1973: fig. 8b, used with the permission of the author. B, Zhudova, A. M., 1969a: fig. 48. C, Matsumoto, W. M., 1959: fig. 11.*)

present at tips of snout and lower jaw. At 9.3 mm, pigmentation on first dorsal fin restricted to outer half of fin membrane, but number increased to 22; decrease in pigmentation over midbrain; 4 light, well-spaced chromatophores evident on side of head posterior to eye; series of midventral chromatophores about 6, 4 along posterior part of anal fin base and 2 evenly spaced at bases of 4th and 6th anal finlets. From 10.7–11.5 mm, margin of lower jaw bears two groups of chromatophores and upper jaw has single row of chromatophores along 2/3 of its length; about 4–5 closely grouped chromatophores seen at angle of jaws; about 8 large chromatophores present on surface of opercle; band of pigment along dorsal edge of body, tapering to single row of chromatophores at about 12th dorsal spine and continuing to origin of 2nd dorsal finlet; midventral line of body with 1 or 2 chromatophores under second dorsal fin; about 16 chromatophores along anal fin base and first 4 finlets.[1]

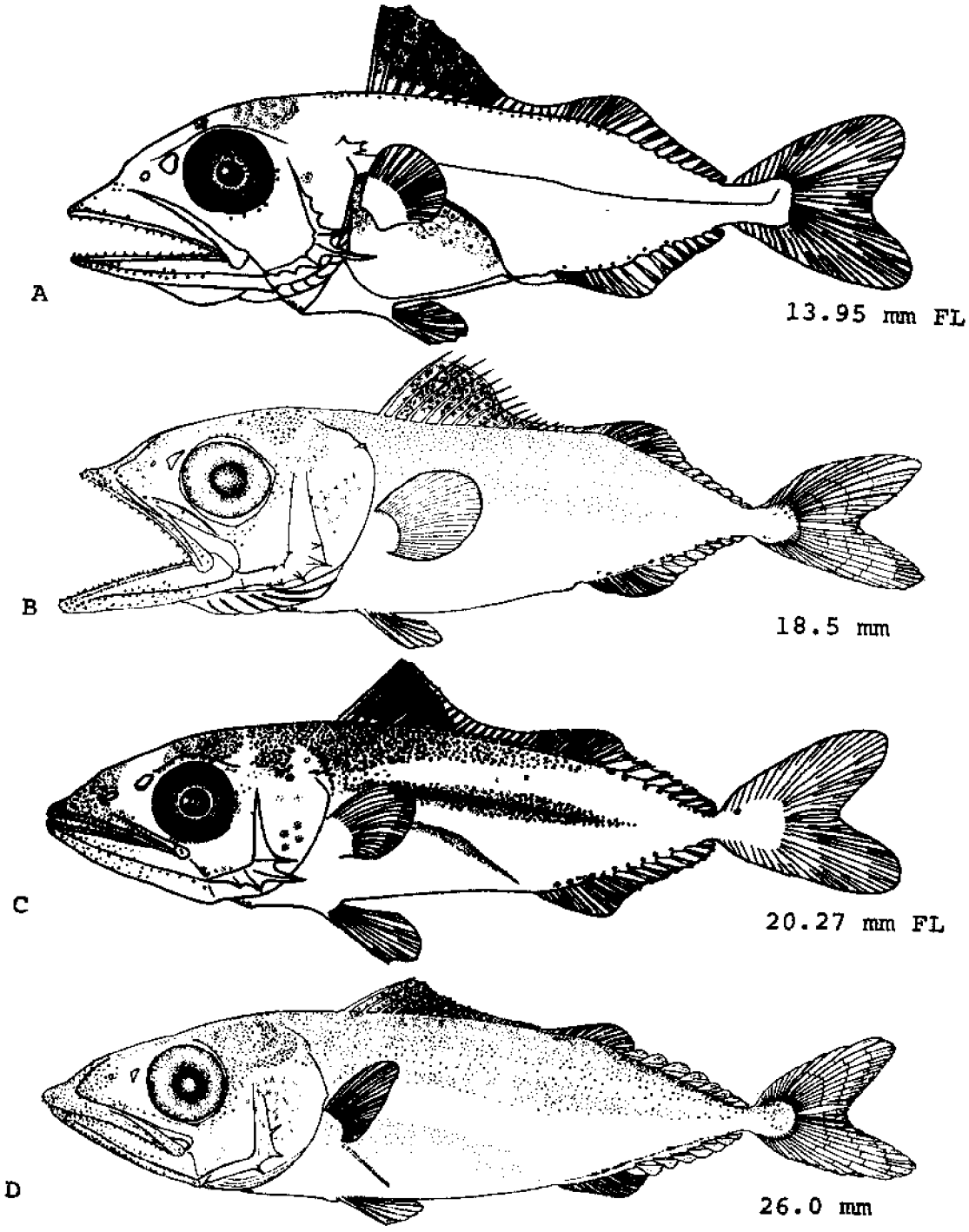

Fig. 38. *Euthynnus alletteratus*, Little tunny. A. Larva, 13.95 mm FL. B. Juvenile, 18.5 mm. C. Juvenile, 20.27 mm FL. D. Juvenile, 26.0 mm. (*A, C, Marchal, E., 1963b: figs. 8–9. B, C, Matsumoto, W. M., 1959: figs. 12–13.*)

JUVENILES

Specimens described 14.61 *mm* FL [28]–174 *mm.*[10]

D. XIV to XVI, 11–13+7–9; A. 12–14+7–8; C. 10+17+10; [13] vertebrae 20+19,[1,12,13,25] or 19+20, or 20+20; [25] gill rakers more or less strong, blade-like,[13] 3+1+20 at 26.3 mm FL, 8+1+29 at 41.5 mm FL, 9+1+30 at 51.4 mm FL, 25–28 on lower limb of first arch at 40–94.3 mm; [1] preopercular spines still 3 at 26.32 mm FL, absent *by* 51.4 *mm* FL.[19]

Body elongate, fusiform,[13,19] somewhat compressed, dorsal and ventral outlines evenly curved; head large, compressed, tapering to conic snout; mouth large, slightly oblique, lower jaw slightly in advance of upper; maxillary

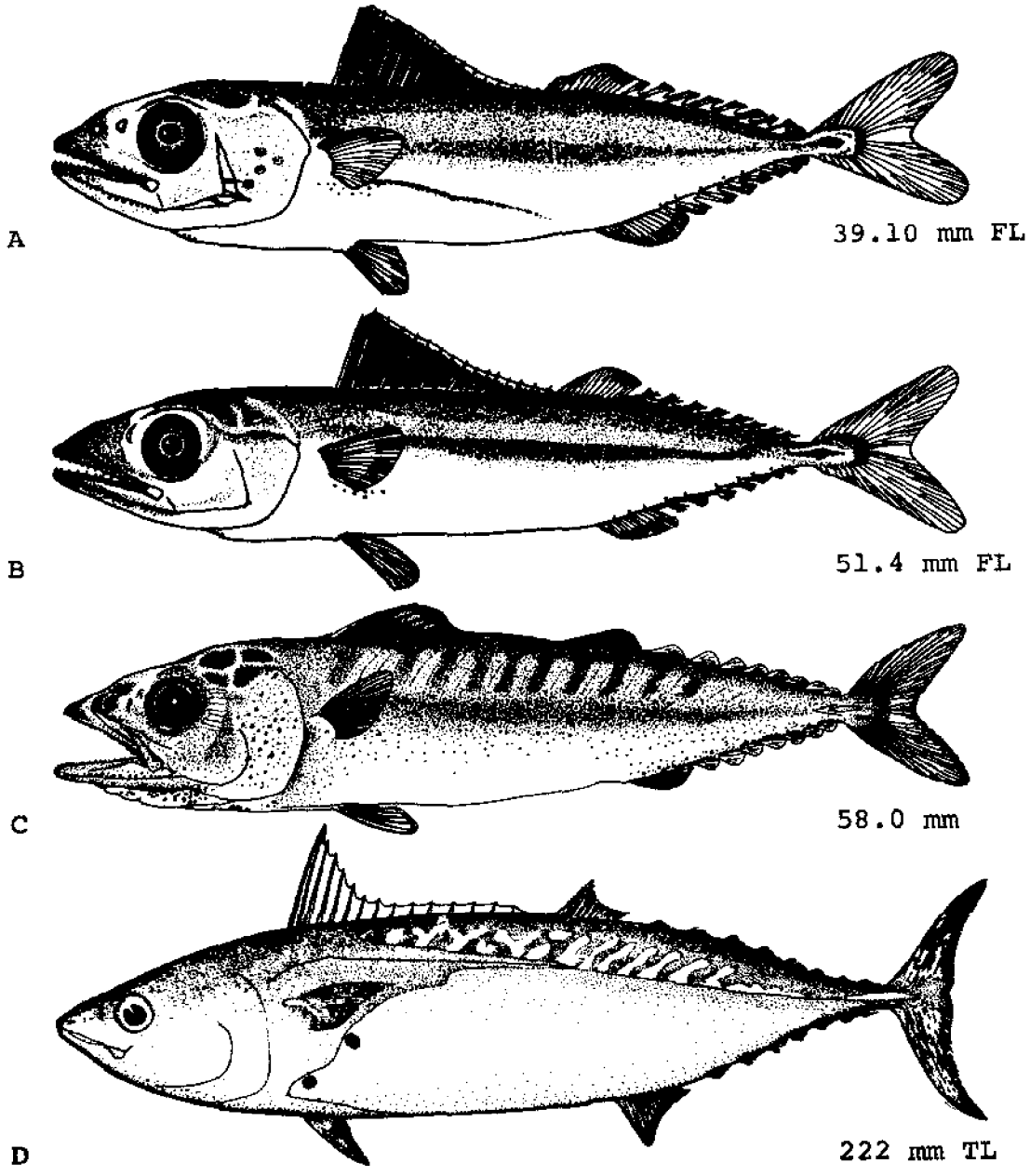

Fig. 39. *Euthynnus alletteratus,* Little tunny. A. Juvenile, 39.10 mm FL. B. Juvenile, 51.4 mm FL. C. Juvenile, 58.0 mm. D. Juvenile, 222 mm TL. *(A-B, Marchal, E., 1963b: figs. 10–11. C, Matsumoto, W. M., 1959: fig. 14. D, Suarez Caabro, J. A., and P. P. Duarte Bello, 1961: fig. 20.)*

reaching to or slightly past center of pupil; jaws with single row of small, inward curved conic teeth,[13] 18 upper and 15 lower at 14.61 mm; [19] similar teeth on palatines; teeth absent on vomer and tongue; eye small, rounded; adipose eyelids little developed; anterior nostril small pore, closer to eye than tip of snout, posterior nostril vertical slit close before eye; interorbital broad and somewhat convex; gill opening wide, membranes not united, free from isthmus; lateral line little arched over pectoral, then straight to caudal; pectoral fins falciform, short; pelvic fins short; caudal peduncle very slender, depressed, with well-developed keel on each side, small keel at base of each caudal lobe; trunk naked, except corselet and lateral line.[13]

Pigmentation: At 14.61 mm FL, weak pigment on snout in advance of anterior nostril; line of 11 chromatophores on upper jaw; double row, 7 superior and 15 inferior, of chromatophores on lower jaw; cleithral symphysis with 5 small chromatophores; series of chromatophores on dorsal fins; anal base with 6 pale spots; first dorsal fin pigmented back to 9th spine. At 26.32 mm FL, head pigmented in advance of eye and posterior nostril; cleithral symphysis with 4 chromatophores; back and sides pigmented to 3/5 way posterior, especially along lateral line; caudal peduncle pigmented.[19] Pigmentation generally increases over 26.0 mm. At about 40 mm, 13 very faint spots or vertical bars seen along dorsal third of body, increasing to 10 bars by 58.0 mm, and 13 at 94.3 mm.[1] Larger juveniles steel-blue above, silvery to whitish below; [13] about 6 [6]–15 dark stripes start from dorsal outline and run vertically down and disappear gradually below lateral line; area between pectoral and pelvic fins with 1–4 irregular dark spots; dorsal, pectoral, and caudal fins dusky; pelvic fins partly or completely silvery white; anal fin whitish; anal finlets and distal parts of dorsal finlets pale or whitish.[13]

GROWTH

Specimens 2.4 mm long reach 24 mm in 410 hours; [10] Mediterranean specimens 10 cm in July and 15–28 cm in August; [12] 30 cm in less than 1 year, 30–45 cm at 1–2 years, 45–60 cm at 2–3 years and 60–75 cm at 3–4 years; [7] generally about 160 mm FL per year.[3]

AGE AND SIZE AT MATURITY

Females maturing at 272 mm [3]–386 mm; [7] males maturing at slightly less than 400 mm.[3,7]

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Katsuwonus pelamis (Linnaeus), Skipjack tuna

ADULTS

D. XV to XVI [44] (usually XV [32]), 12–16 [44] (usually 14 [32])–7–8; [44] A. 11 [26]–15 [27] (usually 14 [32]) + 7 [26]–8; [27] C. 9 + 8 (RAF); P. 26–27; [26,27] V. I, 5; [26] body naked except for anterior corselet and lateral line; [27,60] vertebrae 20 + 21 = 41, [26] *occasionally 19 + 22 or 21 + 20*; [49] *gill rakers long*, slender, 15–20 + 36–40 [27] = 53–63 [2] on first arch; teeth in jaws in single series, short and rather stocky, [27] absent on vomer and palatines; first closed haemal arch on 12th vertebra. [20]

Head 3.0–3.2, depth 3.8–4.1 in SL. Snout 3.3–3.7, eye 5.7–6.1, interorbital 3.7–4.0, maxillary 2.6–2.8, pectoral fin 1.9–2.1 in head.

Body robust, tapering strongly posteriorly, caudal peduncle slender, depressed, with strong lateral keel; head somewhat compressed, convex above; [27] interorbital slightly convex, broad; [57] snout long, pointed; eye moderate, round; *mouth slightly oblique*, terminal; maxillary reaching nearly to or opposite middle of eye. Lateral line rising anteriorly, curved downward at midlength, attaining mid-lateral position under about first dorsal finlet, then straight to caudal keel. First dorsal fin composed of slender spines, anterior ones long, posterior ones short, scarcely extending above dorsal groove, origin of fin a little behind insertion of pectoral fin; second dorsal fin somewhat elevated anteriorly, margin deeply concave; anal fin similar to second dorsal, origin little in advance of vertical from base of last ray of second dorsal; pelvic fin somewhat shorter than pectoral fin; pectoral fin moderately pointed. Complex trellis or basket-work formed by haemal arches. [27]

Pigmentation: Dark blue above, with metallic reflections; silvery below; lower part of head, chest and area around pelvic fins dirty white; lower part of body with 2 [27]–5 prominent dark longitudinal stripes; several dark stripes *running along body ventrally*; [58] *spines of first dorsal fin* dusky, anterior margin of first spines and membranes pale or white; second dorsal, dorsal and anal finlets, caudal and pectoral fins more or less dusky; pectoral fins much darker on inner side than outside, upper rays *generally silvery; pelvic fin white on outside, inner side* dusky; mouth largely dusky inside; [27] can change to pattern of dark vertical bars in life. [38]

Maximum size: To 1 m [6,26] and 17.5–25 kg. [26]

DISTRIBUTION AND ECOLOGY

Range: Cosmopolitan in tropical and subtropical seas; [2] in western Atlantic from the Gulf of Maine to Rio de *Janeiro and throughout the Gulf of Mexico*; [62] *present in* the Mediterranean Sea, [26,56] but absent from the Black Sea. [56]

Area distribution: Recorded from off Monmouth County, New Jersey. [26]

Habitat and movements: Adults—oceanic; schooling, [56] appear to be more frequent around islands; in mixed layer; [25] collected during autumn under flotsam in eastern Pacific. [9] *Migration in Pacific Ocean, at different* ages, well documented; [27,50] move northward along Japan from May–July [52] with 20 and 21 C isotherms [25] and southward from September–October; [52] most abundant off Florida during fall and winter; [47] move north along Mexico and Baja California *in spring and summer with* 20 C isotherm and south again in fall and winter; abundant off Ecuador during April–June and at boundary of Peru Current, September–December. [21,25] Occur almost entirely within mid-ocean geographic areas where permanent or seasonal salinity *maximum present*; [6] *maximum* salinity 35 ppt [49] and minimum 33 ppt. [54] Recorded from 15 [25]–29 C, [17] prefer 17–28 C [49] with optimum of 20–22 C. [54] Larger individuals usually at greater depths, [25] within upper one or two hundred meters. [27]

Larvae—primarily occupy upper isothermal layer; [10] found across Pacific Ocean from 30° N to 20° S [22] (but only to 25° N in winter). [25] Recorded from 31.4 [5]–37.01 ppt [37] salinity; 23.4 [3]–29.8 C, [27] with 24 as lower limit; [47] rarely below 140 m depth, [27] usually from 0–100 m; [37] generally in open ocean but sometimes as close as ca. 185 m from shore. [27]

Juveniles—*tend to occur in deeper water*; [10] *closer in*shore than adults or larvae in eastern Pacific; 23–31 C (usually 29–30 C). [17]

SPAWNING

Location: Occurs far offshore; [48] tend to favor year-round presence of shallow subsurface salinity maximum; [58] around Laccadive Islands and Minicoy, [1] between Seychelles and Durban, [6] near Phoenix Islands [14,31] in Hawaii area, [3] near Marquesas Islands, [34] some in eastern Pacific, [26] and probably in Florida Current. [12]

Season: From November–July in Laccadive Sea, [1] November–July in the Marquesas, [34] March–September near Hawaii, [18] April–December at Islas Revillagigedo, [40] northern mid-summer throughout most of Pacific, [50] throughout year near equator, [53] May–July in Cuban waters, summer–fall in Caribbean-Mexican Basin, [35] peak during late June–early July off North Carolina, [55] and end May–June near Cape Verde. [26] Probably spawn more than once per season. [18]

Temperature: Above 25 C; in Pacific bounded by 25.3 C in south and 25.9 C in north. [42]

Fecundity: Females 468 mm long produce 113,364 eggs, 562 mm produce 609,730 eggs,[27] and 704 mm produce 1,200,000 eggs.[55]

EGGS

Unfertilized eggs: 1.07 [18]–1.125 [1] mm diameter, smooth, round; [19] oil globule single, yellow,[1,19] 0.22 [19]–0.809 [1] mm *diameter.*
Fertilized eggs: Golden,[24] 0.80–1.17 mm diameter; [20,35] oil globule 0.22–0.27 mm diameter.[35]

EGG DEVELOPMENT

Yellow chromatophores on posterior part of developing dorsal finfold, above mid-posterior notochord, behind optic cups, in tissues between oil globule and notochord, and rarely associated with dorsal surface of oil globule; anterior dorsolateral surface of embryo heavily pigmented with large stellate melanophores, arranged into two rows in late-stage eggs.[24]

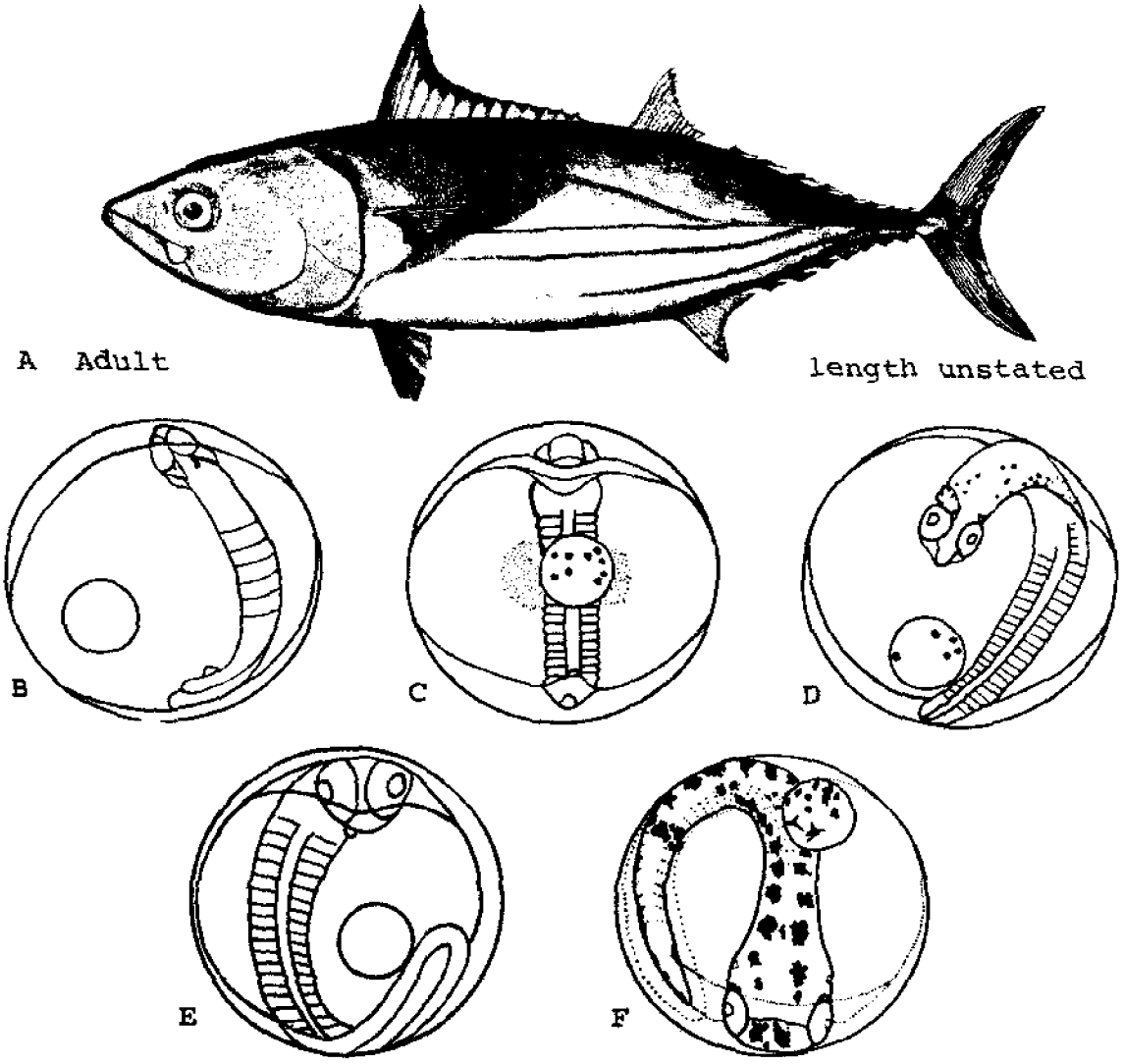

Fig. 40. *Katsuwonus pelamis,* Skipjack tuna. A. Adult, length unstated. B. Egg, 10 hours after fertilization, 0.95 mm diameter. C. Egg, 12 hours after fertilization, 0.979 mm diameter. D. Egg, 14 hours after fertilization, 0.975 mm diameter. E. Egg, 17 hours after fertilization, 0.963 mm diameter. F. Egg, 0.94 mm diameter. Spotted areas indicate colored pigment. *(A, Goode, G. B., 1884: pl. 95B. B-E, Inoue, M., et al., 1974: fig. 1 a-d. F. Mayo, C. A., 1973: fig. 2c, used with the permission of the author.)*

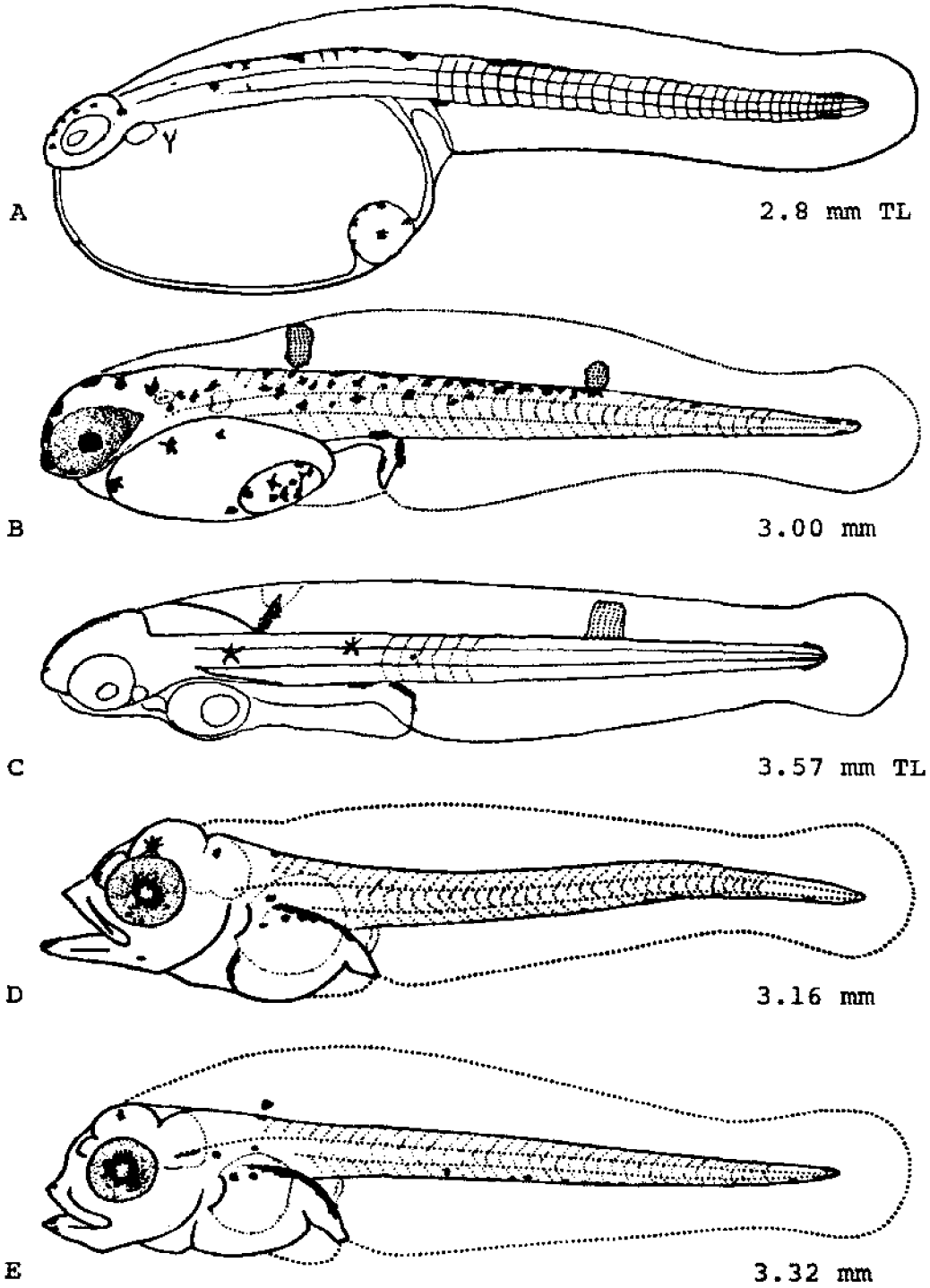

Fig. 41. *Katsuwonus pelamis*, Skipjack tuna. A. Newly hatched larva, 2.8 mm TL. B. Yolk-sac larva, 3.00 mm. C. Yolk-sav larva, 3.57 mm TL. Spotted areas indicate colored pigment described in text. D. Larva, 3.16 mm. E. Larva, 3.32 mm. (*A, C, Inoue, M.*, et al., *1974: fig. 1 e-f. B, D, E, Mayo, C. A., 1973: fig. 5a-c, used with the permission of the author.*)

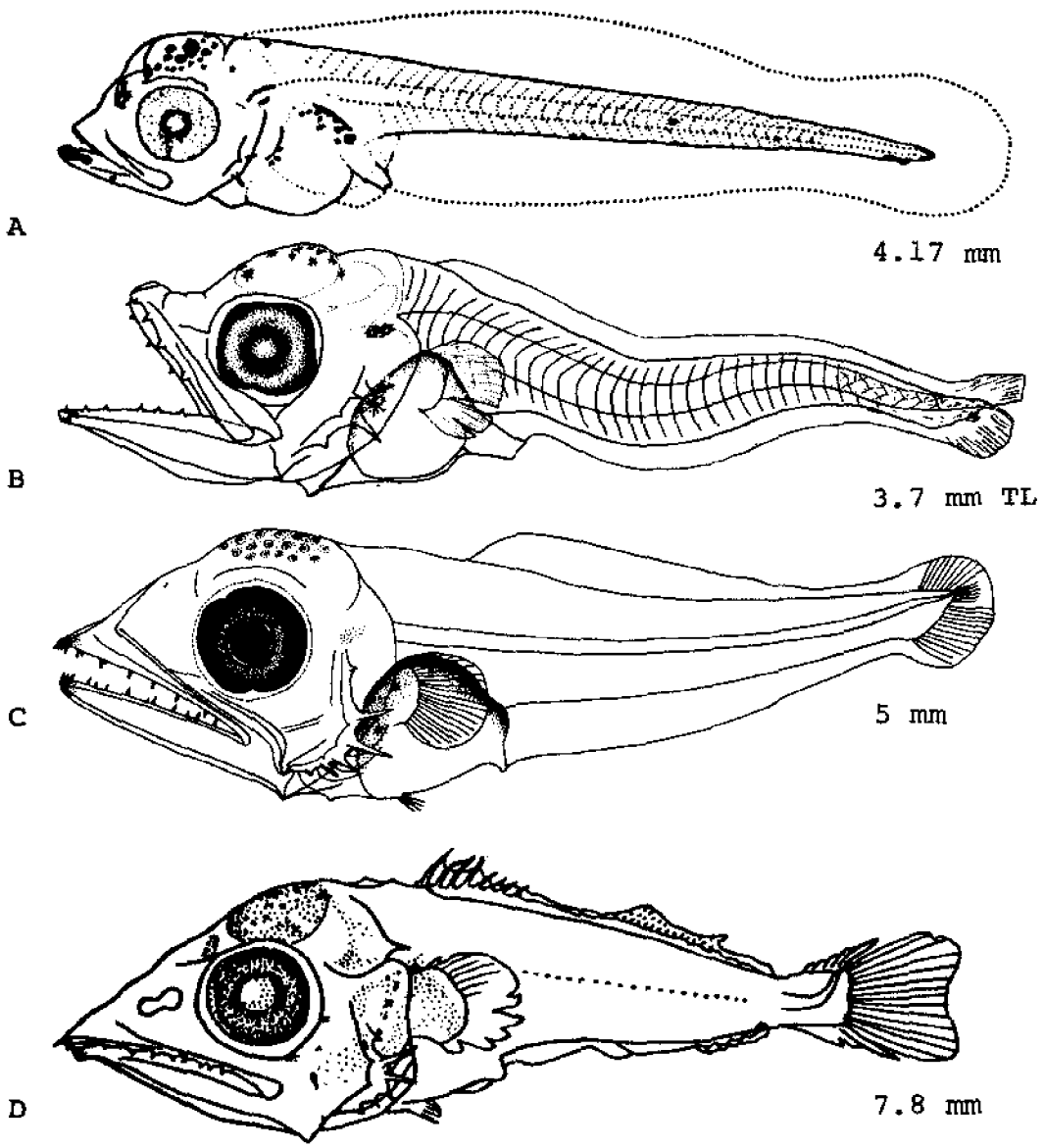

Fig. 42. *Katsuwonus pelamis*, Skipjack tuna. A. Larva, 4.17 mm. B. Larva, 3.7 mm TL. C. Larva, 5 mm. D. Larva, 7.8 mm. (*A, Mayo, C. A., 1973: fig. 5d, used with the permission of the author. B, Matsumoto, W. M., 1958: fig. 11. C, Wade, C. B., 1951: fig. 12. D, Ueyanagi, S., and H. Watanabe, 1962: fig. 5.*)

YOLK-SAC LARVAE

Hatch at 2.44–3.04 mm; [30] yolk absorbed from 3 [26]–4.0 mm.[24]

Body long and slender; head large; [7] yolk mass absorbed in about 50 hours; eyes pigmented at 27–30 hours; [24] abdominal sac characteristically small and situated posteriorly.[7]

Pigmentation: Yellow chromatophores retain embryonic positions: above mid-posterior notochord, in anterior dorsal finfold, behind optic cups, and in vicinity of oil globule. Intense melanin on snout, midbrain, and notochord becomes diffuse after hatching.[24]

LARVAE

Specimens described 2.97 mm [15]–21.71 mm FL.[48]

D. IV at 6.7 mm TL; [46] VI at 7.08 mm; [15] X, 22–25 at 8

mm TL; [23] IX, 15+7 at 9.0 mm SL; [36] XIV, 15+8 at 9.1 mm TL; [45] XIII, 15+8 at 10.9 mm TL; XVI, 15+8 at 14.5 mm TL.[46] A. 10+5 at 8.2 mm TL; [45] 15+7 at 9.0 mm SL; [36] 14+7 at 10.9 mm TL. C. 18 at 6.7 mm TL; 12+11 at 7.1 mm TL; 16+16 at 10.9 mm TL; 20+22 at 14.5 mm TL; 22+22 at 20 mm TL. P. 20 at 14.5 mm TL. V. I, 5 at 8.75 mm TL.[46] Total myomeres 41 at 5.08 mm,[15] 41–42 at 5.35 mm,[40] 40 at 5.60 mm SL.[36] Vertebrae 41 at 8 mm,[23] 20+22 at 10.9 mm TL.[46] Branchiostegals 3 at 8 mm TL.[23] Preopercular spines very inconspicuous at 2.97 mm; [15] 3 spines at 3.7 mm; [46] 6 at 5 mm TL; [45] *putative maximum number (8) by about 8* mm; [7] 9 at 10.9 mm TL, all but two longest at angle overgrown with bone.[46] Post-temporal spine develops at 7.08 mm.[15] 8 teeth in upper jaw and 5 in lower at 4.17 mm,[24] 10–11 upper and 11–12 lower at 5.5–5.9 mm, 10–15 upper and 12–14 lower at 6.0 mm,[37] 10–13 on each side of each jaw at 7.15 mm TL,[45] total of 27 upper and 21 lower at 8 mm TL,[23] 15 upper and 17 lower at 14.5 mm TL.[46] Palatine teeth, 3–4 at 7.15 mm TL,[45] 5 at 8.75 mm TL, and 6 at 14.5 mm TL.[46]

Head large; snout almost equal to diameter of orbit at 7.1 mm TL; [46] mouth large,[7,45] slightly oblique,[45] tip of lower jaw extends beyond tip of upper jaw; [31] maxillary reaches to posterior edge of eye.[7,15,45] Nares beginning to separate at 7.08 [15]–8 mm TL,[23] almost separate by 9.1 mm TL,[45] separate at 8.75 mm TL.[46] First dorsal fin rudiments appear at about 6.7 mm,[7] posterior portion of second dorsal rudiments formed at 7.08 mm [15]–7.1 mm; [46] caudal fin with rudimentary rays at 5.08 mm,[15] rays formed by 6.5 mm; [37] pectoral fins with rudimentary rays at 5.08 mm,[15] complete ray complement at 30 mm; [27] pelvic fins appear as buds at 5 [45]–5.08 mm, well developed rays at 7.08 mm.[15] Notochord flexion beginning at 5 [45]–5.08 mm,[15] complete by 5.35 mm TL [40]–8.16 mm SL.[36] *Urostyle visible at 8 mm TL.*[23] *Hypural plate beginning* to develop by 5.35 mm TL [46]–7 mm TL.[45] Anus situated anterior to midpoint of total length up to 9 mm.[7,45]

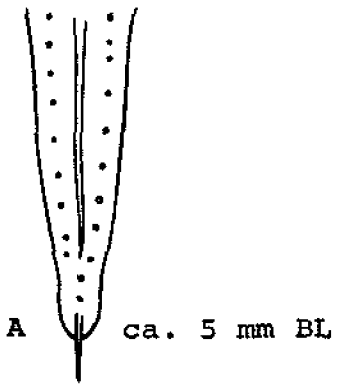

Fig. 43. *Katsuwonus pelamis*, Skipjack tuna. A. Ventral rows of red chromatophores, ventral view, ca. 5 mm BL. (*A, Ueyanagi, S., 1966: fig. 3c.*)

Pigmentation: At time of complete yolk sac absorption all yellow chromatophores, except for one in anterior dorsal finfold, are lost. This chromatophore may persist to 3.2 mm and 60 hr. old. Melanin restricted to small spots on ventral notochord at 3.2 mm, 60 hr. Pigmentation along ventral margin of trunk of larger specimens reduced to four (in 3.32 mm, 97 hr. old) and finally to three spots (4.17 mm, 157 hr. old). Caudal melanophores remain intense throughout early larval development. Small melanophore on hindbrain remains visible. Proliferation of fore- and midbrain melanophores continues through *development up to 4.17 mm. Lower jaw pigmented in* specimens longer than 3.2 mm. Pectoral symphysis and preanal finfold unpigmented.[24] Red chromatophores (0.01–0.04 mm) distributed on sides of body, lower side of lower jaw, margin of hypural plate and also on isthmus and anterior to anus.[58]

At 5.08 mm, small patch of chromatophores at tip of lower jaw, an isolated one on each side about midway between tip of jaw and angle of mouth; postorbital chromatophore absent in some. Few isolated chromatophores on upper aspect of opercle.[15]

At 7.1 mm TL, pigment extends over almost entire midbrain area; two additional chromatophores appear, small one on lower jaw about one-fourth distance from tip and one on first dorsal fin at outer edge of second interradial membrane.

At 8.75 mm TL, several dark chromatophores scattered on top of snout and chromatophore on lower jaw now one-half distance from tip; posteroventral edge of orbit lined with about 10 small chromatophores, and about 6 large, faint chromatophores on preopercle posterior to eye; 3–4 small chromatophores in posttemporal region, 6–8 along first dorsal fin base and 1 near second dorsal insertion; outer edges of 3rd–6th interradial membranes of first dorsal fin with 6 large chromatophores; anal fin base with 3 chromatophores.

At 10.9 mm TL, number of chromatophores over brain increases, also over tips of jaws and along posteroventral margin of orbit; area posterior to brain between posttemporal spine and dorsal edge of body bears numerous small chromatophores, which extend posteriorly and gradually disappear near base of first dorsal finlet; four small, chromatophores present along base of anal fin and one dark chromatophore on ventral midline of caudal peduncle; six large chromatophores appear on mid-lateral line of body between second dorsal fin insertion and first dorsal finlet.

At 14.5 mm TL, chromatophores on snout increase in number and line entire length of upper jaw and two-thirds of lower jaw; midbrain completely covered with dark, close-set chromatophores and small patches over forebrain and on side of head more intense; 7–8 chromatophores on surface of opercle; pigmentation on posteroventral margin of orbit more intense and extends along half circumference; dorsally, band of chromato-

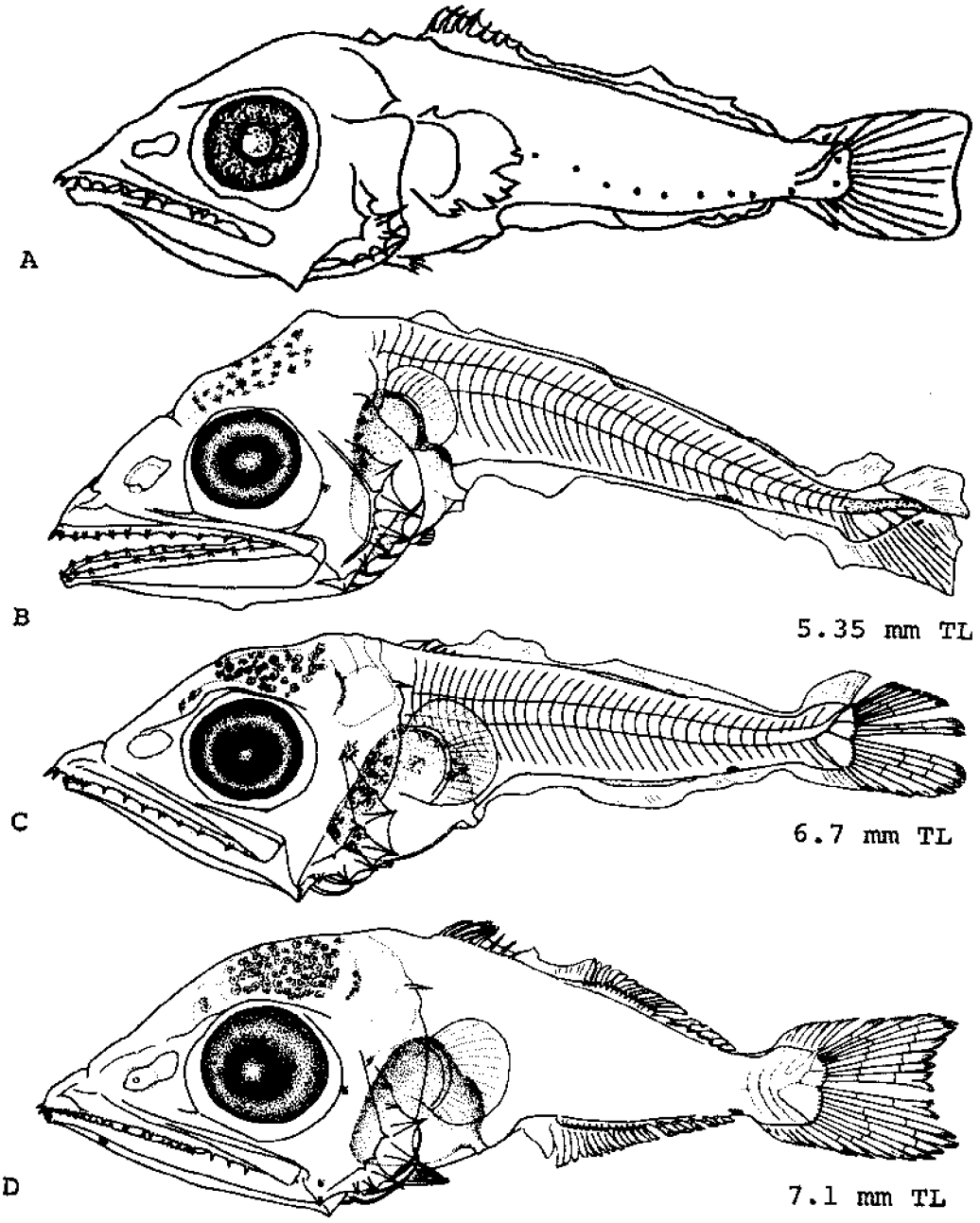

Fig. 44. *Katsuwonus pelamis*, Skipjack tuna. A. Pattern of red chromatophores, lateral view. B. Larva, 5.35 mm TL. C. Larva, 6.7 mm TL. D. Larva, 7.1 mm TL. (*A,Ueyanagi, S., and H. Watanabe, 1962: fig. 11. B-D, Matsumoto, W. M., 1958: figs. 12–14.*)

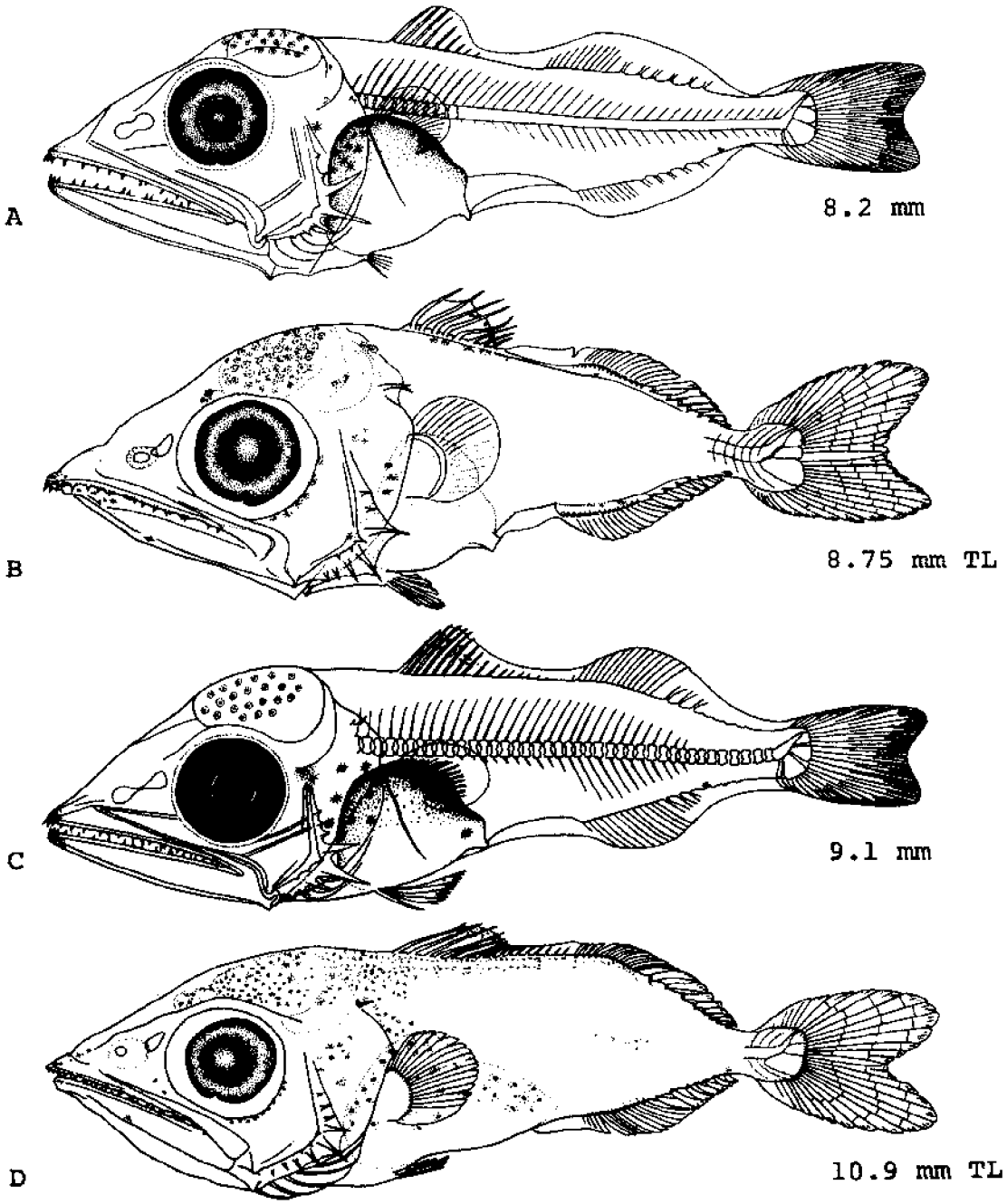

Fig. 45. *Katsuwonus pelamis*, Skipjack tuna. A. Larva, 8.2 mm. B. Larva, 8.75 mm TL. C. Larva, 9.1 mm. D. Larva, 10.9 mm TL. (*A, C, Wade, C. B., 1951: figs. 14–15. B, D, Matsumoto, W. M., 1958: figs. 15–16.*)

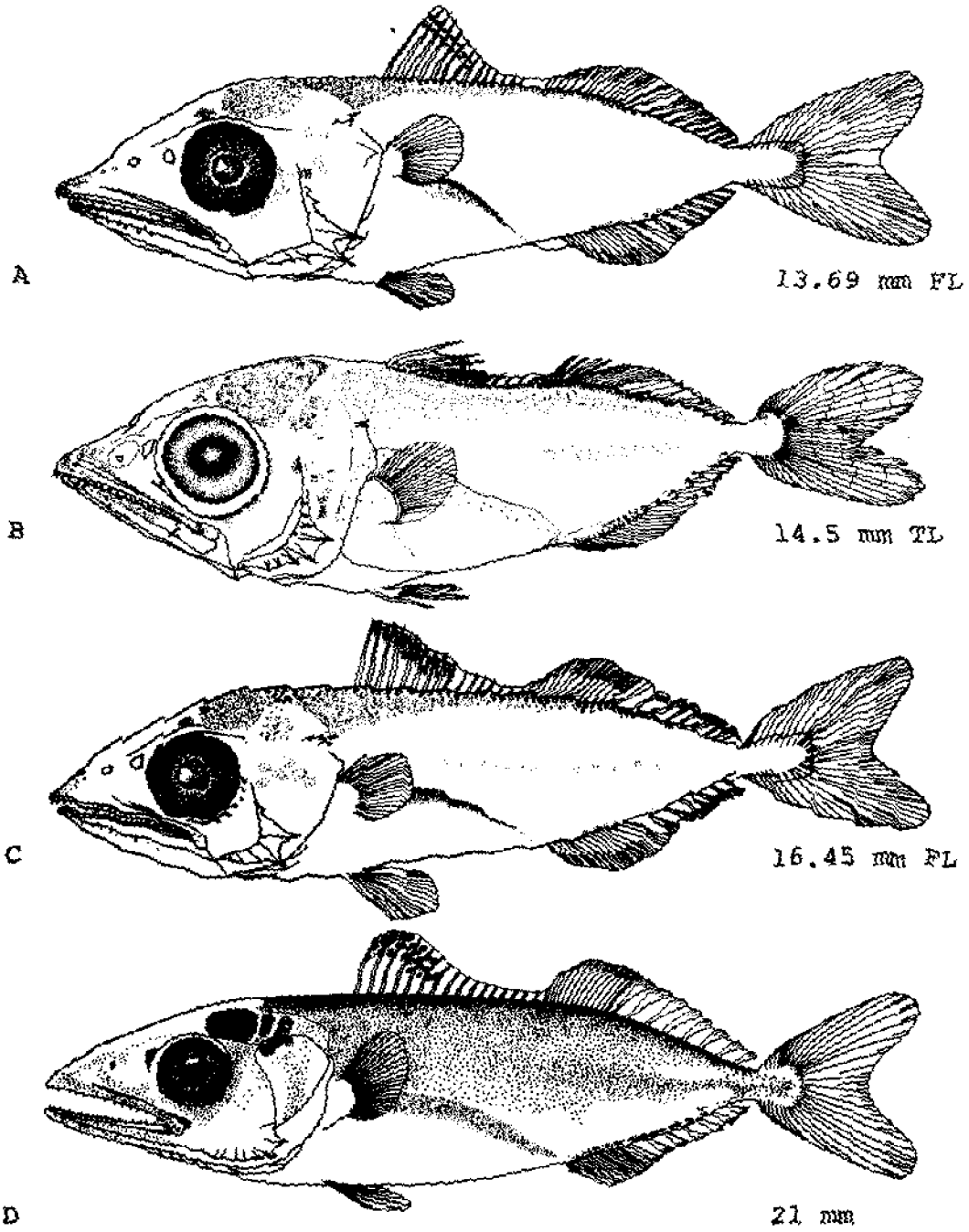

Fig. 46. *Katsuwonus pelamis*, Skipjack tuna. *A. Larva*, 13.69 mm FL. B. Juvenile, 14.5 mm TL. C. Juvenile, 16.45 mm FL. D. Juvenile, 21 mm. *(A, C, Marchal, E., 1963c: figs. 12–13. B, Matsumoto, W. M., 1958: fig. 17. D, Schaefer, M. B., and J. C. Marr, 1948: fig. 5.)*

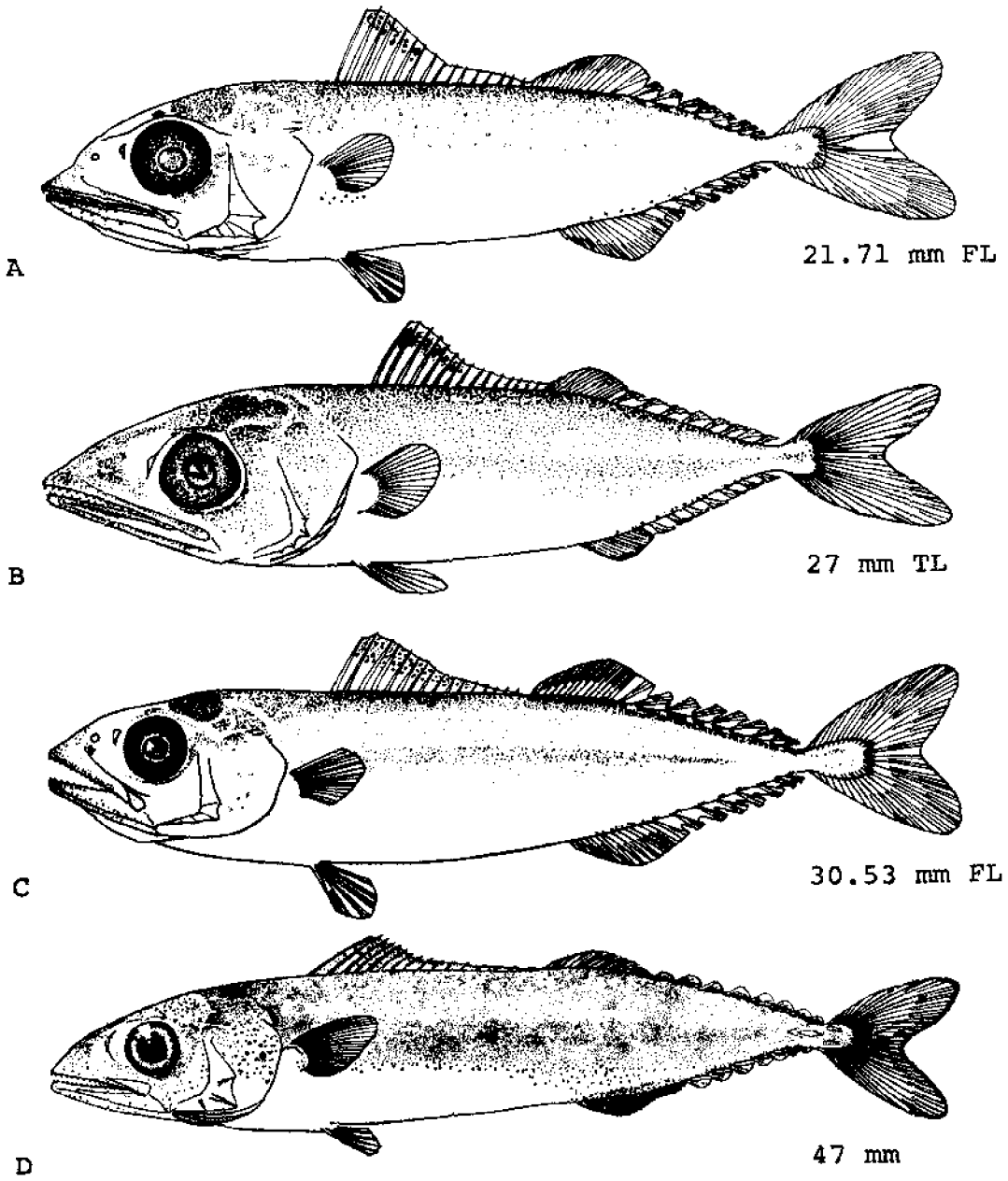

Fig. 47. *Katsuwonus pelamis*, Skipjack tuna. A. Juvenile, 21.71 mm FL. B. Juvenile, 27 mm TL. C. Juvenile, 30.53 mm FL. D. Juvenile, 47 mm. (*A, C, Marchal, E., 1963c: figs. 14–15. B, Jones, S., 1960: fig. 6. D, Matsumoto, W. M., 1961: fig. 2.*)

phores on caudal trunk much wider, terminates near base of fifth dorsal finlet; 6–7 dark spots on outer edge of interradial membranes of first dorsal fin between 2nd–10th spines; anal fin base with tiny chromatophores and three large chromatophores at base of first three anal finlets; band of small chromatophores present on mid-lateral line; single chromatophore on ventral tail and those over abdominal sac persist.[46]

At 16.45 mm FL, chromatophores along three-fourths upper jaw; three chromatophores at symphysis; double row over two-thirds of lower jaw; chromatophores on ventral part of orbit, opercle, and abdominal mass; pigment along dorsal profile to 4th finlet; mid-lateral line with series of chromatophores to 4th finlet; six small spots along anal base to first two finlets; first dorsal fin with pigment to 10th spine.

At 21.71 mm FL, upper jaw with single row of chromatophores over four-fifths length, lower jaw with double row; pigmentation anterior to nares, posterior border of orbit, and in vertical line on opercle; dorsal two-thirds of body pigmented, reinforced on mid-lateral line; line of pigment at base of anal finlets; first dorsal fin still pigmented; pectoral fin with trace of pigment on 12th ray, remainder of fins colorless.[48]

JUVENILES

Specimens described 30 mm [27]–450 mm.[17]

D. XIV [8] to XVI,[13,28] 15+7–8; A. 14 [13]–15,[13,28] +7; [13,28,31] P. 25 [36]–27; [31] V. I, 5; [31,36] vertebrae 20+21; [7,11,13,28,29] gill rakers 2+1+22 at 24 mm FL,[13] 4+1+20 at 25 mm, 5+1+27 at 35 mm,[4] 8+33 at 44 mm TL,[28] 7+1+33 at 48 mm, 9+1+33 at 54 mm, 10+1+36 at 69 mm,[4] 16+40 at 113 mm FL; [8] preopercular spines gradually atrophy,[7,13] 4 rudiments of spines at 27 mm TL,[15] almost entirely lost by 44 mm TL; first haemal arch on 12th vertebra.[28] Teeth in jaws, 21 upper and 26 lower on each side at 24 mm FL,[13] 30 upper and 30 lower at 72.6 mm FL; [48] palatine teeth, 8 and vomerine teeth absent at 24 mm FL,[13] palatine teeth disappear between 94–130 mm.[20]

Body fusiform.[48] Lateral line curves slightly upward over opercle,[8] first visible at 44 mm TL; [28] caudal peduncle with lateral keel and small dorsal and ventral keels; [8] finlets united by membrane at 13 [13]–27 mm TL.[15]

Pigmentation: At 44 mm TL, second dorsal fin unpigmented; first dorsal fin with few moderately large pigment spots toward distal ends of rays; pigmentation similar to 21 mm stage but heavier.

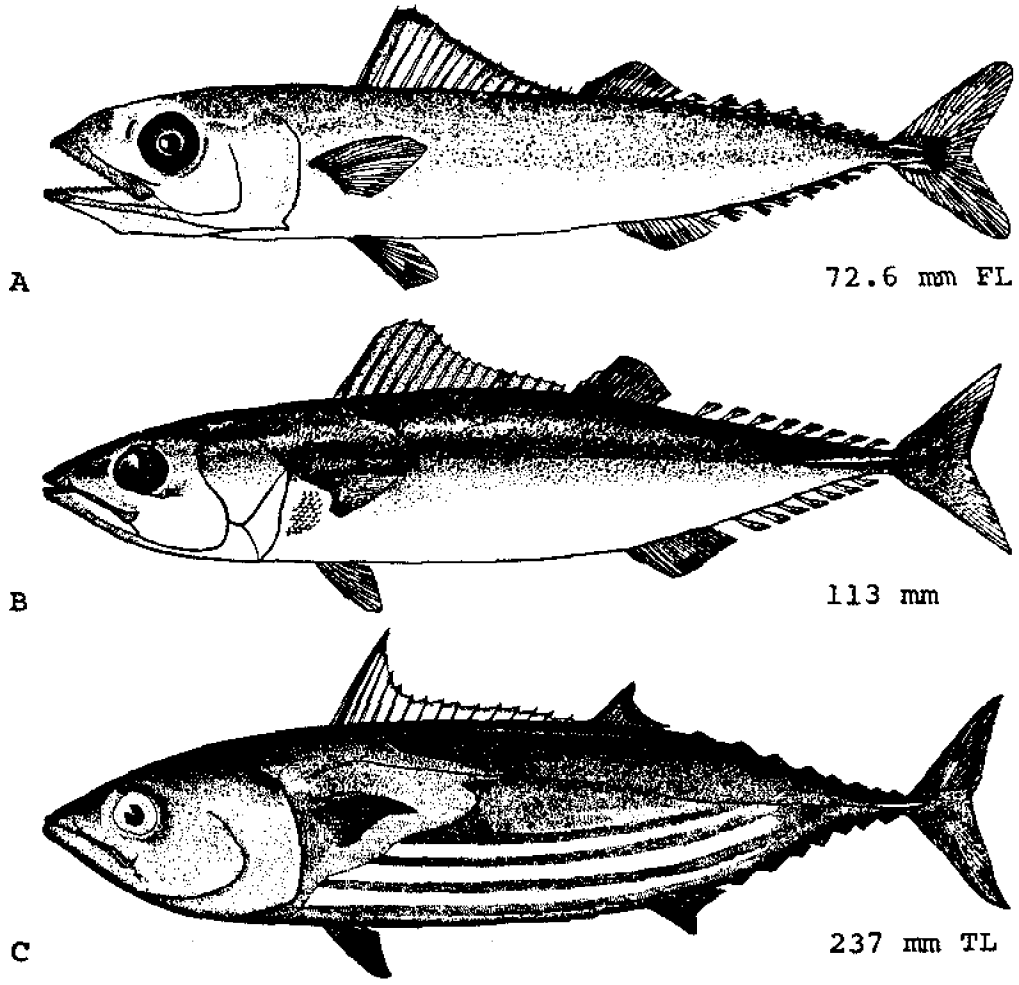

Fig. 48. *Katsuwonus pelamis*, Skipjack tuna. A. Juvenile, 72.6 mm FL. B. Juvenile, 113 mm. C. Juvenile, 237 mm TL. (*A, Marchal, E., 1963c: fig. 16. B, Eckles, H. H., 1949: fig. 1. C, Suarez Caabro, J. A., and P. P. Duarte Bello, 1961: fig. 19.*)

At 52.7 mm FL, head entirely pigmented except behind nostrils; dorsal two-thirds of body uniformly pigmented; line of pigment along anal finlets; pigment dorsally on first dorsal fin, second dorsal fin pigmented on basal fourth; dorsal finlets with chromatophores on inferior border; caudal fin base pigmented; anal fin, anal finlets, and pelvic fin not pigmented; pigmentation on pectoral fin consisting of base of rays, entire first two rays, and next seven with median part pigmented.

At 72.6 mm FL, head entirely pigmented except one-fourth of area between nostrils and eye; dorsal two-thirds of body pigmented blue or violet, rest yellow; line of pigment along anal fin base and finlets; first dorsal fin with distal pigment and first two rays pigmented entirely; pigment on proximal part of second dorsal fin and inferior border of finlets; anal fin, anal finlets, and pelvic fins not pigmented; pectoral fins pigmented on superior part.[48]

At 113–118 mm FL, belly unpigmented except for faint yellowish streak just posterior to pelvic base; no lateral stripes; pigmentation concentrated at level of pectoral fin, and entire dorsal surface of pectoral pigmented; pigmentation extends beyond and below caudal peduncle to base of caudal rays; snout, upper and lower jaws and head anterior to nape darkly pigmented subcutaneously; upper posterior part of operculum lightly pigmented; most anterior dorsal spines pigmented except distal end; pigment concentrated in lower two-thirds of 2nd and 3rd spines and base of 4th and 5th spines; coloration lacking on remainder of spines; first six rays of second dorsal bear pigment spots extending two-thirds their length.[8]

Adult coloration reached at 200–250 mm.[27]

GROWTH

In Japan, 27–37 cm in 1 year, 37–46 cm in 2, 46–55 cm in 3, 55–64 cm in 4, 64–72 cm in 5, 72–80 cm in 6, and greater than 80 in 7 years.[16]

AGE AND SIZE AT MATURITY

Maturing in 1 year;[19] 390–396 mm SL in Laccadive Sea,[1] 435 mm for males and 454 mm for females off North Carolina,[55] some indication of larger size at maturity in eastern Atlantic.[33]

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Sarda sarda (Bloch), Atlantic bonito

ADULTS

D. XX to XXIII,[5,23] 13–18+6–9 (modally 8); A. 14–17+6–8 (modally 8); [5] *C. 10+17+10*; [18] *P.* 23–26; [5] *V.* I, 5; body covered with tiny scales; [23] vertebrae 26–28+23–27=50–55; inner gill rakers 9–22 on first arch; teeth in jaws simple, rather strong, slightly compressed, uniserial,[24] 12–24 in lower jaw and 16–26 in upper; teeth on palatines 8–21; [5] teeth sometimes present on vomer, none on tongue; [23] 22–33 lamellae in nasal rosettes; 24 pleural ribs; 31–45 intermuscular bones; 5–10 keels on vertebrae; [5] 7 branchiostegals.[28]

Proportions given as thousandths of FL: Snout to anal fin origin 668, snout to first dorsal origin 270, head 264, depth 214, pectoral fin length 115, snout 94, bony orbit 57, interorbital 64 (northwest Atlantic specimens); first dorsal fin base 291–330, 494–520. Good evidence for geographic variation.[5]

Body elongate, fusiform, somewhat compressed, thicker

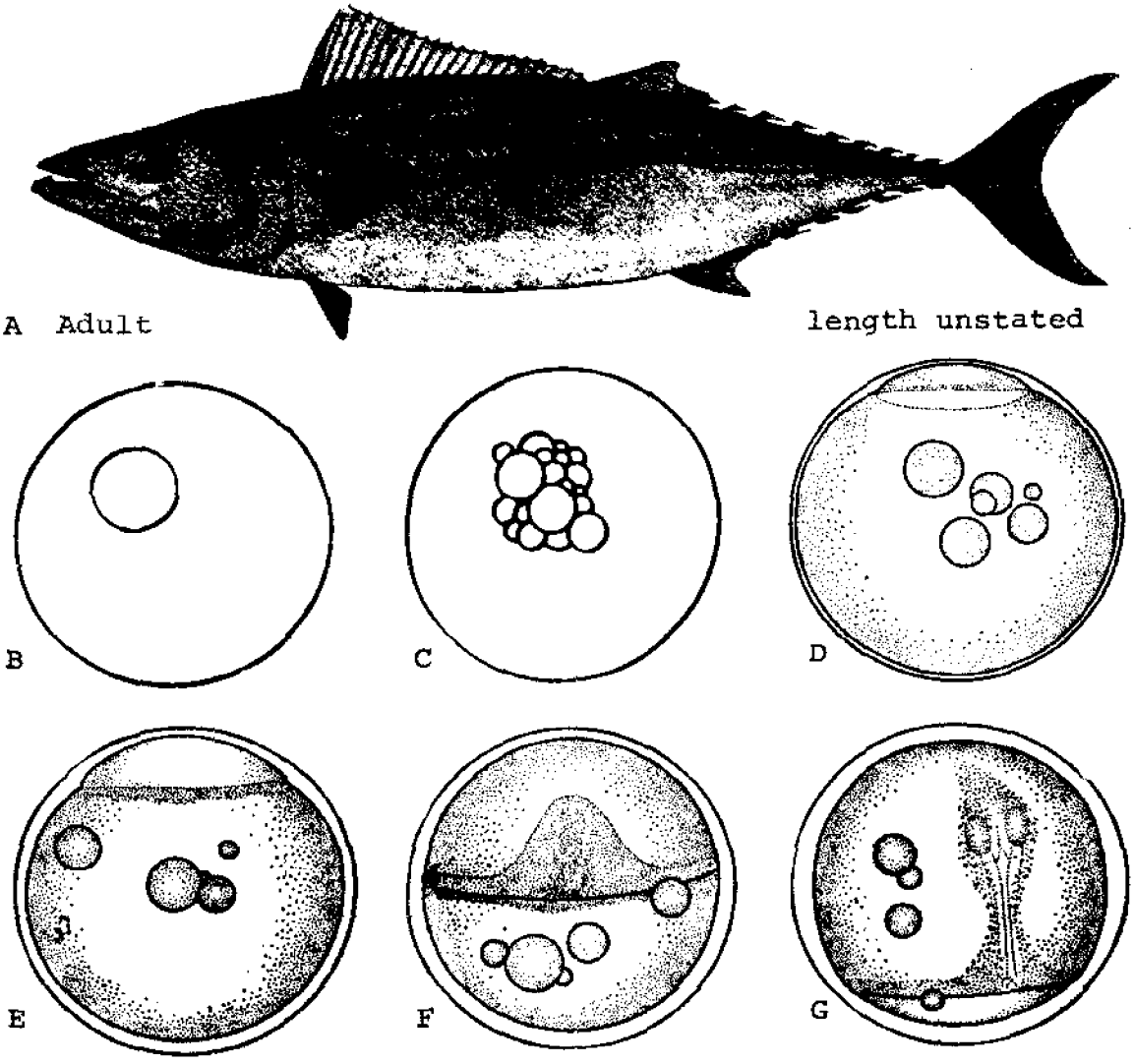

Fig. 49. *Sarda sarda*, Atlantic bonito. A. Adult, length unstated. B-C. Unfertilized eggs showing absence of perivitelline space and variation in number of oil globules. D-G. Fertilized eggs. (*A, Smith, F. A., 1893: fig. 30. B-C, Demir, M., and N. Demir, 1961: figs. 4 a & m. D-G, Dekhnik, T. V., 1973: fig. 50 a-d.*)

with age, dorsal and ventral outlines evenly curved,[18] caudal peduncle very slender, small keel at base of each caudal fin lobe; [18,24] head large,[18] compressed,[18,24] tapering to pointed snout; mouth large, slightly oblique, upper jaw slightly in advance of lower; [18] maxillary reaches to [18,24,42] or slightly beyond posterior margin of eye.[18,24] Lateral line undulates below second dorsal fin.[6,18,25] First dorsal fin triangular, upper edge slightly concave; second dorsal fin longer than high, deeply concave,[25] base covered with minute scales; [24] anal fin deeply concave,[25] base covered with minute scales; [24] caudal fin lunate, much broader than long,[25] base covered with minute scales.[24] Interorbital broad, convex; eye small, rounded; [18,24] corselet distinct, small, not extending beyond pectoral; [24] anterior nostril small; posterior nostril vertical slit; [18,24] liver three-lobed.[5]

Pigmentation: Steel-blue above; silvery below; [18,22,25] 5 [23]–11 dark oblique stripes running downward and forward on back and sides; dorsal and caudal fins dusky; pectoral fins pale; remainder of fins more or less silvery.[18,23]

Maximum size: To about 914 mm and 4.5–5.4 kg.[25]

DISTRIBUTION AND ECOLOGY

Range: Along tropical and temperate coasts of the Atlantic Ocean, including the Gulf of Mexico, Mediterranean and Black Seas; apparently absent from most of the Caribbean Sea. Along the eastern coast of United States *from Cape Breton Island, Nova Scotia, to around Miami,* Florida.[5]

Area distribution: Recorded from the entire Chesapeake Bay [10,30,31,32] and Mid-Atlantic Bight.[5]

Habitat and movements: Adults—school; [25] more inshore than offshore; [25] migrate to Black Sea for feeding in spring and return to Bosphorus during end of August to mid-September,[8] also migrate vertically in Aegean Sea; [12] 16 ppt (Black Sea) to 38.5 ppt (Mediterranean),[18] 10 ppt-marine (Chesapeake Bay); [31] 9 [8]–25.5 C in Black Sea.[18]

Larvae—recorded 80 [17] to 160 [20] km from coast in Black Sea; *16.7–19.6* ppt; *18.6–24.0 C.*[17]

Juveniles—5–10 ppt in Chesapeake Bay.[10]

SPAWNING

Location: Occurs 4.8 [15]–52 [11] km from shore in Black Sea,[3,8,11,13] also in Marmara and Aegean Seas [9] and possibly in northcentral Gulf of Mexico.[4]

Season: May–July in Mediterranean,[18] May to June or July in Black Sea,[13,14,20] May–July in Marmara and Aegean seas; [18] June south of Gulf of Maine [25] and possibly in winter in western Atlantic.[2]

Temperature and salinity: 13.9 [11,20]–24.0 C in Black Sea; 16.7–18.6 ppt in Black Sea.[17]

Fecundity: Females, 56–65 cm, produce 732,160–3,233,580 eggs; [11,20] larger and older individuals have larger gonads and more eggs than younger and smaller fishes.[18]

EGGS

Unfertilized eggs: Yellowish,[1] 1.176–1.369 ($\bar{x}$=1.29) mm diameter.[19]

Fertilized eggs: Pelagic; [1,14] spherical; [1,6,18] transparent [1,18,19] to yellowish; [1] 1.15 [27]–1.57 [22] mm diameter; egg membrane thick and elastic,[18,19] finely striated; [1,18,19] oil droplet number variable 1–9 or possibly 19,[19] 4 [14,22]–6 [14] *most frequent, gradually merging,*[16,27] 0.28 [1]–0.364 [18] when single, 0.02–0.24 for remainder,[1] faded carrot or dried straw color; [18,19] perivitelline space small,[14] reduced,[1] or absent.[9]

EGG DEVELOPMENT

6–7 hours after blastopore closure—embryo extends about halfway around yolk and has short tail separated from yolk sac and pigmentation appears. Otic vesicle differentiating. Some small yellow chromatophores on distal part of yolk sac.[1] Melanophores appear on yolk sac, oil globules and embryo. Melanophores on yolk localized on surface of yolk sac at side of embryo. On surface of embryo, melanophores appear first on dorsal side of body and later on head and tail.[18,19]

7 1/2 hours after above—end of tail has reached head and 10 myomeres are present. Eyes quite large. Heart embryonic in position and beating. Pigmentation unchanged and oil droplets not yet fused.[1]

Before hatching—pigment cells on oil globules become large and prominent. Gray and brown pigment also appears on body.

Hatching occurs in 1 1/2–2 days,[14] 1 day after blastopore closure.[2]

YOLK-SAC LARVAE

Reported as hatching at 4.3 [14]–4.32 mm [1] or 4.8 mm in Black Sea; [16] yolk sac absorbed at 4.7 mm.[14]

Preanal myomeres 15 at hatching, 11 one day later; postanal myomeres 35 at hatching, 39 one day later; 2 spines in otic region at 4.2 mm.[1]

At hatching 1.90 mm preanal length, 2.42 mm postanal.[1]

Yolk elongate,[14] reaching from eye to anus at hatching,[1] absorbed in three days; [10] oil globules posterior in yolk sac,[1,14,16] not fused at hatching, iridescent one day later; otoliths, 2 one day after hatching; pectoral fins membranous; finfold large on trunk, beginning dorsally at otic vesicles; [1] anus immediately behind yolk sac and

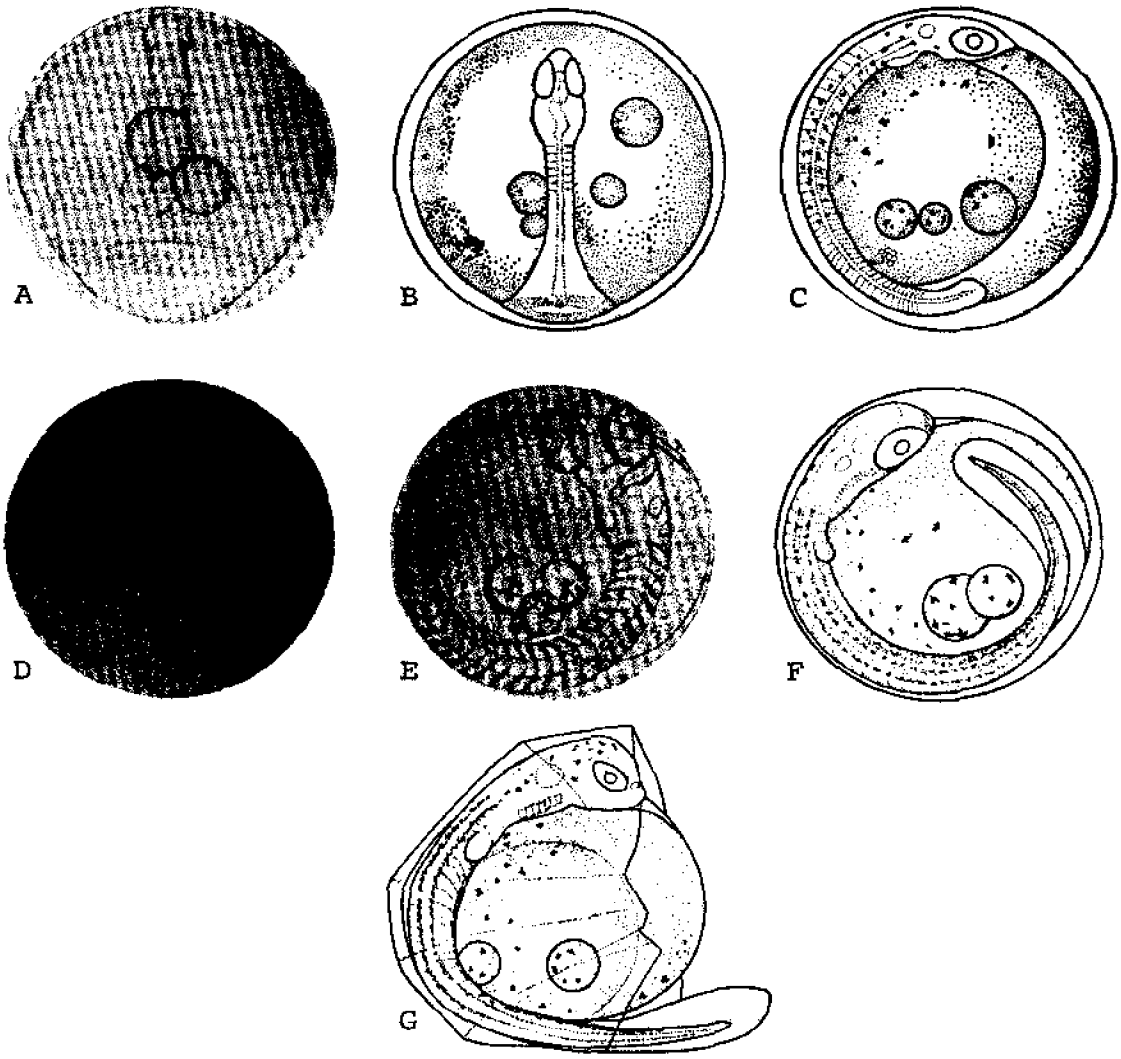

Fig. 50. *Sarda sarda*, Atlantic bonito. A. Egg, about time of blastopore closure. B-F. Eggs. G. Hatching egg. (*A, D-E, Sanzo, L., 1932: figs. 1–3. B-C, F-G, Dekhnik, T. V., 1973: figs. 50 e-f and 51 a-b.*)

anterior to midpoint of body,[14,16] migrate forward one day after hatching.[2]

Pigmentation: At hatching—yellow spots on margin of dorsal finfold, larger posteriorly; ventral finfold with large yellowish spots anteriorly; two series of spots on trunk and in same form as those on finfold; very small yellow spots diffusely cover distal part of yolk sac and along dorsal profile of trunk and head; few stellate melanophores along ventral profile caudally, on oil globules and in supraorbital region.[2]

One day after hatching—yellow pigment on caudal trunk forming series of marginal spots; stellate melanophores sparse along trunk and limited to ventral caudal trunk; melanophores forming in peritoneum.[2]

During yolk sac absorption, black pigment intensifies on head, in area of intestine, on oil globule and on ventral portion of body up to tail tip; brown pigment distributed along margin of dorsal finfold, on dorsal portion of body, on posterior portion of head, along gut, and along margin of ventral finfold;[14,16] eyes attain black pigment.[16]

LARVAE

Specimens described 4.68[1]–26.5 mm.[7]

D. 6 at 17.5 mm; 18 at 26.5 mm; finlets forming at 17.5 mm. C. complete at 17.5 mm. V. complete at 17.5 mm.[7] Preanal myomeres 9 at 4.68 mm. One triangular preopercular spine at 4.68 mm;[1] 3 at 5.45 mm; 5 at 7 mm;[14]

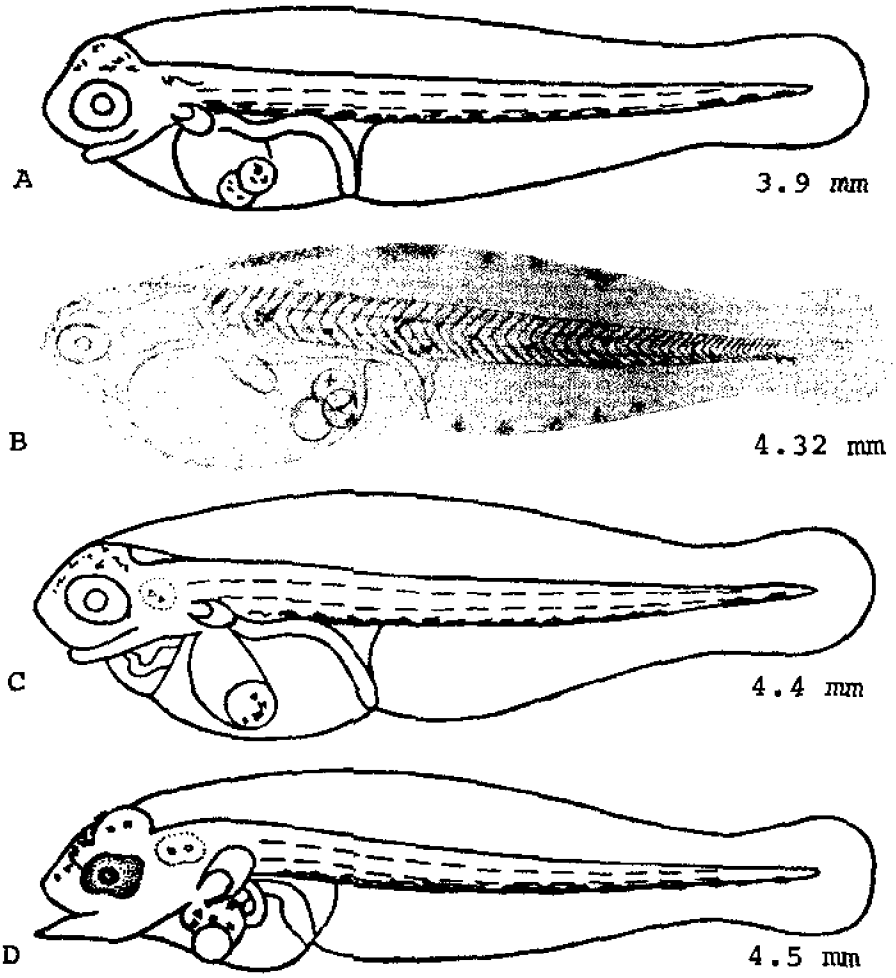

Fig. 51. *Sarda sarda*, Atlantic bonito. A. Yolk-sac larva, 3.9 mm. B. Yolk-sac larva, 4.32 mm. C. Yolk-sac larva, 4.4 mm. D. Yolk-sac larva, 4.5 mm. *(A, C-D, Dekhnik, T. V., 1973: fig. 51 c-e. B, Sanzo, L., 1932: fig. 4.)*

9–10 with central 3 largest at 17.5 mm; 5 at 26.5 mm.[7] Spines appear above eyes at 9.5 mm.

Preanal distance 44–49% of body length at 9.3 mm.[14]

Head large, very deep; mouth very large; articulation of jaws extending past middle of eye;[14] teeth present at 4.68 mm; eye round;[1] unpaired fins formed at 9.5 mm with spines of first dorsal forming first; pelvic fins formed *at about 7 mm.*[14]

Pigmentation: 4.68 mm—yellow pigment on finfolds still present; yellow pigment on body almost gone; black pigment still present on ventral caudal trunk.[1]

At 7.2 mm—2 large pigment spots and perhaps a few smaller on base of anal fin, and a very small one above and below urostyle; pigment also on pectoral rays and jaws; larger and thicker pigment in peritoneum and on nape.[29]

At 17.5 mm—3 series of chromatophores postanally; dorsal margin of body spotted, with very small spots behind second dorsal fin; 2 very dense spots over cerebrum; between these and first dorsal fin pigmentation absent; tips of upper and lower jaws with small spots; some chromatophores in peritoneum.[7]

At 26.5 mm—upper jaw without spots; upper part of opercle with fine spots continuing dorsally and back to finlets and forming series of vertical spots or blotches; pigment band along median line of sides; unpigmented area just anterior to tail; spot on caudal peduncle and bases of caudal fin rays; peritoneum with widely spaced chromatophores; first dorsal fin intensely black; pelvic fins with obscure chromatophores; no pigment on 20th to 23rd dorsal fin rays; pectoral, second dorsal, caudal and anal fins transparent.[7]

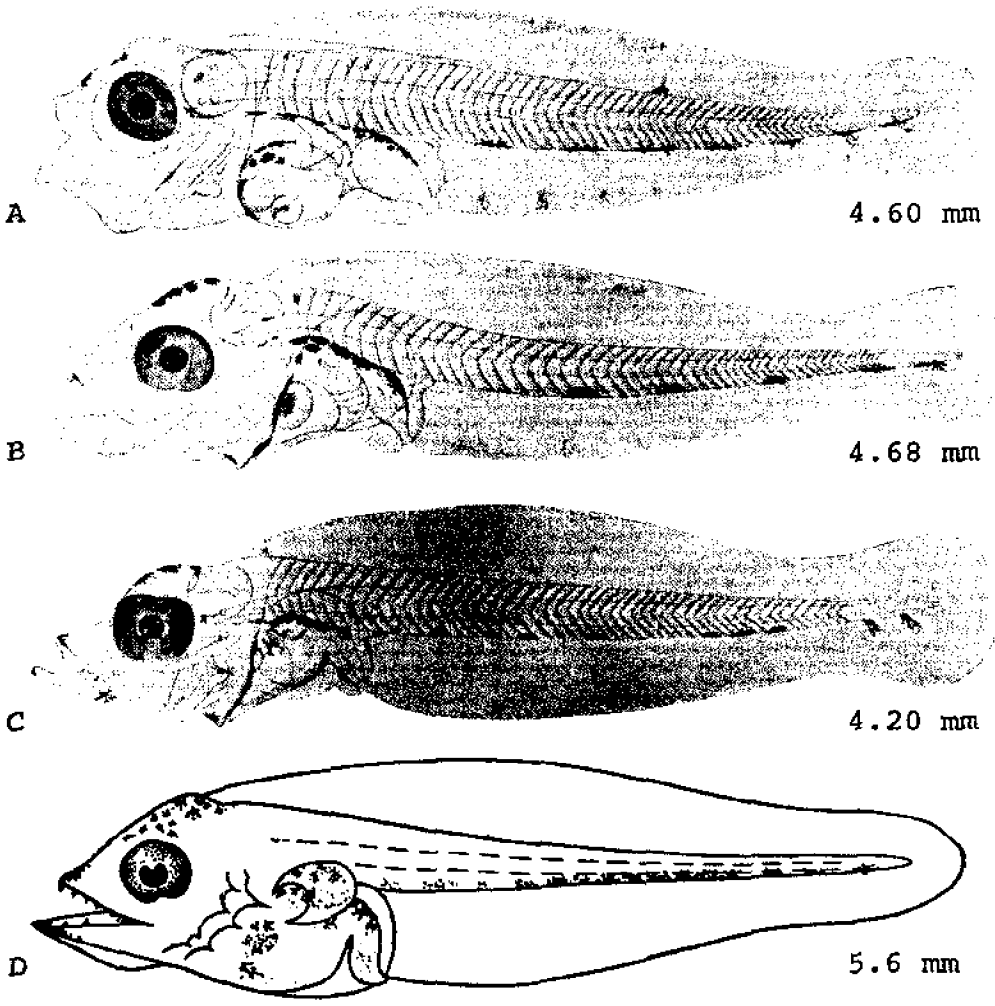

Fig. 52. *Sarda sarda*, Atlantic bonito. A. Yolk-sac larva, 4.60 mm. B. Larva, 4.68 mm. C. Larva, 4.20 mm. D. Larva, 5.6 mm. (*A-C, Sanzo, L., 1932: figs. 5–7. D, Dekhnik, T. V., 1973: fig. 51f.*)

JUVENILES

Specimens described 32 [6,7]–486 [10] mm.

D. XXI, 15+9; A. II, 11+7; [10] C. reported erroneously (RAF) as 15+16+15 at 32 mm; [7] P. 25; V. I, 5; [7] vertebrae 26+25=51; [10] gill rakers 3 [2]–7+11 [4]–12; [10] 3 large preopercular spines with smaller ones below at 32 mm.[7]

Proportions as percent TL at 150–250 mm: Head 22.9–33.6; preanal length 60–60.5; postanal length 41.6–47.[7]

Corselet small, triangular, reaching posteriorly to region of pectoral fins; [26] dorsal and anal finlets separating at 32 mm.[6]

Pigmentation: At 32 mm—body totally pigmented except postanally where pigment more restricted to dorsal line of chromatophores along base of second dorsal fin rays; stripe down mid-side ending before caudal peduncle; base of caudal fin rays with blotch which extends onto central rays; 6 vertical dark, broad bars on dorsum with posteriormost tending to become indistinct; head strongly with pigment extending onto preopercle, opercle/and borders of eye; end of maxillary and mandible spotted; first dorsal fin intensely black without pigment between rays 11 and 13; pelvic fins intensely black; second dorsal fin with spots along rays; caudal fin lobes, pectoral, and anal fins colorless and transparent.[7]

Marked with 10 [6,7,26]–16 [6] dark stripes transversely crossing back; intensely silvery below.[7]

GROWTH

Reaching 7.1 cm in June to 12.8 cm in July in Black

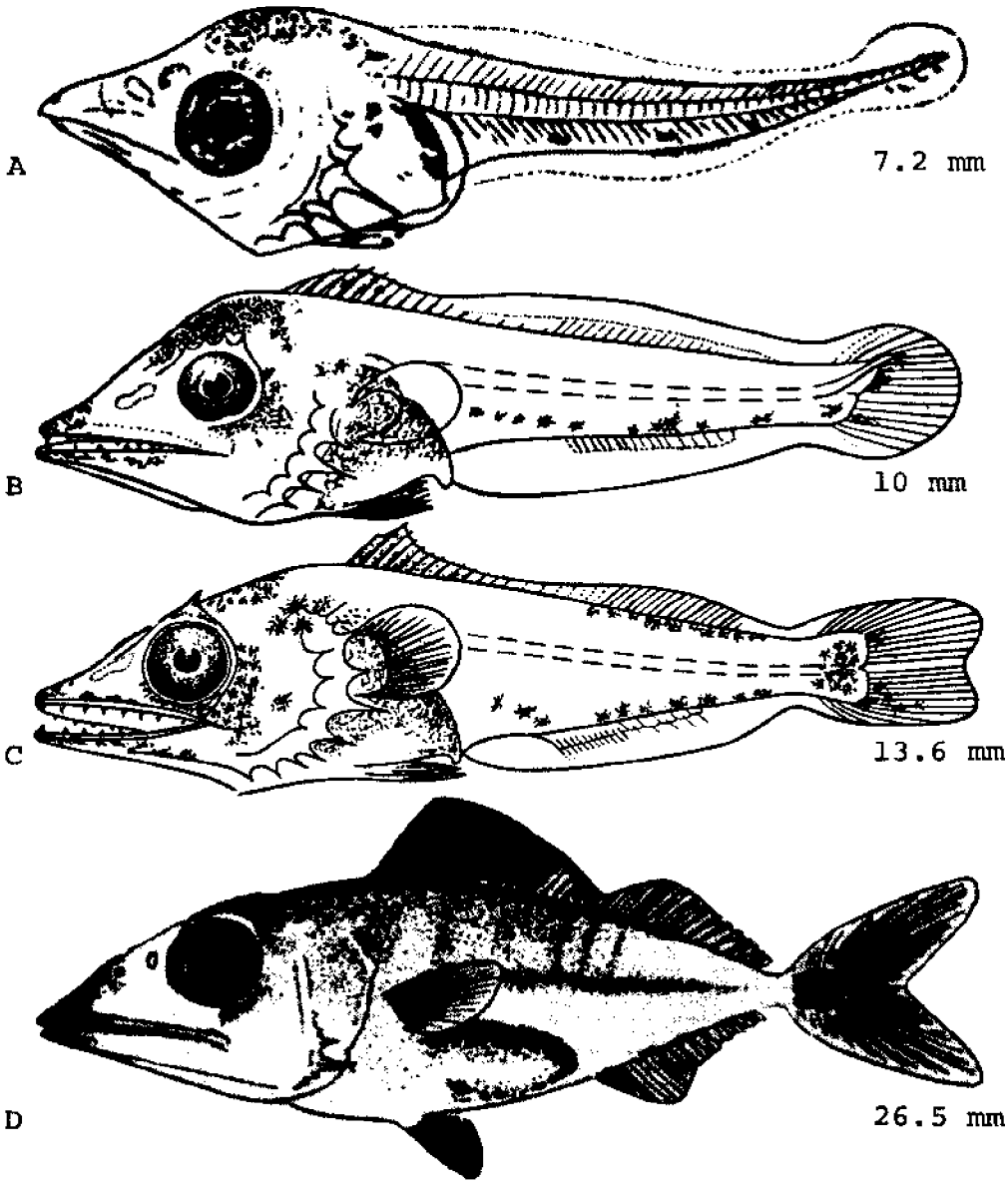

Fig. 53. *Sarda sarda*, Atlantic bonito. A. Larva, 7.2 mm. B. Larva, 10 mm. C. Larva, 13.6 mm. D. Larva, 26.5 mm. (*A, D, Belloc, G., 1954: 308. B, C, Dekhnik, T. V., 1973: fig. 51 g-h.*)

Sea; [6] 41 cm in first year, 52–57 cm in second, and 61–64 cm in third.[13]

AGE AND SIZE AT MATURITY

By end of second year, some mature in one year in Bosporus and Sea of Marmara, 42–48 cm in one year and 52–57 cm in 2.[18]

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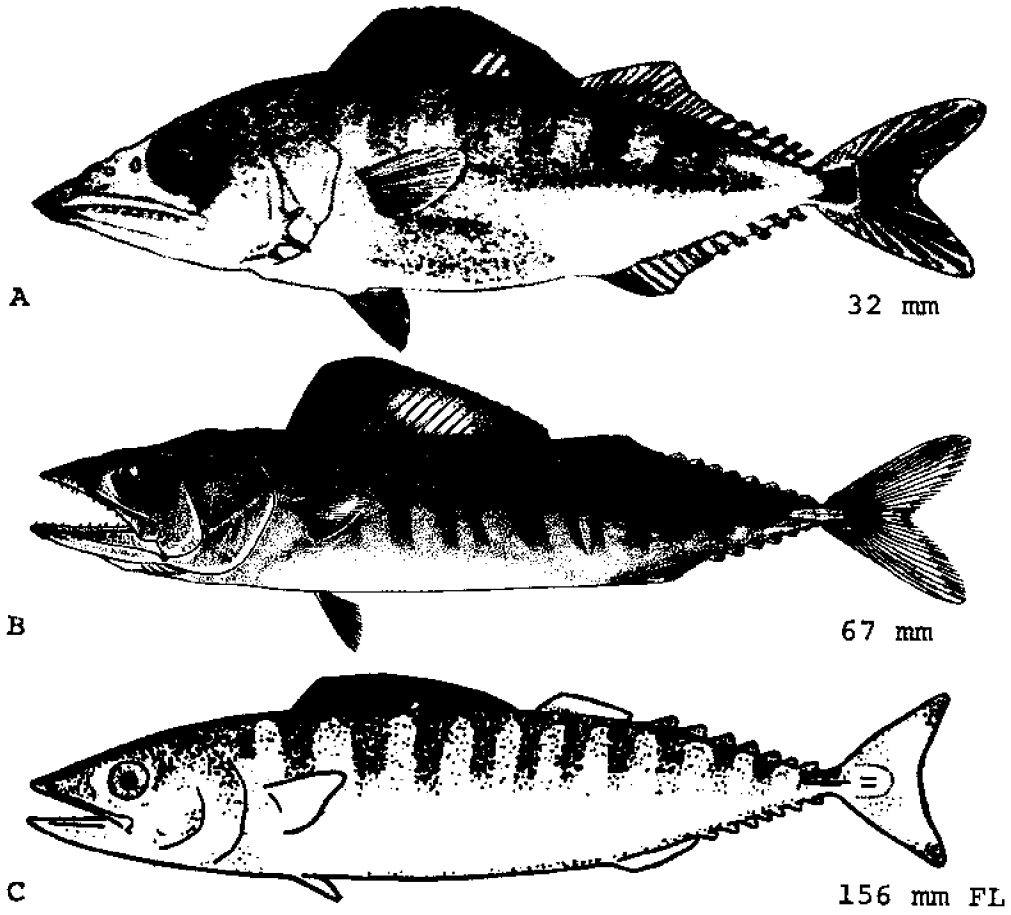

Fig. 54. *Sarda sarda*, Atlantic bonito. A. Juvenile, 32 mm. B. Juvenile, 67 mm. C. Juvenile, 156 mm FL. (*A, Belloc, G., 1954: 308. B, Klawe, W. L., and B. M. Shimada, 1959: fig. 6. C, de Buen, F., 1932: fig. 25.*)

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Scomber japonicus Houttuyn, Chub mackerel

ADULTS

D. IX [1] to XI; [26] 9 [7]–15 [17] + 4 [14,26]–6; [7,17] A. II,[7,26] 9 [7]–11 + 4 [7,26]–6; [7] C. 8–11 + 9 + 8 + 10; [26] P. 17 [7]–21; [17] V. I, 5; [7,17] lateral line scales about 180; [2] vertebrae 14 [1,26] + 16 [26]–17 [1,26] = 30–31; [26] gill rakers slender, 10–12 + 25–27 on first arch; [18] jaw teeth thin, conical,[15] marked with crenulations,[1] uniserial; [15,18] palatine and vomerine teeth in single or double rows; swimbladder present; first dorsal fin interneurals 12–15.[1]

Head 3.0–3.8, depth 3.25–6.25 in SL. Snout 2.75–3.16, eye 4–4.25, maxillary 2.32–2.6, interorbital 3.3–4.5 in HL.[18]

Body fusiform, elongate, little compressed, rather plump,[18] caudal peduncle slender, without median keel,[34] two small keels dorsally and ventrally on caudal peduncle; [7,18] head pointed, compressed; snout conic; mouth large, little oblique, jaws about even; maxillary reaches eye.[18] Scales small.[7,18] Lateral line slopes down along side to median, slightly waved. First dorsal fin rather high, received entirely into groove when depressed, widely separated from second; anal fin origin opposite or posterior to second dorsal; caudal fin small, forked; pectoral fins broad; pelvic fins little behind pectoral origin. Eye rounded, little before middle of head; adipose eyelid broad; interorbital broadly depressed.[18]

Pigmentation: Dark green [7] to blue-black [18] above, with series of about 30 wavy, dark streaks which extend below lateral line; [7,18] lower sides and venter mottled with small dusky blotches; [25] fins dusky, lower ones pale; pectoral fin base dusky.[18]

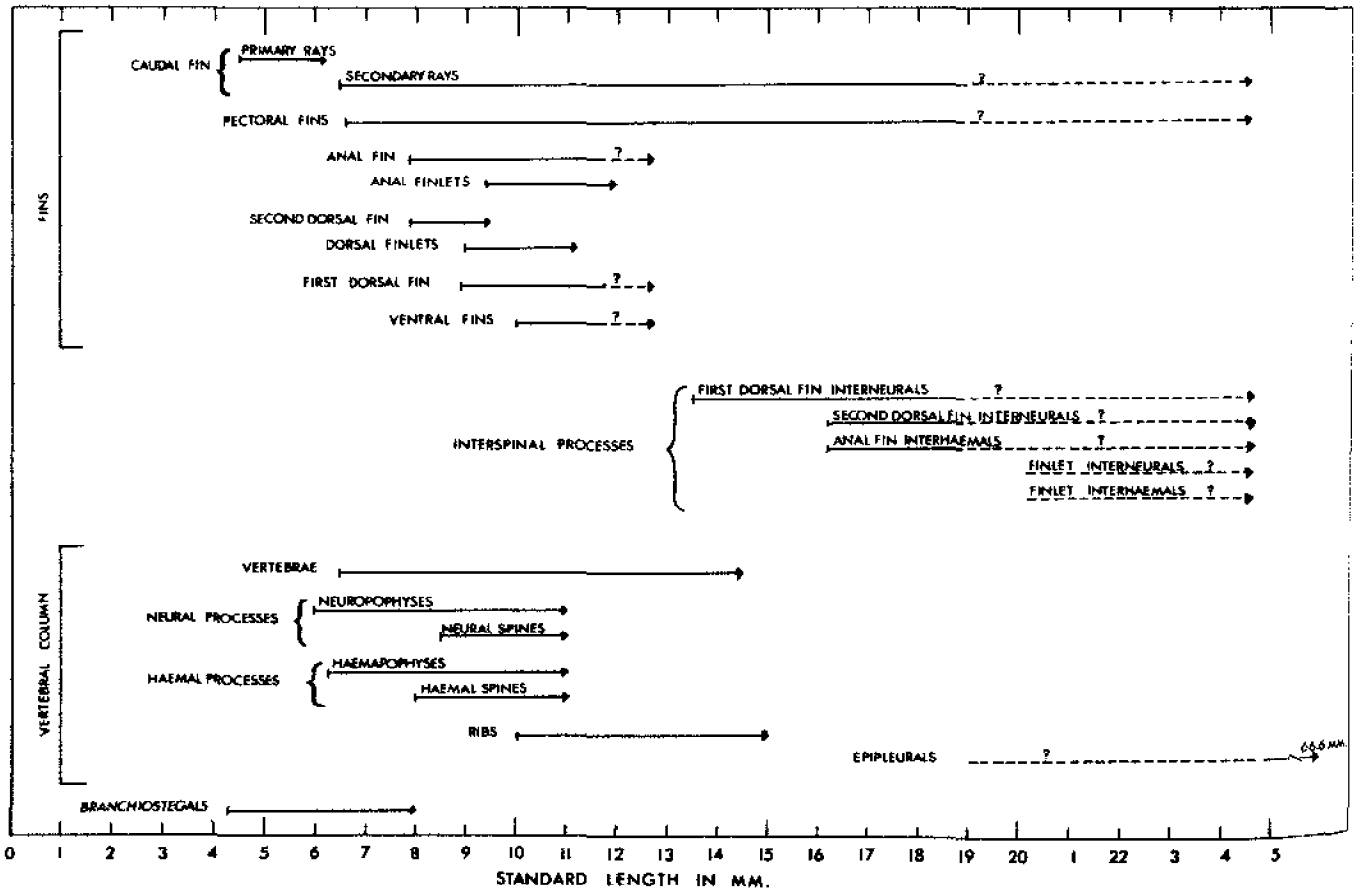

Fig. 55. Diagrammatic summary of the sequences of ossification of basic meristic structures and their parts in Pacific chub mackerel larvae and juveniles. Progressive ossification is indicated by the lines and the symbols attached to them: vertical bars, beginnings of ossification; solid lines, serial growth and additional numbers; broken lines and question marks, absence of specimens in series where growth and numbers are known to increase; arrows, achievement of final counts and continued growth. (*Kramer, 1960.*)

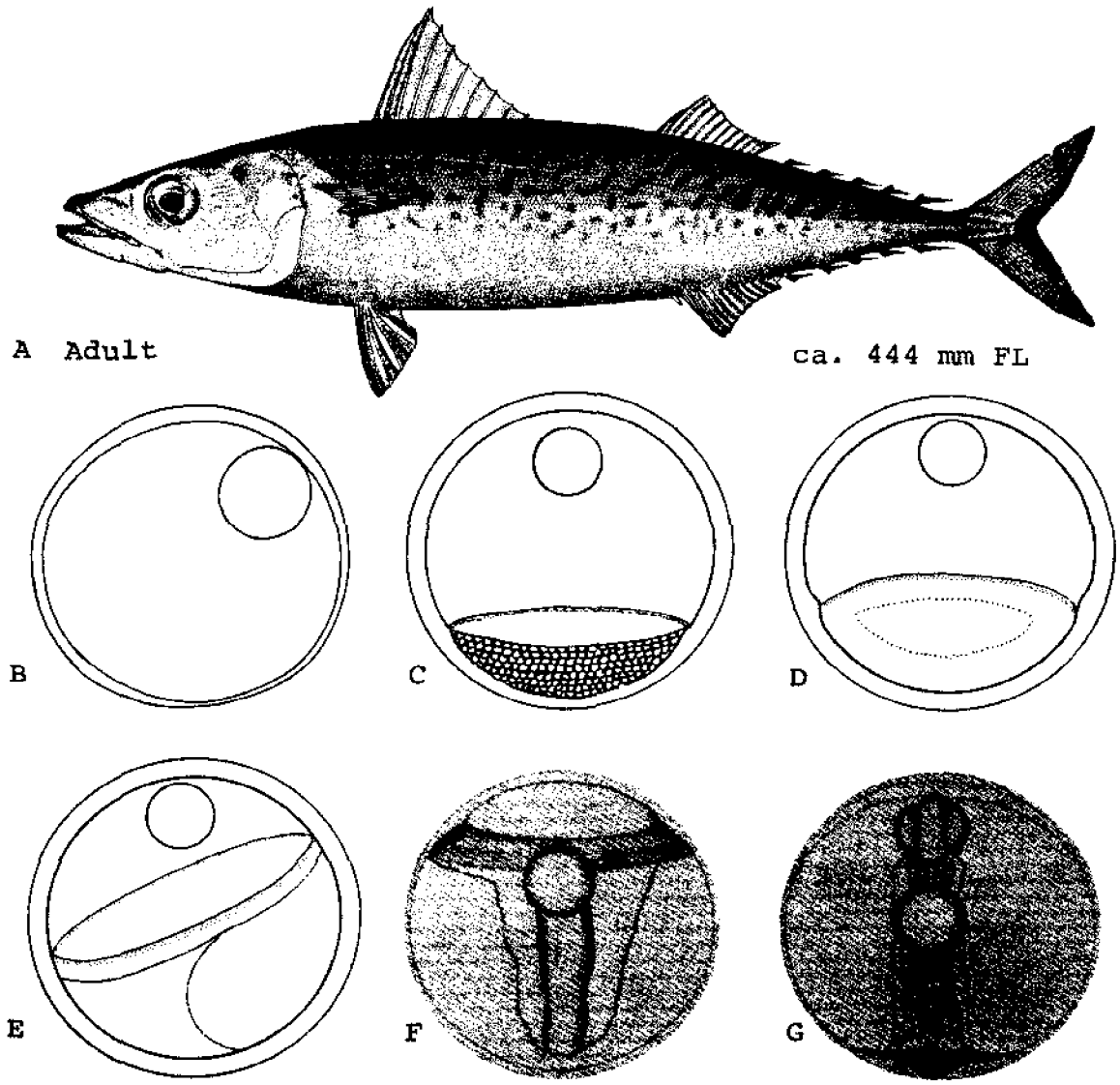

Fig. 56. *Scomber japonicus*, Chub mackerel. A. Adult, ca. 444 mm FL. B. Egg. C. Egg, 5 hr. 40 min. after fertilization. D. Egg, 6 hr. 40 min. after fertilization. E. Egg, 15 hr. after fertilization. F. Egg. G. Egg. (*A, Goode, G. B., 1884: pl. 91. B, Uchida, K., et al., 1958: pl. 48, fig. 1. C-E, Watanabe, T., 1970: fig. 27a, C-E. F-G, Fry, D. H., Jr., 1936a: fig. 12 A-B.*)

Maximum size: To 565 mm.[6]

DISTRIBUTION AND ECOLOGY

Range: Nova Scotia[25] southward to Florida, the Bahamas, the Gulf of Mexico and Venezuela. Also along west coast of Africa; the Mediterranean, Black and Red seas; Japan; and west coast of America from California to Panama and Chile.[1]

Area distribution: Throughout Mid-Atlantic Bight;[1] recorded from Atlantic, Cape May, Monmouth, and Ocean counties, New Jersey[27] and Worcester County, Maryland.[23]

Habitat and movements: Adults—pelagic;[6] school by size;[7] migrate north in summer in Japan. Japanese populations at 100–200 m in winter, 18.8–19.25 ppt chlorinity and 11–17 C; at surface in summer, 19.1–19.25 ppt chlorinity and 14–18 C.[18]

Larvae—come to surface at night in Japan[18] and usually distributed in upper 50 m with larger larvae seldom

deeper than 25 m; [13] associated with 14.1 [4]–21.5 C.[16]

Juveniles—schooling observed at about 20 days after hatching [8] or 30 mm TL in Japan; found above 50 m,[13] close to shore off sandy beaches, in kelp, and open bays,[6] sometimes abundant in current rips at night.[13]

SPAWNING

Location: Open ocean,[6] in Japan from shore to 3 km offshore; [21] occurs in South Atlantic Bight,[24] in Baja California from Bahia Sebastian Vizcaino south to Cabo San Lucas,[15] in Japan in Ishikari Bay, west coast of Hokkaido,[10] Boso Peninsula and Izu-Shoto Islands.[13]

Season: From winter–spring in South Atlantic Bight,[24] April [6]–July [5,6] in southern California with peak from May–early July,[6] March [13]–July [19] in Japan with peak from April–May, and throughout year off central Baja California; [14] younger fish spawn later in Japan.[16]

Temperature and salinity: Depth to 72 m; [6] temperature between 13.5–21 C, particularly when over 15 C [13] in Japan, 13.9–22.2 C in California; [6] chlorinity 19.1–19.3 ppt in Japan.[13]

EGGS

Pelagic; [3,6] abundant to 10 m with later stages to 20 m.[11]

Unfertilized eggs: Average 1.2–1.35 mm in diameter off California [5] and ovulating at 0.9–1.1 mm off Japan.[13]

Fertilized eggs: Spherical; [12,13] 0.9–1.2 mm ($\bar{x}$=1.05–1.08) on Pacific coast,[5] 1.14–1.24 mm ($\bar{x}$=1.18, n=11) in Florida Current,[8] and 0.93 [21]–1.15 [13,21] mm off Japan; membrane unsculptured; [14] nonadhesive; [13] yolk clear,[7,12] homogenous [14] with tiny vacuoles,[7] about 1.0 mm in diameter; [12] oil droplet single,[3,5,13,21] slightly yellowish [21] to colorless,[12] 0.26 mm diameter on Pacific coast,[5] 0.28–0.32 mm ($\bar{x}$=0.30) in Florida Current; [8] and 0.25–0.30 mm off Japan; [13] perivitelline space very narrow,[5,12,13] 0.02 mm.[5]

EGG DEVELOPMENT

Eyes differentiate at time of blastopore closure and pigment appears on dorsum of embryo from area just posterior to eyes, extending almost to end of tail, and laterally to yolk mass. At this time, head begins to widen laterally, forming triangle with widest part posterior to eyes and narrowest part just posterior to pectoral region. By time of tail bud formation, head twice body width. Between tail bud formation and tail twisting, pigment on back divides to form V with open end posterior to eyes and closed end on dorsum behind pectoral region. Posterior to this point, pigment divides again to form two lines on either side of midline, extending to tip of tail. As tail begins twisting out of embryonic axis, body becomes deeper and pigment on sides begins to coalesce into definite pattern of two, lightly scattered lines, pigment on tail being more or less patchy. Heaviest pigment in area forming V, line of pigment connects open end of V across area behind eyes. Heavy line or fold to oil globule now defined from point where tail leaves yolk mass. Caudal finfold develops at this time. When tail halfway to head, pigment appears on head slightly forward of eyes and on sides of head behind eyes. Pigment now lightly scattered on oil globule hemisphere oriented toward head.[15] When embryo encircles three-fourths circumference of egg, pattern of pigment on body and oil globule does not change radically until just prior to hatching.[6] By time tail extends as far forward as head, pigment migrates ventrally on sides of body; pigment can be seen migrating from sides of body onto yolk sac, and as development proceeds it spreads out and forward over yolk to areas on yolk sac near head. Just before hatching tail extends forward of head. Head heavily covered with pigment to snout. All pigment on sides of body migrating ventrally. Single ventral line of pigment near tail and some still dorsolateral on both sides above it.[15] Yellow pigment present at posterior edge of eye and in closely grouped cluster of chromatophores which form band around tail.[5] Embryo with green pigment present on mid-posterior portion of notochord behind optic cups between oil globule and notochord, and laterally on anterior part of notochord.[8] Anus and intestine well formed behind oil globule.[15] Hatching occurs tail first.[12]

Incubation period 49 hours at 19.5 C [21] and 50 hours at 20 C.[12]

YOLK-SAC LARVAE

Size at hatching 2.7 [21]–3.0 mm.[3,5,7]

Yolk absorbed by 4.0 mm TL [13]–4.04 mm.[21] Caudal fin actinotrichia reach edge of finfold at about 3.5 mm; total myomeres 26 [8]–34, gradually becoming 31 with development; [5] preanal myomeres 8 at hatching, 9 at 3.5 mm; postanal myomeres 19 at hatching, 22 at 3.5 mm.[12]

Measurements given as percent SL: Snout-anus 46.94–48.82, head 25.83–25.52, eye 10.48–11.80.[15]

Head projecting over yolk; [12] yolk mass little over twice as long as wide,[5] absorbed in 100 hours; [8] oil globule posterior in yolk sac; [14] mouth opens at 3.6 mm TL; [12] gape to below middle of eye at 5 mm; [8] teeth present as 1 on premaxillary and 1 on dentary at 3.42 mm,[15] 2 or 3 pairs at 5 mm; [8] first dorsal fin spines form anterior to posterior; second dorsal and anal fins with middle rays forming first; pectoral fins form as buds at 3.1 mm; [12,15] finfold well-developed in newly hatched; [13] anus immediately behind yolk sac,[5] shifting anterior with yolk absorption.[13]

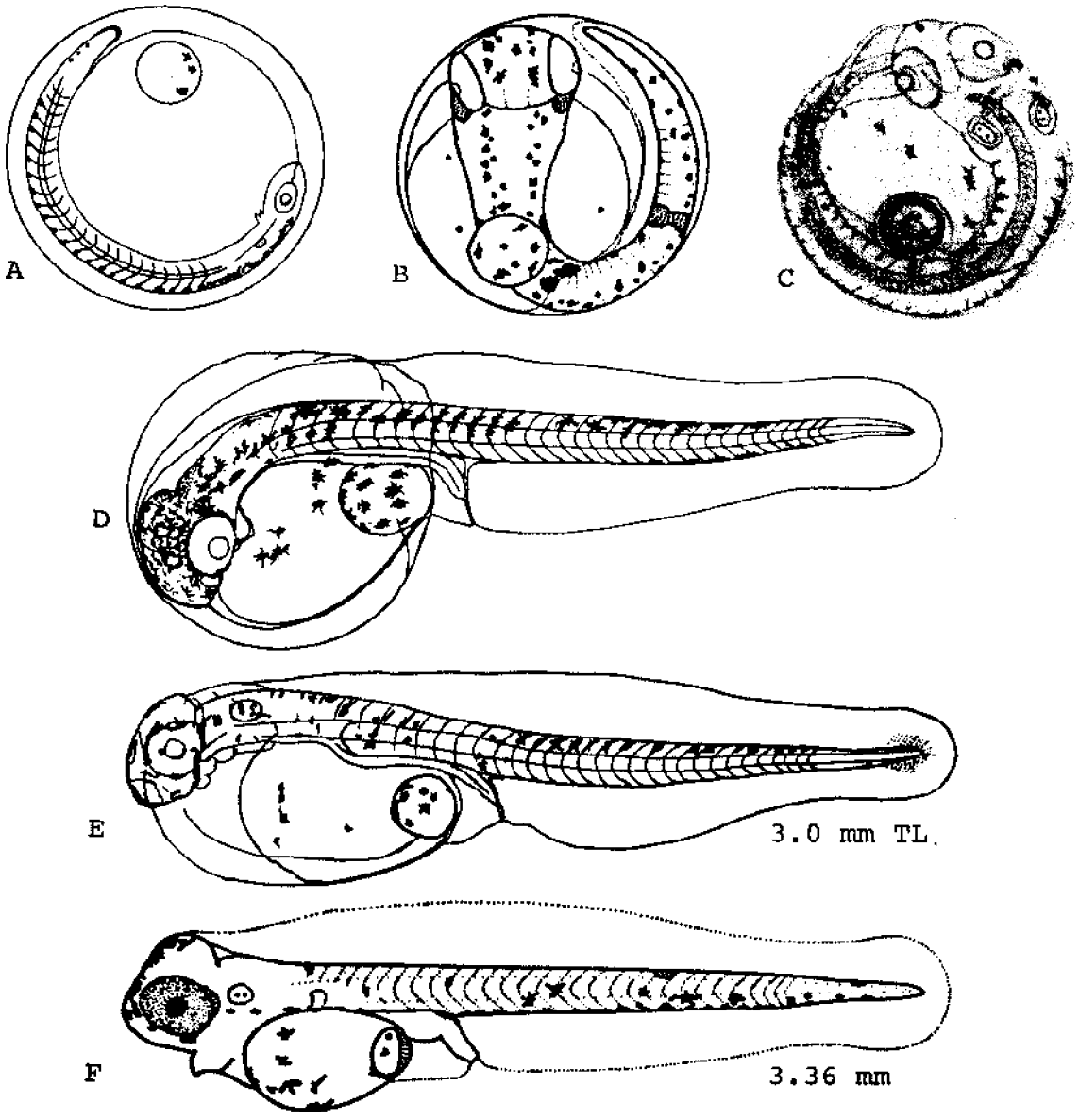

Fig. 57. *Scomber japonicus*, Chub mackerel. A. Egg, 23 hr. 40 min. after fertilization. B. Egg, 1.18 mm diameter. C. Egg. D. Hatching, tail first. E. Yolk-sac larva at hatching, 3.0 mm TL. F. Yolk-sac larva, 3.36 mm. (*A, E, Watanabe, T., 1970: figs. 27aJ, 27bA. B, F, Mayo, C. A., 1973: figs. 3c, 11a, used with the permission of the author. C, Fry, D. H., Jr., 1936a: fig. 120. D, Uchida, K.*, et al., *1958: fig. 3.*)

Pigmentation: 3.0 mm—no definite pattern of pigment. Pigment on head often rather heavy, extending from region over brain forward to and under snout. Pigment on body migrating ventrally with some already on ventral surfaces. Pigmentation on yolk sac light and generally restricted to dorsolateral surfaces. Oil globule heavily pigmented on anterior hemisphere with some pigment scattered on its posterior sections.[15]

At 3.5 mm—yolk sac 2/3 absorbed. Pigment on head forms ring over each eye and forward part of head from dome to snout. Pigment sometimes extends laterally and posteriorly in lines along junction of eyes and head. These lines sometimes extend and meet pigment in horizontal lines in back of eyes, on lateral surface of head, and body just above yolk sac. Pigment generally migrated completely to ventral surfaces of body. Heavy concentration of pigment on top of body cavity extending almost to anus. Posterior to anus ventral pigment of body in two lines one on each side of finfold. Heavy pigment on remnant of yolk.[15] Chromatophore pigment

pale green after hatching and appears (1) either as band or as two spots on midposterior portion of notochord, (2) as one or two granules on surface of developing midbrain, (3) on posterior portion of hindbrain, (4) behind optic cup, and (5) on posterior portion of yolk sac, associated with oil globule.[8]

LARVAE

Specimens described 4.0 mm [15]–15 mm (Japan) [13] (?) or 24.6 mm.[15]

D. 6 at 7.5–7.99 mm; IV, 7–11 + 1–4 at 8.0–8.49 mm; VI–VIII, 11 + 5–6 1/2 at 11.0–11.99 mm; XI, 11 + 6 1/2 over 12 mm. A. 10 at 7.5–7.99 mm; 7–I, 11 + 1–4 at 9.0–9.4 mm; I, 11 + 5–6 1/2 at 11.0–11.99 mm; II, 11 + 6 1/2 over 12 mm. C. 2–8 at 4.5–4.99 mm; 0 + 6–7 + 1 at 6.0–6.49 mm; 3–6 + 9 + 8–6 at 11.0–11.99 mm; 9 + 9 + 8 + 9 by 16.0–16.99 mm. P. 2–5 at 7.0–7.49 mm; 5–10 at 9.0–9.49 mm; 10–14 at 11.0–11.99 mm; 16–17 at 15.0–15.99 mm. V. I at 10.0–10.49 mm; I or I, 3 or I, 4 at 11.0–11.99; I, 5 over 12 mm.[5] *Total myomeres* 30–32.[8] Preanal myomeres 11 at 6.4 mm TL, 13 at 7.5 mm TL, and 15 at 8.5 mm TL. Postanal myomeres 21 at 6.4 mm TL, 19 at 7.5 mm TL, 18 at 8.5 mm TL.[12] *For sequence* of ossification see Fig. 53. Vertebrae 5–14 at 7.0–7.49 mm; 23–31 at 9.5–9.99 mm, and 31 at 10–5 mm and over. Branchiostegals 1–2 at 4.49 mm, 3–5 at 5.5–5.99 mm.

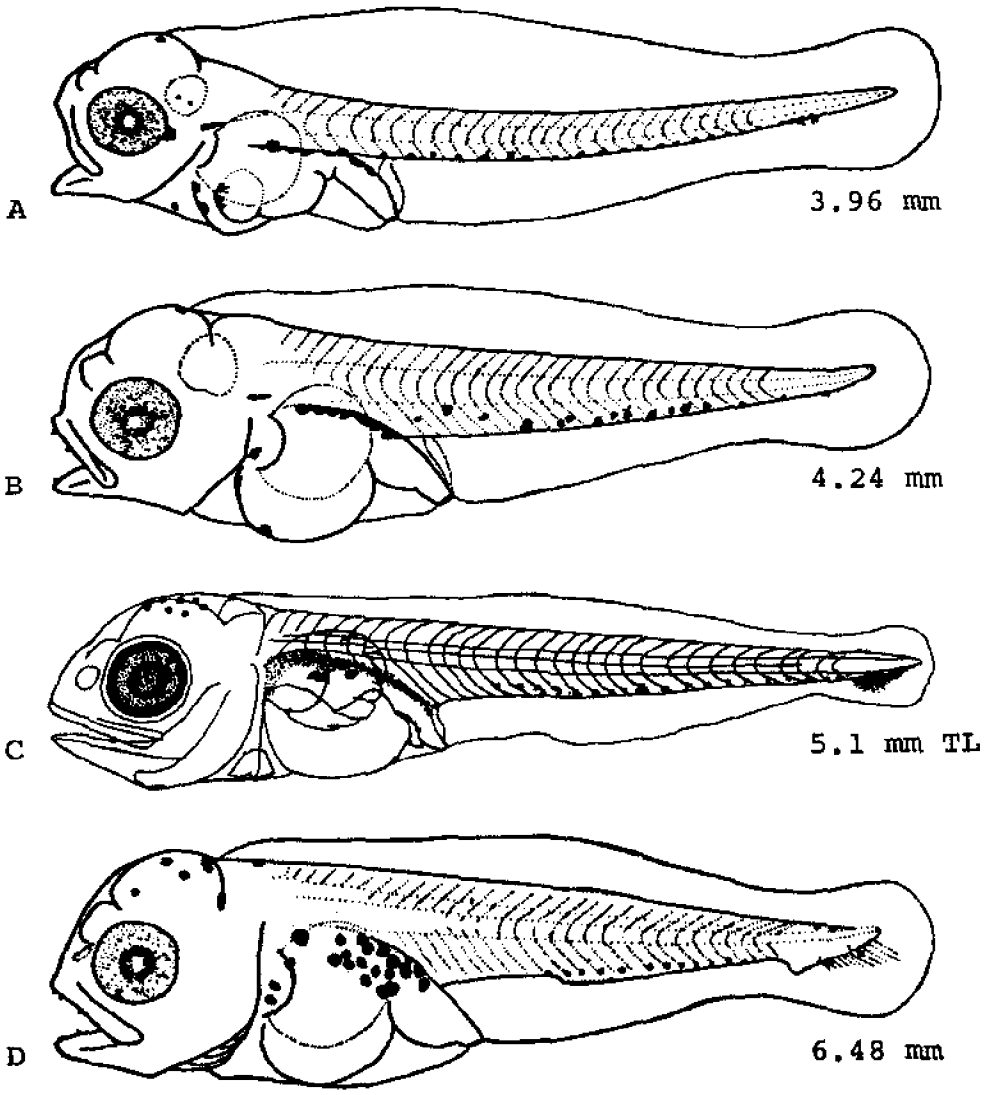

Fig. 58. *Scomber japonicus*, Chub mackerel. A. Yolk-sac larva, 3.96 mm. B. Larva, 4.24 mm. C. Larva, 5.1 mm TL. D. Larva, 6.48 mm. (*A, B, D, Mayo, C. A., 1973: fig. 3b-d, used with the permission of the author. C, Watanabe, T., 1970: fig. 27c G.*)

4–7 at 7.5–7.99 mm, and 7 at 8.5 mm and over. Gill arches appear at about 4.5–5.0 mm; gill rakers 0+0+6 at 6.6 mm, 1+1+11 by 13–24 mm, 2+1+13 at 17.15 mm.[15] No head spination.[8]

Measurements as percent SL (showing range of change with growth): Head 23.56–29.10; eye 13.3–9.52, depth 23.35–22.19, snout-anus 45.97–66.67.[15]

Teeth, 3 on each premaxillary, +3 on each dentary at 4.67 mm, 7+8 at 8.45 mm, 11+12 at 13.50, 13+15 at 17.15 mm in California; [15] 2+2 at 4.24 mm, 5–6+5–6 at 8.45 mm in Florida Current; short, weak and needle-like.[8]

Bases of dorsal and anal fins present at 4.0–5.5 mm TL. Rays form in second dorsal, anal, and pelvic fins at 5.5–8.5 mm; full complement at 8.5–15 mm TL.[15] Caudal fin ray ossification begins ventral to tip of tail; [15] rays forming by 5.0 mm TL. Pectoral rays develop at 10.6 mm TL.[12] Notochord flexion occurs between 4.72 [8] and 6.8 [15] mm.

Pigmentation: All pigment disappears on head except about 3–5 melanophores on occipital region. This condition persists until 5.0 mm. These melanophores increase in number and size and persist throughout larval and early juvenile stages.[15]

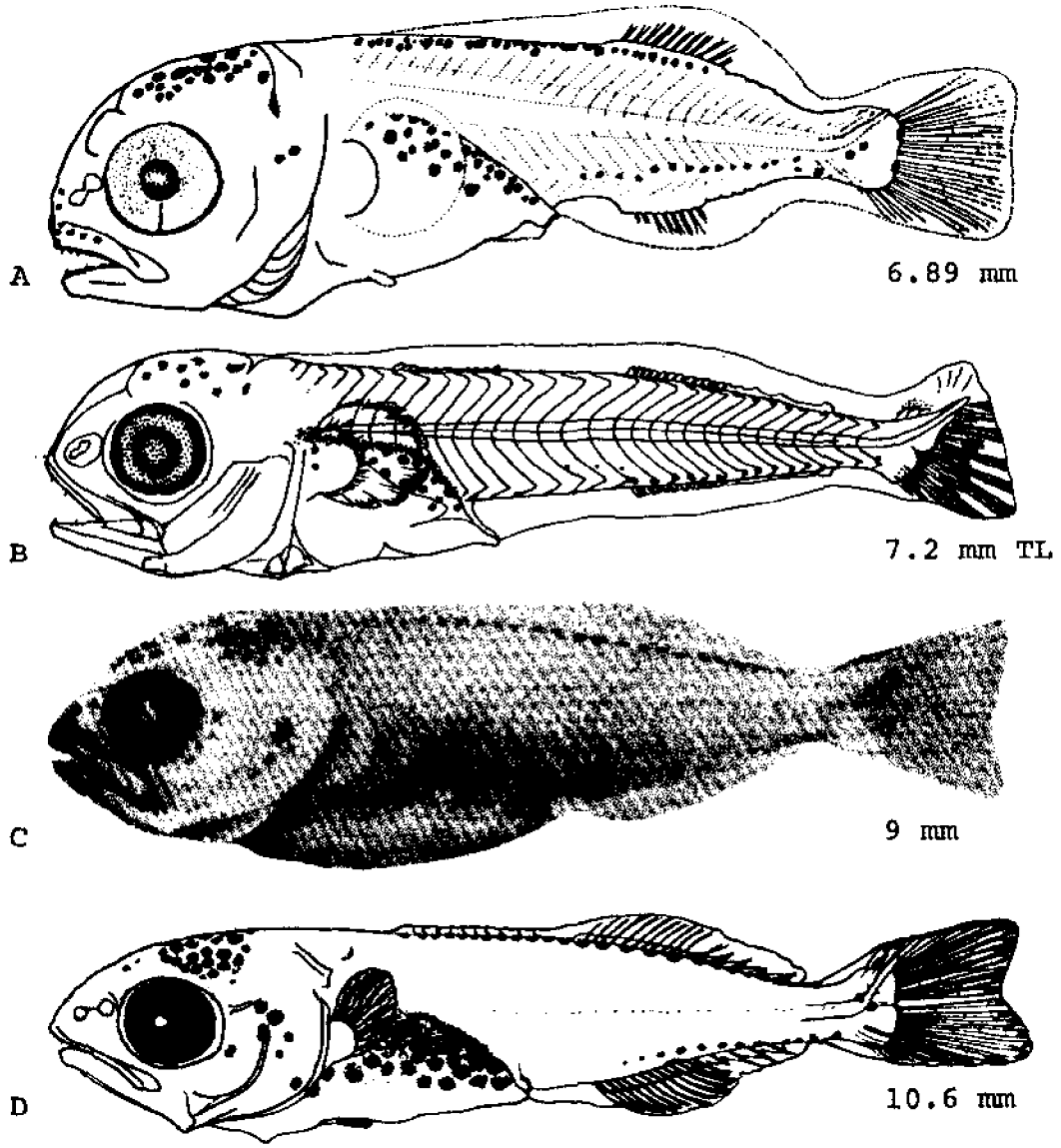

Fig. 59. *Scomber japonicus*, Chub mackerel. A. Larva, 6.89 mm. B. Larva, 7.2 mm TL. C. Larva, 9 mm. D. Larva, 10.6 mm. (*A, Mayo, C. A., 1973: fig. 12d, used with the permission of the author. B, Watanabe, T., 1970: fig. 27c I. C, Roedel, P. M., 1949: fig. 35. D, Uchida, K., et al., 1958: fig. 15.*)

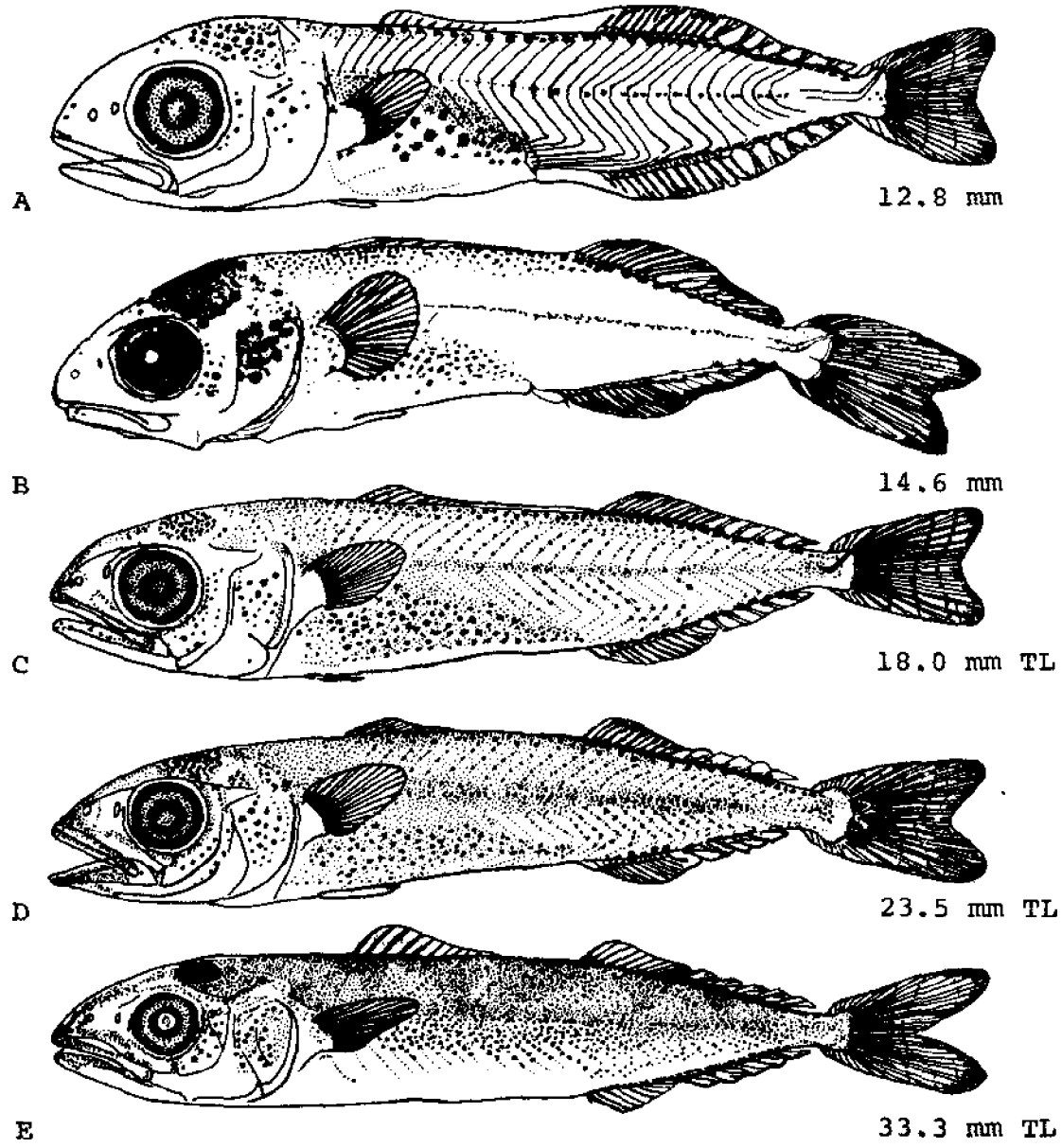

Fig. 60. *Scomber japonicus*, Chub mackerel. A. Larva, 12.8 mm TL. B. Larva, 14.6 mm. C. Juvenile, 18.0 mm TL. D. Juvenile, 23.5 mm TL. E. Juvenile, 33.3 mm TL. (*A, C-E, Watanabe, T., 1970: fig. 27d K-N. B, Uchida, K., et al., 1958: fig. 17.*)

At about 7.0 mm, pigment appears forward of occipital region, and very shortly thereafter on snout. These pigment areas increase rapidly in size until about 7.5 mm, *top of head covered from snout to nape. Also, melano-*phores begin to appear on mandible and operculum. Pigmentation increases both on top and sides of head until completely covered, no pigment on underside of head. Two or three characteristic pigment spots appear on ventral surface of gut and are retained there until they are absorbed or disappear. Pigment in region of developing caudal fin becomes apparent at about 5.0 mm, scattered without discernable pattern. In area ad*jacent to last myomeres, small patch of pigment* appears and retained through further growth. At about 6.0 mm, pigment spots form vertical line at base of caudal fin. At 7.0 mm, well defined pigment at about 16th myomere. Dorsal pigment spreads rapidly and at about 8.0 mm, double row of melanophores between 16th and 27th

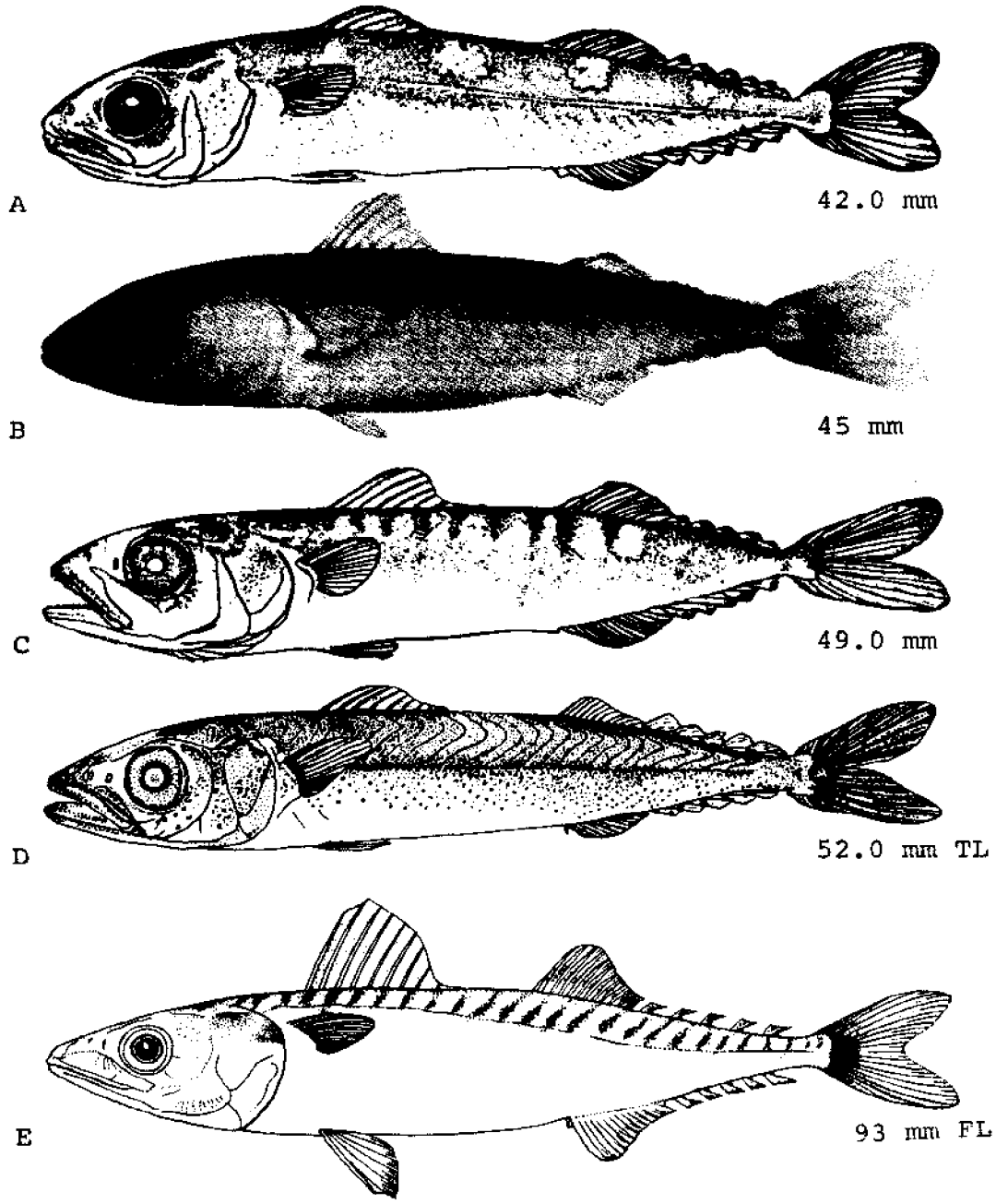

Fig. 61. *Scomber japonicus*, Chub mackerel. A. Juvenile, 42.0 mm. B. Juvenile, 45 mm. C. Juvenile, 49.0 mm. D. Juvenile, 52.0 mm TL. E. Juvenile, 93 mm FL. (*A, D, Uchida, K., et al., 1958: figs. 21–22. B, Roedel, P. M., 1949: fig. 37. D, Watanabe, T., 1970: fig. 27d O. E, Fowler, H. W., 1944: fig. 146.*)

myomeres. Simultaneously, second group of melanophores appears approximately at 7th and 8th myomeres, and increases rapidly to meet group at point above origin of anal fin. At about 7.4 mm, lateral line pigment appears. Pigment in gut region confined to peritoneal cavity until larva 7.5 mm, then few melanophores appear on sides of gut and gradually increase in number until lateral areas covered with pigment. Peritoneal cavity becomes opaque at about 9.0 mm, dark pigment still defined up to 15.0 mm.[15]

Green chromatophores may persist for several hours

after yolk sac absorption.[8] Yellow tail band decreases in size, becoming small patch at 2 1/2 days and disappears by 4 days.[6]

JUVENILES

Specimens described 15 mm TL (Japan) [13] or 18.9 to 24.6 mm [15]–300 mm TL.[13]

D. X to XI + 11 + 6 1/2; A. II, 11 + 6 1/2; C. 10–11 + 17 + 10–11; P. 19–21; V. I, 5; vertebrae 31; branchiostegals 7; gill rakers 5 + 1 + 18 at 24.6 mm, 9 + 1 + 23 at 66.6 mm; upper jaw teeth 20+, lower jaw teeth 22 at 30.0 mm, 34 + 27 at 66.6 mm; vomerine teeth 2 at 66.6 mm.[15]

Pigmentation: 19.0 mm TL—dorsal and lateral sides bluish-green, ventrolateral sides silvery-white; four broad dark marks near first dorsal fin and between second dorsal fin and finlets.[12]

At 42.0 mm TL—four dark marks extended onto body, reaching lateral line.[12]

At 45 mm—beginning characteristic zebra stripes of adult. Markings consisting of few rather heavy but slightly wavy bars.[9]

GROWTH

Japanese population reaching 12 cm in September, 15 cm in October, 18 cm when 1 year old; [20] California population averaging 28 cm TL after 1 year, 33 cm in 2 years, and 38 cm when 4 years old.[6]

AGE AND SIZE AT MATURITY

Most spawn when 2 years old; [6,16] some at 30 cm, and most at 33 cm.[6]

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Scomber scombrus Linnaeus, Atlantic mackerel

ADULTS

D. XI [27,28] to XII,[27] 11 [28]–12 [27] + 5; [27,28] A. II,[28] 11–12 [27] + 5; [27,28] C. 9 + 8; [28] P. 20–22; V. I, 5; [23] vertebrae 14 + 17 = 31; [28] gill rakers long, slender, about 30 on lower limb of first arch; teeth small, in single row on jaws, palatines and vomer.[27]

Head 3.6 [27]–4.5, depth 3.5 [24]–6 [24,27] in SL. Depth caudal peduncle 10–11,[27] snout 2.8 [24]–3.25; [27] eye 4.2–8, interorbital 3.0 [24]–4.75,[27] maxillary 2.2–2.75,[24] pectoral fin 1.9–2.2 [27] in head.

Body fusiform, little compressed, caudal peduncle slender, broader than deep,[27] bearing short horizontal keel on each caudal lobe; [24] head long, slender; snout pointed; mouth moderate, terminal, oblique; maxillary reaching nearly to middle of eye. Scales very small,[27] no corselet. Lateral line slopes down from shoulders in slight waves.[24] First dorsal fin with slender spines, its origin an eye's diameter behind pectoral base; second dorsal fin very small; caudal fin forked; anal fin similar to and opposite second dorsal; pelvic fins small, inserted under or slightly in advance of dorsal; pectoral fins short. Adipose eyelids broad.[24]

Pigmentation: Bluish black [27] to dark blue [24] above with about 23 [31]–35 wavy, transverse, blackish streaks; [24] sides and lower surface bright silvery; [24,27] dorsal, caudal, and pectoral fins largely dusky [27] to grayish; axil of pectoral black; peritoneum black.[24]

Maximum size: To about 559 mm and 1.8 kg.[27]

DISTRIBUTION AND ECOLOGY

Range: North Atlantic Ocean–Straits of Belle Isle [4,13] (seasonal in Newfoundland [3]) south to Cape Hatteras, and from northern Norway to Mediterranean and Adriatic.[4,13]

Area distribution: Entire Mid-Atlantic Bight [4,13] and in lower Chesapeake Bay.[27,30]

Habitat and movements: Adults—typically schooling in open sea [26] over continental shelf waters.[15] Appear in April near southern end of range and by July are near New England; disappearing again in September in northerly region and vanishing by December; spend winter in warm zone along continental edge from Cape Hatteras to southern edge of Georges Bank,[15] 48–161 km offshore and 91–182 m depth.[26] From east coast of Newfoundland, movement southwards in fall to overwintering grounds off New England coast, return migration during May–June.[3] Spend winter at or near bottom off Irish [12] and Baltic [18] seas. Arrive in the Skagerak and northern Kattegat about April–May and disappear October–November.[8] Migrate vertically in Aegean Sea.[14] Salinities of 37–38 ppt near Turkey.[21] North American waters above 8 C but can tolerate perhaps 4.5 C.[15] Depth limited by thermocline, 60–90 m near Turkey and surface to 183 m off North America.[26]

Larvae—planktonic; perform diurnal vertical migration to thermocline.[5] Found in hyponeuston when about 19–20 mm.[19] Recorded from 16.0–30.5 ppt and 3.2–7.0 C near Kiel.[16]

Juveniles—closer inshore than adults, not tending to go to deeper water; often enter estuaries in search of food.[26]

SPAWNING

Location: Occurs in several major areas listed in order of decreasing importance; continental shelf from Cape Cod to Cape Hatteras, Gulf of St. Lawrence, Gulf of Maine, and coast of Nova Scotia. Usually 16–48 km from shore, but also to 129 km.[5] In Irish Sea over shelf, rarely over 180 m line,[2,12] spreading over entire Irish Sea as season progresses.[2] In Sea of Marmara between 30–190 m, maximum at 60–65 m.[9]

Season: Beginning mid-April off Chesapeake Bay, May off New Jersey and New York, extending into June off southern Massachusetts; [5] May–September in Gulf of Maine; [26] and May–mid-June off Nova Scotia; [5] mid-May to early August in North Sea; [6] June–July near Kiel; [18] December–April peaking in February–March in Mediterranean; [17] March [11]–August [2] in Irish Sea, peak in April–May; [2,11] March–May in Sea of Marmara.[9]

Temperature and salinity: Recorded spawning temperatures from 7.3–17.6 C,[5] mostly over 8 C; [5,26] eggs taken at 4.3–6.4 C in Block Island Sound.[25] Salinities usually over 30 ppt.[8,9]

No evidence spawning occurs more often during day or night.[5]

Fecundity: Female of about 0.7 kg contains 546,000 eggs.[4]

EGGS

Remain pelagic in water over 34 ppt,[9] but often found down to thermocline.[5] Spherical; [1,9,17] 0.97–1.38 mm in diameter,[6,26] however, cultured eggs 1.13–1.25 ($\bar{x}$=1.20) mm diameter; [1] some evidence for two races, 1–1.38 mm in North Atlantic and 0.86–1.04 mm in Mediterranean; [20] egg membrane greatly reduced in thickness,[17] unsculptured,[1,9] elastic; [9] yolk homogeneous,[6,9,17] transparent; [17] oil droplet spherical, 0.22–0.38 ($\bar{x}$=0.29) mm diameter,[1] colorless [17] to pale amber or yellow; perivitelline space about 0.05 mm wide.[1]

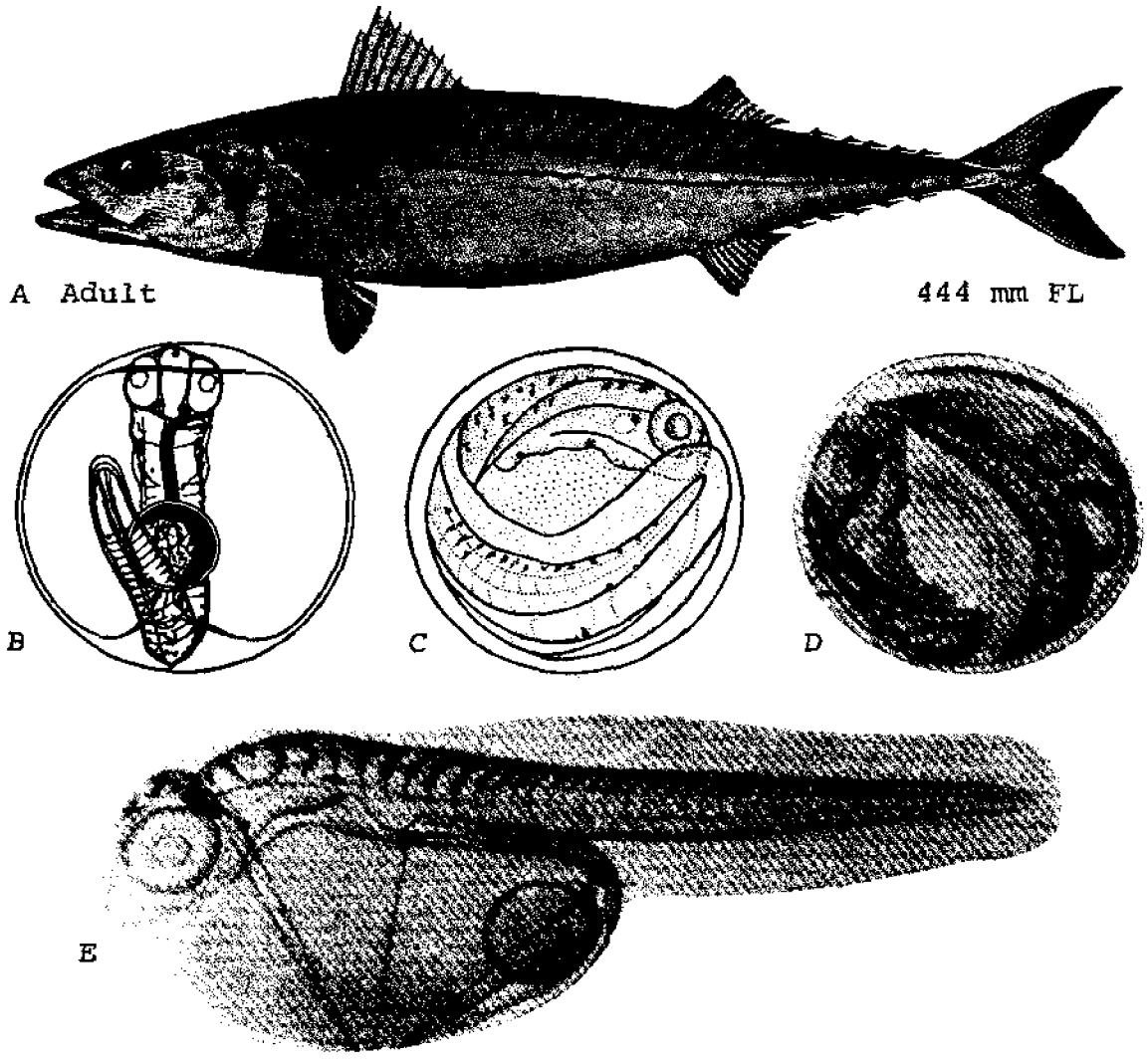

Fig. 62. *Scomber scombrus*, Atlantic mackerel. A. Adult, 444 mm FL. B. Egg, 1.18 mm diameter. C. Egg. D. Egg. E. Yolk-sac larva. (*A, Brice, J. J., 1898: 208. B, Ehrenbaum, E., 1905: fig. 15a after Holt, 1893. C, Dekhnik, T. V., 1973: fig. 49a. D, E, Sella, M., and O. Ciacchi, 1925: figs. 1–2.*)

EGG DEVELOPMENT

From fertilization to 36 hr.—single yellow oil globule, off-center at vegetal pole, opposite blastodisc at first and slightly posterior to tail at time of blastopore closure.

At 36–72 hr.—pigmentation on embryo after blastopore closure, numerous scattered fine points on dorsal surface of thoracic region and few black ones along trunk. As development progresses, these pigment cells become more intense and increase in number on trunk and tend to line up into 2 dorsolateral rows. Lateral melanophores in thoracic region become dendritic and dense, while middorsal melanophores fade. This distinct thoracic pattern persists until hatching. Melanophores appear on anterior surface of oil globule at same time as those on embryo. Embryo increases in length, growing past oil globule and encircling 3/4 of egg by end of this stage. Tail twists and flexes near oil globule until it lies flat against yolk surface. Finfold begins to develop on posterior third of embryo. Optic vesicles become prominent and up to 6 myomeres are discernable.

At 72–102 hrs. (hatching)—2 dorsolateral rows of melanophores extending back from just behind brain, well past oil globule, few melanophores below these rows on flanks. Pigment on anterior half of oil globule, and usually some on snout and in row behind eyes across head. Trunk melanophores migrate, they become scattered on flanks and some posterior to oil globule nearly reaching ventral edge of body. Pigment lacking on extreme caudal portion of body. Melanophores on oil globule

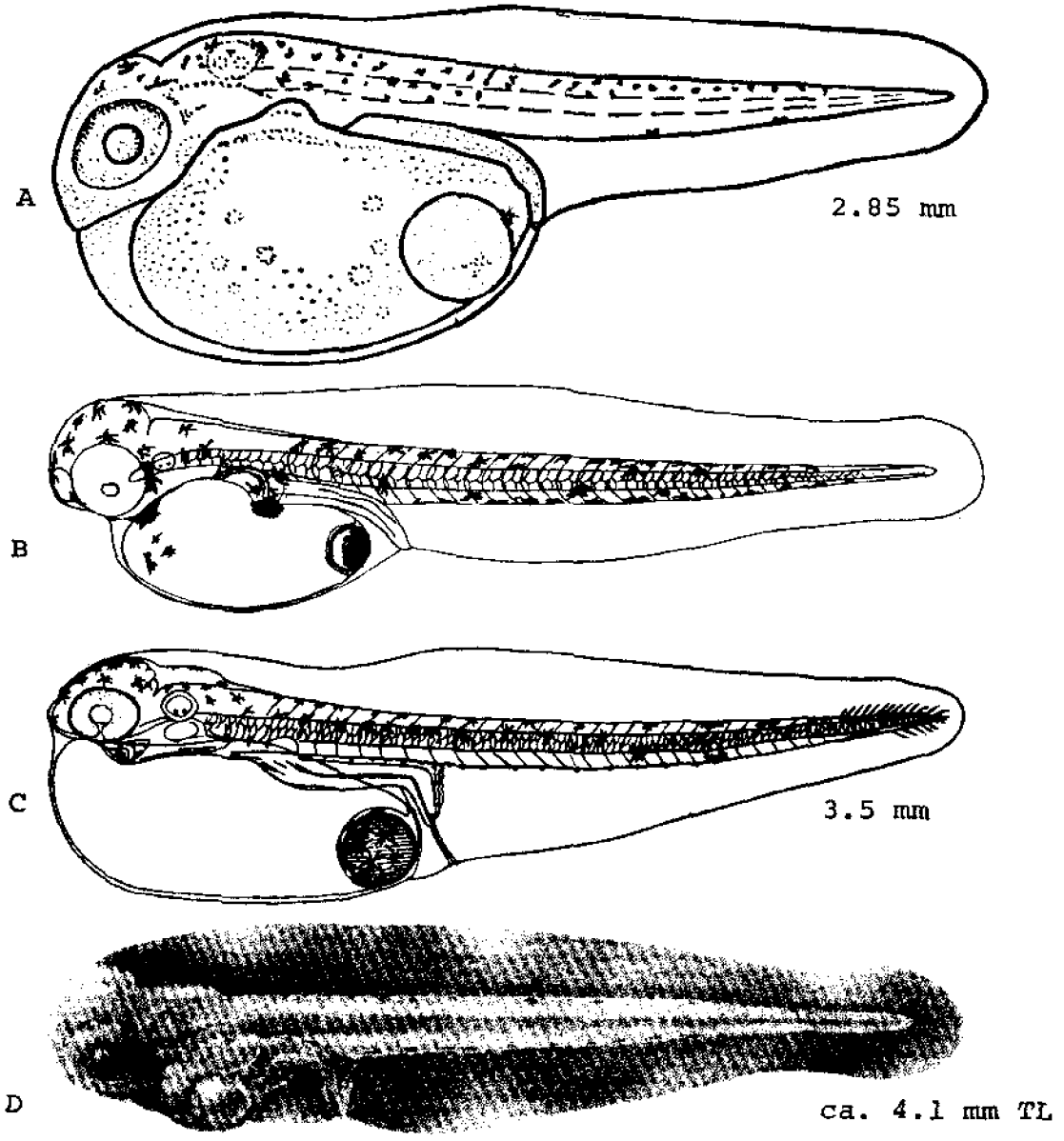

Fig. 63. *Scomber scombrus*, Atlantic mackerel. A. Yolk-sac larva, 2.85 mm. B. Yolk-sac larva, newly hatched. C. Yolk-sac larva, 3.5 mm. D. Yolk-sac larva, ca. 4.1 mm TL. (*A, Dekhnik, T. V., 1973: fig. 49b. B, Cunningham, J. T., 1891: fig. 4. C, Ehrenbaum, E., 1905: fig. 15b after Holt, 1893. D, Berrien, P. L., 1975: fig. 2A.*)

darken and increase in number and coverage. Myomeres 24 before hatching. Eyes unpigmented. Embryo increases in length until it encircles yolk. Oil globule lies midway along body, at posterior end of yolk sac. Finfold deepens and extends forward to occupy posterior 2/3 of embryo.[1]

Incubation period varies: 209 hours at 10 C, 150 hours at 12 C,[5] 90–102 hours at 12.1–14.4 C,[1] 95 hours at 16 C, 70 hours at 18 C, and 50 hours at 21 C.[5] Eggs have been collected from 4.5–13.1 C and 16.5–30.5 ppt near Kiel.[13]

YOLK-SAC LARVAE

Size at hatching from slightly less than 3 mm [5,17]–4.23 mm; [22] yolk sac absorption complete at 4 [5]–6 mm.[26]

Total myomeres 30 [5]–31; [1] teeth first visible at 6 mm.[26]

Snout-vent length reduced from 41.9–43.5% at 60 hours after hatching to 39.6–41.7% at 100 hours.[17]

Yolk sac copious,[17] absorbed by 137 hours after fertilization; [1] oil globule posterior in position; [17] mouth opens at

completion of yolk sac absorption; [1] eye pigmented after 60 hours; [17] otoliths visible at hatching; caudal fin actinotrichia visible at hatching,[1] first rays at 6 mm; [26] pectoral fin buds present at hatching, becoming fan-shaped with fleshy base at 66 hours after hatching; [1] finfold elevated in anterior portion after 100 hours.[27]

Pigmentation: American specimens—at hatching, some melanophores in dorsolateral rows, extending on each side from snout over eyes to about 9/10 body length, while others scattered on flanks. Melanophores also on nape, on each side of yolk sac close to otocysts and scattered on oil globule. Pigment on head reduced to a

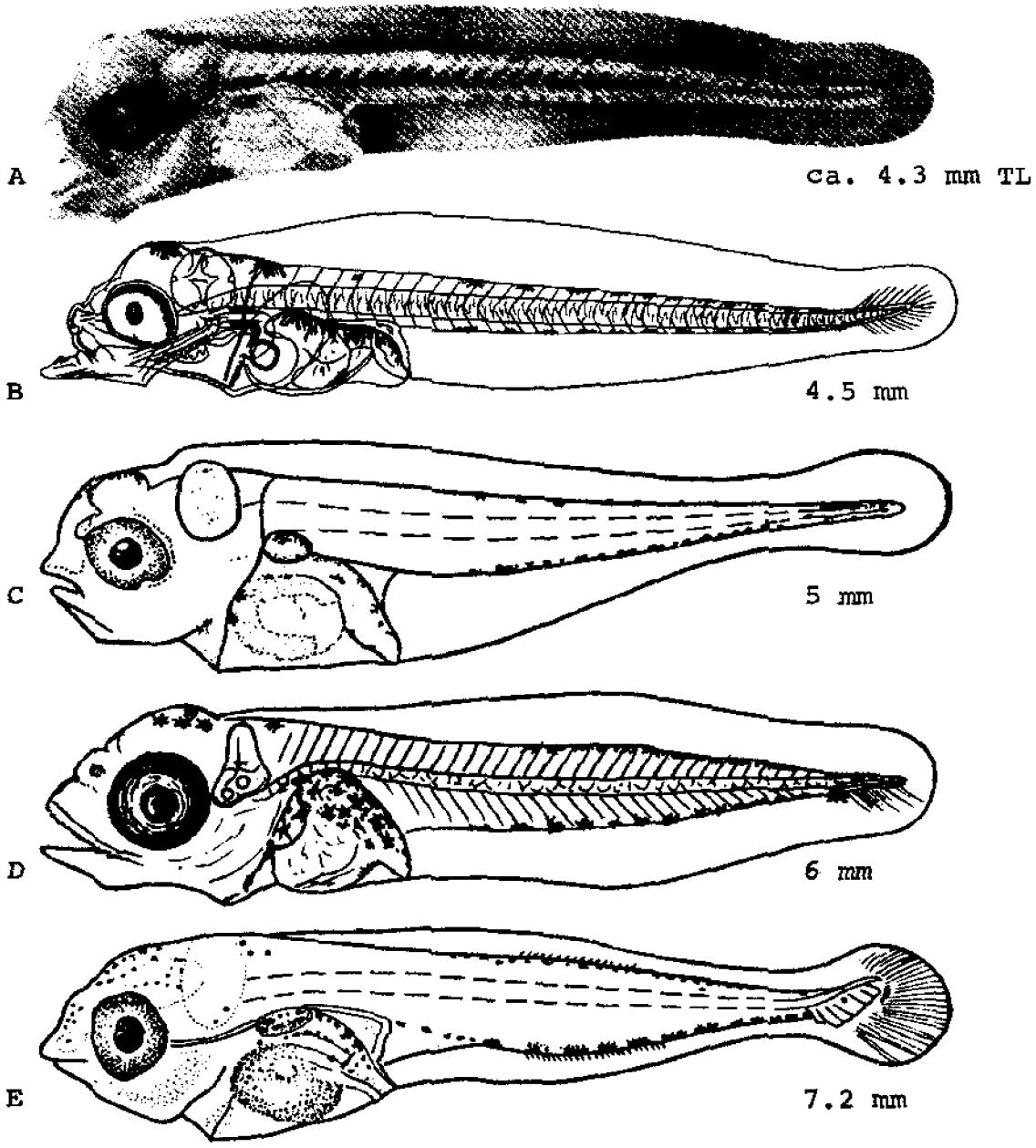

Fig. 64. Scomber scombrus, Atlantic mackerel. A. Yolk-sac larva, ca. 4.3 mm TL. B. Larva, 4.5 mm. C. Larva, 5 mm. D. Larva, 6 mm. E. Larva, 7.2 mm. (*A, Berrien, P. L., 1974: fig. 2B. B, D, Ehrenbaum, E., 1905: figs. 15 c-d, c after Holt, 1893, d modified. C. E, Dekhnik, T. V., 1973: fig. 49 c-d.*) (***Illustrations B-E of doubtful accuracy and should only be used with caution.*** RAF)

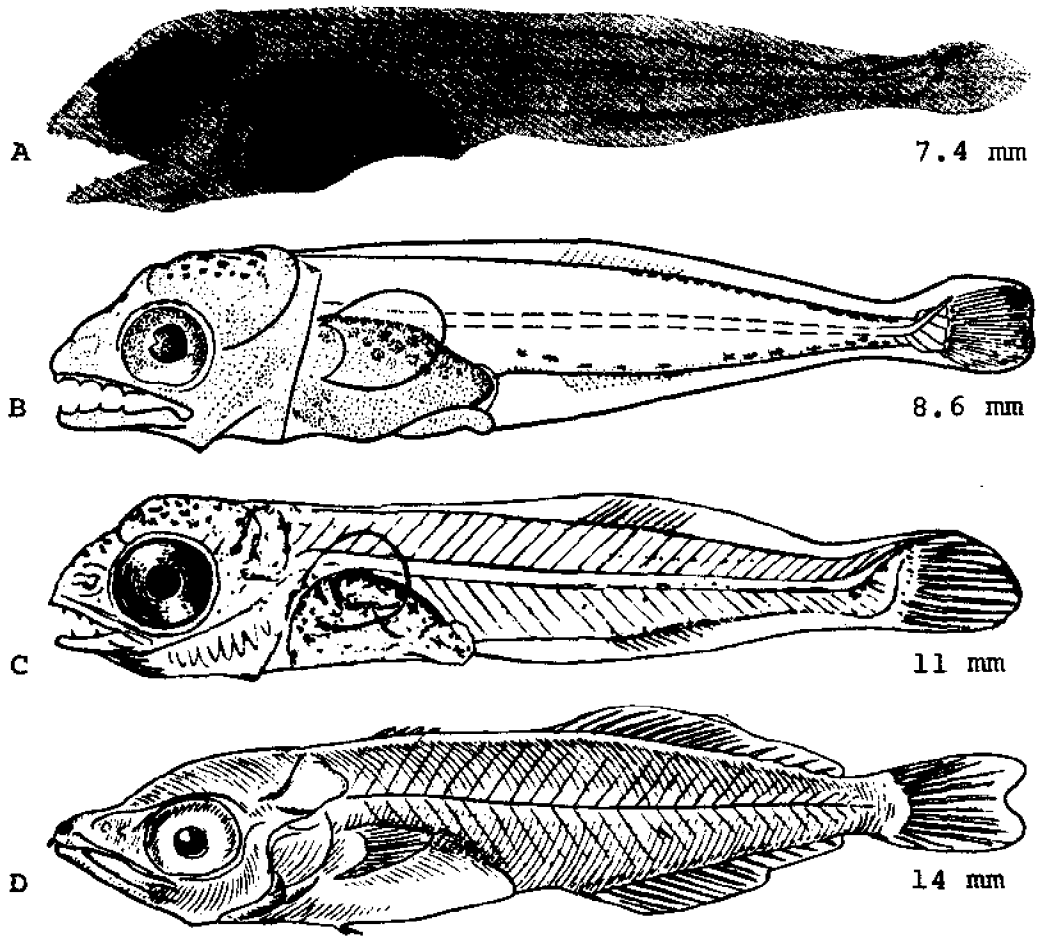

Fig. 65. *Scomber scombrus*, Atlantic mackerel. A. Larva, 7.4 mm. B. Larva, 8.6 mm. C. Larva, 11 mm. D. Larva, 14 mm. (*A, Ehrenbaum, E., 1924: fig. 1b. B, Dekhnik, T. V., 1973: fig. 49e. C, D, Ehrenbaum, E., 1905: figs. 15 e-f, e reversed.*) (***All illustrations of doubtful accuracy and should be used with caution.*** RAF)

few melanophores dorsal to eyes and on nape. Pigment forms in eyes at 66 hrs. Some specimens, between 13.7–192 hr., have melanophore on ventral midline between developing dentaries where basihyal forms. Melanophores present on oil globule at hatching and at 6 hr. start migrating to ventral surface of yolk sac; mostly on surface by 42 hr.; subsequently coalescing forward of gut cavity and on ventral surface of hind gut. At 18 hr. some melanophores migrating ventrally and inward over yolk mass; situated over midgut and hindgut by 66 hr.; large dendritic melanophores directly over gut cavity by 192 hr. Melanophores on dorsal finfold base decrease to about 6 by 192 hr. and located posteriorly; those in ventral row increase to about 20–25 and extend from near vent back to caudal extremity, exclusive of finfold.[1]

Mediterranean specimens—at 2.83 mm, branched melanophores sparsely scattered on lateral surface of body, from cephalic region to extreme caudal, generally more abundant on dorsal and anterior regions of trunk. Chromatophores missing or poorly visible on yolk sac. Yellow pigment present and localized: 1 or 2 spots behind eye; between eye and otocysts; 1 or several little spots branched over posterior surface of oil globule; and between oil globule and anus. Small spot directly posterior and ventral to heart and one under fold of pectorals. Usually small comma-shaped spot on musculature near center of post-anal section of body. At 60 hr. (3.2–3.5 mm), melanophores increase on cephalic surface and distributed more or less uniformly over trunk. Yellow pigment does not spread.[23]

LARVAE

Specimens described 4[5] or 6 mm[3]–43[20] or 50 mm.[5]

Vertebrae 13 + 17–18 at 14–18 mm; [6] teeth strong but sparse at 8.6 mm.[20]

Snout-vent length 34% TL at 5.8 mm,[16] 50% at 17–20 mm, and 55% at 50 mm.[32]

Body compressed; first dorsal fin just forming at 13 [6]–15 [20] mm, all rays formed by 16 mm; dorsal finlets formed by 19 [20]–22 mm; anal fin rays appear at 9 mm,[26] complete by 11 mm; [20] anal finlets separate by 22 mm; [26] caudal fin forms first rays at 7.2 mm, all rays by 11 mm, begins to fork at 13.2 mm,[20] and lunate by 22 mm; [26] pectoral fins evident by 16 mm; [20] pelvic fins small at 6–7 mm,[6] rays appear at 9 mm; [26] scales absent; notochord flexion and urostyle formation occurs by 7.2 mm.[20]

Pigmentation: At 5 mm, pigmentation similar to yolk-sac larvae with melanophores more numerous on ventral profile of posterior trunk, on peritoneum, and on swim bladder. Pigmentation becoming more intense at 7.2 mm. At 11 mm, pigment in two well defined lines on dorsal and ventral profiles of trunk, in cephalic and peritoneal areas.[20]

JUVENILES

Specimens described 43 [20] or 50 [5] mm and over.

Scales not present by 43 mm; finlets relatively closer together than in adult.

Pigmentation: Coloration similar to that of adult.[20]

GROWTH

Hatching in early May, reach 4 mm by about May 20, 7 mm by June 1, 12 mm by June 15, 22 mm by July 1, 48 mm by July 22,[5] 203–229 mm by fall, 254–279 mm by spring of second year, 363 mm in third autumn, 381 mm *in fourth year, 394 mm in fifth year, 406 mm in sixth* year, 414 mm in seventh year, and 425 mm in eighth year.

AGE AND SIZE AT MATURITY

Reported to mature at 1 1/2–2 [3,5] years, females maturing sooner. Maturity reached by 29–30 cm in Plymouth; 32–38 cm in Newfoundland, with 50% maturity point at 34 cm for females and 35 cm for males; [3] 26 cm for males and 29.5 cm *for females in northwestern Atlantic.*[5]

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Scomberomorus cavalla (Cuvier), King mackerel

ADULTS

D. XV [15] to XIX,[6] 14–16 [9,15] + 8 [15]–11; [9] A. II [6,7,15] to IV,[9] 14 [9,15]–17 [15] + 6, 9–10; [15] C. 12 + 9 + 8 + 12; [9] P. 20 [6]–23; [15] V. I, 5 (RAF); vertebrae 17 [9]–19 + 23 [16]–26 [9] = 42–43; [1,9] gill rakers 1–2 + 7–9 on first arch,[6] very short; [16] teeth triangular, strongly compressed,[7,16] about 30 [7]–60 [15] on each jaw.

Head 4.25–4.55, depth 5.5–6.25 in SL. Snout 2.45–2.5, eye 5.0–5.85, maxillary 1.65, pectoral fin 1.62–1.7 in head.[16]

Body elongate, slender, little compressed, back scarcely elevated, ventral outline slightly more rounded than dorsal, dermal keel on caudal peduncle rather large; head long and low; snout pointed; [16] mouth large,[7,16]

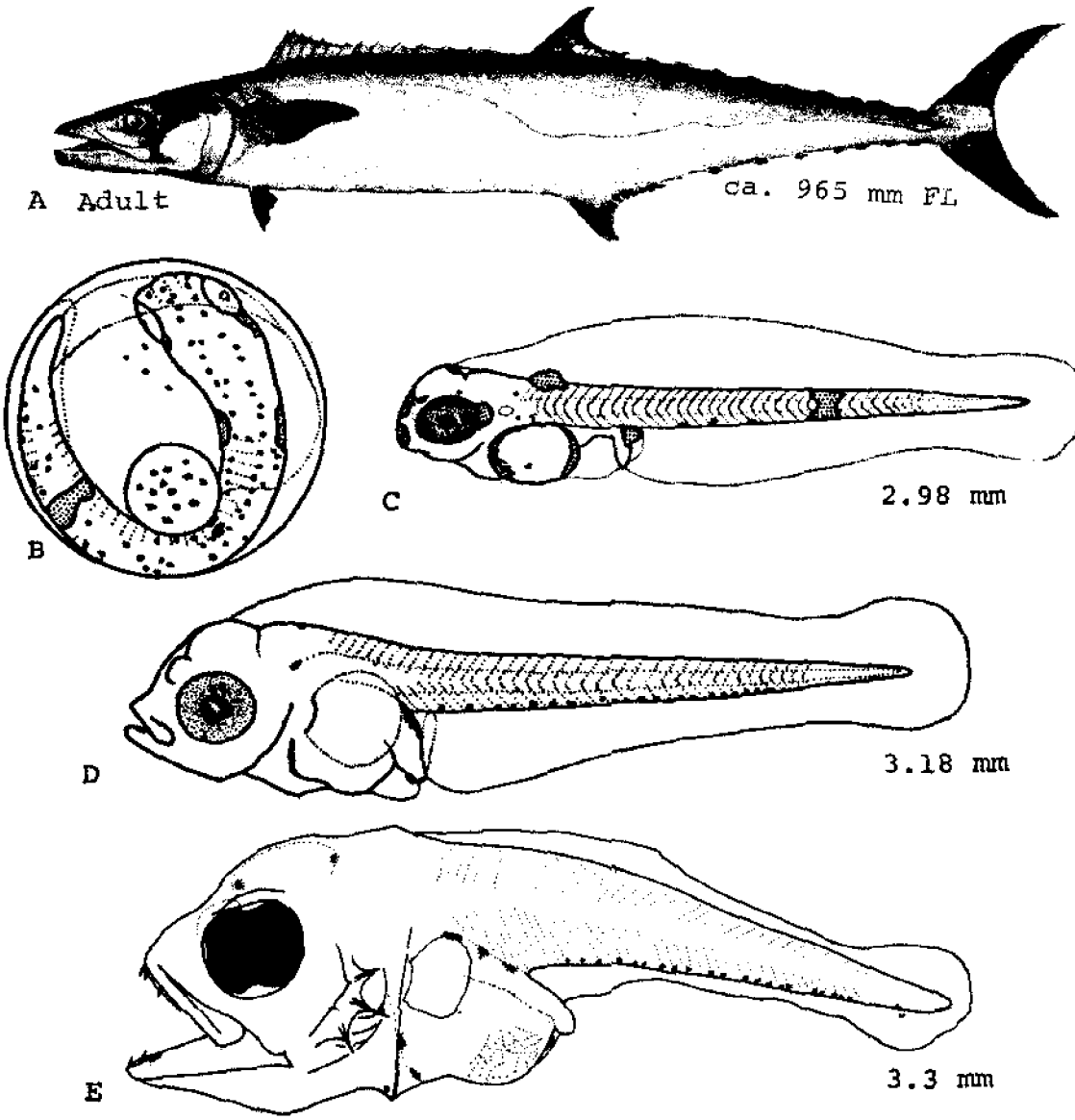

Fig. 66. *Scomberomorus cavalla*, King mackerel. A. Adult, ca. 965 mm FL. B. Egg, 0.88 mm diameter. C. Yolk-sac larva, 2.98 mm. D. Larva, 3.18 mm. E. Larva, 3.3 mm. Spotted areas indicate colored pigment. (*A, Goode, G. B., 1884: pl. 94. B-D, Mayo, C. A., 1973: figs. 3a, 9 a-b, used with the permission of the author. E, Wollam, M. B., 1970: fig. 2a.*)

oblique, jaws subequal;[16] maxillary reaching to[7,16] or slightly past posterior margin of eye.[16] Lateral line with abrupt downward curve under origin of second dorsal fin.[6,7,14,16] Second dorsal and anal fins similar, densely scaled; origin of second dorsal fin in advance of anal fin; pelvic fins notably longer than eye and shorter than snout; pectoral fins of moderate length,[16] without scales.[6,16]

Pigmentation: Iron gray[7] to plain bluish above; pale below; *spinous dorsal fin mostly pale, other fins pale or* more or less dusky.[16]

Maximum size: To 176 cm and 36 kg.[6]

DISTRIBUTION AND ECOLOGY

Range: Maine south to Rio de Janeiro,[6,8] including the Gulf of Mexico.[8]

Area distribution: Recorded from Chesapeake Bay[12,13,15] and the entire Mid-Atlantic Bight.[6,8]

Habitat and movements: Adults—pelagic;[12] move northward in spring and southward in fall along east coast of U.S.;[1,5] becoming abundant during winter off Florida;[4,14] salinities from 5[15]–38.5 ppt and temperature of 25.8 C.[2]

Larvae—26.92–35.5 ppt; 26.3–31.0 C.[5]

Juveniles—no information.

SPAWNING

Occurs 1–6 km offshore in June–August in Florida Current[3] and late July–September along east coast of U.S.[1]

EGGS

0.90–0.98 ($\bar{x}$=0.95, n=8) in diameter; oil globule single,[1] 0.30–0.32 ($\bar{x}$=0.31) in diameter.[3]

EGG DEVELOPMENT

Eight hours before hatching—chromatophores first visible as small, light-colored flecks on head and notochord.

At 2–4 hours before hatching—distinctive patched and banded pattern clearly defined; melanin flecks in two roughly organized rows along dorsolateral surface of embryo; 10–15 granular or stellate melanophores on dorsal surface of oil globule; and one or several melanophores anterior to otic cup.[3]

YOLK-SAC LARVAE

Specimens described 2.98–3.12 or 3.18 mm.

Total myomeres 35–40.[3]

Pigmentation: Primary locations of chromatophores: (1) saddle on posterior hindbrain usually spreading onto anterior dorsal finfold; (2) posterior to developing optic cup and anus; (3) band on mid-posterior portion of trunk; and (4) small granule on midbrain. Sequence of development of melanophores on ventral surface distinctive. After hatching, granules of melanin on dorsal surface of trunk disappear and ventral margin of trunk becomes pigmented with 3–5 relatively small melanophores. Midbrain pigmented by 2.8 mm, first 1–2 large melanophores, later 5–7 large, evenly distributed spots. Green chromatophore band on posterior portion of notochord and green patches behind eyes and lateral aspect of notochord.[3]

LARVAE

Specimens described 3.3–10.0 mm SL.

D. III at 7.6 mm and XVI at 10.0 mm, 6 at 7.6 mm and 22 at 10.0 mm; A. I at 10.0 mm, 3 at 7.6 mm and 21 at 10.0 mm; C. 0+2+2+0 at 5.3 mm, 0+9+8+2 at 7.6 mm, 5+9+8+5 at 10.0 mm; P. 4 at 7.6 mm, 8 at 10.0 mm; V. I, 2 at 10.0 mm;[1] total myomeres 40[3]–43; vertebrae 32 at 10.0 mm; branchiostegals 2 at 3.3 mm, 5 at 3.7 mm, 6 at 5.3 mm, and 7 at 6.5 mm; preopercular spines 3 at 3.3 mm, 5 at 3.7 mm, 7 at 6.5 mm, and 9 at 10.0 mm; teeth in upper jaw 3 at 3.3 mm, 10 at 4.7 mm, 12 at 7.2 mm, 17 at 10.0 mm; teeth in lower jaw 2 at 3.3 mm, 9 at 4.7 mm, 13 at 7.2 mm.[1]

Dorsal, anal, and pelvic rays forming at 4.8 mm; notochord flexion begins at 4.2 mm.[3]

Pigmentation: Two melanophores on midbrain at 3.3 mm, increasing to 4 by 4.7 mm, 8 by 5.6 mm, and 14 by 7.6 mm. Forebrain pigmentation remains at 1–2 melanophores through 7.6 mm. Upper jaw pigmented in specimens longer than 5.5 mm; several melanophores appear mid-dorsally along premaxillary by 7.6 mm, increasing by 12.4 mm. Few melanophores may be present on anterior of dermethmoid. Before 12.4 mm, row of melanophores between maxillary and premaxillary about two-thirds distance back from tip of snout.[1] Melanophores on lower jaw merge into one elongate spot at 4.5 mm and longer and finally break up in specimens of 6.0 mm to form increasing number of pigment spots along lower jaw.[3] By 12.4 mm several melanophores appear on cartilaginous pad at tip of mandibular symphysis. At 3.3 mm, 2 melanophores present on trunk, one in midline anterior to pectoral symphysis, another on small preanal finfold which disappears with finfold at 8 mm. Row of up to 29 small melanophores dot ventral midline from just posterior to anus to caudal peduncle, by 7.6 mm this number decreased to 4 or 5 larger melanophores. At 3.3 mm, about 5 melanophores located along midline of gut which increase and proliferate with growth. Several melanophores appear under presumptive dorsal finlets by 7.6 mm. By 12.4 mm, two rows of melanophores

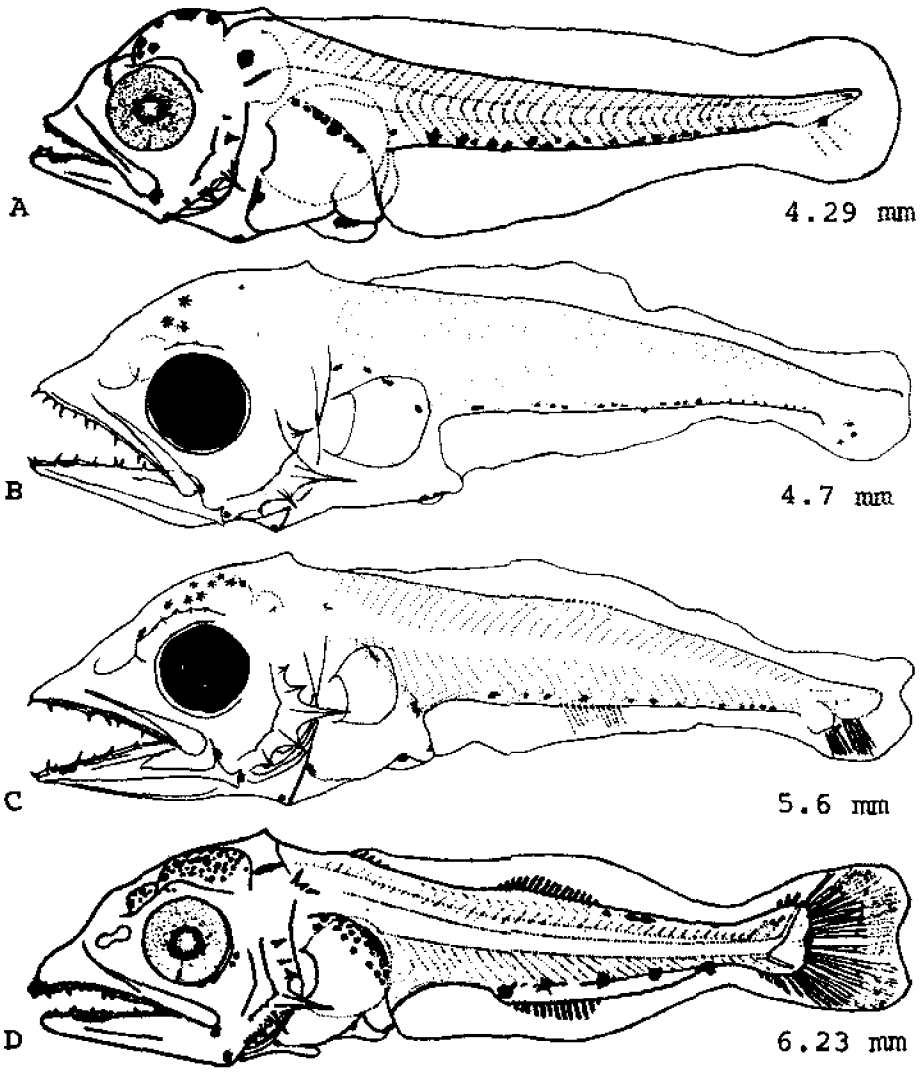

Fig. 67. *Scomberomorus cavalla*, King mackerel. A. Larva, 4.29 mm. B. Larva, 4.7 mm. C. Larva, 5.6 mm. D. Larva, 6.23 mm. *(A, D, Mayo, C. A., 1973: figs. 9 c-d, used with the permission of the author. B, C, Wollam, M. B., 1970: figs. 2b-c.)*

develop anteriorly below first dorsal fin and single row developing under anterior dorsal finlet. At 12.4 mm, melanophores under developing dorsal finlets begin to spread laterally and ventrally across upper two-thirds of flank.[7] Caudal spot usually present in larvae longer than 3.1 mm.[8]

JUVENILES

Specimens described 13–31 mm.

D. XVI, 25–26; A. II, 24–25; C. 12–14 + 9 + 8 + 12–13; P. 14–21; V. I, 5; total myomeres 42; vertebrae 17–18 + 24–25; branchiostegals 7; preopercular spines 5–10; teeth in upper jaw 16 at 13.1 mm and 29 at 31.0 mm; teeth in lower jaw 14 at 13.1 mm and 15 at 31.0 mm.

Pigmentation: Entire midbrain pigmented by 14 mm. Forebrain completely pigmented by 14.4 mm. Snout pigmentation dense anteriorly and confined posteriorly to dorsal portion of premaxillary after 17 mm. At 17 mm, six melanophores extend anteriorly to below dermethmoid and have merged laterally by 23 mm. Between 12.4 and 17 mm, several melanophores develop dorsal to posterior end of maxillary, on cheek below orbit, and on upper portion of operculum. Pigmentation in first two

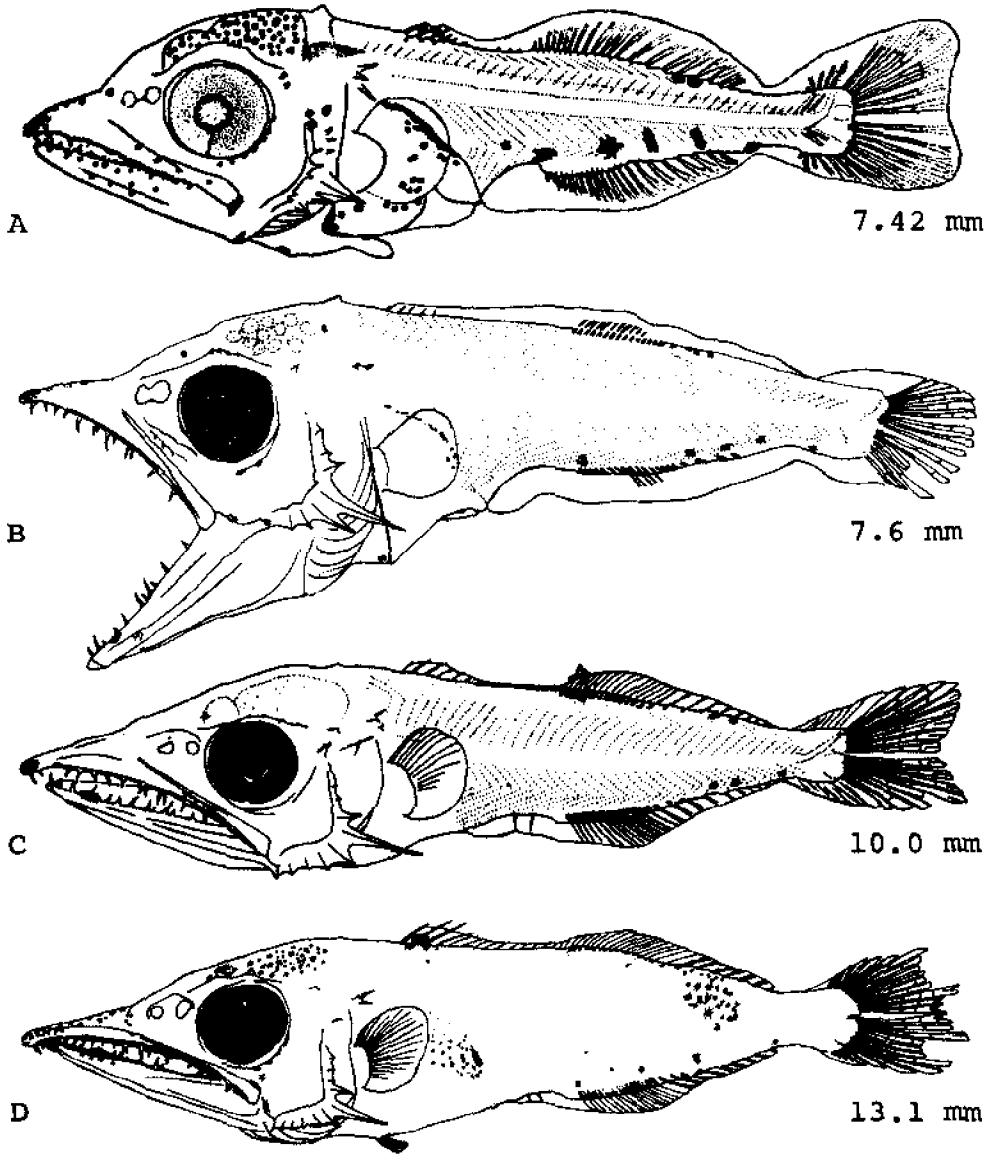

Fig. 68. *Scomberomorus cavalla*, King mackerel. A. Larva, 7.42 mm. B. Larva, 7.6 mm. C. Larva, 10.0 mm. D. Juvenile, 13.1 mm. (*A, Mayo, C. A., 1973: fig. 12c, used with the permission of the author. B-D, Wollam, M. B., 1970: figs. 2d, 3a-b.*)

areas persists without change to 31 mm; however pigmentation on upper operculum increases by 23 mm and merges with anterior trunk pigmentation. Melanophores along midline of gut proliferate after 12.4 mm and complete by 18 mm. Two rows of melanophores under first dorsal fin merge under second dorsal by 17 mm. Melanophores anterior to first dorsal fin proliferate and by 23 mm cover nape and merge laterally with postorbital pigmentation. By 17 mm, distinctive saddle-shaped pigment patch formed; anterior patch projection develops strip of melanophores, and by 31 mm merges with lateral chromatophores at nape. Heavy pigmentation develops between bases of first five and six dorsal finlets at 17 mm. Juvenile trunk pigmentation pattern essentially complete by 20 mm. Pectoral, pelvic, second dorsal and anal fins and finlets remain free of pigmentation to 31 mm. Some small melanophores present near caudal fin base up to 14 mm. First interradial membrane of spinous dorsal fin pigmented at 13 mm. Pigmentation proceeds posteriorly until membranes between first five or six spines pig-

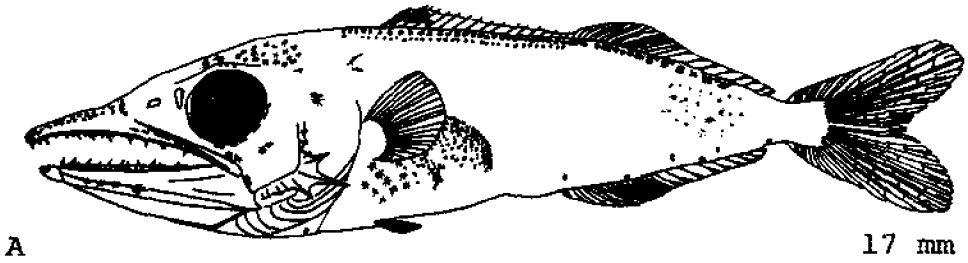

Fig. 69. *Scomberomorus cavalla,* King mackerel. A. Juvenile, 17 mm. (*A, Wollam, M. B., 1970: fig. 3c.*)

mented at about 17 mm. Remainder of first dorsal fin unpigmented until 31 mm when scattered small melanophores begin to develop on remaining interradial membranes.[1] Larger specimens with sides of body marked with yellowish [7] to bronze [6] spots.

GROWTH

Reaching 2.8 mm SL in 3 days, and 28.8 mm SL after one month.[5]

AGE AND SIZE AT MATURITY

No information.

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Scomberomorus maculatus (Mitchill), Spanish mackerel

ADULTS

D. XVII [3] to XIX,[16] 18–19 [3,16] + 7 [1]–9; [3,16] A. II [3]–IV, 14–16 [16] + 7 [1,16]–9; [3] C. 12 + 9 + 8 + 12; [16] V. I, 5 (RAF); vertebrae 21 + 31–32 = 52–53; [16] gill rakers 2 [3] + 8 [19]–11 [3] on first arch; teeth large, sharp [3] and compressed.[3,19]

Head 3.2–4.8, depth 4–5 in SL. Snout 2.45–2.75, eye 4.55–4.9, pectoral 1.5–2.85, maxillary 1.6–1.8 in head.[19]

Body elongate, compressed; [1,19] head small,[3] compressed,[19] pointed,[3,19] profile from snout to dorsal fin straight; [3] mouth large,[1,3,19] oblique, lower jaw slightly shorter than upper; [19] maxillary reaching opposite posterior margin of eye; [3,19] caudal peduncle slender, with median lateral keel and small supplementary keels above and below.[19] Lateral line wavy, with about 175 pores.[3] First dorsal fin with slender spines; second dorsal and anal fins similar, densely scaled; caudal fin broadly forked; pelvic fins small, shorter than snout; pectoral fins not scaly, short.[19]

Pigmentation: Dark blue above,[3,19] with sky blue reflections; [3] silvery below; [3,19] sides with dull yellow or yellowish brown spots forming 2 [3] or 3 [19] rows; first dorsal fin with white base and black distal portion; [3,19] second dorsal fin greenish [19] to yellow [3] with dusky [19] to black edge; anal fin white; pectoral fins yellow [3] to greenish [19] with dusky edge; [3,19] caudal fin greenish dusky, tips of lobes mostly black.[19]

Maximum size: To 941 mm and 11 kg.[3]

DISTRIBUTION AND ECOLOGY

Range: Atlantic Ocean from Maine [10,17] to northern Gulf of Mexico,[17] absent from most of West Indies; [6,20] records from Puerto Rico are based on stray juveniles (FDM) or, on misidentifications.[6]

Area distribution: Recorded from Chesapeake Bay [3,11,19] and throughout Mid-Atlantic Bight.[3,9,10]

Habitat and movements: Adults—schooling,[4,19,20] pelagic; [5,11] prefer neritic coastal waters; [5,7,12] freely enter tidal estuaries.[5,20] Migrate along east coast of U.S., northward in spring and then southward a few weeks or months later; reaching North Carolina in April, Chesapeake Bay in May, Sandy Hook in late July and remaining until mid-September.[4,10] Associated with marine salinities; [14,15] temperatures between 21 [4] and 31 C,[15] seldom below 18 C; [4,10] and in water less than 72 m.[7]

Larvae—nearshore, recorded in open sea in one location in Caribbean Sea; 29.62–36.08 ppt; 28.4–30.5 C.[21]

Juveniles—12.8 [15]–36.08 ppt; 28.4 [11]–32 C.[15]

SPAWNING

Location: Occurs in tidal estuaries [4,5] at numerous points between Narragansett Bay and South Carolina.[4,10]

Season: From latter part of June to end of August off Beaufort; [1] July–September in Florida; [7] late spring–early summer in Chesapeake Bay; [19] and August–late September at Long Island.[4,10]

Notes on spawning: Spawn at night [2,3] at temperatures above 22 C.[3]

Fecundity: 300,000 eggs in a .5 kg fish and 1,500,000 in a 2.7 kg fish.[4]

EGGS

Unfertilized eggs, with membrane formed, perfectly homogeneous, transparent, with minute papular prominences on inner surface confined to poles; 0.9–1.3 mm diameter.[2]

Fertilized eggs: About 1 mm in diameter; float.[3]

EGG DEVELOPMENT

At end of 3 hours—cells of germinal disk no longer arranged in single stratum. At 3 1/2 hours—marginal cells form rim of incipient blastoderm which is beginning to spread out and become thinner.

After 7 hours—blastoderm encloses nearly one-half of yolk; embryo bounds concave side and lies in immediate contact with yolk except for forepart of head. Kupffer's vesicle appears before blastopore closure; anal portion of gut first to form.

After 11 hours—notochord and eyes appear.

After 14 hours—myomeres developing from anterior to posterior, with posterior region of tail remaining unsegmented at hatching; pigmentation present as band on tail and spots on back.

After 18 hours—brain divided into forebrain, midbrain, and medulla oblongata; two otoliths visible in auditory capsules; heart fusiform and open at venous end.

Oil droplet covered with pigment at hatching.[2]

Hatching occurs in 15 1/2 hours at 29 C,[1] and 24–25 hours at 25–26 C.[8,9]

YOLK-SAC LARVAE

Specimens described 2.56 mm (at hatching)–3.18 mm (yolk sac absorbed).[2] Myomeres 51; [18] gill arches begin forming 24 hours after hatching; [2] preopercular spines 3; branchiostegal rays 1; teeth, 5 in upper jaw, 4 in lower jaw.[19]

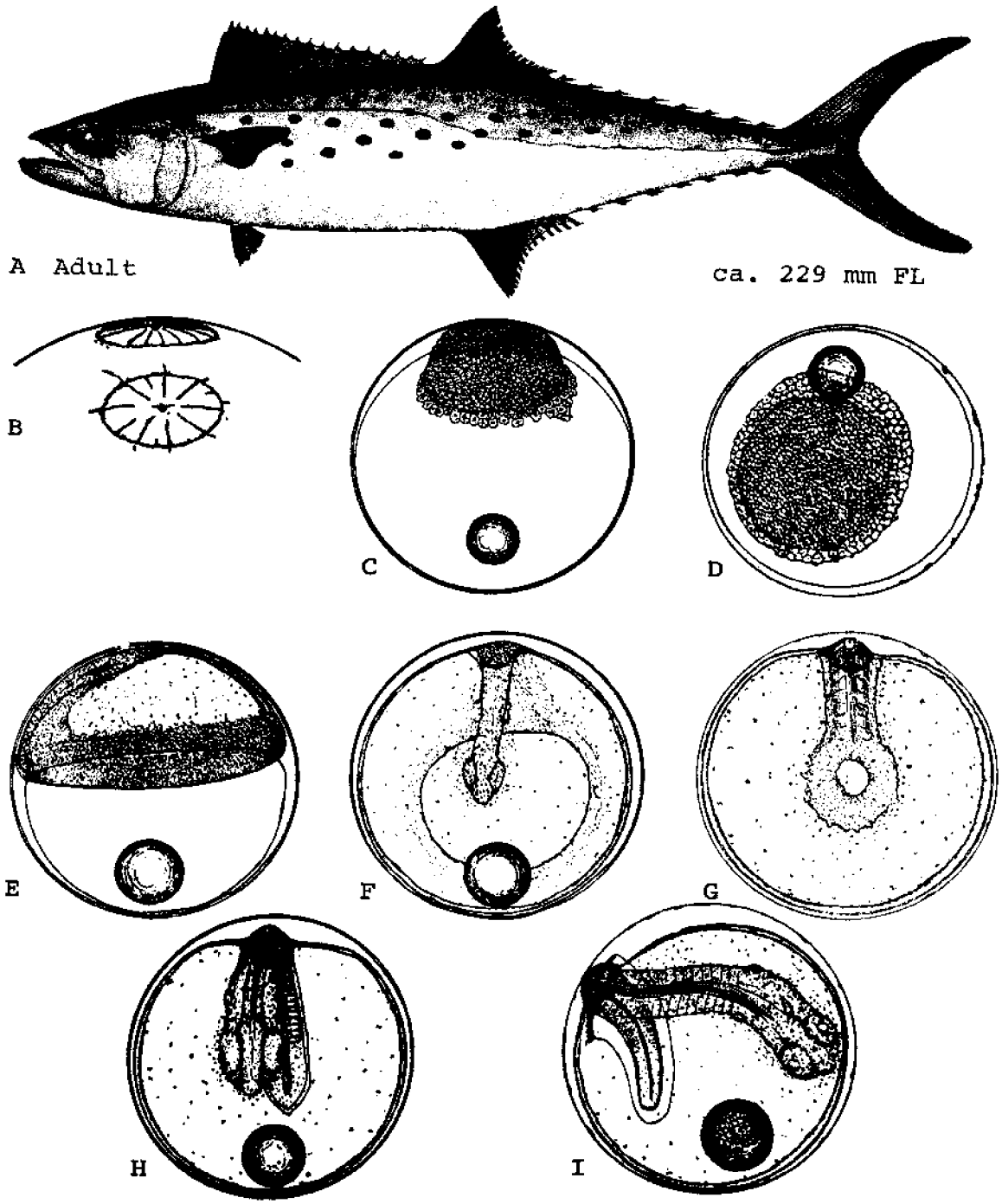

Fig. 70. *Scomberomorus maculatus*, Spanish mackerel. A. Adult, ca. 229 mm FL. B. Micropyle and micropylar area, in two positions, of an unpigmented egg. C. Egg, germinal disc. D. Egg showing blastoderm 3 hr. 30 min. after fertilization. E. Egg, 7 hours after fertilization. F. Embryo, 11 hours after fertilization. G. Embryo, 12 hours after fertilization. H. Embryo, 14 hours after fertilization. I. Embryo, 18 hours after fertilization. (*A, Goode, G. B., 1884: pl. 93. B-I, Ryder, J. A., 1882: figs. 1, 4, 6–10, 12.*)

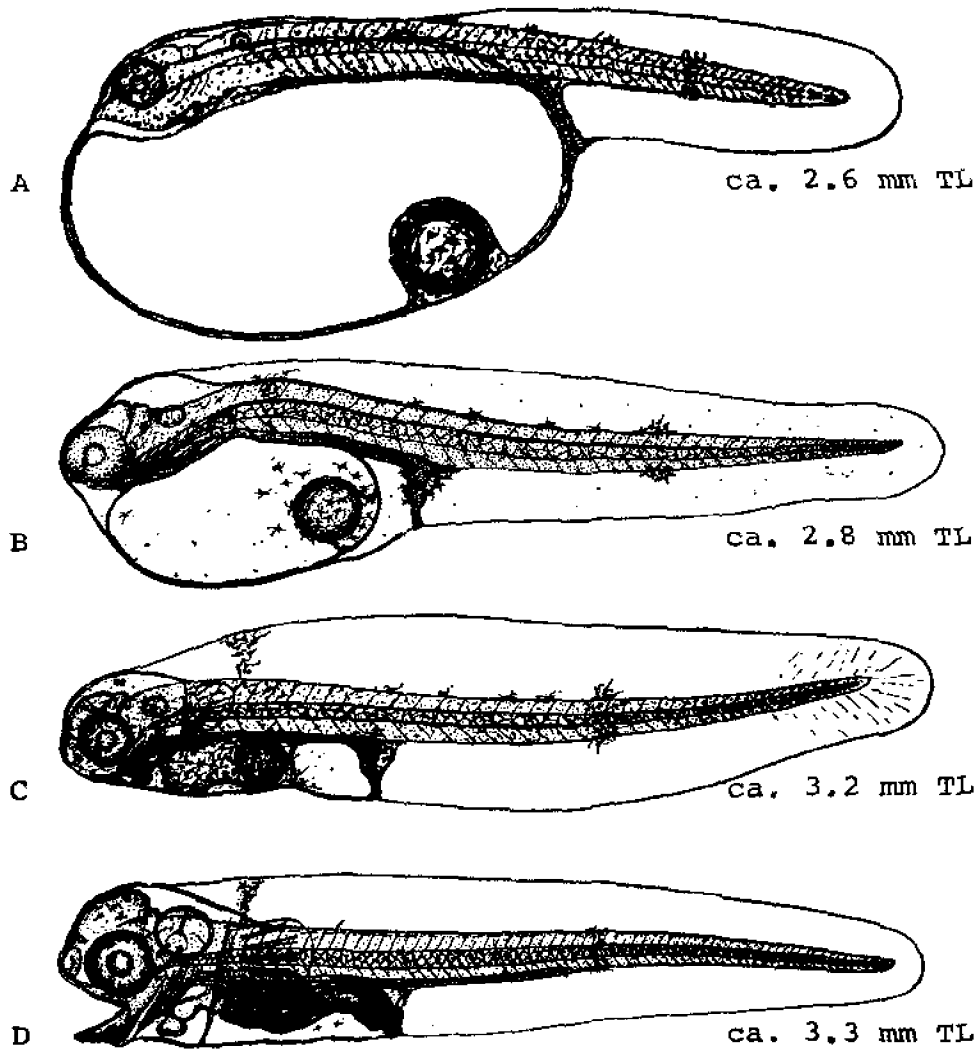

Fig. 71. *Scomberomorus maculatus*, Spanish mackerel. A. Yolk-sac larva, just hatched, ca. 2.6 mm TL. B. Yolk-sac larva, 12 hours after hatching, ca. 2.8 mm TL. C. Yolk-sac larva, 21 hours after hatching, ca. 3.2 mm TL. D. Larva, 3 days after hatching, ca. 3.3 mm TL. (*A-D, Ryder, J. A., 1882: figs. 13–16.*)

Head considerably prolonged; yolk mass lost by 4th day.[2]

Pigmentation: Single melanophore present on midbrain at 3.1 mm; several melanophores along dorsal midline of gut; eleven melanophores along postanal ventral midline; several small melanophores near base of caudal.[18]

LARVAE

Specimens described 4–13.5 mm.

D. VI, 7 at 7.6 mm; XIV, 26 at 13.0 mm. A. 6 at 7.6 mm; II, 25 at 13.0 mm. C. 0+4+3+0 at 5.2 mm; 9+9+8+9 at 13.0 mm. P. 2 at 7.6 mm; 14 at 13.0 mm. V. I, 3 at 9.7 mm; I, 4 at 13.0 mm. Total myomeres 52–53. Vertebrae 22+29–30 at 10.8–13.0 mm. Branchiostegals 2 at 4.3 mm; 5 at 5.2 mm; 7 by 5.7 mm. Preopercular spines 5 at 4.3 mm; 7 by 7.6 mm. Teeth in upper jaw 9 at 4.3 mm increasing to 20 by 13.0 mm. Teeth in lower jaw 8 at 4.3 mm increasing to 14 by 13.0 mm.[18]

Pigmentation: Melanophores on midbrain increase to 5 by 4.3 mm and 10 by 8.0 mm. Forebrain pigmentation consists of 1 melanophore at about 5 mm, second forming on lateral surface by 7.4 mm. Snout pigmentation appears at tip of upper jaw at 5 mm and gradually develops posteriorly along dorsal portion of premaxillary. Melanophores scattered over dermethmoid at 12–13 mm. Several melanophores appear between maxillary and pre-

maxillary just below anterior edge of orbit by 8 mm. Several melanophores begin to develop on posteroventral border of orbit by 8 mm. Single melanophore may be present between rami of lower jaws, about 1/3–1/2 of distance from mandibular symphysis. Melanophores appear on cartilaginous pad at tip of mandibular symphysis as soon as it develops (about 4 mm). Melanophores appear in middle of lateral surface of mandible at about 8 mm. Single melanophore at pectoral symphysis at about 4 mm, also one on preanal finfold. Eleven melanophores on postanal midline reduced to 5 at about 10 mm. At 8 mm, single melanophore at base of developing second dorsal fin; melanophores appear on anterodorsal interradial membranes at 9–10 mm; by 11 mm, first 10–12 membranes pigmented; all pigmented by 13 mm.[18]

JUVENILES

Specimens described 13.5 [18]–225 mm.[1]

D. XIX [1,13,18] to XX,[18] 16–17 + 7–8; [1] A. II [1,13,18]–III,[18] 14–17 + 8–9; [1] C. 11–12 + 9 + 8 + 11–12; P. 18–20; V. I, 5; total myomeres 52; [18] vertebrae 22 [1,18]–23 + 29 [18]–31; [1] branchiostegals 7; [18] gill rakers short, minute, 8 or 9 at 60–70 mm; 8 preopercular spines at 14 mm, 2 at 22–25 mm.[1]

At 97 mm, head 3.8, depth 4.6 in SL; snout 2.8, maxillary 1.8 in head.[1]

Body more compressed than adults; mouth large, maxillary reaches somewhat past middle of eye; [1] teeth 20–24 in upper jaw, 18–22 in lower; [18] caudal fin distinctly concave at 14 mm, forked by 17 mm; caudal keel formed by 200–225 mm; lateral line indicated by 35–40 mm, fairly well defined by 60–70 mm; scales on soft dorsal and anal fins at 210–225 mm.[1]

Pigmentation: Midbrain pigment completely developed by 14 mm; forebrain by 16 mm. Premaxillary heavily pigmented dorsally by 17 mm, with few melanophores extending onto dermethmoid. Snout completely pigmented by 22 mm. Row of melanophores along edge of premaxillary merge anteriorly with lateral snout pigment by 17 mm; by 20–22 mm, another row develops below first and upper jaw becomes almost completely pigmented. Melanophores on posteroventral border of orbit have increased in number by 17 mm. Melanophores appear on upper part of opercular by 13 mm, gradually increasing to about 18 by 20 mm. Melanophores on middle lateral surface of mandible, well defined row of 5 or 6 by 12–14 mm, proliferating rapidly to almost completely pigmented mandible by 22 mm. Melanophores on hyoid developing into several small rows by 22 mm. One or two melanophores on pectoral symphysis after 20 mm. Both sides of gut pigmented by 20 mm. By 12–14 mm, three areas of trunk pigmentation developing: dorsally two rows of melanophores along each side of first dorsal fin base and single row extending along bases of second

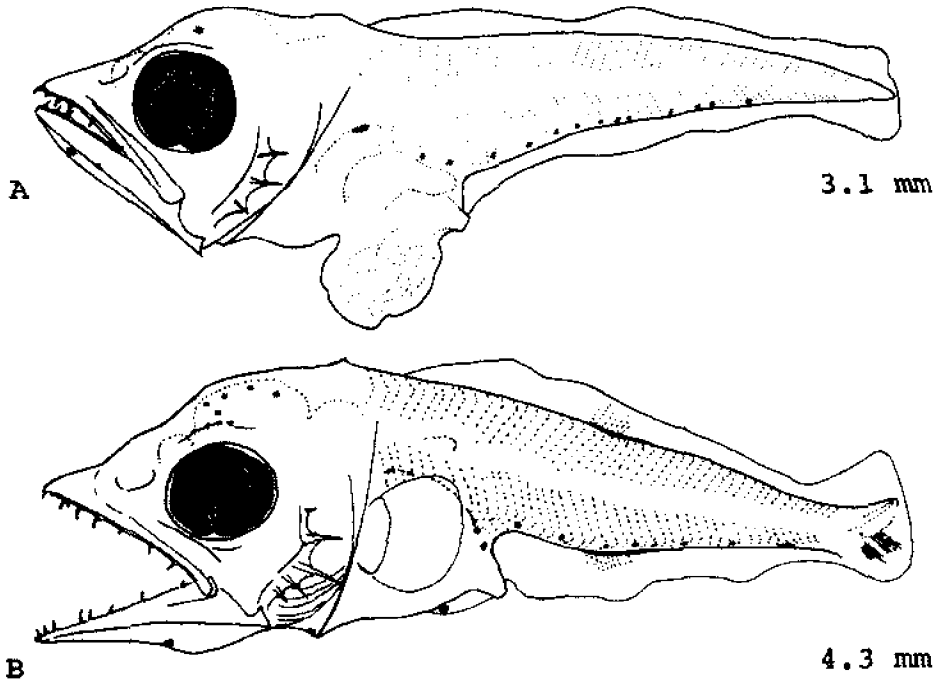

Fig. 72. *Scomberomorus maculatus*, Spanish mackerel. A. Larva, 3.1 mm. B. Larva, 4.3 mm. (*A, B, Wollam, M. B., 1970: fig. 4 A-B.*)

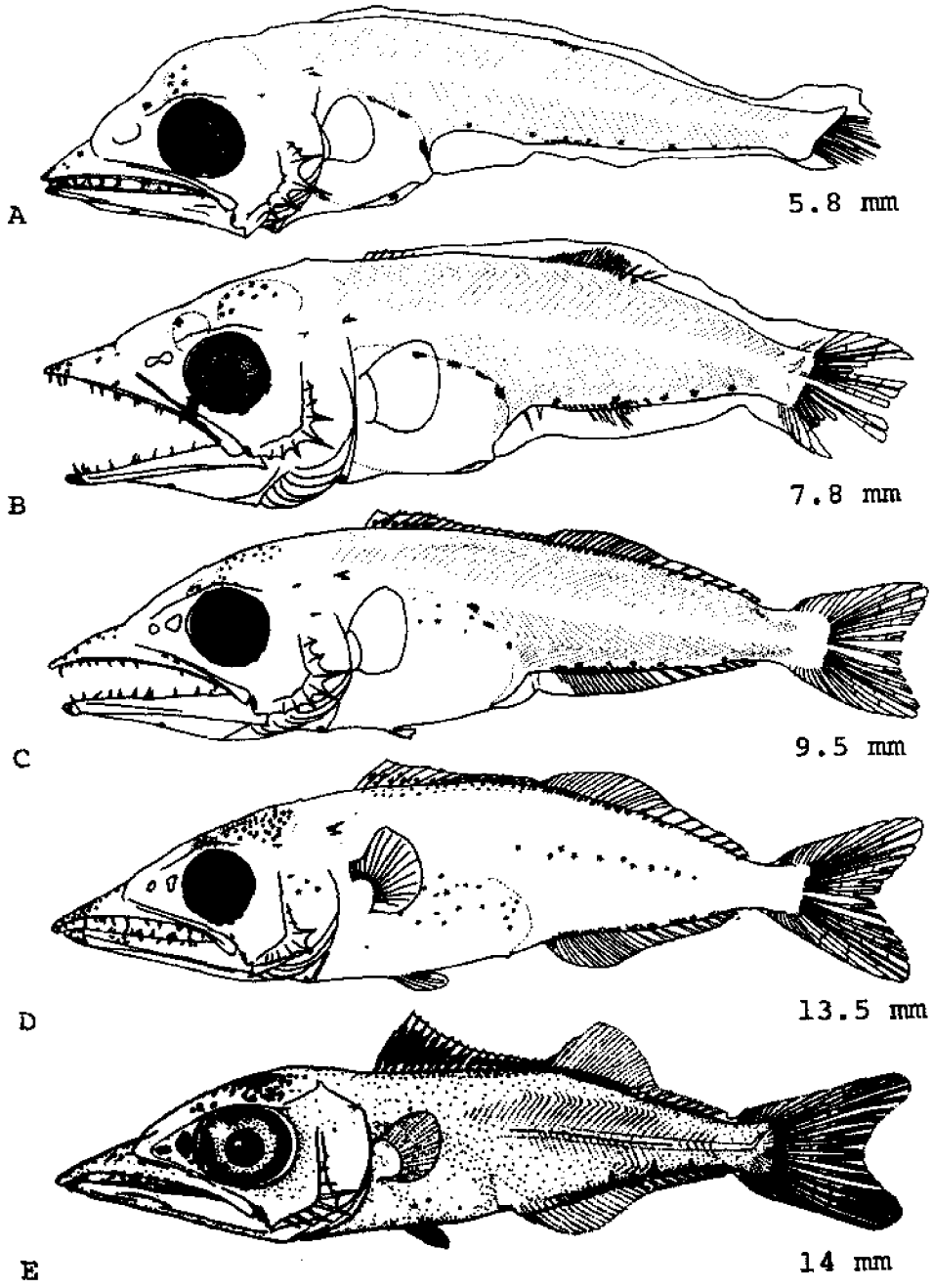

Fig. 73. *Scomberomorus maculatus*, Spanish mackerel. A. Larva, 5.8 mm. B. Larva, 7.8 mm. C. Larva, 9.5 mm. D. Juvenile, 13.5 mm. E. Juvenile, 14 mm. (*A-D, Wollam, M. B., 1970: figs. 4 C-D, 5 A-B. E, Hildebrand, S. F., and L. E. Cable, 1938: fig. 7.*)

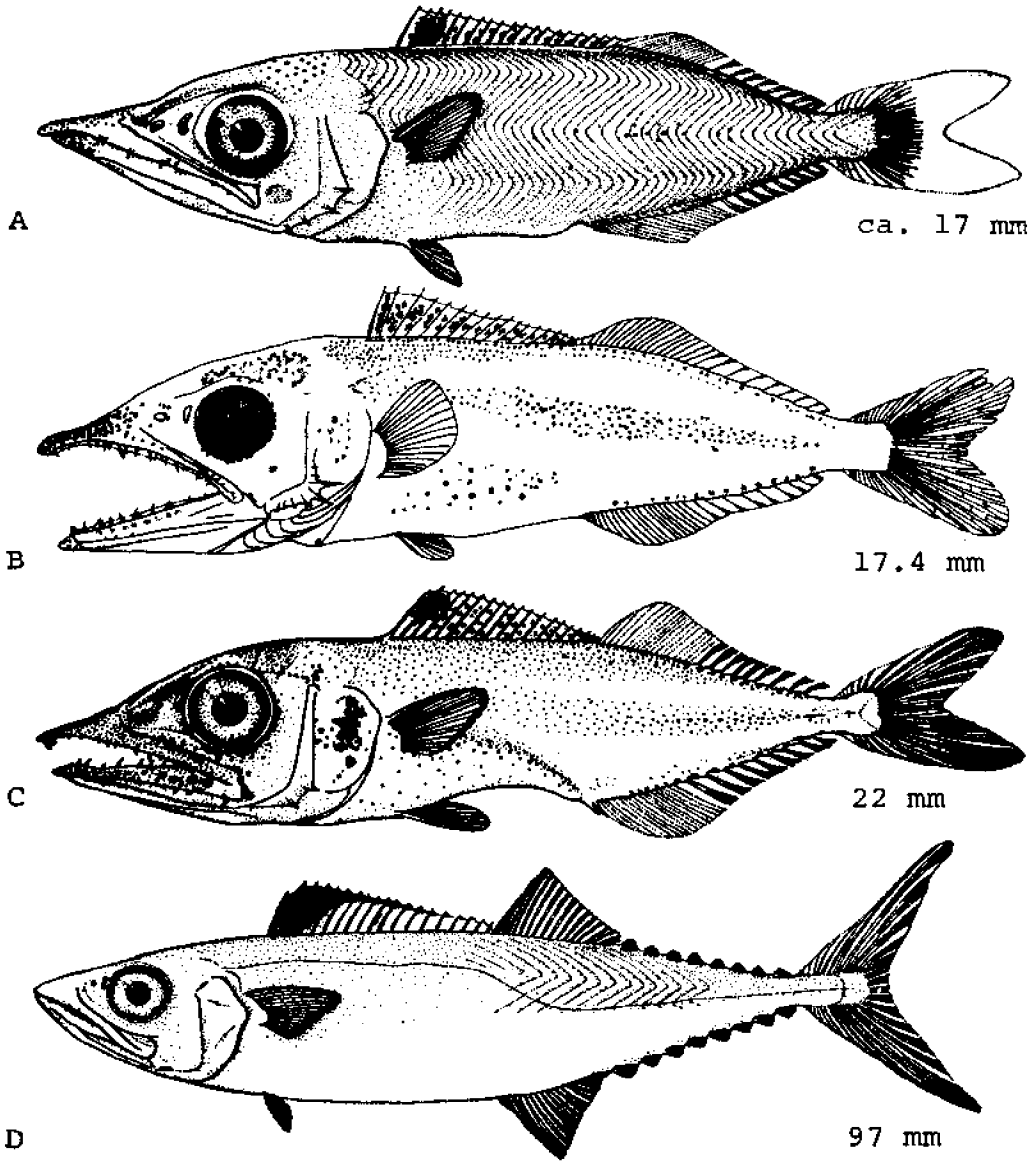

Fig. 74. *Scomberomorus maculatus*, Spanish mackerel. A. Juvenile, ca. 17 mm. B. Juvenile, 17.4 mm. C. Juvenile, 22 mm. D. Juvenile, 97 mm. (*A, C, D, Hildebrand, S. F., and L. E. Cable, 1938: figs. 8–10, fig. 10 reversed. B, Wollam, M. B., 1970: fig. 5C.*)

dorsal and finlets; ventrally a row of melanophores scattered along base of anal fin and finlets; and laterally a row of scattered melanophores developing along presumptive lateral line. Three well defined bands along trunk by 17 mm, dorsal and lateral bands merge anteriorly in neck region. Distinctive juvenile trunk pigmentation well defined by 22 mm. Pectoral, pelvic, second dorsal, and anal fins free of pigment to 29 mm. First dorsal fin becoming conspicuously dark by 22 mm.[1] By 97 mm, bright silvery, rather bluish silvery above without spots or lines.[1]

GROWTH

Length increasing by 18.4 cm in first year, 13.8 cm in second, 14 cm in third, 10.1 cm in fourth, and 1.4 cm in fifth.[7]

AGE AND SIZE AT MATURITY

Females by 3 years,[5] some at 1 or 2 [5,7] and 25–32 cm; males at 28–34 cm.[7]

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Scomberomorus regalis (Bloch), Cero

ADULTS

D. XVI to XVII–I,[7] 15 [2,7] or 16–18 or 9; [7] A. II,[2,7] 14 [2] to 16–7 to 9; [7] C. 9+8 (RAF); P. 20–22; [7] V. I, 5 (RAF); gill rakers 3 [7] +11–13; [6,7] teeth triangular, strongly compressed,[2,7] with 30 [7]–40 [2] in each jaw.

Head 4.25, depth 4.5 in SL; caudal peduncle depth 5.5 in head.[2]

Body elongate,[2,7] its dorsal and ventral curves about equal; caudal peduncle slender,[2] and with three keels; [7] mouth large, maxillary reaching to below eye.[2] Scales small on body, absent on head except nape, pectoral fins scaled.[7] Lateral line descending obliquely below front of second dorsal fin,[2,7] undulate posteriorly. Caudal fins less widely forked than *S. maculatus*.[2]

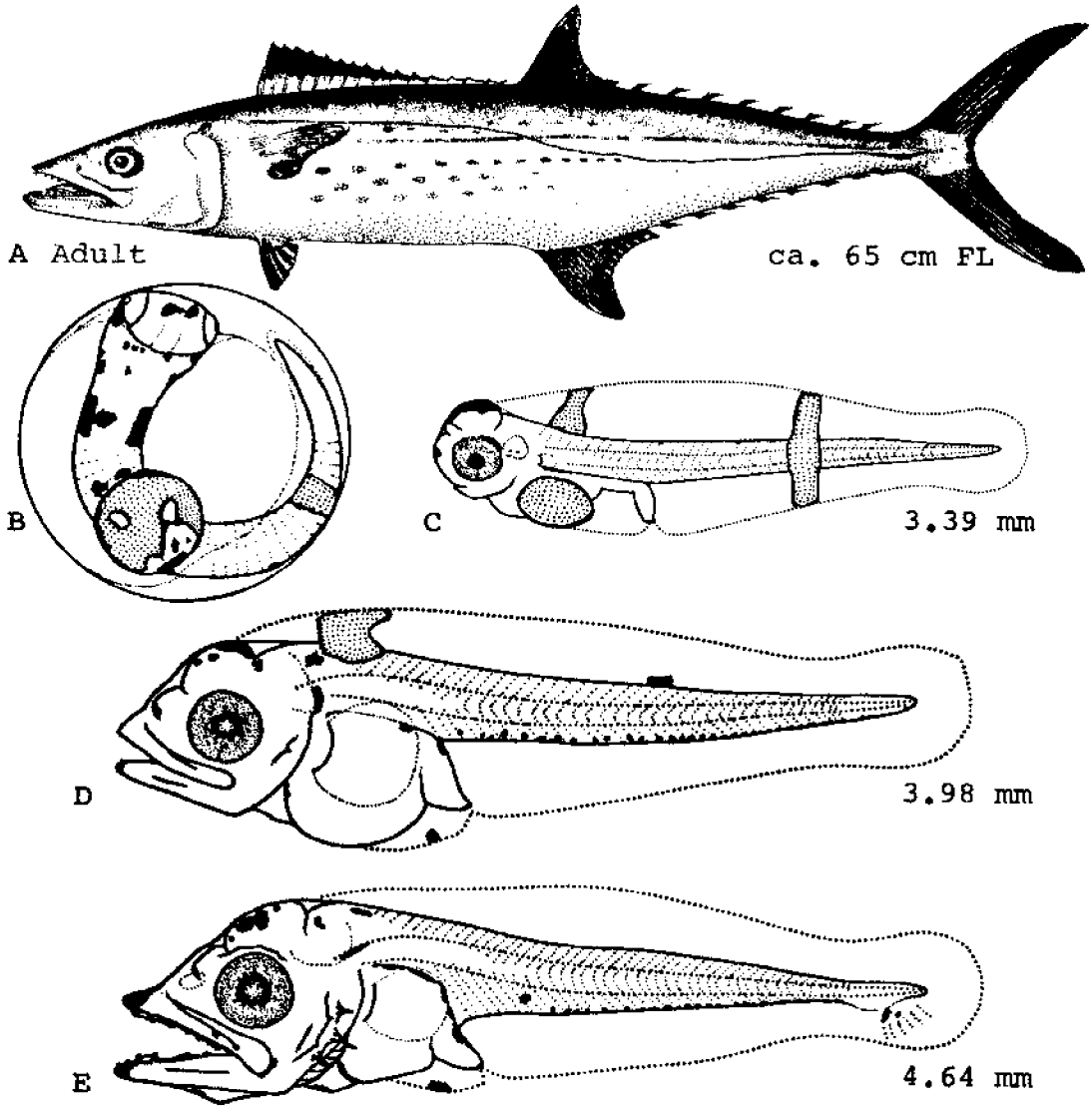

Fig. 75. *Scomberomorus regalis*, Cero. A. Adult, ca. 65 cm FL. B. Egg, 1.22 mm diameter. C. Yolk-sac larva, 3.39 mm. D. Larva, 3.98 mm. E. Larva, 4.64 mm. Spotted areas indicate white pigment. (*A, Goode, G. B., 1884: pl. 94. B-E, Mayo, C. A., 1973: fig. 3a, 10 a-c, used with the permission of the author.*)

Pigmentation: Bluish green [7] to dark blue [6] above; silvery on sides [6,7] and below; [6] elliptical bronze [3] to yellow spots on sides; smaller yellow spots above and below this row; [7] sides with two blackish longitudinal stripes crossing lateral line below soft dorsal; [2,6] first dorsal fin blue [6] or black.[2,6]

Maximum size: To about 183 cm [2,6] in length and a weight of 15.75 kg.[3,6]

DISTRIBUTION AND ECOLOGY

Range: New England [6,7] to southeastern Brazil, including Gulf of Mexico; [6] not common north of Florida.[3]

Area distribution: Recorded from the ocean near Chesapeake Bay.[5]

Habitat and movements: Adults—seen swimming over reefs and may come close to shore in pursuit of prey,[7] also common over turtlegrass beds and shallow open bottoms (*FDM*). Typically solitary, but may be found in small groups.[7]

Larvae—no information.

Juveniles—no information.

SPAWNING

Eggs collected in June at the surface.[4]

EGGS

Diameter of egg ranges from 1.16 to 1.22 mm, mean of 1.2 mm; oil globule 0.34–0.36 mm in diameter, and covered with large, dense chromatophores. Chromatophore pattern of the egg very extensive and white.[4]

EGG DEVELOPMENT

Broad bands and patches of white pigment occur at the midposterior part of the notochord, beneath the pigmented oil globule, behind the optic cups, and as two lateral blocks on the anterior portion of the notochord. Embryo has three to four relatively large melanophores *evenly spaced on the dorsal surface of the notochord*, small flecks on the snout and posterior to the optic cups.[4]

YOLK-SAC LARVAE

Specimens described 2.20–3.39 mm. Yolk sac absorbed at 3.7 mm (70 hr.).

44–45 myomeres present.[4]

Measurements given as percent body length: Orbit diameter 9.4–14.5; pectoral depth 22; snout-vent length 42–48; *snout-pectorals 21*; *anal depth 16–28*.[4]

Pigmentation: The two to four dorsal melanophores on the embryo persist in the newly hatched. Additionally, one or two melanophores on the ventral surface of trunk, a small melanophore on midbrain, and one or two small but characteristic melanin granules in dorsal finfold over hindbrain develop in early yolk-sac larvae.[4]

LARVAE

Specimens described 3.7–10.74 mm.

46–49 myomeres. Anal fin rays first visible at 6.0 mm, dorsal rays at 6.3 mm, and pelvic rays 6.8 mm. *Notochord flexion appears in specimens 4.6 mm long and is* completed by 6.6 mm (about 200 hours old). Ossification of the major bone complexes takes place between 3.39 mm and 5.40 mm.[4]

Measurements given as percent body length: Orbit diameter 8.8–10.0; pectoral depth 23–27; snout-vent length 43–63; snout-pectorals 25–46; head length 23–42; upper jaw 11–30; anal depth 17–19.[4]

Pigmentation: Melanophores on dorsal surface of trunk reduced to one or two and ventral series proliferates into a row of 25–35 small, evenly spaced dots. Ventral and dorsal pigment remains unchanged in specimens smaller than 4.6 mm, when reduction in number of melanophores on ventral margin of trunk occurs. In larvae longer than 5.8 mm, 10 to 25 stellate spots are found on ventral midline of trunk. One to three caudal melanophores are present in all specimens longer than 4.6 mm. Hindbrain melanophore may be paired in specimens between 3.0 and 4.5 mm. Large, intense melanophores first develop on anterior surface of forebrain at 3.7 mm and proliferate in specimens longer than 5.4 mm. Midbrain melanophores appear first in specimens about 3.9 mm. A distinctive melanophore present on isthmus in most specimens longer than 3.9 mm. Melanophore on the *preanal finfold develops in specimens 3.9 mm long* and persists throughout larval development. Intense melanization of tips of jaws of late larvae is characteristic of this species. The upper and lower jaws are first pigmented at 4.6 and 3.4 mm, respectively.[4]

JUVENILES

Specimens described 36–50 mm SL.

D. XVII or XVIII–I, 13–15+8 finlets; gill rakers rudimentary, 2+11.[1]

Body depth 4.2–5.0, head 3.0–3.3 in SL.[1]

Body thin and moderately elongate; snout sharply acuminate, upper jaw ending in a pointed hook; teeth narrowly triangular canines; second dorsal inserted far back, midway between end of hypural and posterior rim of orbit.[1]

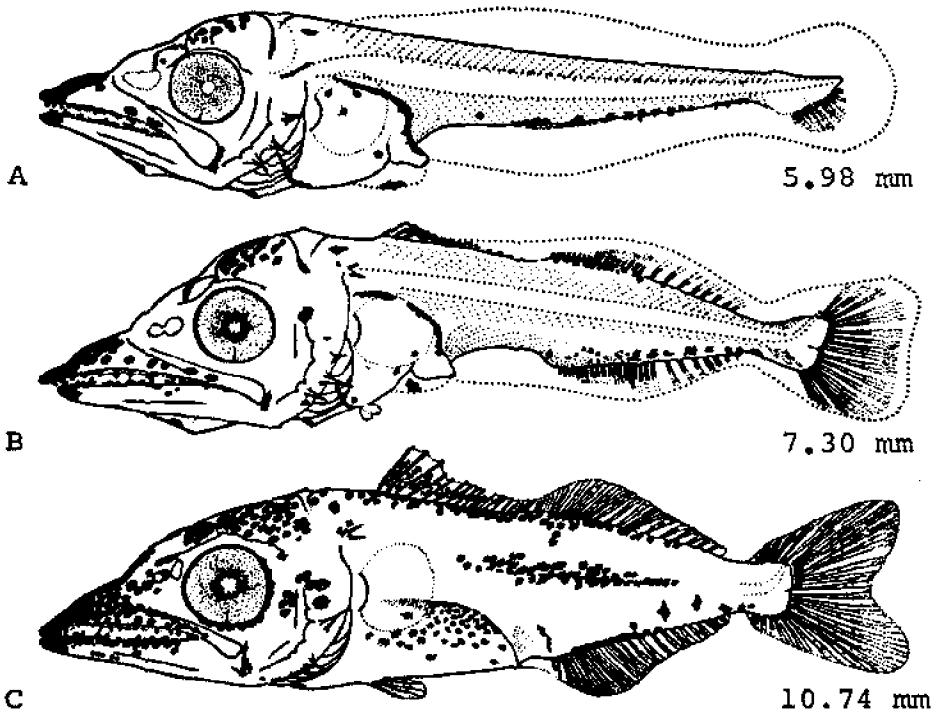

Fig. 76. *Scomberomorus regalis,* Cero. A. Larva, 5.98 mm. B. Larva, 7.30 mm. C. Larva, 10.74 mm. (*A-C, Mayo, C. A., 1973: figs. 10d, 12 a-b, used with the permission of the author.*)

Pigmentation: Body in alcohol dark on the slightly mottled back; pale yellow on sides and belly; a more or less developed lengthwise streak most conspicuous posteriorly; lower sides largely clear of melanophores; dorsal fin with front portion and margin jet black.[1]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Thunnus alalunga (Bonnaterre), Albacore

ADULTS

D. XII [6] to XIV [5,6] (usually XIV [5]), 13–16+7–9; A. 13–15+7–9; [6] C. 9+8 (RAF); P. 30–37; [26] V. I, 5; [10,26] body *fully scaled, with corselet of larger scales in pectoral* region; about 210 scales in longitudinal row; [25] vertebrae 18+21=39,[5,32] rarely 19+20; [5] gill rakers 7–9+19–21 [21]=25–32; [6,7] teeth small, conical, uniserial in jaws; vomer and palatines with minute teeth; [21] array of second dorsal fin pterygiophores between two adjacent neural spines 1, 1, 2, 2, 2, 3, 2, 1; [4] branchiostegals 7.[21]

Proportions as percent FL: Head 29–30, depth 25–27, eye 5.3–5.7, maxillary 10–12, pectoral fin length 40–42, height first dorsal fin 11–12, height second dorsal 11–11.9, height anal 11–12, snout to first dorsal origin 31–34, snout to second dorsal origin 58–60, snout to pelvic fin origin 33–34, snout to anal fin origin 62–66.[21] Pectoral fin over 1.20 HL for Atlantic specimens over 60 cm.[26]

Body moderately robust,[21] deepest at or only slightly before second dorsal fin; [7] caudal peduncle with keel on each side; head conical; mouth terminal; [21] maxillary

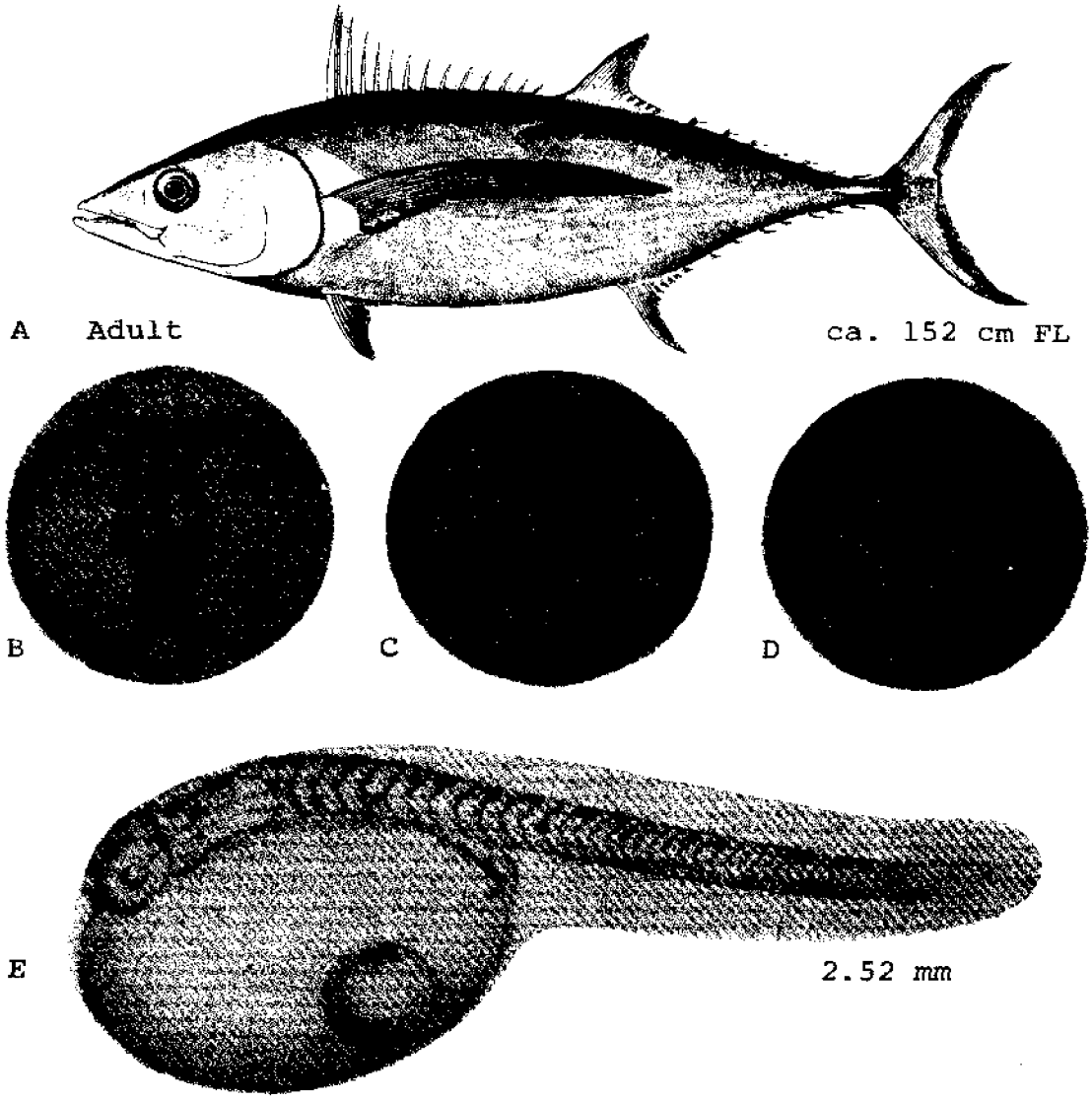

Fig. 77. *Thunnus alalunga*, Albacore. A. Adult, ca. 152 cm FL. B. Egg, 0.92 mm diameter. C. Same egg, 8 hours later. D. Egg, 8 hours after C. E. Yolk-sac larva, just after hatching, 2.52 mm. (*A, Goode, G. B., 1884: pl. 95A. B-E, Sanzo, L., 1933: figs. 1–4.*)

reaching anterior edge of pupil. Lateral line with distinct dip anteriorly, descending posteriorly from upper margin of opercle to point just dorsal to origin of pectoral fin, then rising posteriorly to point below third or fourth dorsal spine, from which it takes normal course to caudal.[26] First dorsal fin long; second dorsal short and space between very short; [21] pectoral fins very long,[26] saber shaped, reaching to first anal finlet; [21] caudal fin lunate.[21,26] Interpelvic process present; [26] interorbital broadly convex; [21] two elliptical infra-central grooves per centrum; [24] ventral surface of liver striated.[6,7]

Pigmentation: Steel-blue on dorsum and sides; silvery on abdomen; [21] pattern usually relieved by narrow and irregular iridescent blue band between dorsal and ventral colors; [26] dorsal and caudal fins dusky brown,[21] caudal with white posterior edge; [1,6,7] dorsal finlets and often two largest anal finlets with central area of yellow ochre; [26] pectoral fins blackish; [21] second dorsal and anal fins with whitish trailing edges; keel on caudal peduncle blackish.[26]

Maximum size: To 137 cm, 31 kg and 128 cm FL, 42 kg.[7]

DISTRIBUTION AND ECOLOGY

Range: Cosmopolitan in tropical, subtropical and temperate waters of the world.[7] Western Atlantic from 39° 45′ N [35] to southern Brazil, no records from Gulf of Mexico; eastern Atlantic from Orkney Islands south to Angola; Indian Ocean from east Africa to Australia between 10° N [6] and 30° S.[6,7] Western Pacific from about 45° N off coast of Hokkaido to 40° S, off southern tip of Australia, fairly continuous distribution between 30° N and 20° S eastward past Hawaiian Islands. Eastern Pacific from about 50° N off Vancouver Island to about 42° S.[6]

Area distribution: As far north as southern New Jersey.[35]

Habitat and movements: Adults—typically schooling.[31] In Philippine Sea prespawning individuals are concentrated from November to March and are scattered over North Equatorial Current in March–April; [34] in the Pacific 1) southward movement caused by seasonal movement of location of North Pacific Current, 2) southward migration, and 3) westward movement of more than 2700 km; [36] in the Atlantic, seasonal movement in east–west direction and migration toward warm waters of low latitudes with growth and sexual maturation,[28] also seasonally move northward and into waters of continental slopes and occasionally those of the shelves as they become warmer.[31] Associated with salinity of 32.7–33.8 ppt off eastern Pacific and 34.1–34.7 ppt off Japan; [22] 16–30 C in Pacific Ocean, 16–26 C for feeding and up to 30 C for spawning,[36] follow 17–18 C isotherms; [29] usually from 27–150 m in North Atlantic.[31]

Larvae—concentrated in subtropical areas centering around 20° Lat. in North and South Pacific and in Indian Ocean, not found in equatorial waters; [33] 35.45 [15]–38.8 ppt [8] in Gulf of Guinea. Temperature range typically 24.9 [15]–27 C,[8] but recorded as low as 24 C in Gulf of Guinea.[16] Recorded from surface to 50 m,[17] greatest occurrence at 20–30 m.[33]

Juveniles—only found at high latitudes in central and western Pacific,[9] southern part of subtropical gyre in Indian Ocean,[20] more poleward areas in Atlantic Ocean from 40° N or 30° to 35° S; often forming large schools.[28]

SPAWNING

Location: In broad areas of tropical and subtropical waters of North and South Pacific,[12] from 10° N to 30° N and 8° S to 25° S but eastern limit not certain, however, in South Pacific 105° W is eastern limit; no spawning in equatorial waters; [17] South Equatorial Current in Indian Ocean; [20] centered in southern Atlantic north of 30° S and west of 10° W.[29]

Season: From March to September, peak in May, in Hawaii; [19] mid-July to September in Straits of Messina; [3,10] June–July in North Pacific and southern summer in South Atlantic,[23] however, all year in some areas south of 20° N; summer in Indian Ocean.[33]

Temperature: Over 24 C.[29,33,36]

Fecundity: Females produce 0.8–2.6 million eggs.[21]

EGGS

Unfertilized eggs: About 1 mm in diameter.[37]

Fertilized eggs: Buoyant; micropyle single, in center of narrow zone of lenticular form; [3] spherical; highly transparent; 0.84–0.9 mm in diameter; egg membrane with delicate network; oil droplet single, 0.24 mm in diameter.[3,13]

EGG DEVELOPMENT

When embryo extends halfway around full circumference of egg, cephalic region rather large; secondary otic vesicles formed; otocysts and about 10 myomeres present; heart in embryonic position and begins beating about 2–3 hours later; epidermal layer has elements which protrude in form of short appendages into perivitelline space; some black pigment in form of small dots on sides of trunk, and some larger chromatophores scattered around position of oil globule.[3]

6–7 hours later, tail turned upward and forward over anterior surface of oil globule; 40 myomeres; black pigment extended to caudal region and some yellow elements on head, abdominal region and around oil globule.[3]

Hatching occurs in about 2 days.[3]

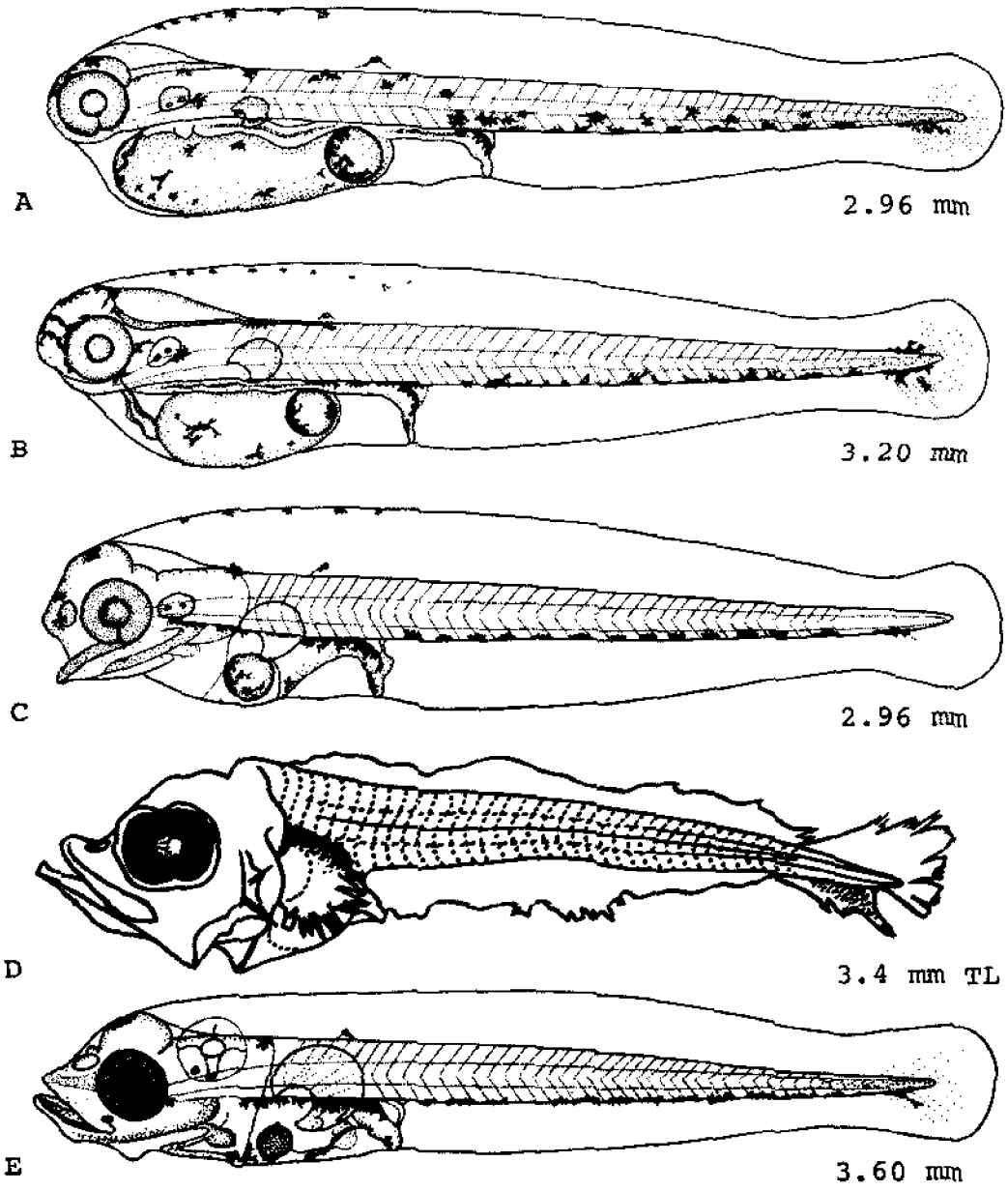

Fig. 78. *Thunnus alalunga*, Albacore. A. Yolk-sac larva, first day after hatching, 2.96 mm. B. Yolk-sac larva, end of first day, 3.20 mm. C. Yolk-sac larva, on second day after hatching, 2.96 mm. D. Yolk-sac larva, 3.4 mm TL. E. Larva, 3.60 mm. *(A-C, E, Sanzo, L., 1933: figs. 5–8, redrawn by Daniel M. Carver. D, Ueyanagi, S., 1969b: fig. 2.)*

YOLK-SAC LARVAE

Size at hatching 1.52–2.76 mm ($\bar{x}$=2.60) and yolk absorbed by 3.60 mm.

Total myomeres 39–40 (usually 40); gill arches not formed at hatching, differentiated by second day (2.91 mm); anus located somewhat anterior to middle of total length; head free of yolk sac at 2.96 mm; yolk sac relatively large and rotund at hatching, elongate at 2.96 mm, absorbed in fifth day (3.60 mm TL); oil globule located in posterior part of yolk; mouth not open at hatching, open by second day (2.96 mm); Meckel's cartilage formed at second day (2.96 mm); eye unpigmented at hatching, pigmented on second day (2.96 mm); pectoral fins not formed at hatching, primordial fin formed at 2.96 mm; finfold rather low anteriorly at hatching; heart rotated from embryonic position at 2.96 mm.[3]

Pigmentation: At hatching—mostly ramified melanophores along dorsal profile of trunk, on ventral profile of caudal region and on head; sparse melanophores on sides of trunk and on oil globule; yellow elements dorsally on head and anterior portion of trunk, and on terminal part of intestine and around oil globule.[3]

At 2.96 mm—yellow chromatophores along dorsal margin of finfold; melanophores along dorsal margin of trunk disappear, while those on ventral caudal portion augmented; melanophores on lateroventral region of caudal portion of trunk and on abdominal region, others on oil globule and yolk sac; more prominent spot persists on bend in terminal part of intestine.[3]

At 3.20–3.50 mm (1st day)—black pigment on dorsal profile of trunk reduced to few traces at boundaries of cephalic region and caudal extremity; lateral pigmentation of trunk disappears, while that on ventral part of tail persists; spot near bend in intestine spreads anteriorly over inferior profile of abdominal portion of trunk; characteristic yellow pigmentation persists on anterior portion of primordial dorsal fin and on oil globule and yolk sac.[3]

At 2.96 mm (2nd day)—all remnants of black pigment gone from dorsal profile, while that on ventral caudal portion of trunk remaining; black pigment on head reduced; characteristic yellow pigment still in primordial dorsal fin.[3]

LARVAE

Specimens described 3.60[3]–13 mm SL, smallest identifiable size 4.5 mm SL.[4]

D. XIV, all rays except last 2 finlets by 8 mm SL; A. all rays except last 3–4 finlets by 8 mm SL; C. 27–31 at 8 mm SL, 41–43 at 12 mm SL;[5] total myomeres 40;[3,18] gill rakers 6–7 on ceratobranchial by 8 mm SL, additional rakers develop distally from angle toward hypobranchial;[5] body length gradually decreases after yolk absorption.

Body slender; snout subconical; gape to anterior edge of eye; small tooth on edge of upper jaw at corner of mouth on 7th day; eye large and round. Otoliths 2 at 3.60 mm TL. Pectoral fins still membranous at 3.60 mm,[3] 8–12 rays at 8 mm SL, 16–20 at 12 mm SL; pelvic elements present by 8 mm SL except spine not discernable as such.[5]

Pigmentation: 3.60 mm—yellow chromatophores on anterior part of primordial dorsal fin have disappeared; remaining yellow pigment scattered on cephalic and abdominal regions about to disappear; black pigment of trunk remains limited to ventral profile in form of series of slight traces; melanophores on head region even more sparse; pigmentation on peritoneal fold and along ventral profile of abdomen more marked and extensive.[3]

At 3.20 mm (7th day)—yellow pigment absent; black pigment along ventral profile of caudal region appears broken-up or resolved into fine granules; pigment of peritoneal fold more conspicuous and has extended to sides of abdominal cavity.[3]

Upper jaw melanophores appear at about 5 mm SL; lower jaw melanophores appear at 9–10 mm SL (sometimes at less than 3.0 mm SL) at tip on outer edge; no melanophores on dorsal edge of trunk, lateral line or ventral edge of trunk.[4] Red pigmentation consisting of chromatophores 0.01–0.04 mm in size,[30] 2–3 (4) ($\bar{x}$=2.6) from caudal peduncle to mid-second dorsal fin base, (2) 3–4 (5) ($\bar{x}$=3.5) along lateral line, and 5–12 ($\bar{x}$=8.0) on ventral edge of trunk.[4]

JUVENILES

Specimens described 13.0–860 mm FL.[4]

C. 45–47 at 14 mm SL, 48–50 at 27 mm SL; P. 26–32 at 20 mm SL, 32–33 at 28 mm SL; vertebrae usually 18+21=39,[2,4] few 19+20=39; gill rakers 14–15 (16) on first ceratobranchial over 40 mm SL,[2] all elements by 53 mm SL,[5] 7–9+1+19–21=27–30 at 88–184 mm SL;[12] first haemal arch on vertebra 10;[2,4] first prezygapophysis on vertebra 15 or 16, low; postzygapophysis near first prezygapophysis short, directed posteriorly; first haemal spine extremely wing-like over 30 mm SL.[5]

Body more or less fusiform; snout short and somewhat pointed; mouth moderate. Teeth in single row on each jaw, pointed; villiform teeth on palatines and vomer.[12] Lateral line above base of pectoral fin obtuse over 25 mm SL.[4] Pectoral fin shorter than similar size *T. obesus* and *T. albacares* less than 300 mm.[28] First lateral line scale at 16–18 mm SL near dorsoposterior edge of pectoral girdle, 9–10 scales by 23 mm SL, at 60 mm SL scales fuse to form continuous line occurring first anteriorly and then proceeding posteriorly.[5]

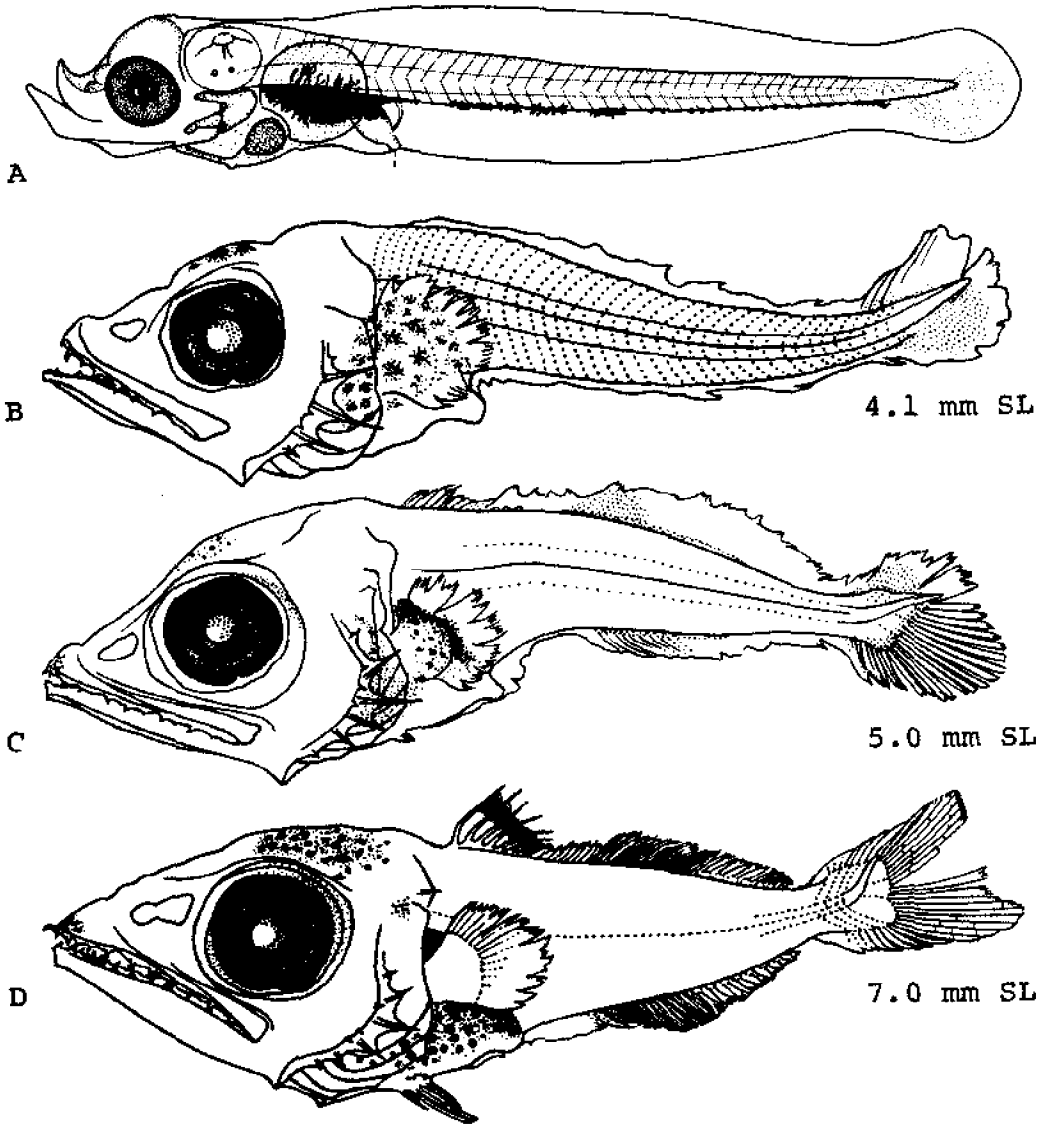

Fig. 79. *Thunnus alalunga*, Albacore. A. Larva, from beginning to 7th day after hatching. B. Larva, 4.1 mm SL. C. Larva, 5.0 mm SL. D. Larva, 7.0 mm SL. (*A, Sanzo, L., 1933: fig. 9, redrawn by Daniel M. Carver. B-D, Ueyanagi, S., 1969b: figs. 3–5.*)

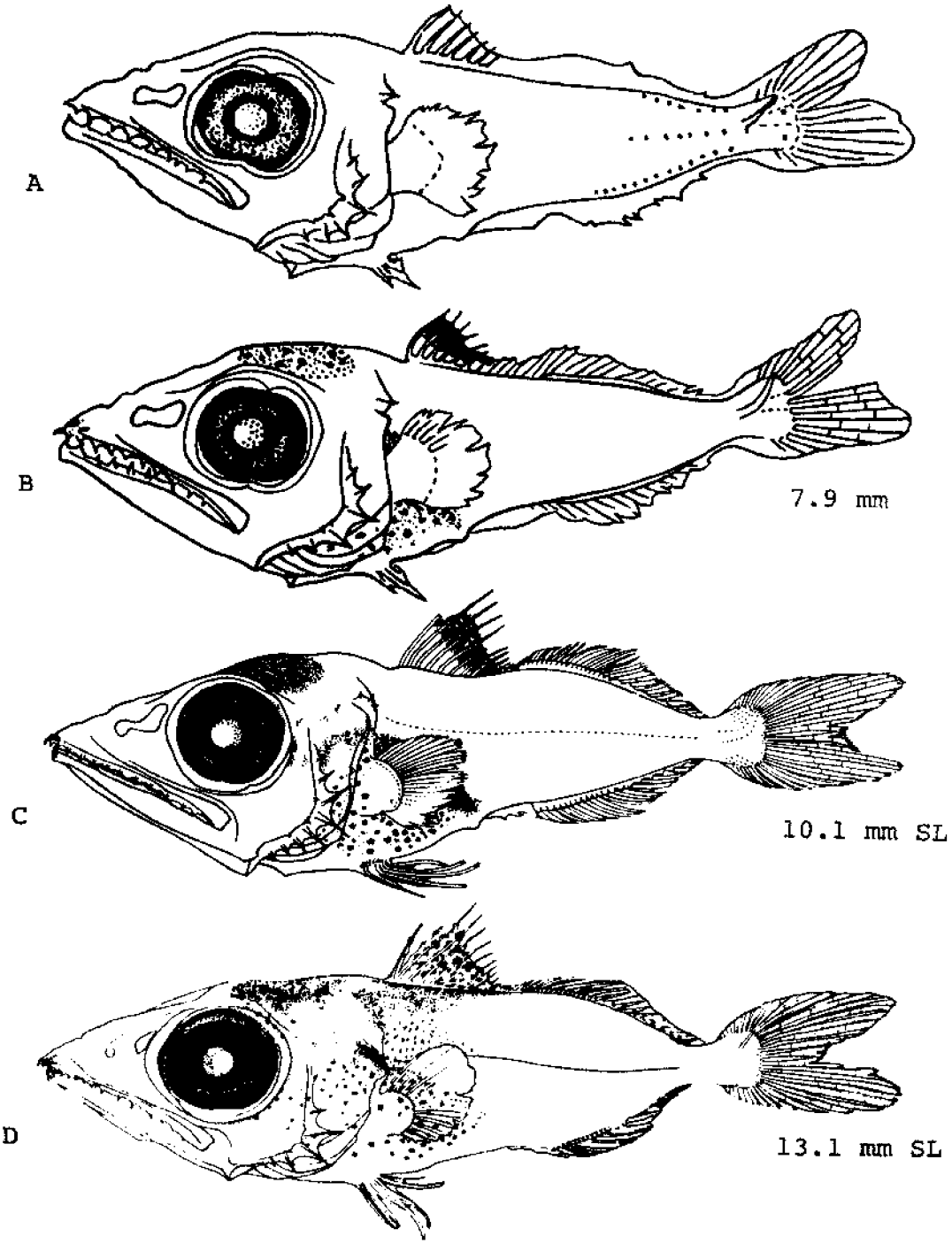

Fig. 80. *Thunnus alalunga*, Albacore. A. Larva, showing pattern of red pigment. B. Larva, 7.9 mm. C. Larva, 10.1 mm SL. D. Juvenile, 13.1 mm SL. *(A, Ueyanagi, S., and H. Watanabe, 1962: fig. 11. B, Ueyanagi, S., and H. Watanabe, 1964: fig. 10. C-D, Ueyanagi, S., 1969b: figs. 6–7.)*

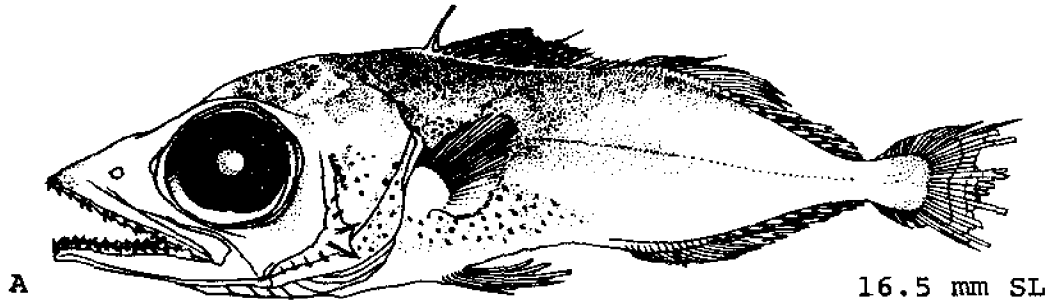

Fig. 81. *Thunnus alalunga*, Albacore. A. Juvenile, 16.5 mm SL. (*A, Ueyanagi, S., 1969b: fig. 8.*)

Pigmentation: At about 60 cm—5 or 6 dark, irregularly longitudinal bands, running near ventral median line, becoming more distinct in caudal region and more or less united in form of irregular network; first dorsal fin nearly colorless, except border dusky; pectorals black; pelvics and second dorsal fin dusky; anal fin colorless; *dorsal finlets dusky, washed with yellow; ventral finlets* more or less silvery; iris silvery tinted with light blue.[14]

GROWTH

Reaching 25 [11]–52 or 57 [21] cm at 1 year; 48 [11]–65 or 65.7 [21] *cm at 2 years; 60* [11]–*76 or* 77.4 [21] cm *at* 3 *years;* 74 [11]–84 or 85 [21] cm at 4 years; 88 [11]–93 cm at 5 years; 100 cm at 6 years; and 105 cm at 7 years.[21]

AGE AND SIZE AT MATURITY

Maturing in 4 to 5 years [11,27] and 75 [27]–89.1 cm.[21]

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Thunnus albacares (Bonnaterre), Yellowfin tuna

ADULTS

D. XII to XIV [41] (usually XIV [5]), 13–16 + 8–10; A. 12–15 + 7–10; [41] C. 9 + 8; [33] P. 33–36; [41] V. I, 5; [23] scales small, covering body, smaller on belly and larger immediately above pectoral fin,[38] about 270 on lateral line; [19] corselet indistinct; [38] vertebrae 18 + 21 = 39; [33] gill rakers elongate, pointed,[23] 7–11 [29] + 18–23 [23] = 27–33; [20] teeth in jaws 31–34 in each side, small, conical and turned slightly inward, granular patch on vomer and palatines; [38] branchiostegals 7.[23]

Measurements given as percent TL: Head 24–29, depth 24–28, eye 3.2–6.2, maxillary 9.6–12, pectoral fin length 24–29, first dorsal fin height 11–13, second dorsal fin height 13–34, anal fin height 11–38, snout to first dorsal fin origin 30–32, snout to second dorsal fin origin 49–56, snout to pelvic fin origin 27–33, snout to anal fin origin 56–62.[19] Maxillary 2.6–2.7 in HL.[5]

Body fusiform,[19] somewhat compressed, upper profile slightly more arched than lower; caudal peduncle with large, rather wide keel; [38] head conic; snout attenuated; mouth moderate, lower jaw protruding; [25] maxillary extending almost to anterior margin of pupil.[25,38] Lateral line forms rather abrupt, high arch over pectoral fin base and gradually slopes to midline of body near soft dorsal and anal fins.[23] Second dorsal and anal fins increasing in length with age,[5] noticeably long even at 70 cm; [18] space between dorsal fins about equal to interspace between first dorsal spines; caudal fin crescent-shaped; pectoral fin originating under origin of first dorsal, tip of fin extending to 6th or 7th ray of second dorsal. Eye large; [38] infra-central groove single, large; [22] liver with right lobe longer than central, and all lobes rather pointed.[24] Array of second dorsal fin pterygiophores between two adjacent neural spines 1, 2, 2, 2, 3, 2, 1, 1; first prezygopophysis on haemal arch 13 or 14, placed low.[39]

Pigmentation: Dark metallic blue above, becoming silvery below, with purple and lilac iridescence in an indefinite band on each side of belly from gills to anal fin; [38] brilliant gold lateral band; lower sides usually have whitish pattern of vertical bars or rows of closely spaced spots, pattern changing to elongate white spots with increase in size; [18] pectoral fin silvery below, dark blue above; dorsal fin spines surrounded by narrow zone of yellow; second dorsal fin orange-yellow, darker anteriorly, with narrow dark posterior edging and small white tip; dorsal finlets bright yellow with dark margins; anal fin silvery at base, remainder orange-yellow; anal finlets similar to dorsal but with considerable white posteriorly; pelvic fins white below, rays orange when spread open.[38]

Maximum size: Reported to reach 213 cm,[25] but fish over 170 cm are not common.[17]

DISTRIBUTION AND ECOLOGY

Range: Pantropical.[15,41] Western Atlantic from about 42° N south through Sargasso Sea to Gulf of Mexico and Caribbean Sea and in South America from 10° N to 32° S. Eastern Atlantic from Spain and Portugal south to Angola but not in Mediterranean Sea, continuous around South Africa. Along East African coast and from 20° N to 30° S in Indian Ocean. Western Pacific from 40° N, off Japan, to 30° S, off Australia, extending across Pacific from 30° N to 20° S.[41]

Area distribution: Recorded from Ocean City, Maryland [34] and as part of summer sport catch from Cape Hatteras to Delaware Bay.[28]

Habitat and movements: Adults—oceanic, but often approaching shore; schooling, often mixed with skipjack; [17] associated with flotsam in spring in eastern Pacific.[32] Some tendency for eastward migration in Pacific as growth occurs, also some evidence for north–south latitudinal migration; [17] advance into northwestern Atlantic slope water during spring and present from late June to early October, leaving as water cools; [28] regular occurrence not far off continental shelf south of New England during fall.[30] Recorded from 14 [21]–31 C,[2] never less than 18.3 C in North Atlantic,[28] and from 0–150 m.[2]

Larvae—found 19–912 km off west coast of Africa; [7] Indian Ocean in low latitude areas north of 10° S; [42] northernmost record 25° 49′ N in Pacific.[20] Salinities from 34.23–35.90 ppt in Gulf of Guinea [9] and 36.18 ppt in Atlantic; [8] temperatures from 24.0–28.2 C off Japan,[27] 27.5–28.5 C in Indian Ocean,[16] 20 [9]–28.9 C off west coast of Africa,[1] with low limit of 26 C in Atlantic; [12] mainly from 0–50 m.[3,6]

Juveniles—form mixed schools near surface.[24] Known to occur as far north as ca. 31° N near Japan and 23° N near Hawaii, two records as far south as 23° S; in central Pacific reported from 2° and 6° N; in eastern Pacific from ca. 24° N just off Baja California, none from south of 2° S just off coast of Ecuador.[6]

SPAWNING

Location: Recorded from throughout high temperature zone around equator; [13] including central Pacific,[15] eastern Pacific from Baja California to Ecuador and Islas Revillagigedo,[10] Hawaii,[20] Senegal,[23] and Pacific coast of Japan.[27]

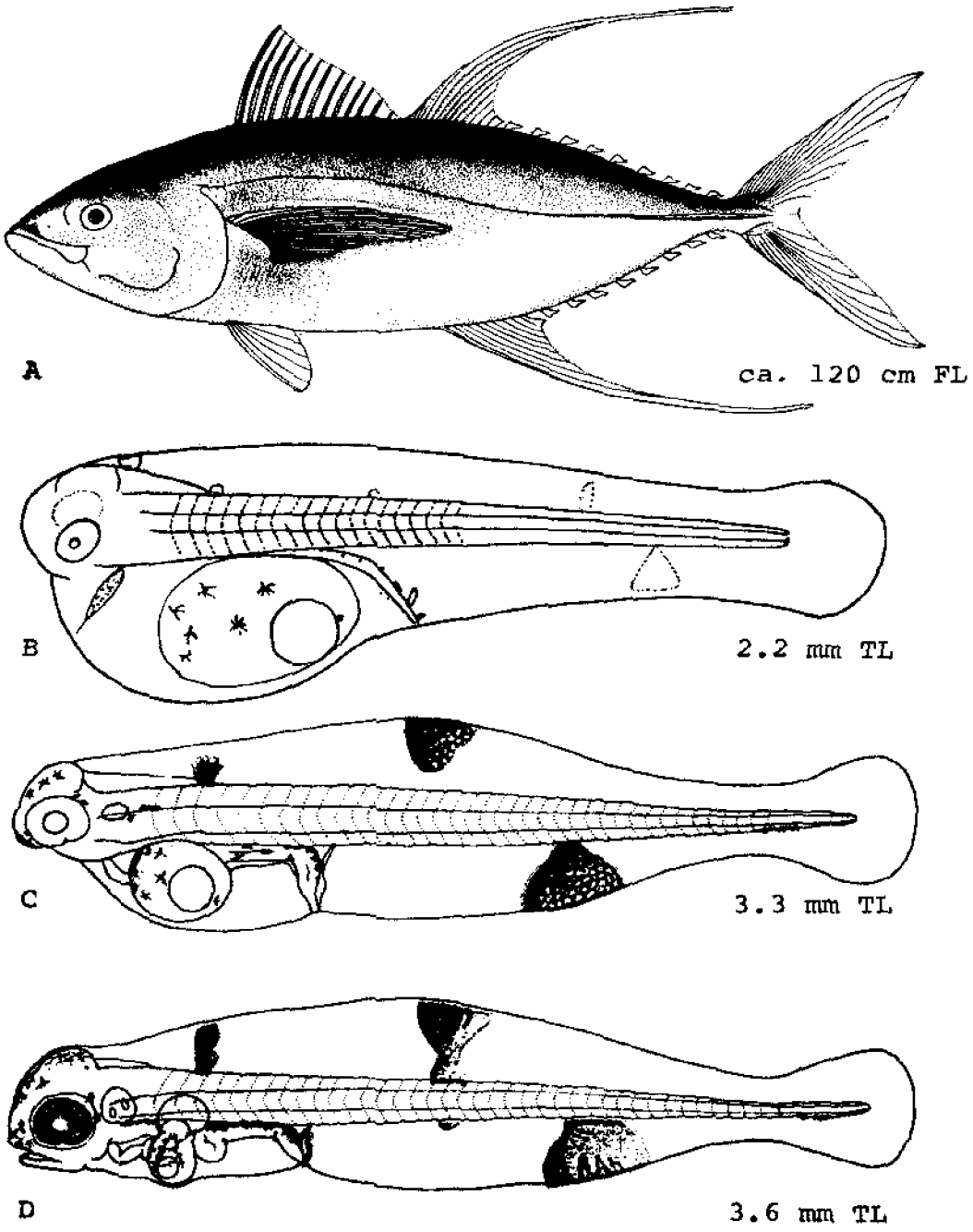

Fig. 82. *Thunnus albacares*, Yellowfin tuna. A. Adult, ca. 120 cm FL. B. Yolk-sac larva, 2.2 mm TL. C. Yolk-sac larva, 3.3 mm TL. D. Larva, 3.6 mm TL, areas outlined in dots or appearing gray indicate yellow pigment. (*A, Fowler, H. W., 1940: fig. 189. B, Inoue, M.*, et al., *1974: fig. 5a-b. C-D, Mori, K.*, et al., *1971: figs. 4–5.*)

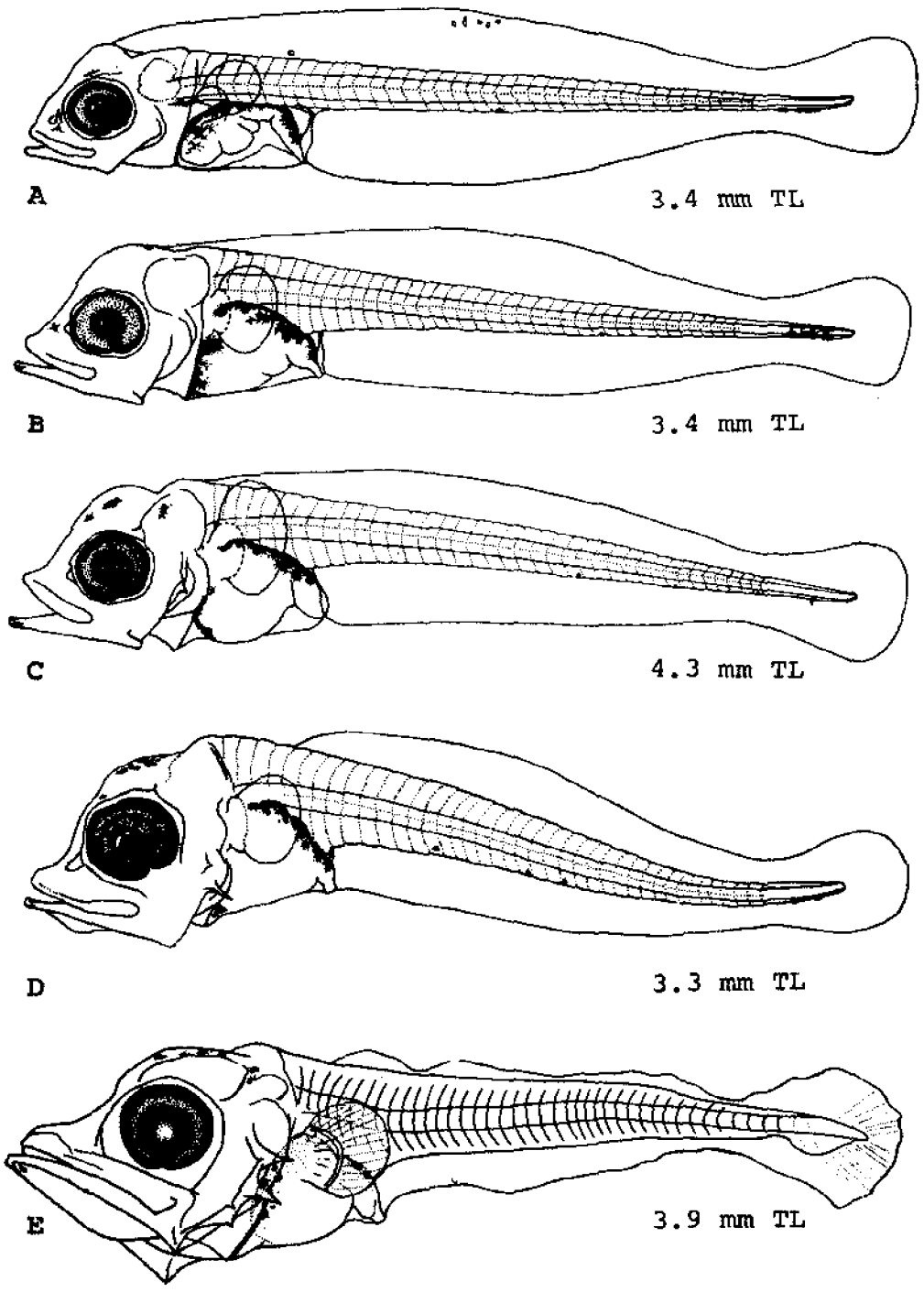

Fig. 83. *Thunnus albacares*, Yellowfin tuna. A. Larva, 3.4 mm TL, 3 days after hatching. B. Larva, 3.4 mm TL, 5 days after hatching. C. Larva, 4.3 mm TL, 7 days after hatching. D. Larva, 3.3 mm TL, 8 days after hatching. E. Larva, 3.9 mm TL. (*A-D, Mori, K.*, et al., *1971: figs. 6–9. E, Matsumoto, W. M., 1958: fig. 4.*)

Season: Occurring throughout year in central Pacific,[15] June–August near Kapingamarangi Island,[35] May–July in Marshall Islands; [4] March or April–August in Hawaii; [20] *spring–summer in* Cuban waters; [3] *June–July in* waters south of 35° N off Pacific coast of Japan; [27] May–October in Revillagigedos,[14] November–April near Clipperton Island, January–March or April off northern South America,[10] January–April off Central America.[4] Some evidence of more than one spawning per year per fish.[19]

Fecundity: 2–8 million eggs; [3] 1,300,000 eggs at 118 cm, 5,431,000 at 144 cm.[23]

EGGS

Unfertilized eggs: Diameter 0.76–1.23 mm; [17] grayish, translucent; conspicuous golden yellow oil globule averaging 0.26 mm diameter.

Fertilized eggs: Buoyant, spherical; [36] diameter 0.90–1.04 (mode 0.98) mm; [37] oil globule single.[36]

EGG DEVELOPMENT

Hatching occurs in about 25–36 hours in laboratory at 23.7–27.0 C.[36]

YOLK-SAC LARVAE

Size at hatching 2.6 [1]–2.7 mm TL.[36,37]

Yolk sac absorbed in 3 days at 25–28 C; total myomeres 37–39.[37]

Pigmentation: Yellow pigment spots on finfold; small black pigment spots along ventral edge of trunk.[37]

LARVAE

Specimens described 3.9 mm [15]–12.93 mm FL.[31]

D. IV at 6.4 mm; VII at 7.15 mm; X+6–7 finlets at 9.2 mm; [15] XII, 24 at 9.87 mm FL; XIV, 13+8 at 12.93 mm FL.[31] A. 14+7 at 9.2 mm; [15] 14+8 at 12.9 mm FL.[31] C. 10 incomplete rays at 5.5 mm, 12 at 6.4 mm, 19 at 7.15 mm, 14+5 at 9.2 mm. V. I, 5 at 7.95 mm. Total myomeres 39–40 at 4.75 mm,[15] usually 40–41.[39] Vertebrae 18+21 at 10.8 mm FL [31] and 18+20 at 12.0 mm.[15] First haemal arch formed on 11th vertebrae at 10–13 mm SL.[39] Preopercular spines 3 at 3.9 mm, 6 at 5.5 mm, 7 at 9.2 mm,[15] 9 at 9.87 mm FL; middle ones longest.[15,31]

Nuchal spines 1 at 6.4 mm [15] and 2 at 12.93 mm FL.[31]

Anal opening well ahead of midpoint of body at hatching, becoming closer to midpoint at 7.15 mm.[15]

Body evenly tapered caudally, abdominal sac roundly triangular with anal region of gut sharply directed downward; [15] snout in form of beak.[31] Teeth absent at 3.9 mm, 5 in upper jaw and 3 in lower at 4.75 mm,[15] becoming 15 upper and 14 lower by 10.8 mm FL; [31] nostrils separate by 7.95 [15]–9.87 mm FL. Dorsal finlets united by membrane at 12.93 mm FL; [31] anal finlets not separate at 9.2 mm; [15] anal fin with membrane to anus at 9.87 mm FL; [31] pectoral fins membranous at 3.9 mm, rays indistinct at 7.95 mm; pelvic fins emerging at 4.75 mm, still *very short at 7.95 mm. Urostyle beginning to ossify at* 7.45 mm.[15]

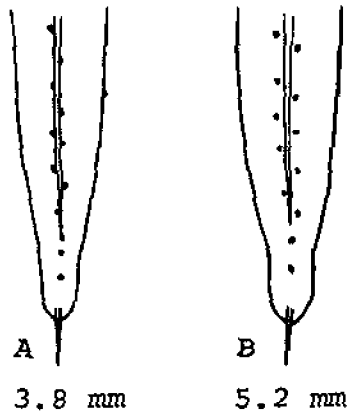

Fig. 84. *Thunnus albacares*, Yellowfin tuna. A. Larva, 3.8 mm. B. Larva, 5.2 mm. Both ventral views showing ventral rows of erythrophores. (*A-B, Ueyanagi, S., 1966: fig. 3a-b.*)

Pigmentation: At 3.9 mm, head pigmentation rather *sparse, with only about 4 very small scattered chromato*phores over membrane covering brain and 2 internal chromatophores along posterior margin of brain; several large chromatophores present over anterior and posterior regions of abdominal sac; remainder of body unpigmented.[15]

At 4.5 mm, black pigment appears on tip of lower jaw between 4.5 and 6.0 mm SL. Pigment appears on upper jaw at about 7.0 mm SL.[39]

At 7.15 mm, increase in pigmentation over brain, at tips of both jaws and over abdominal sac; band of pigment at posteroventral margin of brain and chromatophores near dorsal end of opercle increasing in number; 2 chromatophores near posterior edge of orbit, darkly pigmented distal half of interradial membrane of first dorsal fin rather prominent.[15]

At 9.0–10.8 mm, jaw pigmented on inner and sometimes outer margin.[39]

At 9.87 mm FL, snout bears few chromatophores in form of spot; lower jaw with 5–6 chromatophores on *each side; visceral* mass pigmented; 2–3 chromatophores on opercle; 3 chromatophores on dorsal profile from 5th to 7th dorsal spine; first dorsal colored with large melanophores, other fins colorless.[31]

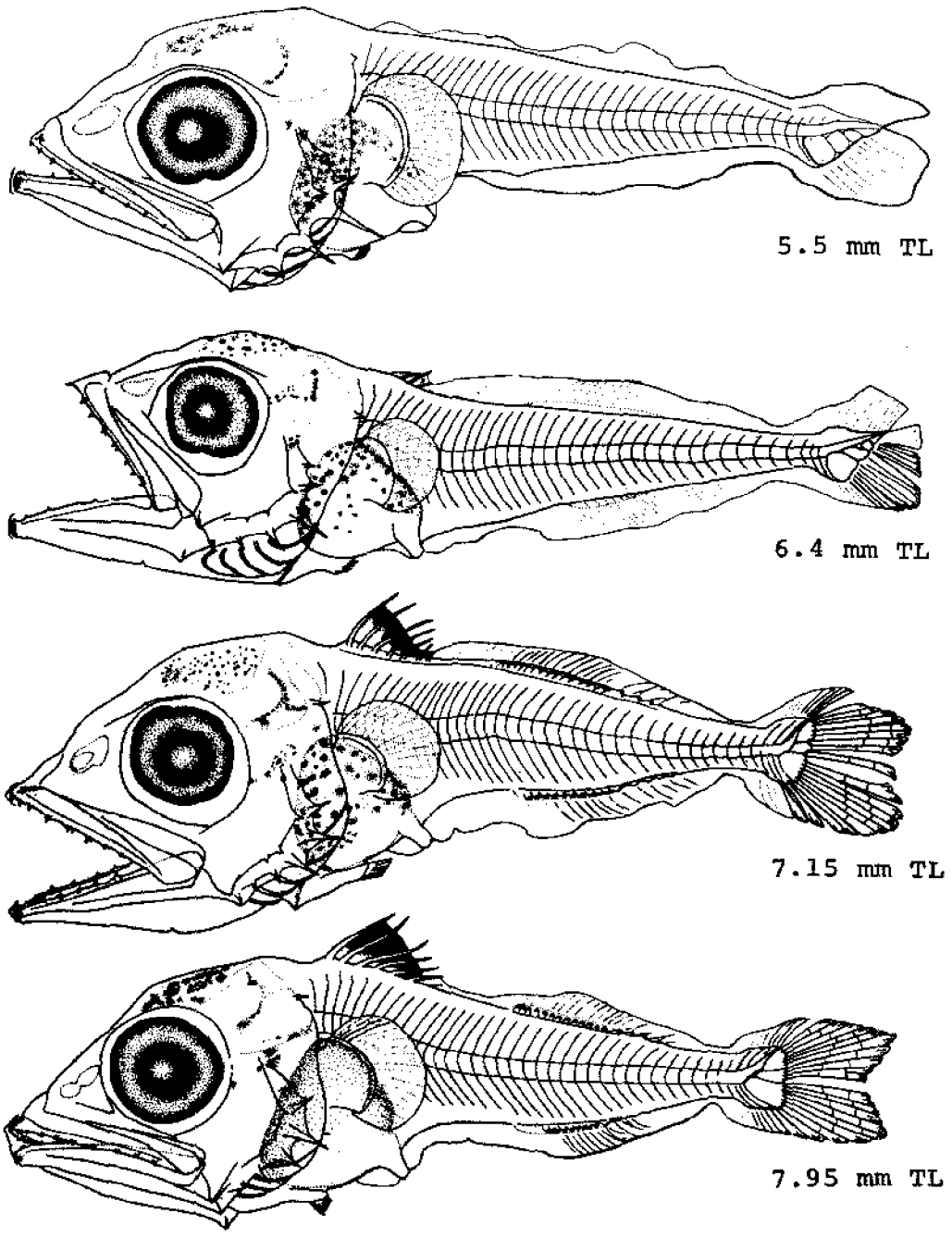

Fig. 85. *Thunnus albacares*, Yellowfin tuna. A. Larva, 5.5 mm TL. B. Larva, 6.4 mm TL. C. Larva, 7.15 mm TL. D. Larva, 7.95 mm TL. (*A-D, Matsumoto, W. M., 1958: figs. 5-8.*)

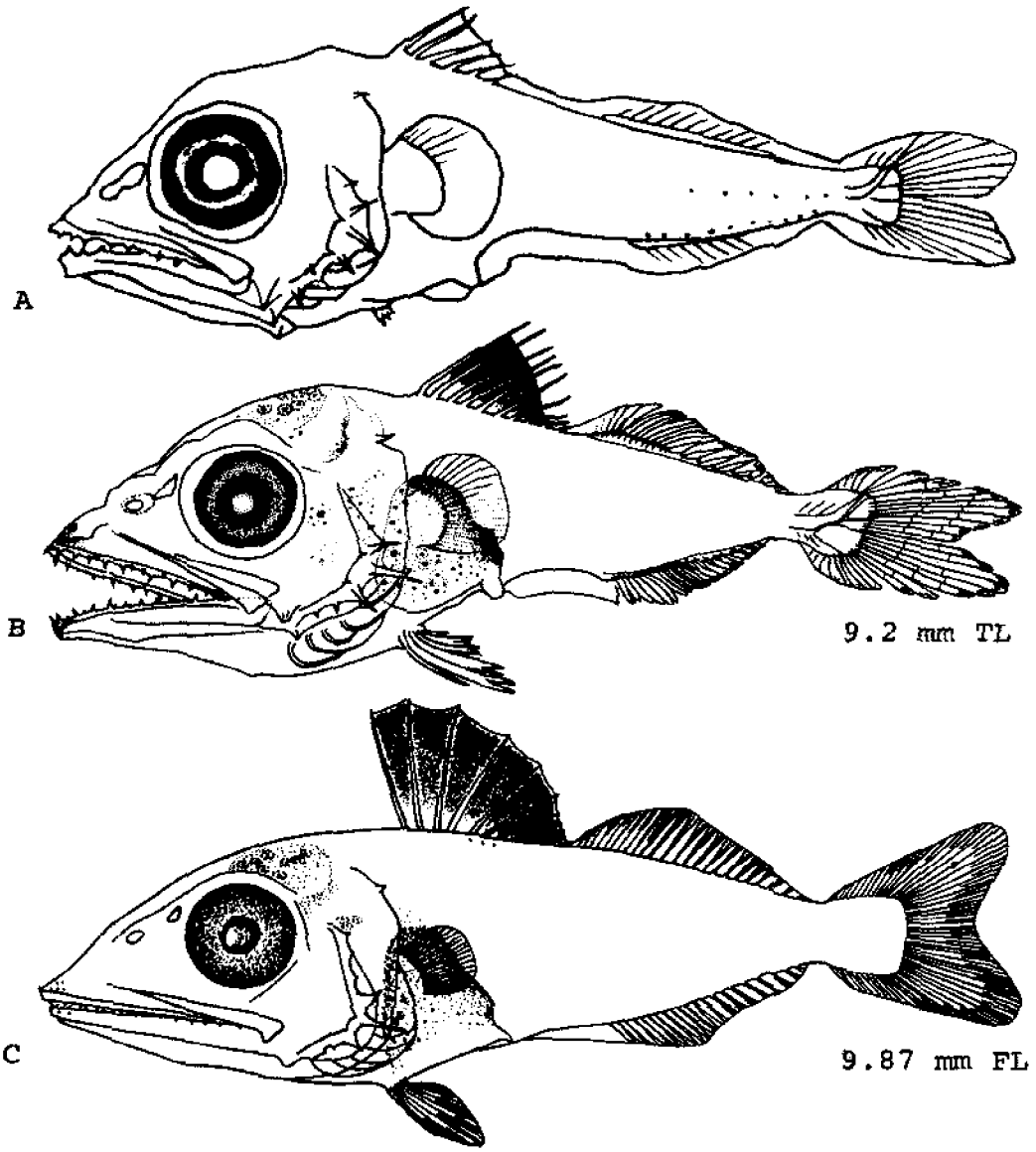

Fig. 86. *Thunnus albacares*, Yellowfin tuna. A. Larva showing pattern of red pigmentation on side. B. Larva, 9.2 mm TL. C. Larva, 9.87 mm FL. (*A, Ueyanagi, S., 1966: fig. 2d. B, Matsumoto, W. M., 1958: fig. 9. C, Marchal, E., 1963C: fig. 2.*)

At 12.93 mm FL, lower jaw bears 10 chromatophores; some chromatophores behind eye on opercle; line of pigment from origin of first dorsal to base of 15th ray in second dorsal; spot at base of 12th, 13th, and 14th anal rays; first dorsal fin still dark.[31]

Red pigment present on dorsal edge of trunk as 0–3 ($\bar{x}=0.6$) spots, on lateral line as 0–5 ($\bar{x}=2.4$), and on ventral edge of trunk as 3–12 ($\bar{x}=7.0$); [40] appears just at time of yolk sac absorption. Laboratory reared specimens agree with the above description of pigmentation.[37]

JUVENILES

Specimens described 13–700 mm FL.[39]

D. XIV, 15+8; [15,31] A. 14 [31]–15 [15]+8; [15,31] C. 18+19; P. 30; [15] gill rakers on lower limb of first arch 19 at 32.9 mm FL; total gill rakers 6+1+20 at 53.1 mm FL; preopercular spines 6 at 14.25 mm,[15] remaining evident at 18.16 mm FL; nuchal spines remain visible at 53.1 mm FL.[31]

Body with dorsal and ventral profiles almost parallel; head large; snout short; teeth in jaws very small at 53.1

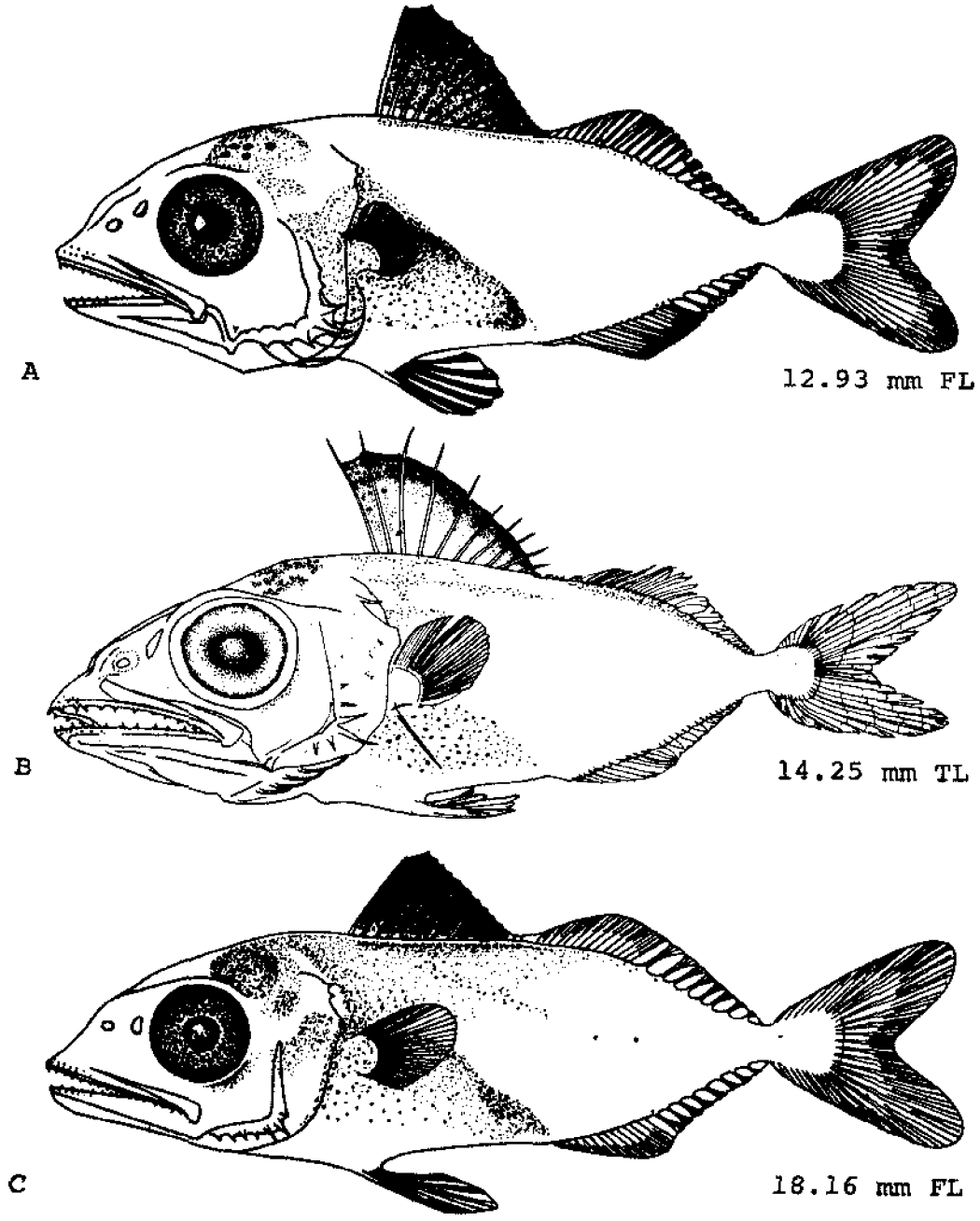

Fig. 87. *Thunnus albacares*, Yellowfin tuna. A. Juvenile, 12.93 mm FL. B. Juvenile, 14.25 mm TL. C. Juvenile, 18.16 mm FL. (*A, C, Marchal, E., 1963C: figs. 3–4. B, Matsumoto, W. M., 1958: fig. 10.*)

mm FL,[31] 13 in upper jaw and 14 in lower at 14.25 mm,[15] and 15 upper and lower at 18.16 mm FL; lateral line visible at 53.1 mm FL.[31]

Pigmentation: At 14.25 mm, large chromatophores over small area of brain; numerous very minute chromatophores over posterior part of head extending posteriorly in band to point beneath origin of second dorsal fin; a patch of similar pigmentation immediately behind opercle and dorsal to pectoral fin insertion; small chromatophores line posteroventral margin of orbit; 5–6 large chromatophores present on surface of opercle posterior to eye; pigmentation over abdominal sac remains unchanged; first dorsal fin completely pigmented; faint line of chromatophores present along bases of first and second dorsal fins, extending posteriorly to about second dorsal finlet; remainder of body unpigmented.[15]

At 18.16 mm FL, snout with spot; double row of 10 chromatophores on upper jaw; single row of 15 chromatophores on lower jaw; dorsal part of head, upper opercle and area posterior to orbit pigmented; no pigment on body posterior to 15th dorsal ray; one spot at base of 15th anal ray; dorsal fin dark.[31]

At 23.16 mm FL, vertical bands on sides begin to appear.[31]

At 32.9 mm FL, snout pigmented anterior to anterior nostril; upper jaw with one row of chromatophores and lower jaw with double row; preopercle, upper part of opercle and most of head pigmented; anterodorsal part of body pigmented to 5th dorsal finlet, forming characteristic 5 vertical bands separated by clear areas and last two bands becoming diffuse near anal fin base; some dark areas visible in visceral mass; first dorsal uniformly black; second dorsal pigmented; bases of caudal rays pigmented; 2 superior pectoral rays pigmented; anal and pelvic fins colorless.[31]

At 53.1 mm FL, snout entirely pigmented; border of orbit pigmented except anteriorly; preopercle, opercle, and head pigmented; upper jaw and distal part of lower jaw pigmented; flanks pigmented for three-fourths of length; sides with six dark bands; median line of body pigmented; base of anal fin with dark band; first dorsal entirely black; dorsal finlets with 1–3 chromatophores at inferior border; caudal rays pigmented at base; anal finlets colorless; anal fin colorless except for few dark spots at proximal part of anterior rays; first 2 pectoral rays pigmented; pelvics colorless.[31]

GROWTH

Reaching 38–60 cm in first year, 54–103 cm in second, 70–136 cm in third, 85–155 cm in fourth, 100–168 cm in fifth, and 109–134 cm in sixth.[17]

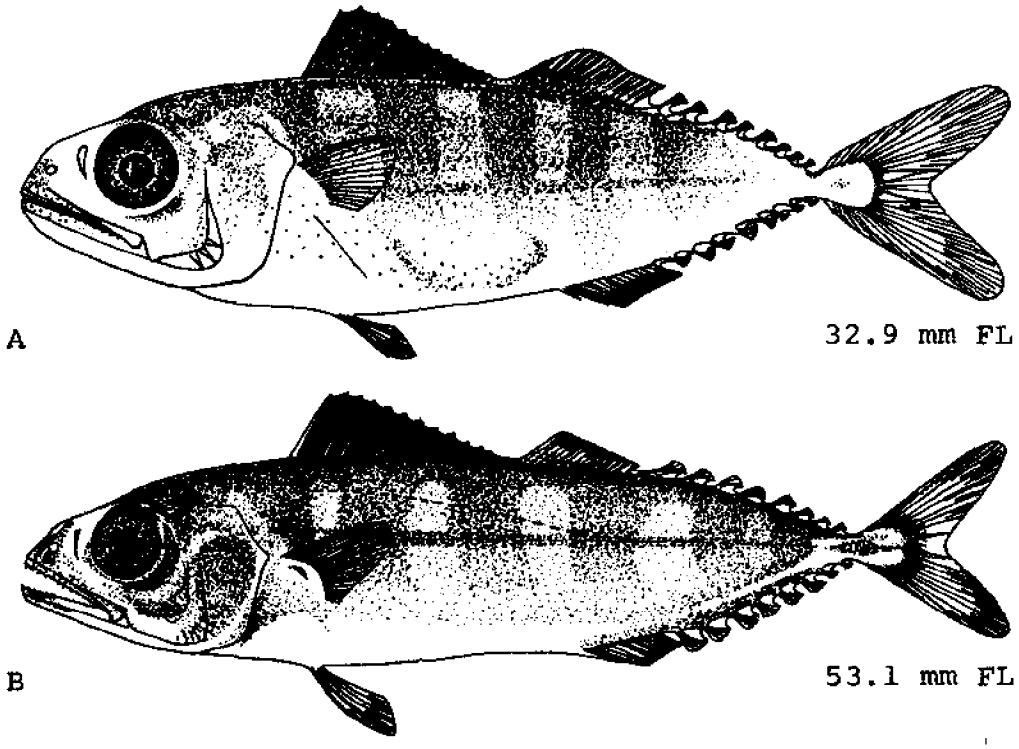

Fig. 88. *Thunnus albacares*, Yellowfin tuna. A. Juvenile, 32.9 mm FL. B. Juvenile, 53.1 mm FL. (*A-B, Marchal, E., 1963C: figs. 5–6.*)

AGE AND SIZE AT MATURITY

Some reaching maturity at age 1 and most by age 2;[17] males and females mature by 66 cm;[4,11] but active spawning only in specimens 120 cm or larger.[17]

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Thunnus atlanticus (Lesson), Blackfin tuna

ADULTS

D. XIII[2,15] *to XV*[15] *(usually XIV, RAF), 13–17*[15]+7–9;[4,15] A. I[17] to III, 10[15]–12[15,17]+7–8;[15] C. 9+8;[17] P. 30–37; V. I, 5;[6] *vertebrae* 19+20=39;[4,6,17] *gill rakers* strong, slender,[15] 15–19 on lower limb of first arch;[2] teeth in jaws moderate, uniserial, single, conical; upper jaw with 33–40 teeth on each side, lower with 32–41; vomer, palatines, and patch on tongue with finely granular teeth.[15]

Measurements as percent FL: Depth 23–29; width 15–21.5; head 25–32. Maxillary 9.5–11.8, snout 8–10.5% HL.[6] Body robust,[6] fusiform,[6,7] caudal peduncle slender with 3 short keels on each side;[7] head subconical;[6] mouth oblique;[15] maxillary not reaching beyond vertical from center of eye.[2] Scales small, compact,[15] completely covering body,[6,15] smallest below; corselet small, inconspicuous,[15] largely over base of pectoral fin.[6,15] Anterior portion of lateral line with distinctive dip, descending posteriorly from upper margin of opercle to point just dorsal to pectoral fin origin then rising to point below 3rd or 4th dorsal spine and continuing straight to caudal keel.[6] Second dorsal spine highest, first almost as high; soft dorsal fin low; anal fin lobe similar in shape and

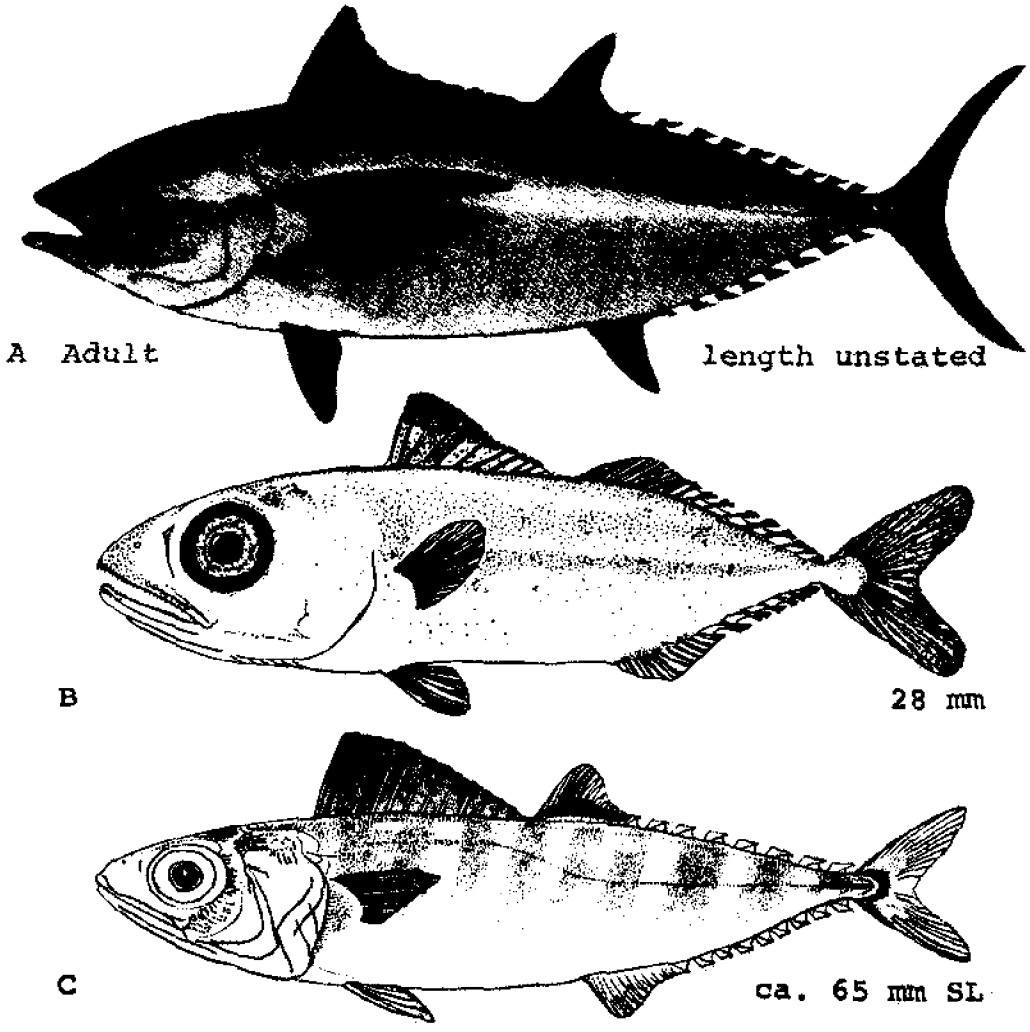

Fig. 89. *Thunnus atlanticus*, Blackfin tuna. A. Adult, length unstated. B. Juvenile, 28 mm. C. Juvenile, ca. 65 mm SL. *(A, Beebe, W., and J. Tee-Van, 1936: pl. I, fig. 1 after Fowler. B, Klawe, W. L., and B. M. Shimada, 1959: fig. 2. C, Fowler, H. W., 1944: 149.)*

size to soft dorsal fin; [15] caudal fin lunate; interpelvic process between pelvic fins.[7] Posterior nostril and elongate vertical slit; anterior nostril very small.[15] Liver without striations on ventral surface.[6]

Pigmentation: Dorsum bluish black; silvery white below; [7] gold lateral band prominent in life; [6] dorsal finlets black to dusky bronze while ventrals usually gray; [6,7] second dorsal fin yellow.[7]

Maximum size: To 90 cm.[7]

DISTRIBUTION AND ECOLOGY

Range: Restricted to western Atlantic,[16] from southern Brazil through the Caribbean, through the Gulf of Mexico, Bermuda, and Cape Cod.[7]

Area distribution: Coastal waters of the Mid-Atlantic Bight.[3,7]

Habitat and movements: Adults—school [3] near land or in relatively shallow water; [1,16] abundant off Florida during fall, winter, and spring; [5] prefer cold water [10] less than 180 m deep.[16]

Larvae—found in open sea from 0–50 m.[1]

Juveniles—no information.

SPAWNING

Location: Occurs well offshore in clear, "blue" oceanic water of Florida Current [11,23] and in coastal waters of northern Brazil.[5]

Season: During April–November off Miami [3] and June, August–September in Gulf of Mexico.[12]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Specimens described 5.1 [4]–13 mm SL.[18]

Caudal fin rays forming at 5.1 mm SL, rays added outward from center, all rays, including procurrent rays, completely developed by 15–24 mm SL; notochord flexion slight at 5.1 mm SL, complete by 6.5–7.7 mm SL; vertebral column develops from anterior to posterior end; urostyle begins ossifying at 6.5 mm SL and is completed by 11.0 mm SL.[4] It is suspected that the larvae resemble those of *T. obesus*.[13,18]

JUVENILES

Specimens described 15 or 24 mm SL [4]–99 mm TL,[11] probably range 13–200 mm SL.[18]

D. XIII–XV, 22–24 [8] + 8; [10] A. 20–22 [9] + 7; [10] lateral line scales 2–13, number increasing with growth; [9] vertebrae 19 + 20; [10,14] gill rakers 6–7 + 1 + 15–17; [11] array of second dorsal fin pterygiophores between two adjacent neural spines 1, 2, 2, 2, 3, 2, 1, 1; first haemal arch on vertebra 11; first prezygapophysis long, directed vertically or slightly anteriorly; first haemal spine wing-like.[18]

Pigmentation: Not extending caudally beyond 5th dorsal finlet; concentrations of pigment present along lateral line and in some areas along dorsal and lateral regions, resulting in faint pattern of 6 vertical bars; scattered chromatophores in peritoneum visible through body wall; first ray of pectoral fin slightly pigmented; several

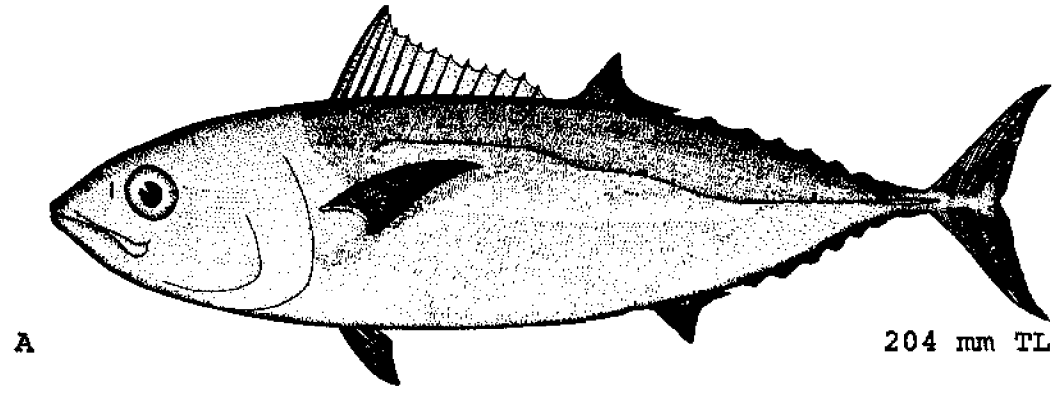

Fig. 90. *Thunnus atlanticus*, Blackfin tuna. A. Juvenile, 204 mm TL. *(A, Suarez Caabro, J. A., and P. P. Duarte Bello, 1961: fig. 16.)*

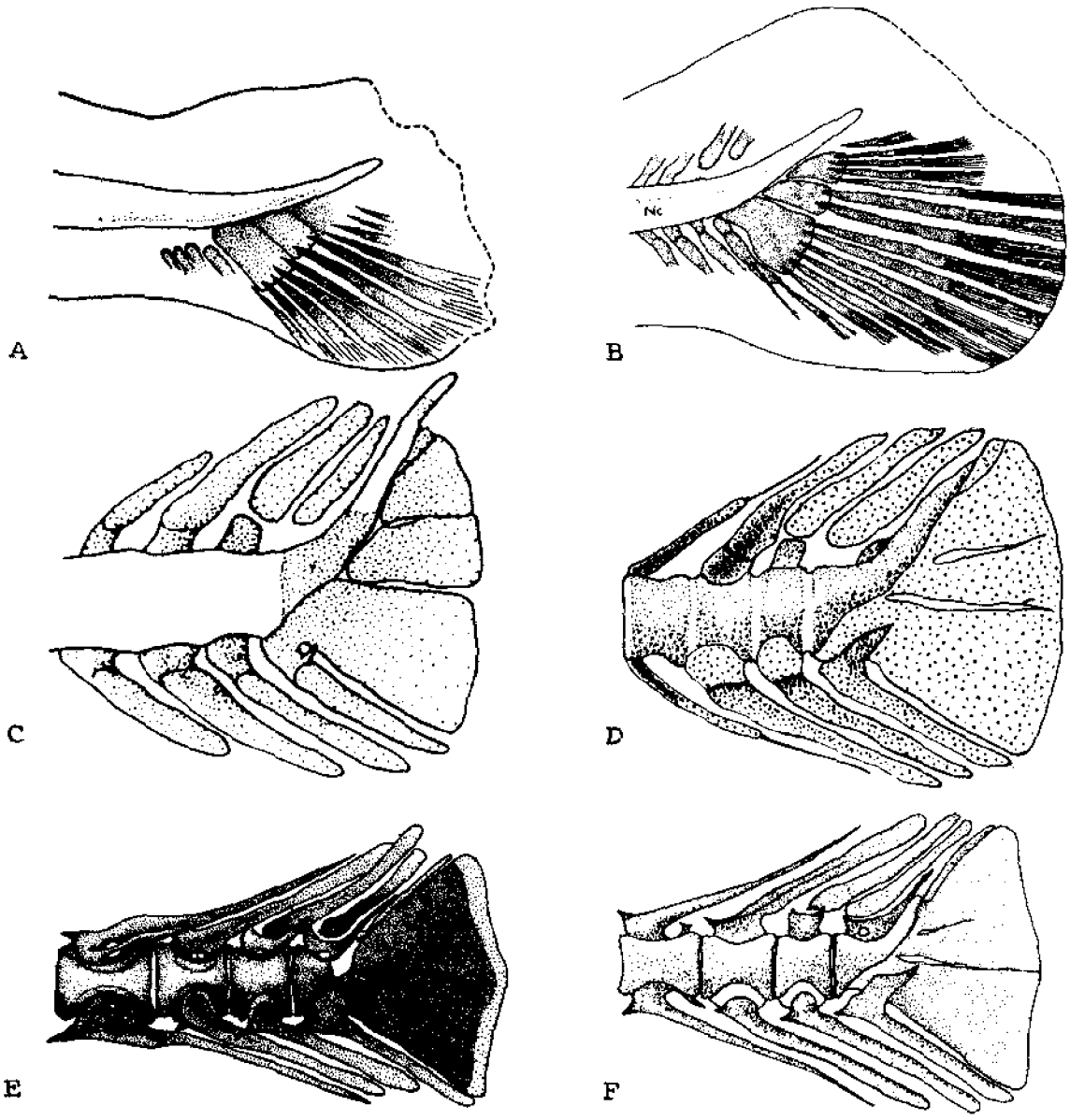

Fig. 91. *Thunnus atlanticus*, Blackfin tuna. A. Caudal complex at 5.1 mm SL. B. Caudal complex at 5.9 mm SL. C. Caudal complex at 7.7 mm SL. D. Caudal complex at 11.0 mm SL. E. Caudal complex at 17.6 mm SL. F. Caudal complex at 34.2 mm SL. (*A-F, Potthoff, T., 1975: figs. 1, 3, 5, 7, 9, 11.*)

large chromatophores present on operculum; posterior margin of orbit, and tips of lower jaw and snout pigmented; portion of snout between anterior nares marked by scattered chromatophores; base of caudal fin marked by some chromatophores, these more concentrated in upper half.[12]

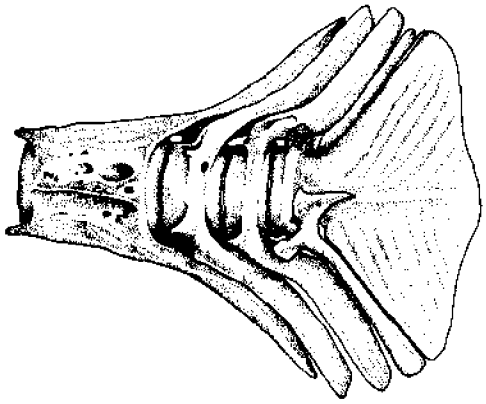

Fig. 92. *Thunnus atlanticus*, Blackfin tuna. A. Caudal complex at 504 mm SL. (A, *Potthoff, T., 1975: fig. 13.*)

GROWTH

About 1–1.5 cm/month.[5]

AGE AND SIZE AT MATURITY

Females reported to mature at 50.5–52 cm FL and 2 years, males at 48.3–50.8 cm FL and 2 years.[3]

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Thunnus obesus (Lowe), Bigeye tuna

ADULTS

D. XIII [12] to XV [12] (usually XIV, RAF), 13 [8]–15 + 8–9; [12] A. 13 [8,12]–14 + 8–9; [12] C. 9 + 8 (RAF); lateral line scales about 190; [8] vertebrae 18 + 21 = 39; [14,24] gill rakers 7 [12]–10 [8] + 18 [8,12]–20 [12] = 25 [11]–28.[12]

Proportions as percent FL (128–188 cm specimens): Head 24–29; depth 25–28, eye 3.5–4.6, maxillary 10–11, pectoral fin 20–27, height first dorsal fin 11–13, height second dorsal fin 13–16, height anal fin 13–16, snout to first dorsal fin 26–31, snout to second dorsal fin 52–54, snout to pelvic fin 29–33, snout to anal fin 60–62.[12]

Body very broad, caudal portion short, dorsal outline much curved, ventral outline much more curved; [8,12] head conic,[16] large; eyes large,[8,12,16] mouth large, lower jaw little protruded; maxillary reaching opposite eye.[16] Scales large in corselet. Lateral line with gentle wave-like elevation above pectorals. Pectoral fins long, gradually pointed towards distal end; second dorsal and anal fins little higher than first dorsal, narrow and falciform; posterior margin of first dorsal fin with convex outline; [8,30] caudal fin widely forked; [8,12,16] two infra-central grooves per centrum.[14] Liver divided into 3 subequal lobes, ventral surface striated.[11,24]

Pigmentation: Dorsal surface metallic dark blue [25] to nearly black; sides silvery [8] to yellowish purple; [15] iris silvery with bluish tint; [8] dorsal fins grayish tinged with yellow, dorsal finlets yellow [8,15] tinged with black; [15] pectoral fins black on dorsal side, gray on ventral side, tip sometimes washed yellow; anal fin white with yellow tip, anal finlet grayish with yellowish margin.[8]

Maximum size: To 239 cm.[8]

DISTRIBUTION AND ECOLOGY

Range: Worldwide in tropical and subtropical seas; to 42° N in eastern North Pacific, 22° S in eastern South Pacific, 35° S in western South Pacific and Indian Ocean; [1] in Atlantic Ocean from 42° 18′ N, 64° 02′ W south along coast of United States to Florida, Bermuda, the Caribbean Sea around West Indies, south to Margarita Island, Venezuela; Brazil Current of South America; eastern Atlantic from Portugal, Spain, the Azores and Madeira south to Angola, absent from Mediterranean, and continuous around tip of South Africa.[24]

Area distribution: Common near Ocean City, Maryland during July–September.[17]

Habitat and movements: Adults—typically deep swimming beyond edges of continental shelves [20] at or near thermocline; [10] in Atlantic Ocean small-sized fish at low latitudes, medium-sized disperse to higher latitudes, and, finally, large-sized converge again to equatorial waters; [27] 13.9 [20]–22 C; 20 [2]–183 m.[20]

Larvae—found at latitudes north of 10° S in Indian Ocean; [10] 35.34 ppt in Gulf of Guinea; over 26 C.[28]

Juveniles—individuals less than 100 cm feed in compact schools at surface, in vicinity of land masses; [12] in subtropical gyre in Indian Ocean.[10]

SPAWNING

Location: No verified record in western Atlantic (WJR). From 6° N to 10° S in Indian Ocean and 10° S to 12° N in Pacific Ocean.[12]

Season: From late winter–early spring in eastern Pacific,[15] all year in Indian Ocean,[12] October–February in vicinity of Indonesia and off of east coast of Australia; [7] larvae available over a broad time period in the Gulf of Guinea.[3,4]

Fecundity: Female of 39 kg produced 2.9 million eggs and one of 109 kg produced 4.1 million eggs.[9]

EGGS

Unfertilized eggs: 1.00–1.38 mm in diameter; oil globule yellow, 0.24–0.27 mm in diameter.[9]

Fertilized eggs: Buoyant; spherical; 1.03–1.08 mm in diameter; egg membrane and yolk clear and unsculptured; oil droplet single, 0.23–0.24 mm in diameter.[23]

EGG DEVELOPMENT

At 30 minutes after fertilization, blastodermal cap and perivitelline space already formed; first cleavage 40 mm after fertilization. At intervals of 15 min., 2nd, 3rd, 4th, and 5th cleavages occurred and eggs reached morula stage 2 1/2 hours later. Embryonic shield developed by 6 hours after fertilization and embryo well differentiated after 8 hours. After 14 hours optic vesicles well defined, somites clearly visible and embryo less transparent. After 19 hours, pupils of eyes developed and tail separated from yolk sac; embryo slightly yellowish-brown and capable of movement. Hatching in 21 hours at 28.1–29.4 C and complete in 30 min.[28]

YOLK-SAC LARVAE

Hatching at 1.5 mm.

Oil globule situated in posterior part of yolk sac.[28]

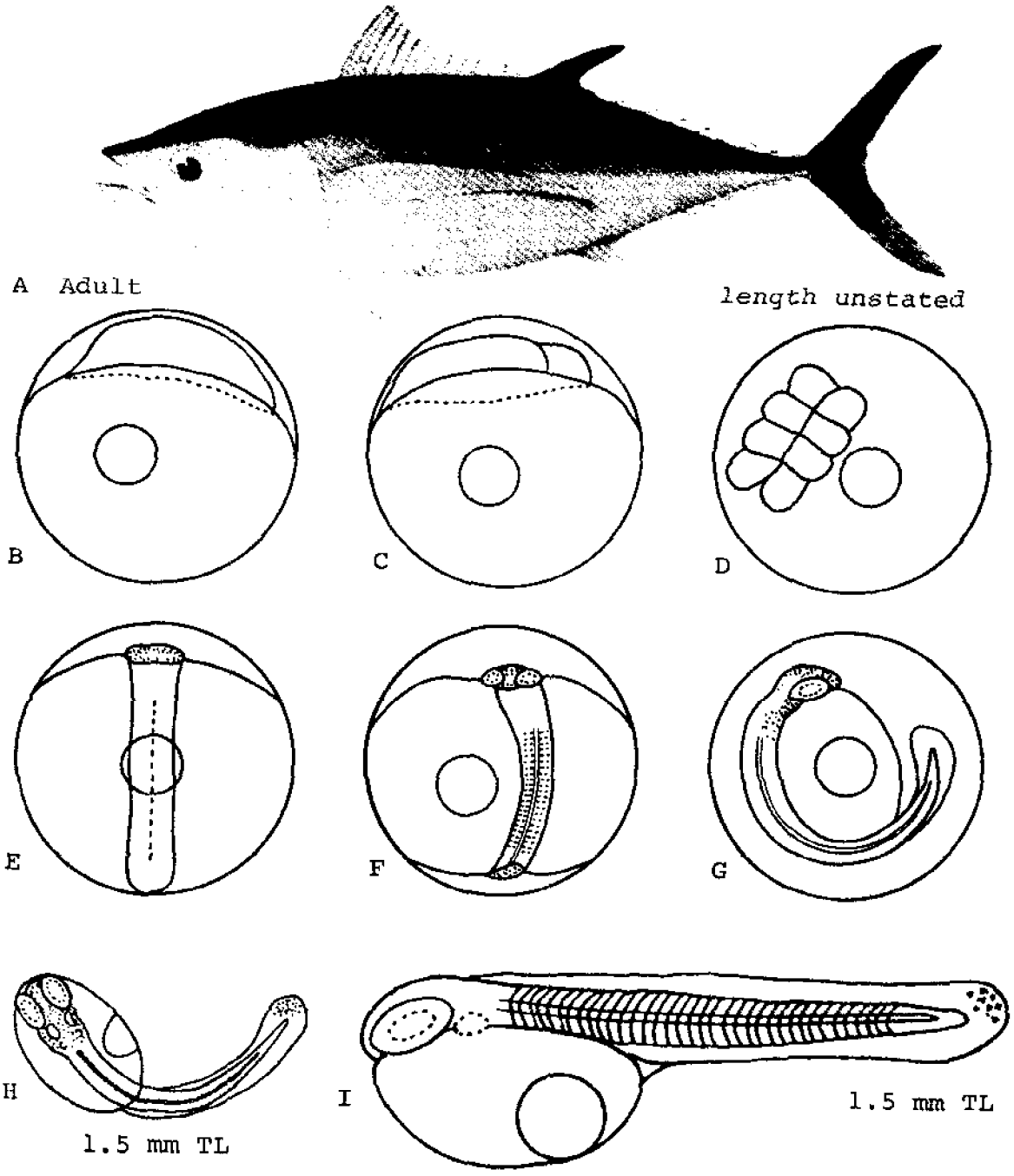

Fig. 98. *Thunnus obesus*, Bigeye tuna. A. Adult, length unstated. B. Egg, 30 minutes after fertilization. C. Egg, 40 minutes after fertilization. D. Egg, 70 minutes after fertilization. E. Egg, 6 hours after fertilization. F. Egg, 14 hours after fertilization. G. Egg. H. Newly hatched larva, 1.5 mm TL. I. Newly hatched larva, 1.5 mm TL. (*A, Kishinouye, K., 1923. B-I, Kume, S., 1962: fig. 3 A-C, F-J.*)

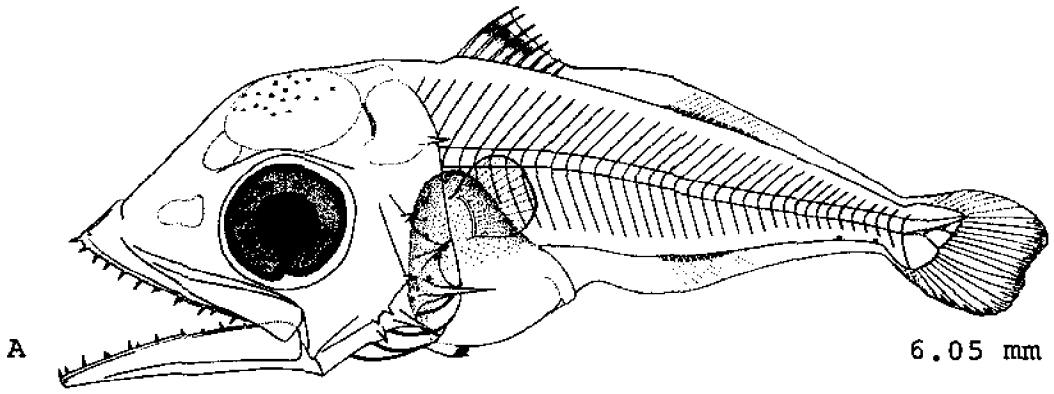

Fig. 94. *Thunnus obesus*, Bigeye tuna. A. Larva, 6.05 mm. (*A, Matsumoto, W. M., 1962: fig. 2.*)

LARVAE

Specimens described 4.3–8.1 mm.[22]

D. VIII at 6.05 mm; total myomeres 40 at 6.05 mm; [6] preopercular spines 7 at 5.8 mm,[5] 6 at 6.0–6.5 mm.[22]

At 5.8 mm, head 32.7%, snout 12.0%, eye 12.0%, depth 27.8%, and maxillary 17.2% of body length.[22]
Body slender; 9 teeth on both upper and lower jaws at 5.8 mm; [5] *rays forming in all fins at 6.0–6.5 mm;* [22] *origin* of second dorsal fin at 16th myomere; [6] urostyle slightly curved at 5.8 mm.[25,26]

Pigmentation: Few spots on tip of upper jaw at 5 mm SL; 0–2 black pigment spots on inner edge of lower jaw below 4 mm SL.[25,26] At 5.8 mm, lower margin of tail region bearing 1 melanophore.[5] At 6.05 mm, no pigment over forebrain, at cleithral symphysis or along dorsal margin of trunk exclusive of caudal fin; pigmentation of first dorsal fin appears quite early; pigment along ventral edge of trunk (along base of posterior half of dorsal fin) [25] consisting of 1–4 chromatophores; [6] pigment absent on bases of anterior dorsal finlets.[25,26] *Red chromatophores* (0.01–0.04 mm) on sides of body, lower side of lower jaw, and margin of hypural plate [19] consisting of 0–2 on dorsal edge of trunk, 0–4 along lateral line; 1–8 ($\bar{x}$=5.3) on ventral edge of trunk, and 1 on each side near tip of lower jaw.[25,26]

JUVENILES

Specimens described 143–173 mm SL, probable range 13–200 mm SL.[25]

D. XIII–XIV + 8 finlets; A. 8 finlets; [21] array of second dorsal fin pterygiophores between two adjacent neural spines 1, 2, 2, 2, 3, 2, 1, 1 at 10 mm SL; vertebrae 18 + 21 at 13 mm SL.[25]

Teeth as series of denticles on upper and lower jaws, villiform on vomer and palatine. Pectoral fin long, *reaching 17th vertebra.*[25]

Liver with 3 lobes, middle lobe longest, striations not yet developed.[21] First haemal arch on vertebra 11; first prezygapophyses on vertebra 15 or 16, placed low; postzygapophyses near first prezygapophysis short, directed posterior.[25]

Pigmentation: Sides grayish with transverse rows of colorless lines and dots.[12]

GROWTH

Reaching 45–50 cm at 1 year old, 70 cm in 2 years, 94 cm in 3 years, 116 cm in 4 years, 138 cm in 5 years, and 155 cm in 6 years.[9]

AGE AND SIZE AT MATURITY

Maturing at about 3 years [9] and 90–100 cm.[9,18]

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Thunnus thynnus (Linnaeus), Bluefin tuna

ADULTS

D. XII to XIV (usually XIV), 13–15 + 8–10; A. 13–16 + 7–9;[7] C. 15 + 9 + 8 + 13;[37] P. 30–36;[7] V. I, 5;[36] vertebrae 18 + 21 = 39;[7,37] gill rakers slender, 9–16 + 22–28[12,33] = 34–43;[7,30] teeth simple, conical, small, uniserial in jaws and minute on vomer and palatines;[12,33] infracentral grooves 2 per vertebral centrum.[29]

Head 3.25–4, depth 3.75–4.25 in SL. Snout 2.8–3.75, eye 6.8–8.25, maxillary 2.6–2.75, interorbital 3–3.8 in HL.[33] Pectoral fin less than 80% HL.[8]

Body fusiform, compressed, and especially robust in front;[12,32,33] caudal peduncle greatly depressed, slender, with keel on each side; head large, broadly convex above, well compressed; snout conic, slightly wider or not as wide as long; mouth curved slightly, large; jaws about even; maxillary reaches opposite pupil. Scales minute, covering entire body, also on soft dorsal and anal fins and pectoral and caudal fin bases; corselet of larger scales in pectoral region. Lateral line, composed of minute scales, slopes rather irregularly down to caudal peduncle. Spinous dorsal fin inserted midway between snout tip and soft dorsal fin origin or about opposite pectoral region or little before, interspace between dorsal fins very short; soft dorsal fin inserted nearer spinous dorsal origin than caudal fin base; anal fin inserted just behind base of soft dorsal; finlets alike, first increase, then decrease in size behind; caudal fin deeply lunate, with evenly pointed lobes; pectoral fins moderate, pointed, inserted about level with eye; pelvic fins inserted opposite pectoral origin. Interorbital wide, convex.[12,33] First long haemal spine on 19th vertebra; anteriormost ventrally directed parapophysis occurring on 8th vertebra; first closed haemal arch on 10th vertebra; first haemal prezygapophyses on vertebra 12–17. Liver with striations on ventral surface, all three lobes subequal in length.[7]

Pigmentation: Dark blue or black dorsally and silvery gray with colorless transverse lines and rows of colorless dots in alternation ventrally; first dorsal fin obscure yellow; second dorsal and anal fins grayish yellow;[32] finlets yellow edged with black;[28,32] caudal keel black in individuals from Atlantic Ocean.[32]

Maximum size: To 458 cm[33] and 684 kg.[19]

DISTRIBUTION AND ECOLOGY

Range: Western Atlantic from Hamilton Inlet, Labrador, and Newfoundland, south along Atlantic coast of United States into Gulf of Mexico and the Caribbean and from Venezuela south to northeastern Brazil; eastern Atlantic from Lofoten Islands off Norway south along coast of Europe and North Africa to Canary Islands; eastern North Pacific from Shelikof Straits in Gulf of Alaska, off Vancouver Island, off Villapa Bay and mouth of Columbia River, regularly off southern California and Baja California; western North Pacific from island of Sakhalin in southern Okhotsk Sea southward on both sides of Japan, to northern Philippines; eastward from Japan between about 30°–40° N to about 160° W; and eastward between about 5°–10° N from about 135°–175° E. Taken occasionally in Hawaiian waters.[7]

Area distribution: Recorded from coast of Maryland,[40] and off Atlantic, Cape May, and Ocean counties, New Jersey.[41]

Habitat and movements: Adults—generally regarded as a temperate zone form;[16] school segregated by size;[12] largely restricted to Gulf Stream and immediate area in western Atlantic.[4] Some evidence of transatlantic migration;[26] congregate on continental shelf July–October between Cape Hatteras and Newfoundland, usually eastern Long Island to New England, during late fall movement to wintering areas, usually along about 1800 m line off New England, Long Island and New Jersey[35] with temperatures between 15–20 C; segregation by size distinct during winter, smaller individuals rarely found south of 36° N in offshore waters or south of Cape Hatteras along coast; occur in North Sea from July–November, reaching middle parts of North Sea three or four weeks after arrival on Norwegian coast;[12] move away from northern Mediterranean during reproductive period;[4] in Japan all schools irrespective of size of fish migrate northward through littoral waters in summer and southward from autumn to winter.[17] Recorded from salinities between 18 ppt[26]–39.34 ppt,[10] temperatures from 5–28 C (prefer temperatures above 26 C[9]), and depths from the surface to 183 m (winter).[35]

Larvae—widely distributed in surface layer; drift north in Kuroshio Current.[34] Recorded from salinities between 36.4 ppt–38.8 ppt in tropical Atlantic[9] and temperatures from 25[36]–over 27 C,[9] none below 24 C.[36]

Juveniles—school,[17,26] sometimes mixed with other species;[32] do not venture below thermocline if gradient 7–10 C.[10] Enter Atlantic from Mediterranean via deep current;[4] tend to concentrate in northwestern Atlantic coastal waters during first year of life; small individuals arrive in northeastern Atlantic feeding areas from mid-June to early July (Chesapeake Capes to Cape Cod) and spend winter above 36° N in offshore waters.[35] Restricted to surface layer warmer than 16–17 C,[36] often in 23–25 C above thermocline.[10]

SPAWNING

Location: Occurs in subsurface waters[19] from 8–10 m;[42]

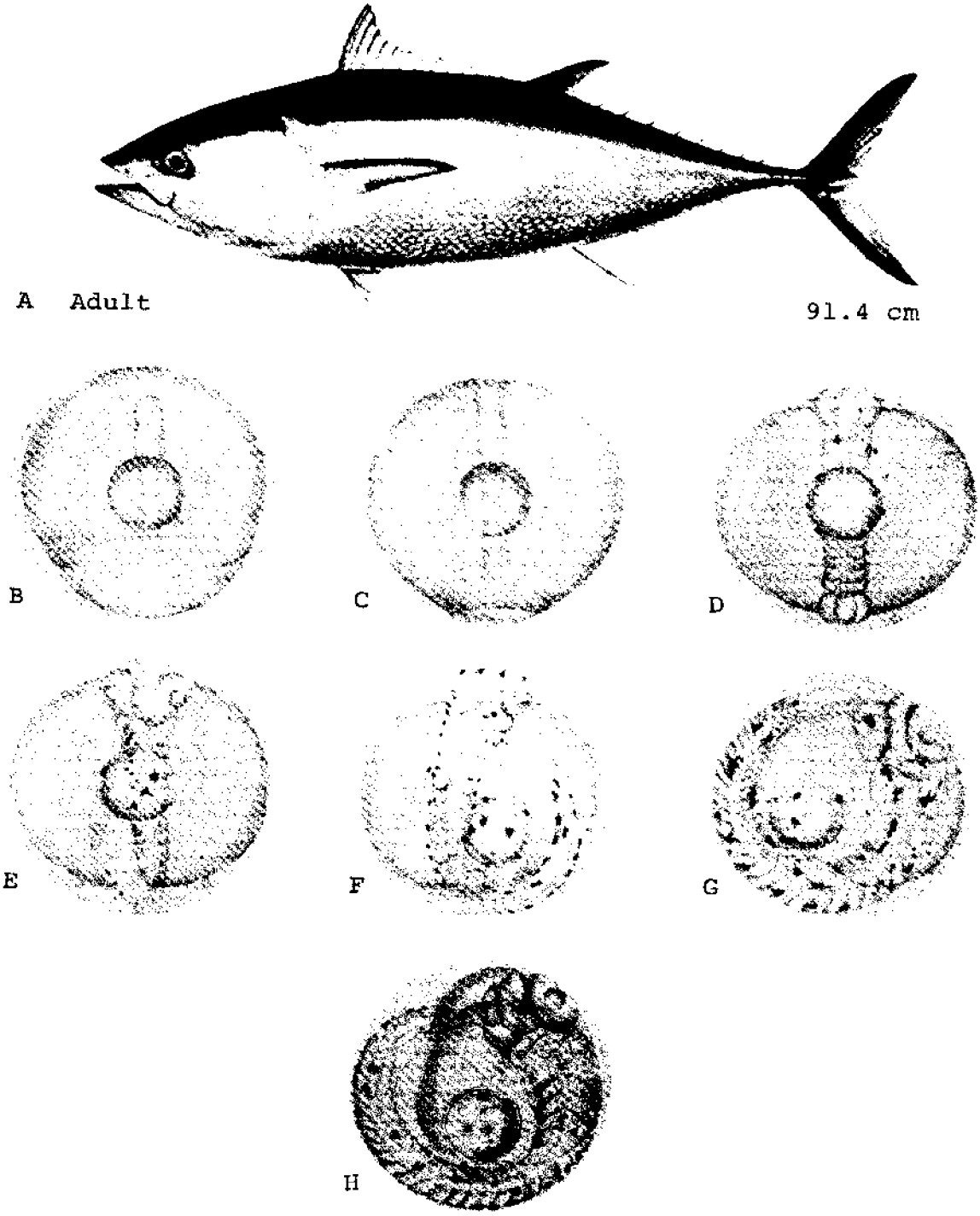

Fig. 95. *Thunnus thynnus*, Bluefin tuna. A. Adult, 91.4 cm. B. Egg, 1.04 mm diameter. C. Same egg, 1 1/2 hours later. D. Same egg, 6 1/2 hours after C. E. Same egg, 5 1/2 hours after D. F. Same egg, 10 1/2 hours after E. G. Same egg, 4 hours after F. H. Same egg, 7 hours after G. (*A, Walford, L. A., 1937: pl. 34. B-H, Sanzo, L., 1932b: figs. 1–7.*)

principal areas near Luzon Island and towards Ryukyu Islands; [17] below 40° N in northwestern Atlantic; [18] the western Mediterranean; [4] and area between eastern Sea of Formosa and Japan Current.[22]

Season: April–May in Dry Tortugas; [1] April–May not far south of Bimini and Cat Cay; [12] spring–summer to fall in Florida region; [18] May–early June in Straits of Florida; [24] May–June south of Japan; [25,36] end of July–beginning of August near Sevastopol; [21] late May–July in Straits of Messina; [3] late July–early September in Turkish waters.[14]

Temperatures: 19–21.6 C ($\bar{x}$=20 C) in central Mediterranean, 24.9–29.5 C in Straits of Florida.[12]

Fecundity: Females of 270–300 kg contain about 10 million eggs.[17]

EGGS

Ovarian eggs: Spherical; transparent; [3,24] *0.7* [24]*–1.12 mm* diameter; single oil globule at vegetative pole, ca. 0.27 mm diameter; chorion with distinct reticulations; micropyle in cavity; yolk completely fills capsule.[3]

Fertilized eggs: Buoyant; [18] spherical; [17,18] nearly colorless and transparent; [17] 0.6 [15]–1.12 [3,11,38] mm diameter, usually 0.94 [18,22]–1.1 [21,22] mm diameter; egg membrane thin,[22] reticulations distinct; [3] yolk homogeneous [3] or somewhat granular; [21] oil globule 0.18–0.32 mm diameter,[24] usually 0.23 [38] or 0.25 [3,23]–0.28 [3,38] mm diameter, somewhat yellowish; [17] perivitelline space small to absent.[3]

EGG DEVELOPMENT

Eggs collected at 0900, blastoderm three-fourths way around meridian. Embryo evident at about blastopore closure.[3] Segmentation of yolk commences at time of embryonic shield formation.[23] At 17 hours after capture, embryo almost completely around meridian; secondary otic vesicles present; chromatophores on oil globule and along trunk; egg less transparent. At 22–30 hours after capture, tail reaches around and overlaps oil globule; heart in embryonic position and beating; sparse scattering of melanophores along trunk and small yellow chromatophores on abdomen, some melanophores in cephalic region. At 0900 of second day, tail reaches almost to head; otic vesicles clearly evident. At 1300 of second day tail reaches head; melanin scattered thinly over yolk and oil droplet; heart beats regularly; myomeres more than 30. At end of second day, egg almost ready to hatch; embryo with 39 myomeres.[3]

YOLK-SAC LARVAE

Size at hatching 2 [22]–3 [3,21] mm and yolk sac absorbed at 3.7 [15]–4 [22] mm.

Myomeres, 39 at hatching, 10 preanal and 29 postanal. Preanal length 47% TL at hatching. Head flexed over yolk at hatching; yolk sac oval at hatching,[3] absorbed in 4 [15,21]–6 days; [3] oil globule in posterior part of yolk sac; [3,27] mouth not open at hatching, open at 3.8 mm; Meckel's cartilage present on second day; dentary formed by third day; eye unpigmented at hatching, becoming pigmented at 3.8 mm; dorsal finfold originates in cephalic region, ventral finfold reaches anus; anus begins to move forward at 3.8 mm.[3]

Pigmentation: At hatching, large pigment spots on head and along dorsal part of trunk and tail partially encroaching on finfold; yellow spots along dorsal finfold from its origin to level of anus; [3] ventral margin of caudal section of body with melanophores; [21] oil globule, yolk sac,[3,21] and head anterior to eyes pigmented.[3]

At 3.8 mm (yolk sac absorption), yellow pigment along dorsal finfold reduced; melanophores along ventral edge of caudal trunk persist [3,21] as do singular spots in dorsal portion of body; [21] melanophores on angle of intestine; [3] eyes blue-black.[21]

LARVAE

Specimens described 3.8–18 mm TL.

D. V or VI at 5–6 mm TL; VII at 6–7 mm TL; XIII, 22 (last 8 as separate fin) at 10 mm TL; [36] XIV or XV at 10+ mm TL.[38] A. 22 (last 8 as separate fin) at 10 mm TL.[36] First lateral line scale formed by 16–18 mm SL, more scales added posteriorly by 60 mm SL but not countable because of fusion, fourth scale at right angle to first three; [6] total myomeres 39 [3,36]–41; [36] vertebrae 18+21=39, occasionally 19+20; [38] gill rakers first develop at 21 mm SL, and first appear on hypobranchial at 28 mm SL; [6] pterygiophores of second dorsal fin between two adjacent neural spines 1, 2, 2, 3, 2, 2, 1, 1 at 10+ mm TL; [5,6,38] first haemal arch on 10th vertebra at 10+ mm TL; [38] preopercular spines 2+3 at 3.8 mm TL [36] becoming more evident at 4–5 mm TL, 5–6 at 4.7 mm, 7–8 at 7–9 mm,[22] 3+9 by 18.1 mm TL; teeth recurved, small, 7–8 on each jaw at 4–5 mm, 10–14 at 6–7 mm TL.[36]

Head begins enlarging at 4–5 mm; [36] otoliths well-developed 6 days after hatching.[3] First dorsal fin spines at 6.8 mm,[22] all spines present by 8 mm SL; [6] second dorsal fin base by 6–7 mm, rays forming by 7–8 mm,[36] all rays and finlets formed by 11–13 mm SL; anal fin rays and finlets formed by 11–12 mm SL; [6] caudal fin rays forming at center of fin by 5–6 mm TL,[36] some with adult count by 15 mm SL; [6] pectoral fins rounded, or fan shaped,[3] rays forming by 8 mm SL, all rays formed by 25–29 mm SL; [6] pelvic fin base formed by 5–6 mm TL, rays beginning to form at 7–8 mm TL,[36] all rays formed by 8 mm SL.[6] Notochord flexion by 5–6 mm TL; urostyle formation at 4–5 mm. Anus opens forward of

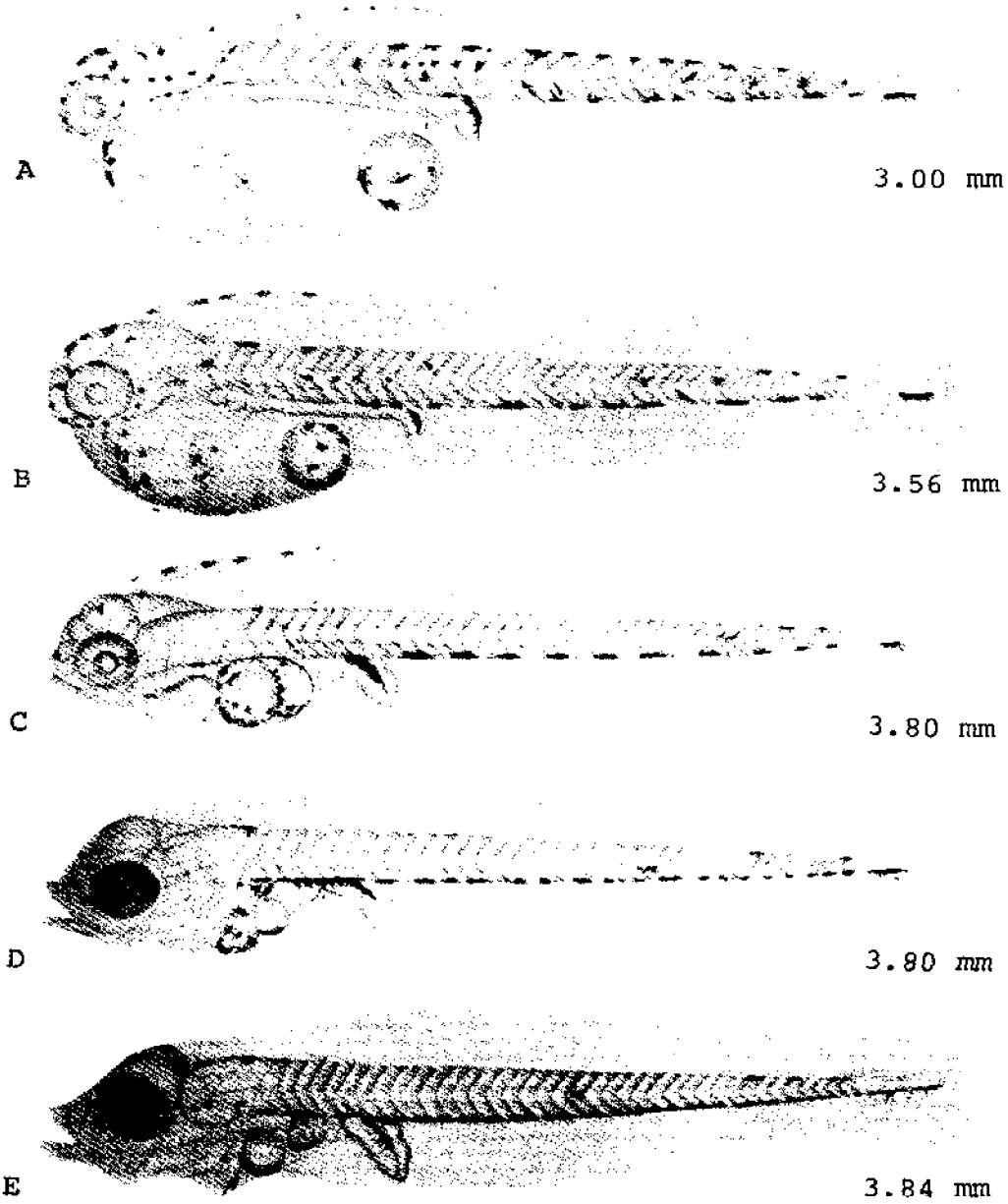

Fig. 96. *Thunnus thynnus*, Bluefin tuna. A. Yolk-sac larva, 3.00 mm. B. Yolk-sac larva, 3.56 mm. C. Larva, at end of first day of culture, 3.80 mm. D. Larva, second day of culture, 3.80 mm. E. Larva, third day of culture, 3.84 mm. (*A-E, Sanzo, L., 1932b: figs. 8–12.*)

mid-body at 3.8 mm TL, more than halfway back at 7–8 mm TL, well back by 13–14 mm TL.[36]

Pigmentation: At 3–10 mm SL, 2 black pigment cells on inner edge of lower jaw tip; 0–2 near mid-trunk (Atlantic Ocean), 1 or 2 on dorsal edge of trunk, 1–4 on ventral edge of trunk; red pigment cells consisting of streak on caudal peduncle (Atlantic) or 1–5 spots (Pacific); lateral line spots indistinct; ventral edge of trunk with streak from anus to caudal peduncle; some pigment on dorsal edge of trunk; a pigment streak along margin of anterior half and midline of lower jaw (Atlantic) or 2 well spaced spots on anterior half of jaw (Pacific).[5] Specifically at 3.8 mm TL, black pigmentation scattered over top and back of head, and inside of peritoneum; 2 distinct pigment cells (near 30th myomere) on dorsal and ventral

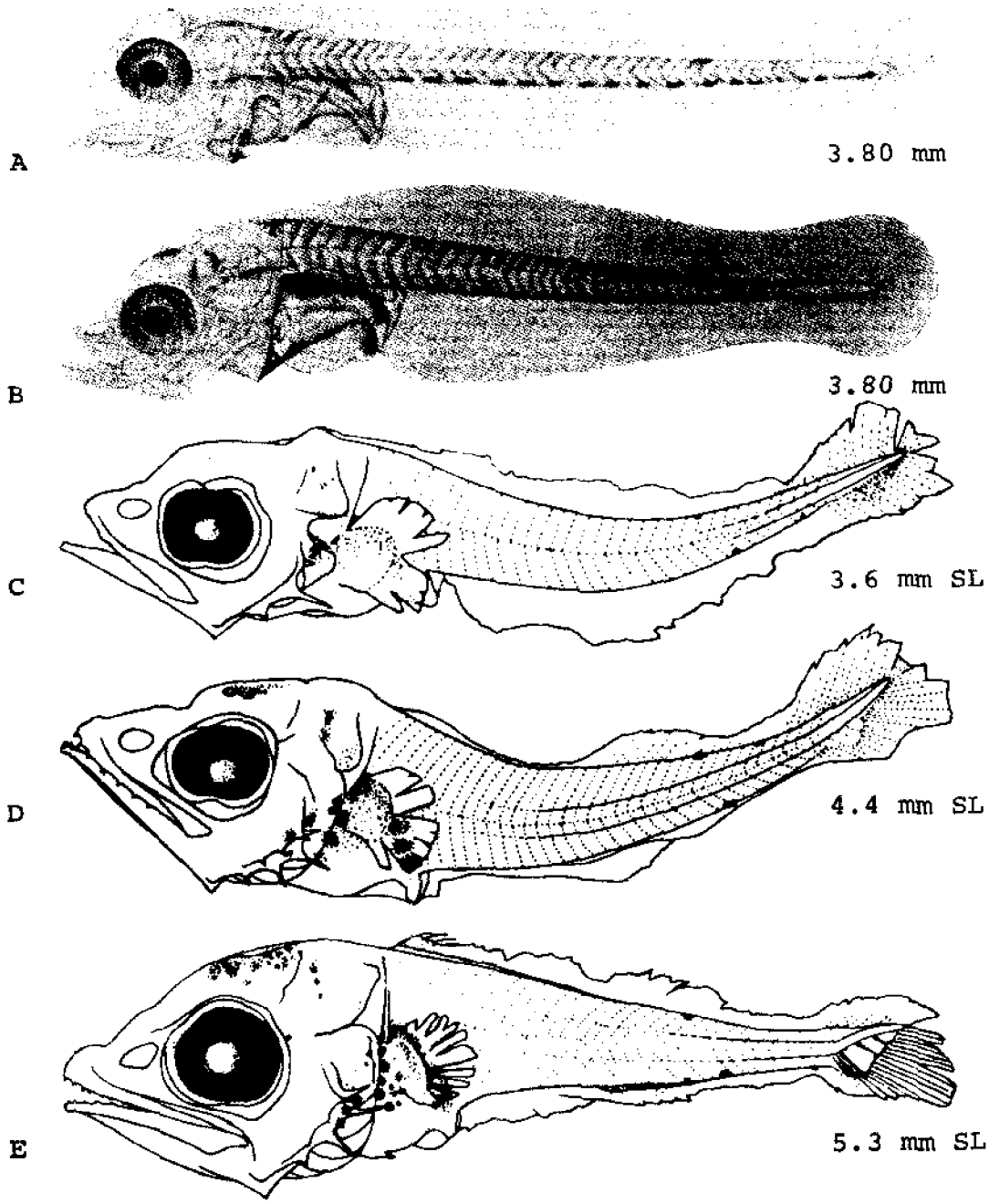

Fig. 97. *Thunnus thynnus*, Bluefin tuna. A. Larva, fourth to fifth day of culture, 3.80 mm. B. Larva, fifth to sixth day of culture, 3.80 mm. C. Larva, 3.6 mm SL. D. Larva, 4.4 mm SL. E. Larva, 5.3 mm SL. (*A-B, Sanzo, L., 1932b: figs. 13–14. Yabe, H.,* et al., *1966: figs. 1–3.*)

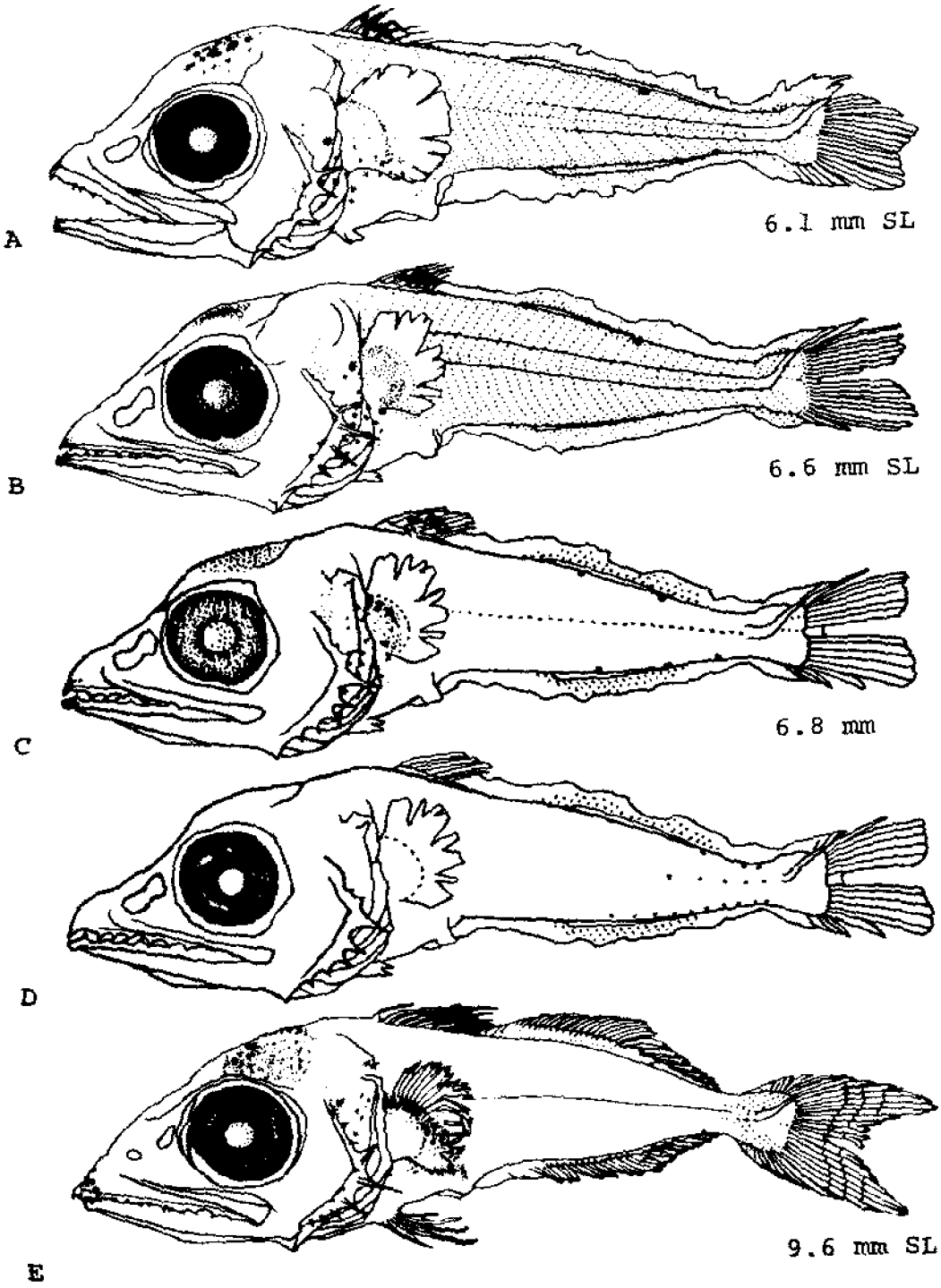

Fig. 98. *Thunnus thynnus*, Bluefin tuna. A. Larva, 6.1 mm SL. B. Larva, 6.6 mm SL. C. Larva, 6.8 mm. D. Larva, showing pattern of red pigment. E. Larva, 9.6 mm SL. (*A-B, E, Yabe, H., et al., 1966: figs. 4–6. C, Ueyanagi, S., and H. Watanabe, 1962: fig. 7. D, Ueyanagi, S., 1966a: fig. 2b.*)

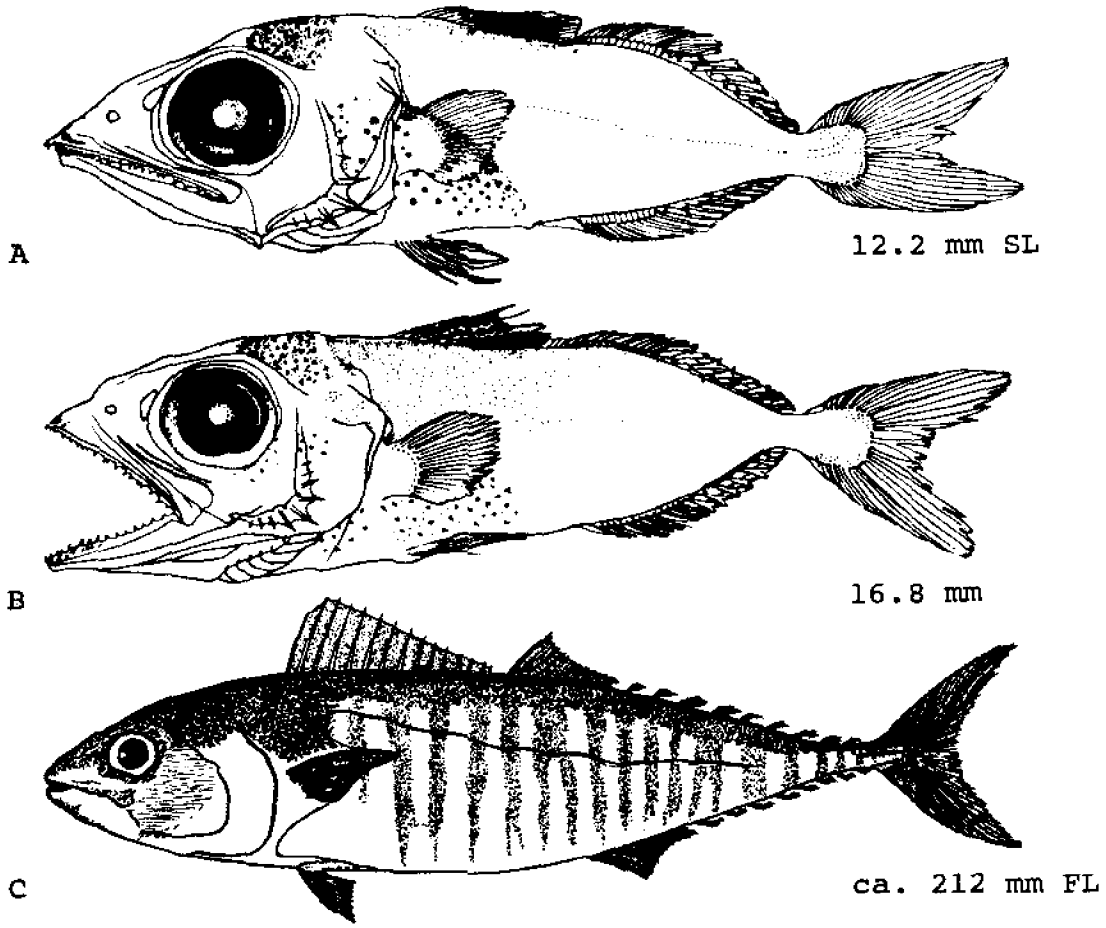

Fig. 99. *Thunnus thynnus*, Bluefin tuna. A. Larva, 12.2 mm SL. B. Larva, 16.8 mm. C. Juvenile, ca. 212 mm FL. (*A-B, Yabe, H., et al., 1966: figs. 7–8. C, Dieuzeide, R., and J. Roland, 1955: fig. 3.*)

midlines near tail; and one or more small pigment cells behind one on ventral line. At 4–5 mm TL, black pigment appears on mandibular tip. At 6–7 mm TL, black pigmentation appears on first dorsal fin membrane and on tip of upper jaw. At 7–8 mm TL, pigment on first dorsal fin membrane more dense and pigment cells widely distributed on back of head and opercle. At 10 mm TL, traces of pigment on forebrain; black pigment cells on ventral and dorsal part of tail small compared to size of body. At 13–14 mm TL, pigment cells on caudal indistinct and some pigment present on back side of head. At 18 mm TL, pigment confined to first dorsal fin.[36]

JUVENILES

Specimens described 24[6]–115 mm SL.[1]

D. XIII[1,6] to XVI (usually XIV), 22–24 (usually 23),[6] including 8 finlets;[1] A. 21–24 (usually 22),[6] including 7 finlets;[1] C. 49–51, rarely 52;[6] P. modally 32; V. I, 5;[27] usually 18+21=39,[1,5,6] rarely 16+22, 18+20, 17+22, 19+20, 18+22, or 19+21;[6] branchiostegals 7 at 39 cm;[27] gill rakers on ceratobranchial 17–20 at 23[6]–40[5] mm SL, full complement on ceratobranchial and 7–9 on hypobranchial at 45 mm SL, 12–13 on epibranchial at 79 mm SL and full complement at over 90 mm SL.[6] First prezygapophysis on vertebra 15–17, placed high; postzygapophysis near first prezygapophysis short, directed posteriorly; first haemal spine wing-like at some stages over 30 mm SL.[5,6] Corselet forms by 17 cm. Teeth small, recurved on jaws and small on palatines and vomer at 37 cm. Eye large and round.[27] Lateral line above base of pectoral fin forming acute angle of nearly 90° at 25 mm SL.[5] Origin of first dorsal fin over upper end of pectoral fin base; caudal keel not formed at 34 mm, two ridges at 68 mm and well formed by 17 cm.[27]

Pigmentation: Blackish or gray dorsally, silver below; first dorsal fin and finlets without pigment; second dorsal fin not pigmented up to 44 mm, some pigment along first

ray at 65 mm, extending to posterior rays in larger specimens and becoming more yellowish; finlet pigmentation very late, forming at 90 mm; pectoral fins transparent up to 44 mm, but later becoming entirely black; pelvic fins without pigment before 90 mm;[27] colorless transverse lines and rows of dots in alternation on sides running vertically.[32]

GROWTH

Reaching 46 cm in half year;[13] in Japan, reaching 50 cm FL at age 1, 90 at age 2, 125 at 3, 154 at 4, 178 at 5, 198 at 6, 215 at 7, 229 at 8, and 241 cm FL at age 9;[17] in Mediterranean reaching 60–70 cm in 1 year, 80–90 in 2, 95–105 in 3, 110–125 in 4, 130–140 in 5, 145–155 in 6, 160–170 in 7, 175–185 in 8, 190–200 in 9, and 260–270 in 16 years.[31]

AGE AND SIZE AT MATURITY

During third year of life and at 97.5 cm or 15 kg.[4]

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Istiophorus americanus
Makaira nigricans
Tetrapturus albidus
Tetrapturus pfluegeri

billfishes
Istiophoridae

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FAMILY ISTIOPHORIDAE

This family contains some of the most popular sports fishes, including the marlins, spearfishes, and sailfishes. They are large fishes and are found in most warm seas, however, they are very poorly known taxonomically, probably because of their large size.

The species covered in this account are those recognized by Richards (1974). There is, however, considerable confusion regarding the status of the sailfish, *Istiophorus*. Morrow and Harbo (1969) recognize only one world-wide species, *Istiophorus platypterus*, but Nakamura, *et al.* (1968), recognize a Pacific species, *I. platypterus*, and an Atlantic species, *I. albicans*. This volume follows Nakamura, *et al.* (1968). However, Beardsley, Merrett, and Richards (1975) have pointed out that *I. albicans* is a *nomen nudum*. Therefore, the next available name, *Istiophorus americanus* (Cuvier), has been used for the Atlantic sailfish.

Richards (1974) has pointed out the difficulty in identifying young (particularly less than 5 mm) billfishes, so the reader should be cautioned that some of the information contained in this section may be based on misidentified specimens. Ueyanagi (1974) has provided one of the best accounts on identification of young billfish.

Definitions and methods of measuring and counting billfish follow Rivas (1956b).

Istiophorus americanus (Cuvier), Atlantic sailfish

ADULTS

D. 37 [2,4]–49,[11] 6–8; [2,4,11] *A.* 8–16,[2,4] 6 [2,4,6,11]–8; [11] *C.* 9+8=17; [2] P. 17 [2,6]–21; [11] V. 3; vertebrae 12+12=24.

Body extremely flat, elongated and laterally compressed; snout long and rounded in cross-section. Scales may have single blunt point; with lateral line curving above pectoral fin and continuing straight toward tail. Dorsal fin extremely high, sail-shaped with middle rays longest; pelvic fin rays very long,[2] decidedly longer than those of pectoral fins; [8] caudal fin deeply forked; pectoral fins low on body, relatively long and narrow; second dorsal and anal fins small. Two peduncular scutes present.[2]

Pigmentation: Back dark blue-black; silvery on sides and belly; [8] sides with ten rows of striped crest patterns, consisting of many light blue dots; [2] dorsal fin spotted.[8]

Maximum size: To 3150 mm and 56 kg.[8]

DISTRIBUTION AND ECOLOGY

Range: Both sides of Atlantic Ocean from 30° N to 30° S on western side and 20° N to 10° S in the east; concentrated near land masses.[2]

Area distribution: Recorded from Ocean County, New Jersey,[13] and as abundant from June through October northeast of Ocean City, Maryland.[8]

Habitat and movements: Adults—pelagic (RAF), perform long-range migrations as well as short-term movements which are most likely based on local environmental conditions.[2] Recorded as being present in the Gulf of Mexico and from Jacksonville–Cape Hatteras in warmer months and off southeastern Florida and Cuba and between Straits of Florida and the Virgin Islands in cool season.[14] Congregate at frontal zone of Canaries Current and the equatorial Countercurrent, then migrates during spring along west coast of Africa from south to north. Associated with salinities between 35.3–35.7 ppt [10] and temperatures above 10 C.[3]

Larvae—pelagic, in the Gulf Stream and Gulf of Mexico at salinities of 35.7–36.8 ppt and temperatures of 22–29.3 C.[7]

Juveniles—no information.

SPAWNING

Location: Recorded as occurring not far from shore [3,5] and closely associated with approximate axis of Gulf Stream, at or beyond 180 m line.

Season: Shifts northward, late April to mid-August in Gulf of Mexico,[7] May–June in Florida,[2] after July in Georgia, September in North Carolina.[7]

EGGS

Pelagic; 0.7–1.4 mm diameter.[9]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Specimens described 3.4–20.9 mm.

Body short and deep, myomeres and urostyle prominent at 3.6 mm; elongate and slimmer at 8.0 mm; [8] snout short at 3.6–3.9 mm, elongated slightly at 5.6, much elongated by 11.3 mm; teeth few in number, large, anterior ones tusk-like at 3.6 mm,[7] large teeth in both jaws at 14 mm,[12] palatine teeth appear at 6.4 mm; [7] gape reaching below posterior part of eye; [12] eye large at 3.6 mm becoming proportionately smaller with growth. At 3.6 mm orbital crest anterior to nostril curves under eye, has a large spine over eye, and continues posteriorly as serrated ridge continuous with dorsolateral keel of pterotic spine; pterotic spine has three serrate keels, directed posteriorly, and parallel to sagittal plane of body; main preopercular spine has three serrate keels, directed posteriorly at 45° from sagittal plane; secondary preopercular spine serrated; keel on opercular face serrate, with acute and medially situated protuberance; two serrate keels on lower jaw.[7] At 3.9 mm opercular spines short and subequal. At 6.3 mm opercular spines show greatest development; preopercular spines disappearing; supraocular crest strongly serrate; lower jaw retains serrate ridges. At 8.0 mm secondary preopercular spine gone.[7] At 9.0 mm orbital rim still serrate; parietal spine about half as long as preopercular spine.[12] At 15.0 mm pterotic spine smaller.[3] At 3.6 [7]–3.9 [4] mm finfold continuous. At 4.7 mm some supporting structures in dorsal and anal fins. At 5.6 mm, separation of finfold onto dorsal, anal and caudal fins is distinct but not complete; caudal flexion complete. At 8.1 mm, 42 dorsal rays, 10 anal rays.[7] At 9 mm caudal fin forked, with rays.[12] By 20.9 mm rays extend to edge of fin,[7] dorsal fin sail-like.[8] Pectoral fin round, with indistinct supporting structures at 3.6 mm; elements forming by 5.5 mm; [8] 16 rays at 6.4 mm; 15 rays at 8.1 mm; 18 rays at 11.3 mm. Pelvic fins present

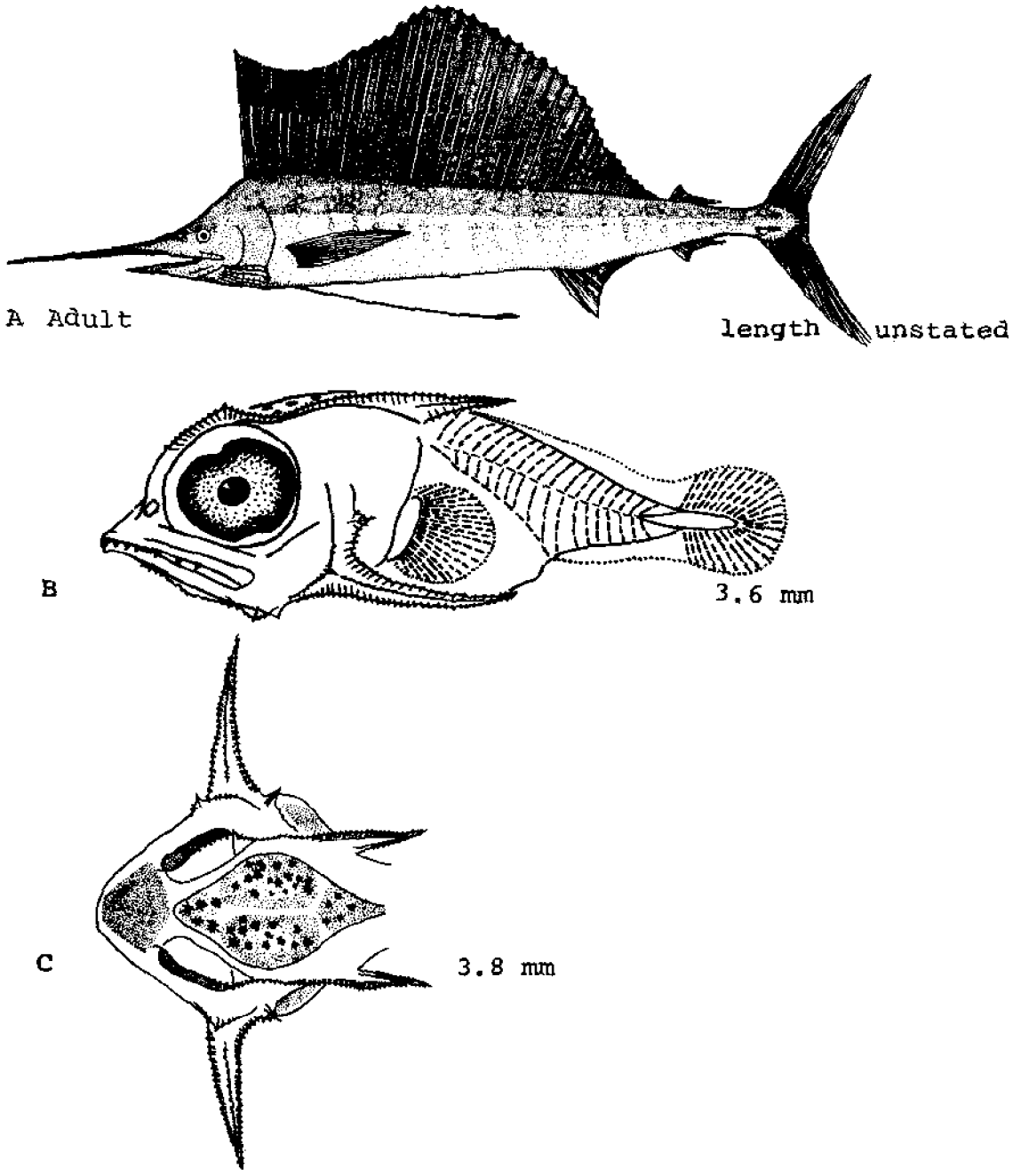

Fig. 100. *Istiophorus americanus*, Atlantic sailfish. A. Adult, length unstated. B. Larva, 3.6 mm long. C. Larva, 3.8 mm, dorsal view of head. (*A, Nakamura, I.*, et al., *1968: fig. 13. B-C, Gehringer, J. W., 1956: figs. 2–3.*)

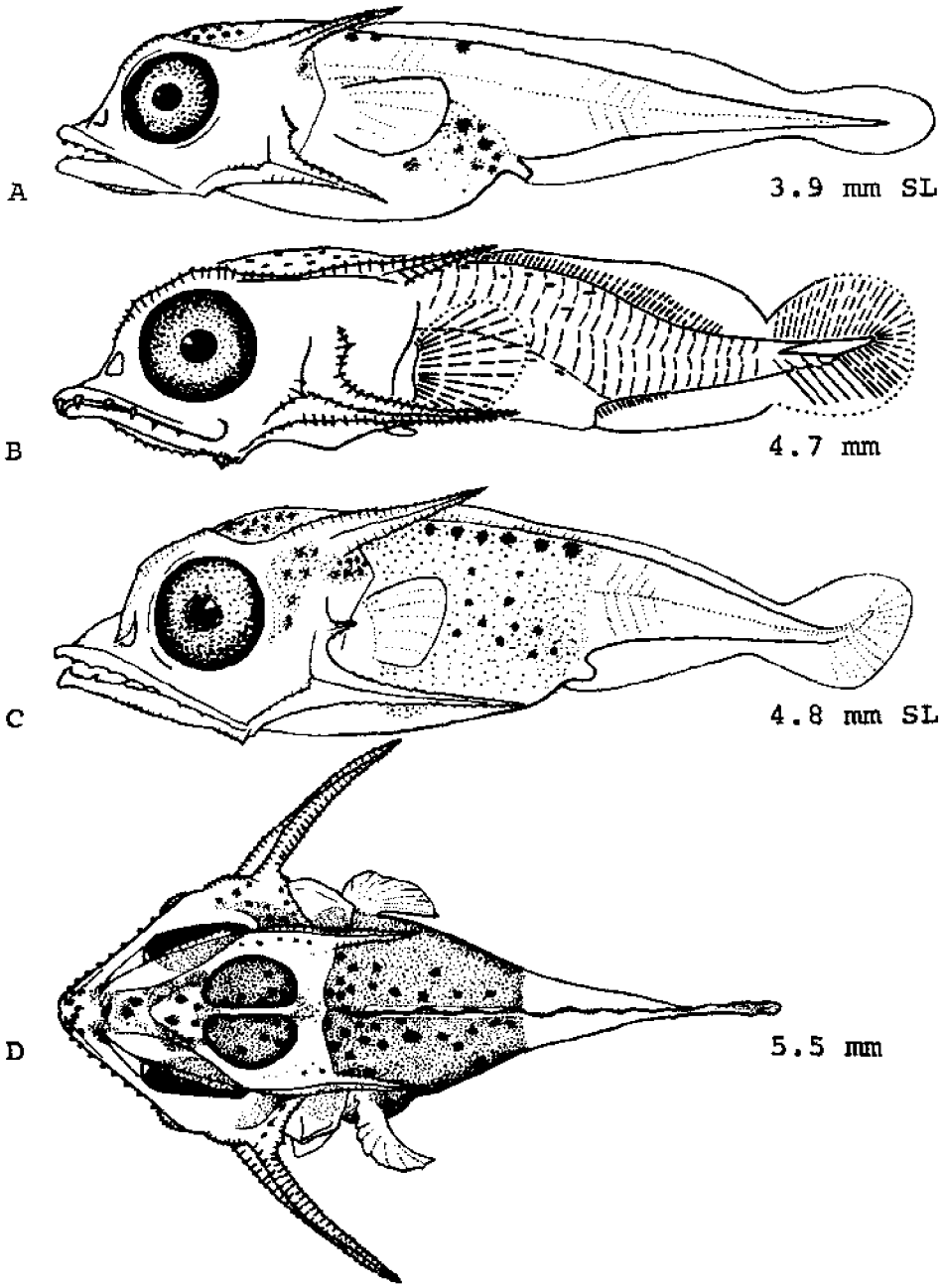

Fig. 101. *Istiophorus americanus*, Atlantic sailfish. A. Larva, 3.9 mm SL. B. Larva, 4.7 mm. C. Larva, 4.8 mm SL. D. Larva, 5.5 mm SL, dorsal view of head. (*A, C-D, Voss, G. L., 1953: figs. 1A-B, 2. B, Gehringer, J. W., 1956: fig. 4.*)

as buds at 4.7 [7]–5.5 mm; [3] 2 rays at 8.1 mm; [7] long by 14 mm.[12] Three-toothed scale appears on each side just below tip of pterotic spine at 14.6 mm; second such scale appears at 18.2 mm.[7]

Pigmentation: At 3.4 mm, few large melanophores on dorsal surface of braincase. Gradual increase in pigmentation extending to dorsal surface of snout and body on specimens of 4 mm; down sides of head and body posteriorly to anus at 5 mm; and to caudal fin at 10 mm. Preopercle and opercle less densely pigmented than dorsal part of snout and body. Over 10 mm, pigmentation similar but more intense, upper jaw and sides of head blue-black; mandible nonpigmented; eye silver with black pupil; upper body dark blue to black; lower sides of

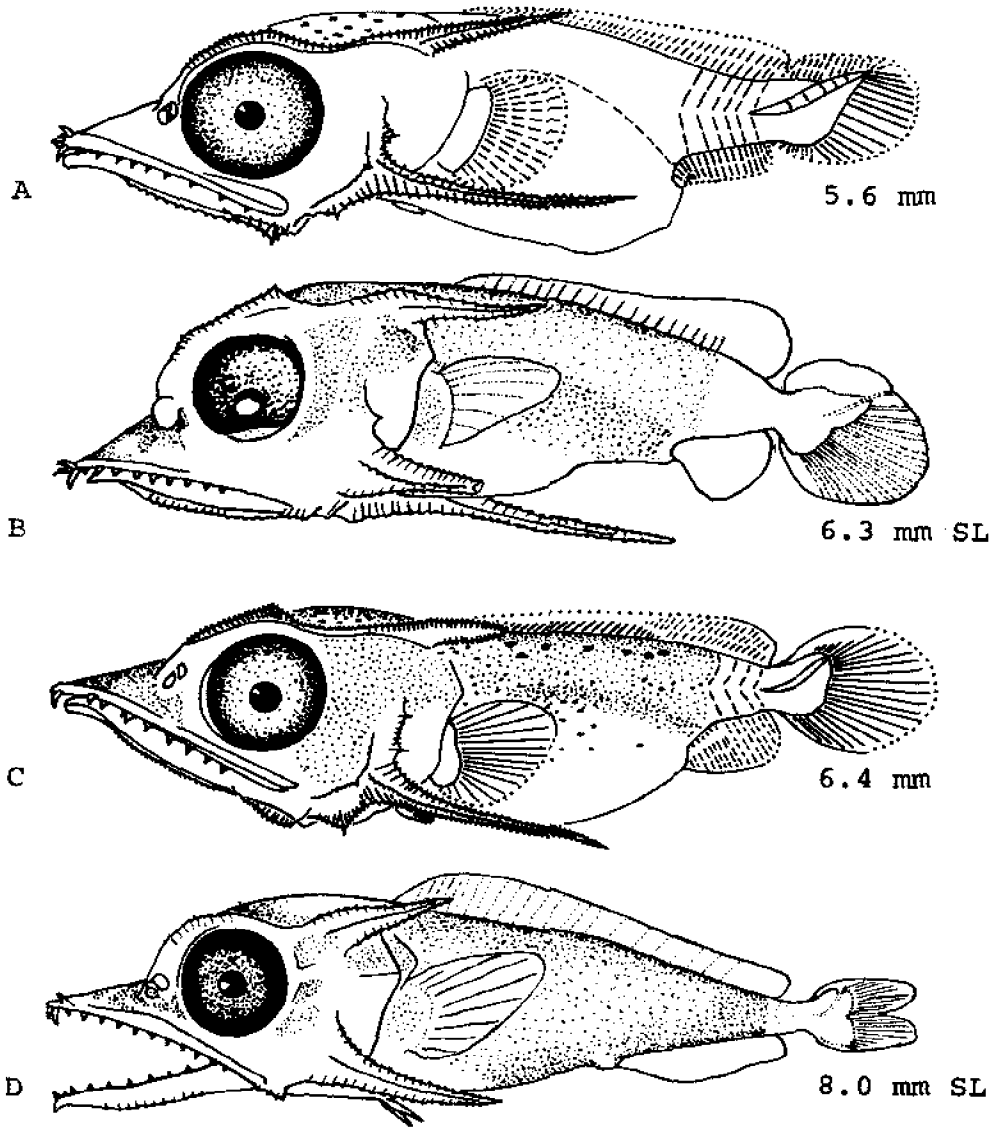

Fig. 102. *Istiophorus americanus*, Atlantic sailfish. A. Larva, 5.6 mm. B. Larva, 6.3 mm SL. C. Larva, 6.4 mm, putative, possibly white marlin (Ueyanagi, S., 1959). D. Larva, 8.0 mm SL. (*A, C, Gehringer, J. W., 1956: figs. 5–6. B, D, Voss, G. L., 1953: figs. 1C-D.*)

body anterior to anus and caudal blue; belly silvery white; fins usually translucent (except dorsal); spines unpigmented. Pigmentation on dorsal fin develops from scattering of chromatophores on lower central portion at 10 mm to generally dense areas at 20 mm; tips of rays unpigmented; pigment usually extends posteriorly to about ray 35. Bars and blotches of chromatophores appear on body at about 35 mm and persist.[7]

Coloration in life for specimens 15–20 mm SL—dorsal surface of head and body steel-blue; sides of head and upper opercles blue-black; eye silvery white with blue tinge and black pupil; ventral sides of body from anus posteriorly blue; pectoral fins hyaline; caudal fin translucent white; anterior portion of dorsal fin blue-black with yellow and white streaks on rays, posterior portion hyaline; pelvic fins tinged with yellow.[7]

JUVENILES

Specimens described 27.4–374 mm.[7]

D. 43–50, 6–7; A. 15–19, 6–7; C. 11–12+9+8+11–12; P. 17–20.[1]

Body slimmer at 56.2 mm; snout increases proportion-

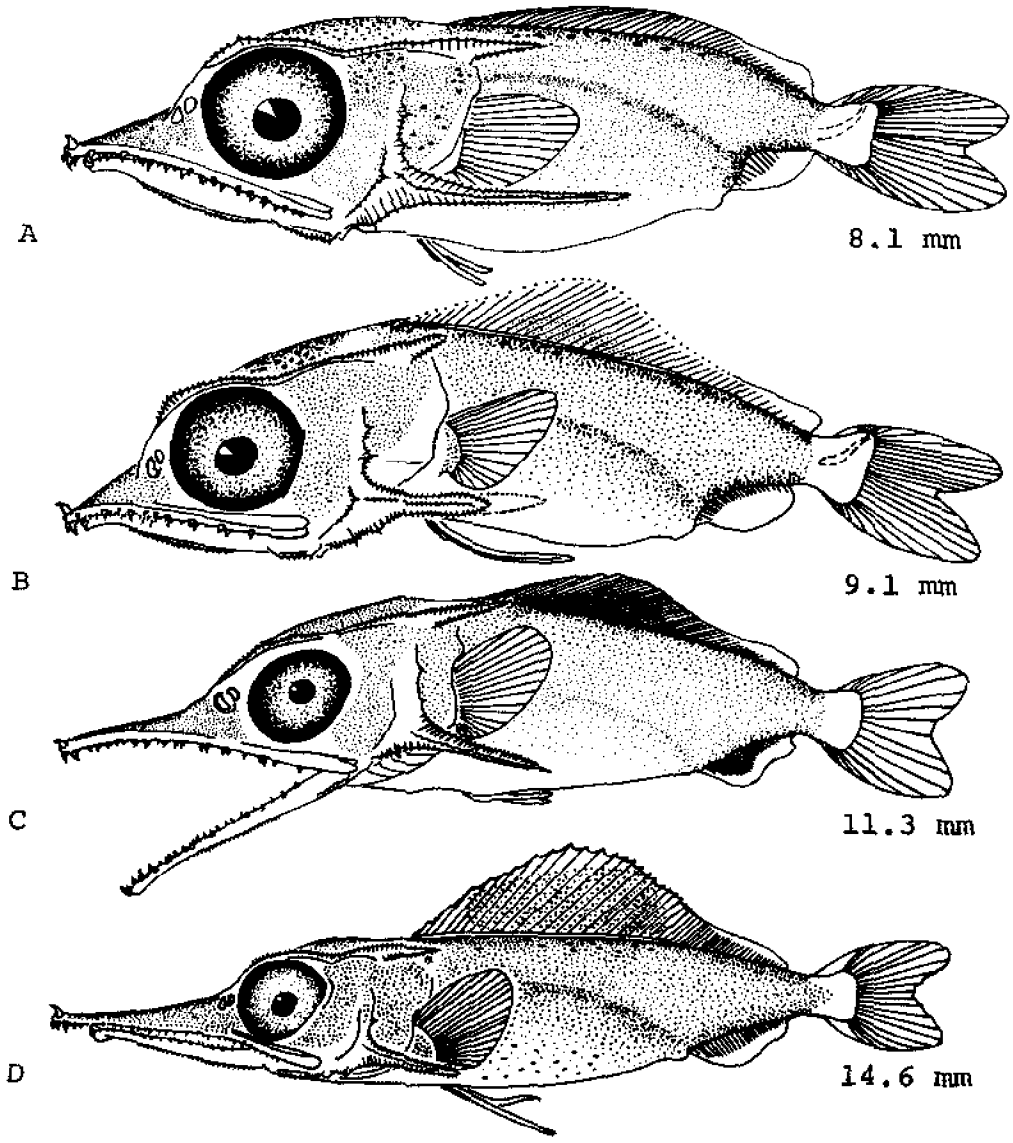

Fig. 103. *Istiophorus americanus*, Atlantic sailfish. A. Larva, 8.1 mm. B. Larva, 9.1 mm. C. Larva, 11.3 mm. D. Larva, 14.6 mm, putative, possibly white marlin (Ueyanagi, S., 1959). (*A-D, Gehringer, J. W., 1956: figs. 7–10.*)

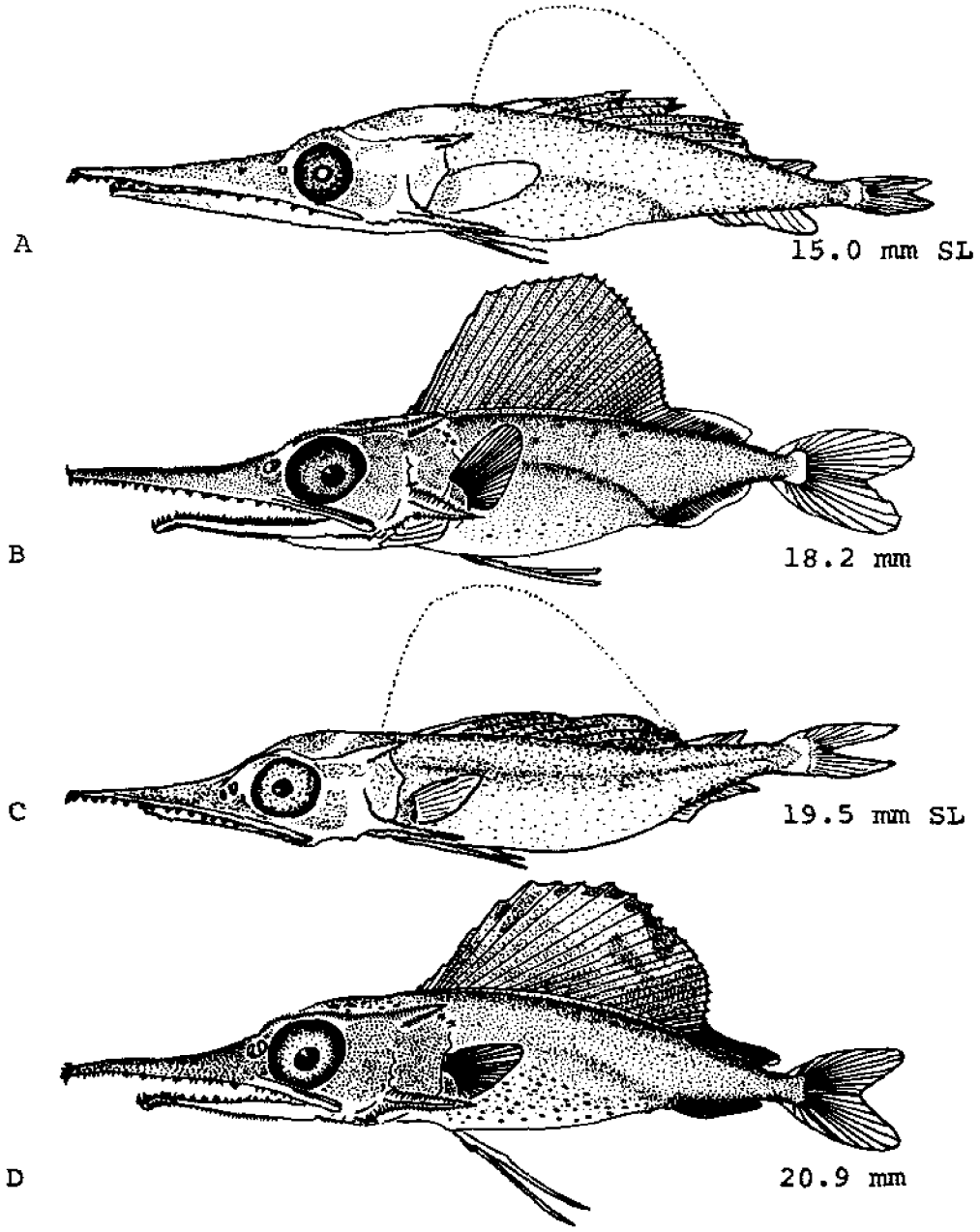

Fig. 104. *Istiophorus americanus*, Atlantic sailfish. A. Larva, 15.0 mm SL. B. Larva, 18.2 mm. C. Larva, 19.5 mm SL. D. Larva, 20.9 mm. *(A, C, Voss, G. L., 1953: figs. 3A-B. B, D, Gehringer, J. W., 1956: figs. 11-12.)*

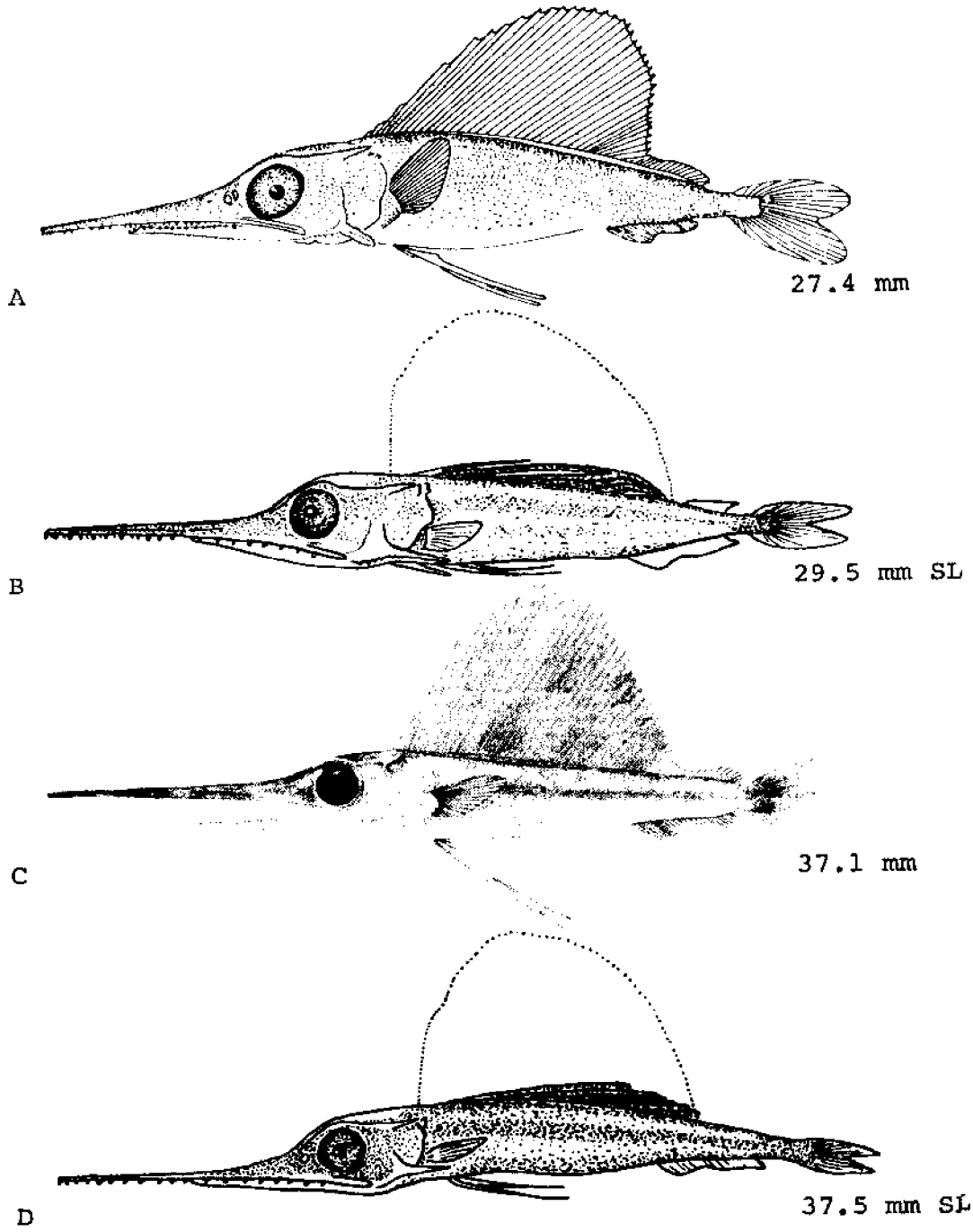

Fig. 105. *Istiophorus americanus*, Atlantic sailfish. A. Juvenile, 27.4 mm. B. Juvenile, 29.5 mm SL. C. Juvenile, 37.1 mm. D. Juvenile, 37.5 mm SL. (*A, Gehringer, J. W., 1956: fig. 13. B, D, Voss, G. L., 1953: figs. 3C, 4A. C, Gehringer, J. W., 1970: fig. 1.*)

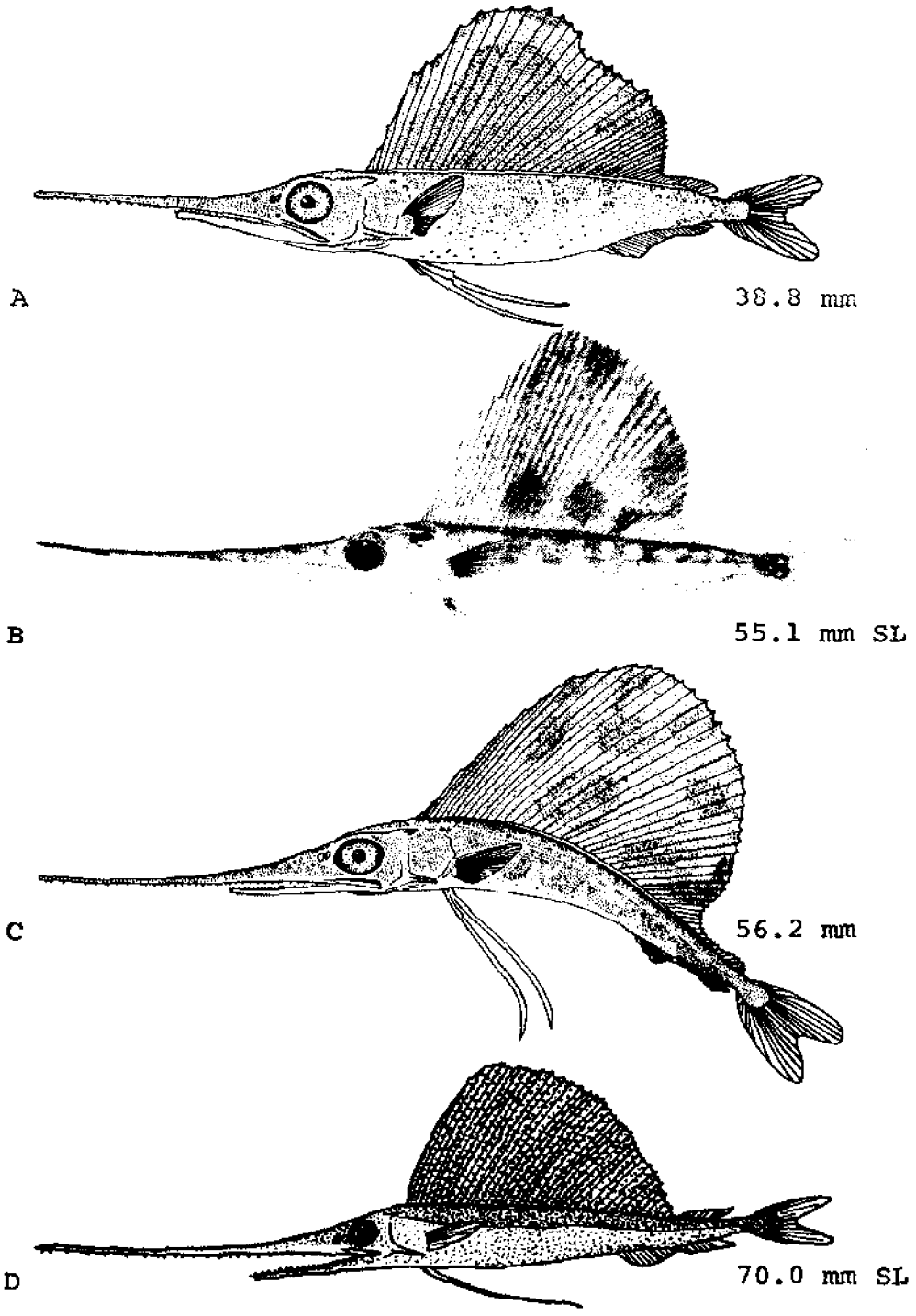

Fig. 106. *Istiophorus americanus*, Atlantic sailfish. A. Juvenile, 38.8 mm, putative, possibly white marlin (Ueyanagi, S., 1959). B. Juvenile, 55.1 mm SL. C. Juvenile, 56.2 mm. D. Juvenile, 70.0 mm SL. (*A, C, Gehringer, J. W., 1956: figs. 14–15. B, Gehringer, J. W., 1970: fig. 2. D,* Voss, G. L., 1953: *fig. 4B.*)

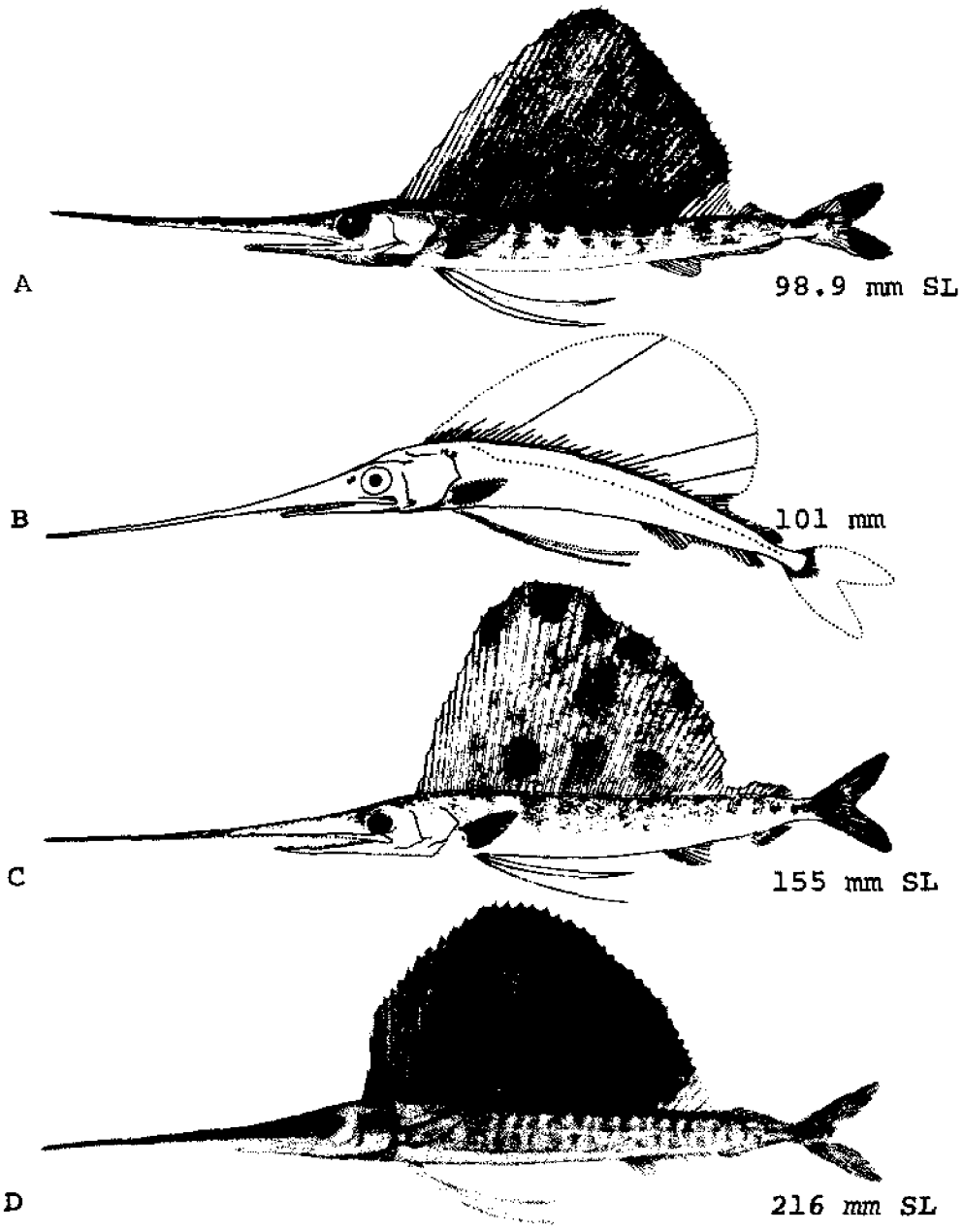

Fig. 107. *Istiophorus americanus*, Atlantic sailfish. A. Juvenile, 98.9 mm SL. B. Juvenile, 101 mm. C. Juvenile, 155 mm SL. D. Juvenile, 216 mm SL. (*A, C-D, Gehringer, J. W., 1970: figs. 3–5. B, Gehringer, J. W., 1956: fig. 18.*)

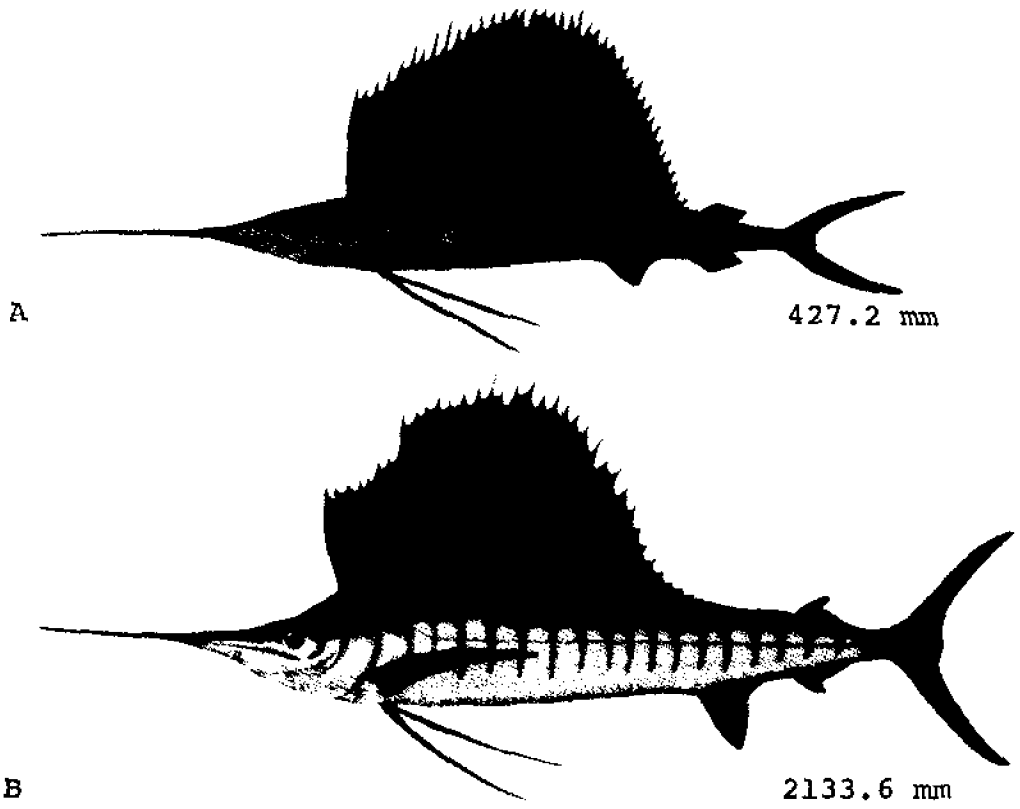

Fig. 108. *Istiophorus americanus*, Atlantic sailfish. A. Juvenile, 427.2 mm. B. Juvenile, 2133.6 mm. (*A, B, Tinsley, J. B., 1964:181.*)

ately with growth. Fangs disappear from snout tip by 27.4 mm; teeth fewer in number by 38.8 mm, teeth few and weak beyond mandible tips, two patches on palatine by 64.1 mm; teeth only present as minute spines on bill beyond mandible by 374 mm. Eye diameter becoming relatively smaller with growth.[7] Lower preopercular spine noticeable, supraocular crest reduced; not serrated by 20–29.5 mm; [3] head spines noticeably shorter by 60 mm; [12] pterotic spines lost by 150 mm; preopercular spine lost by 216–238 mm.[1] Small pore just anterior to nostrils by 27.4 mm; two pores by 38.8 mm; several pores by 64.1 mm. Dorsal fin increases in height by 27.4 mm; [7] sail-like by 70 mm.[3] Anal fin with pronounced notch by 56.2 mm; [7] finlet still attached by 70 mm; [3] fins not separated by 374 mm.[7] Caudal keels not present by 60 mm; [12] developed, upper first by 84–92 mm SL.[1] Pelvic fins long and slender by 70 mm; [3] first two rays fused by 216–238 mm SL.[1] Lateral line first visible by 38.8 mm. Scales appear as dermal spines present on opercle, preopercle and body except for area covered by pectoral fin by 56.2 mm; [7] becoming cycloid by 216–238 mm; [1] two scales appear behind pterotic spine by 20–29.5 mm.[3]

Pigmentation: Pigment on sides of body concentrated in 5–7 bars on fish of about 30 mm SL; 7–12 bars at about 100 mm SL; few specimens with 12–14 bars at 150–200 mm SL; 22 bars on specimens 216 mm SL. Pectoral fins clear except for a few melanophores at bases of first few rays on largest specimens. Pelvic fins lemon yellow with few melanophores on membrane between second and third rays on fish over 155 mm SL. Pigment on anterior portion of dorsal fin uniformly dusky to dark except for two to several large, dark spots scattered in nonuniform pattern over fin; first few rays less densely pigmented than rest of fin in some specimens; pigment extends posteriorly on fin to 34th–40th rays; posterior portion (terminal 6–7 rays) of fin clear, except for pigment on bases of fin rays and fin membrane on specimens longer than 135 mm SL. Anal fin clear. Caudal fin with pigment at 44.2 mm SL; absent by 51.7 mm SL; few melanophores present on lower caudal lobe in fish between 44.2–60.0 mm SL; similar series on upper lobe in fish 50.0–64.0 mm SL; melanophores coalesced into blotches in fish 53.0–67.0 mm SL; larger by 101.0–119.0 mm SL; specimens 216–238 mm SL have clear area on middle of fin reduced to distal third of middle six caudal rays and ray membrane, lobes dusky, and tissue covering ray bases densely pigmented.[1]

GROWTH

Reported to reach 17.8 cm by end of first month; 50.8 cm by end of second month; 89 cm by end of third month; and 111.7 cm by end of fourth month; 183 cm by one year; 216 cm by 2 years; 233.7 cm by 3 years.[10]

AGE AND SIZE AT MATURITY

Mature after 18 months.[10]

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Makaira nigricans Lacépède, Atlantic blue marlin

ADULTS

D. 39 [3,16]–46,[16] 6–7; [2,3] A. 13 [2]–17,[3,16] 6–7; [2,3] C. 9+8 (RAF); P. 18 [2]–22; [3,16] V. 3; scales irregularly set over body except top of head, belly and fins which are scaleless; [1] vertebrae 11+13=24; [2,4,16] gill rakers absent.[1]

Measurements expressed as thousandths of SL: Body depth 202; head 233; snout 101; maxillary 143; bill length 269; first predorsal 772; first preanal 582; height first dorsal fin 158; height first anal fin 134; pectoral fin length 210; pelvic fin length 167.[3]

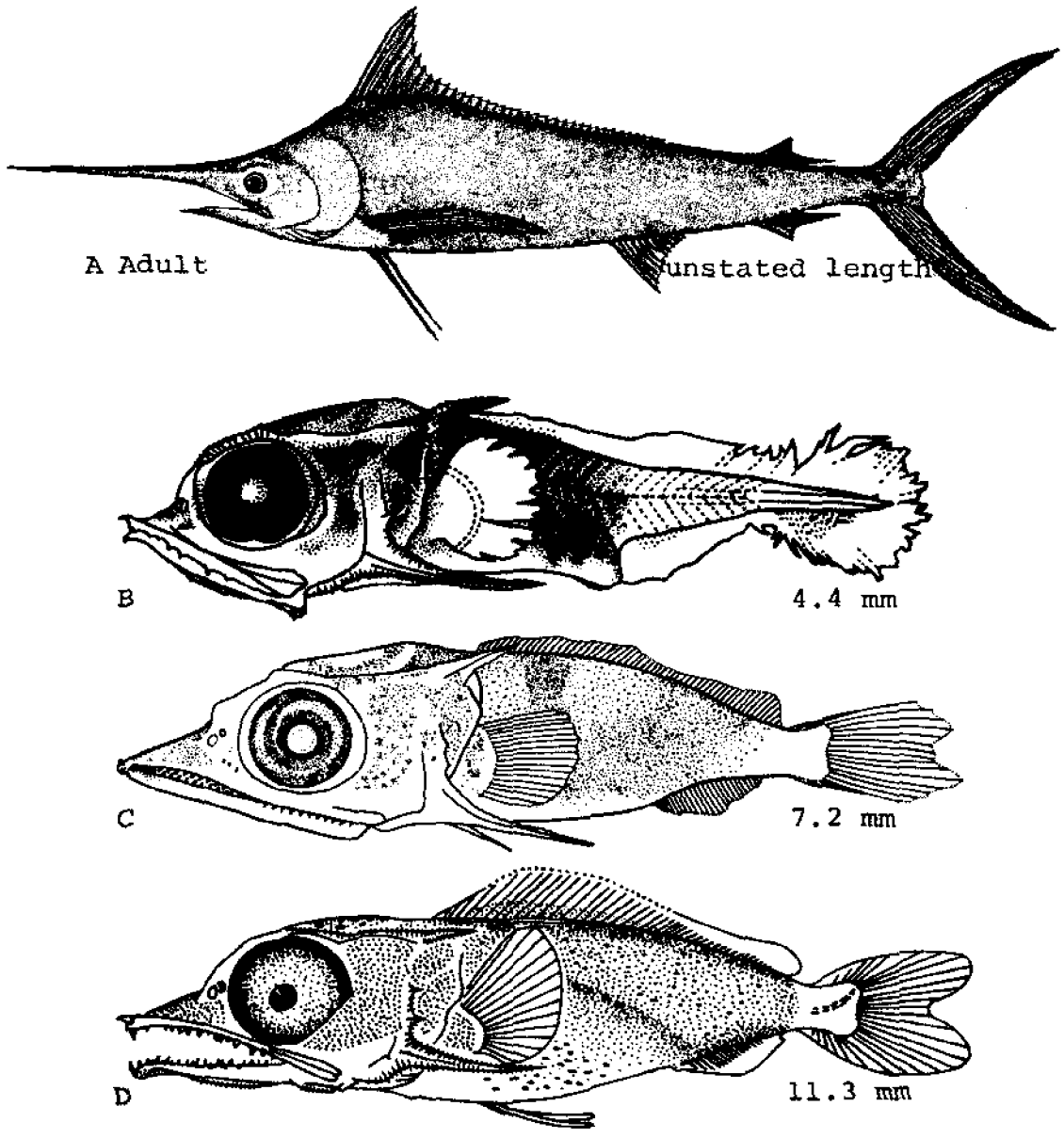

Fig. 109. *Makaira nigricans*, Atlantic blue marlin. A. Adult, unstated length. B. Larva, 4.4 mm. C. Larva, 7.2 mm. D. Larva, 11.3 mm. (*A, Leim, A. H., and W. B. Scott, 1966: 294. B, Strasburg, D. W., 1970: fig. 8d, after Ueyanagi, S., 1963. C, Bartlett, M. R., and R. L. Haedrich, 1968: fig. 1b. D, Gehringer, J. W., 1958: fig. 23.*)

Body streamlined, fusiform, heavy at shoulder, tapering gradually to tail; dorsal outline of head rises from nostrils to dorsal fin origin. Scales more or less flattened, elongate and thorn-shaped, sometimes bifid;[1] lateral line inconspicuous,[1,6] complex, forming reticulate pattern covering sides of body.[6] First dorsal and anal fins with anterior falcate lobe; second dorsal and anal fins shorter and lower; caudal fin lobes long, tips wide apart; pectoral fins not highly modified in shape; pelvic fins very narrow, equal to or shorter than pectorals.[7] Bill rugose and cylindrical, narrowing toward tip; two caudal keels.[1]

Pigmentation: Body bluish or blackish above,[7] becoming brilliant toward median line;[1] silvery below;[1,7] crossbars on sides lighter blue or lavender; dorsal fin cobalt or purplish blue, often marked with darker spots or blotches; pectoral base with spot.[2]

Maximum size: Females to 3980 mm[7] and 351 kg;[5,7] males to 135 kg.[10]

DISTRIBUTION AND ECOLOGY

Range: Both sides of Atlantic Ocean from 45° N to 35° S in the west and from 25° N to 25° S in the east,[18] usually from North Carolina to Florida and southward.[7]

Area distribution: Recorded from Atlantic and Ocean counties, New Jersey [14] and throughout the Mid-Atlantic Bight.[18]

Habitat and movements: Adults—associated with blue water over moderate depths.[1] Concentrations found off easternmost South America during first half of year and in the Gulf of Mexico and Caribbean during middle of the year.[8] Collected in water with temperatures between 21.7 and 30.5 C.[16]

Larvae—captured at the surface during the day, deeper at night, in water between 27.2 and 28.8 C.[15]

Juveniles—no information.

SPAWNING

Occurs near Cuba during May–November.[7]

EGGS

Unfertilized egg opaque white to yellow and 0.3–0.5 mm in diameter.[10]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Specimens described 8.6 [15]–206 [4] mm BL.

D. 42 at 11.3 mm; 44 at 21 mm; 49 at 45 mm;[4] 44 (3 rudimentary), 6 at 194 mm;[9] 42, 6 at 201–206 mm. A. 16 at 11.3 mm; 23 at 21 mm; 24 at 45 mm;[4] 18 (4 rudimentary), 6 at 194 mm;[9] 14, 6 at 201–206 mm.[4] P. 14 at 11.3 mm; 20 at 21 mm; 18 at 45 mm;[11] 21–22 at 201–206 mm.[9] Vertebrae 11 + 13 = 24;[4,9,15] scales small, cycloid at 201–206 mm;[4] caudal keels forming at same stage; teeth at 201–206 mm minute, conical, irregular in size, slightly recurved, and in several rows, extending to tip of each jaw;[4] lateral line shows some branching at 33.5–35.3 mm, more complex at 51.5 mm.[9]

Pigmentation: At 33.5–35.3 mm BL dark pigment concentrated on anterior part of dorsal fin at about midheight of first 4–5 elongate rays and in three spots along base of fin; last nine rays and membranes unpigmented; lateral line appears as pale area on tan background. At 51.5 mm BL dorsal fin pigment concentrated distally.[9] At 201–206 mm first dorsal and pelvic fins dark; first anal fin has dark blotch toward anterior portion; caudal, second anal, and upper surface of pectoral fins blotched with dusky pigment, second anal fin clear; body dark above, lighter below.[4]

Color in life blue-black on back and sides, white underneath; some with darker spots along the back; caudal peduncle and caudal fin colorless; two bright irridescent blue patches on head.[15]

JUVENILES

Specimens described 846–1320 mm.

D. 40–44, 6–7; A. 13, 6–7; P. 20.[3]

Measurements expressed as thousandths of SL: Head 220–239; maxillary 137; first predorsal 183–208; snout 96–100; second predorsal 777; body depth 169; bill length 149–212; first anal base 151; length pelvic fin 218.[3]

GROWTH

Reported to reach 7.7–18 kg in February, 23–26 kg in April, 16–25 kg in May, and 32–36 kg in May–October in Puerto Rico and the Virgin Islands.[10]

AGE AND SIZE AT MATURITY

Males mature at one year and 32 kg; females at 61 kg.[10]

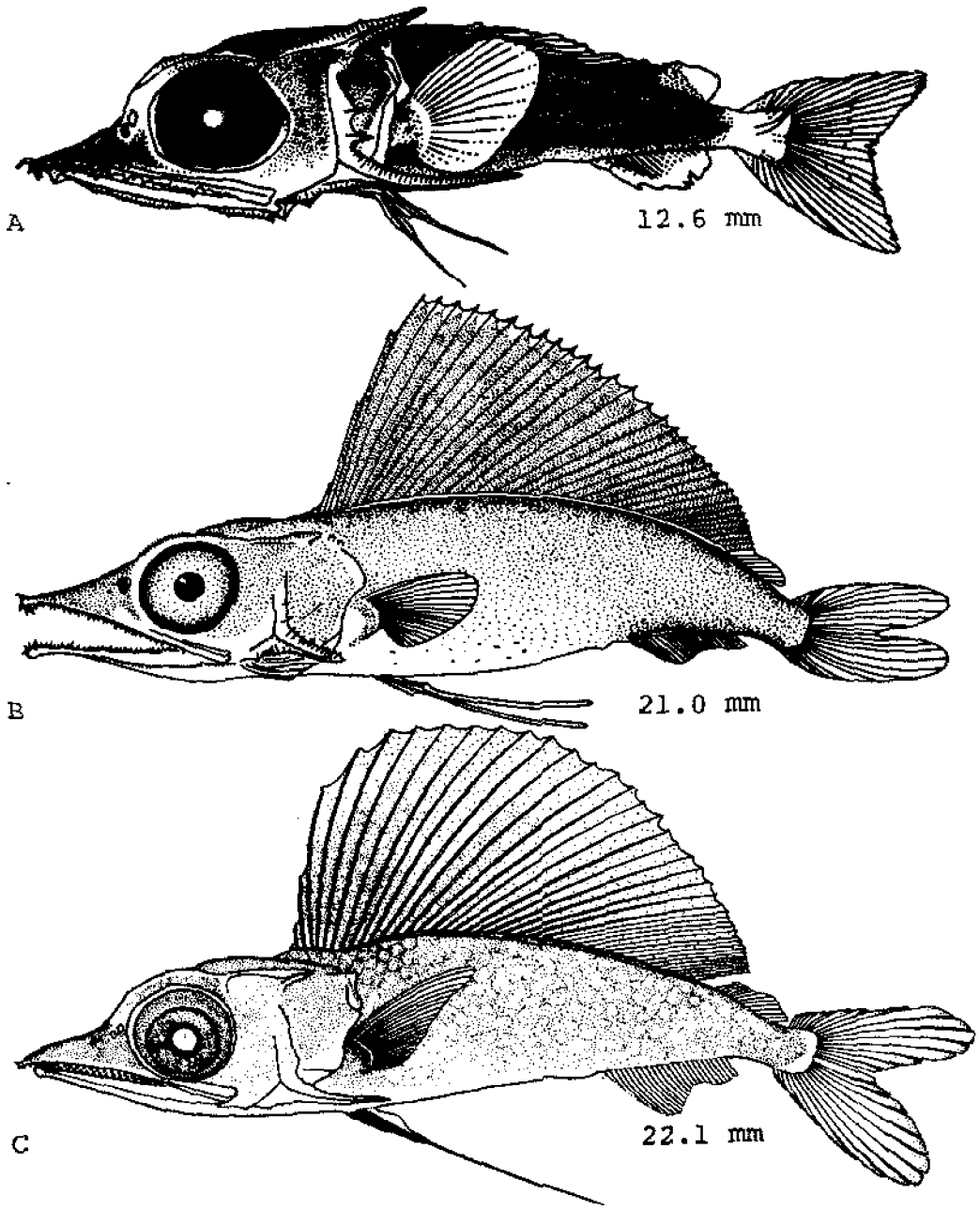

Fig. 110. *Makaira nigricans*, Atlantic blue marlin. A. Larva, 12.6 mm. B. Larva, 21.0 mm. C. Larva, 22.1 mm. (A, *Strasburg, D. W., 1970: fig. 9d, after Ueyanagi, S., 1963. B, Gehringer, J. W., 1956: fig. 24. C, Bartlett, M. R., and R. L. Haedrich, 1968: fig. 1a.*)

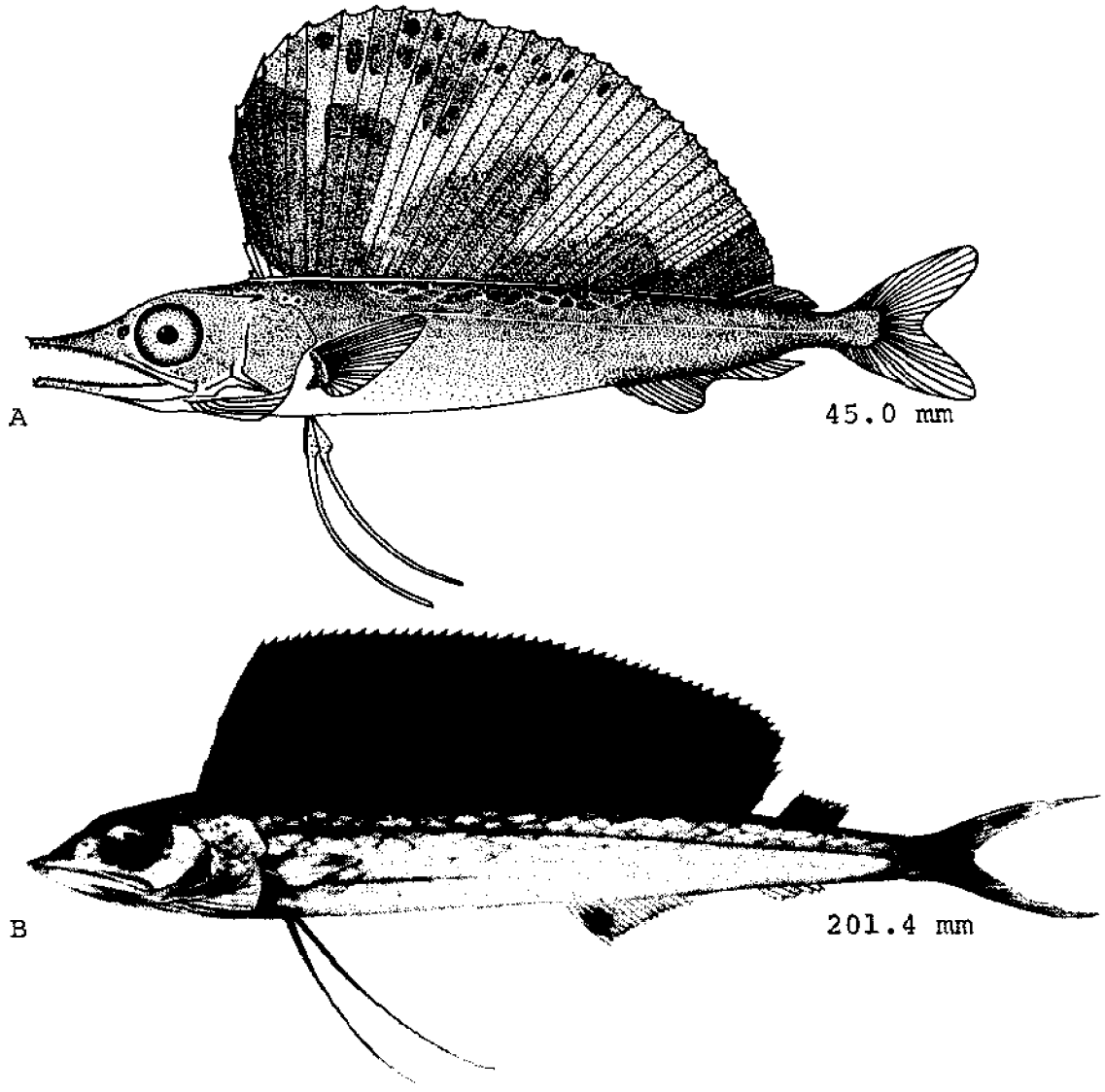

Fig. 111. *Makaira nigricans*, Atlantic blue marlin. A. Juvenile, 45.0 mm. B. Juvenile, 201.4 mm body length. (*A, Gehringer, J. W., 1956: fig. 25. B, Caldwell, D. K., 1962: fig. 1.*)

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Tetrapturus albidus Poey, White marlin

ADULTS

D. 38 [1,9]–46,[1] 5 [1,9]–7; [9] A. 12 [1]–18,[9] 5 [1,9]–7; [9] C. 9; [10] P. 17–22, [9] V. 3; vertebrae 12 + 12 = 24; [1] teeth weak, consisting of small patches of denticles or villiform teeth on jaws, palatines, palatine membrane, and pharyngeals.[9]

Measurements expressed in percent BL: Body depth 14–19; bill length 25–35; head length 24–27; maxillary 15–17; eye 2.8–3.2; caudal keels 2.7–4.7; first predorsal length 22–25; base first dorsal fin 55–58; anterior height first dorsal fin 14–23; height first anal fin 12–16; base first anal fin 14–17; first preanal length 57–62; pectoral fin length 19–27; pelvic fin length 14–22.[9]

Body modified fusiform shape, slender and notably compressed laterally; head tapers rapidly from pronounced dorsal hump to beak-like mouth, dorsal and ventral profiles concave anteriorly, convex posteriorly; mouth opening large, extending beyond posterior margin of orbit by about one-third orbit diameter. Scales very small and delicate, with round, radially marked bases and glassy perpendicular spines; lateral line simple, originating above opercular aperture and running longitudinally for short distance before curving to midline.[9] First dorsal and anal fins high lobed but ends rounded; [4] caudal fin stiff, deeply forked; [9] pelvic fins shorter than pectorals; [4] pectoral fins moderately long, tip rounded.[9] Bill round,[4] spear-like; [9] two horizontal caudal keels; [4,9] eye about midway between tip of mandible and operculum.[9]

Pigmentation: Back and top of head dusky blue to brilliant greenish blue; underparts silvery white; transition from dark dorsal to white ventral areas gradual, passing through lines of rich purplish brown and smokey gray; sides crossed by vertical light blue or light lavender bars. Membrane of first dorsal fin deep blue or bluish purple, with circular dusky spots near base; rays of first dorsal fin blue or black; first anal fin blue or bluish purple distally and pearly white proximally; second dorsal fin deep blue; second anal fin somewhat lighter blue; outer surfaces of pectoral fins dusky with pearly sheen, inner surfaces bluish purple; pelvic fins blue-black; caudal fin dusky bluish or brownish; caudal keels bluish black.[9]

Maximum size: To 2642 mm and 73 kg.[4]

DISTRIBUTION AND ECOLOGY

Range: Both sides of North and South Atlantic from 45° N to 35° S,[3] in western Atlantic ranging along Texas and the gulf coast of Mexico and in surface waters eastward to Cuba and northward to Massachusetts.[4]

Area distribution: Noted as concentrated and abundant along Mid-Atlantic Bight in the summer.[3,6,9]

Habitat and movements: Adults—undergo extensive migrations for both feeding and spawning purposes,[9] tending to congregate over the continental slope in summer in the Gulf of Mexico [6] and Mid-Atlantic Bight,[3,6,9] and along the east coast of South America in all months except from April through June.[7] Generally associated with temperatures between 21 and 28 C,[5] with 24 C considered optimal. Usually found from the surface to 20 or 30 m, but occasionally at 200–250 m at the edge of the continental slope.[9]

Larvae—generally distributed between 24 [2,8] and 26 C.[2]

Juveniles—no information.

SPAWNING

Concentrated along coasts of Cuba, the Greater Antilles, and southern Brazil during a peak in early summer. Spawning occurs at temperatures between 20 and 29 C and at salinities greater than 35 ppt.[9]

EGGS

Probably free floating in the water column.[9]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Specimens described from 124.9 mm BL [2] to 955 mm BL.

D. 43, 6; A. 17, 6; P. 20; vertebrae 12 + 12 = 24.[2]

Body with dorsal profile at nape nearly straight, gradually becoming confluent with straight profile along dorsal base, ventral outline slightly convex. Lateral line straight from point below base of tenth dorsal spine to point between spines 13 and 14, where it drops and again becomes nearly straight. Dorsal fin high, rising abruptly at third spine and sloping gradually upward to about spine 11; first anal fin broadly rounded; caudal fin lobes rounded; pectoral fins somewhat pointed. Bill slender,

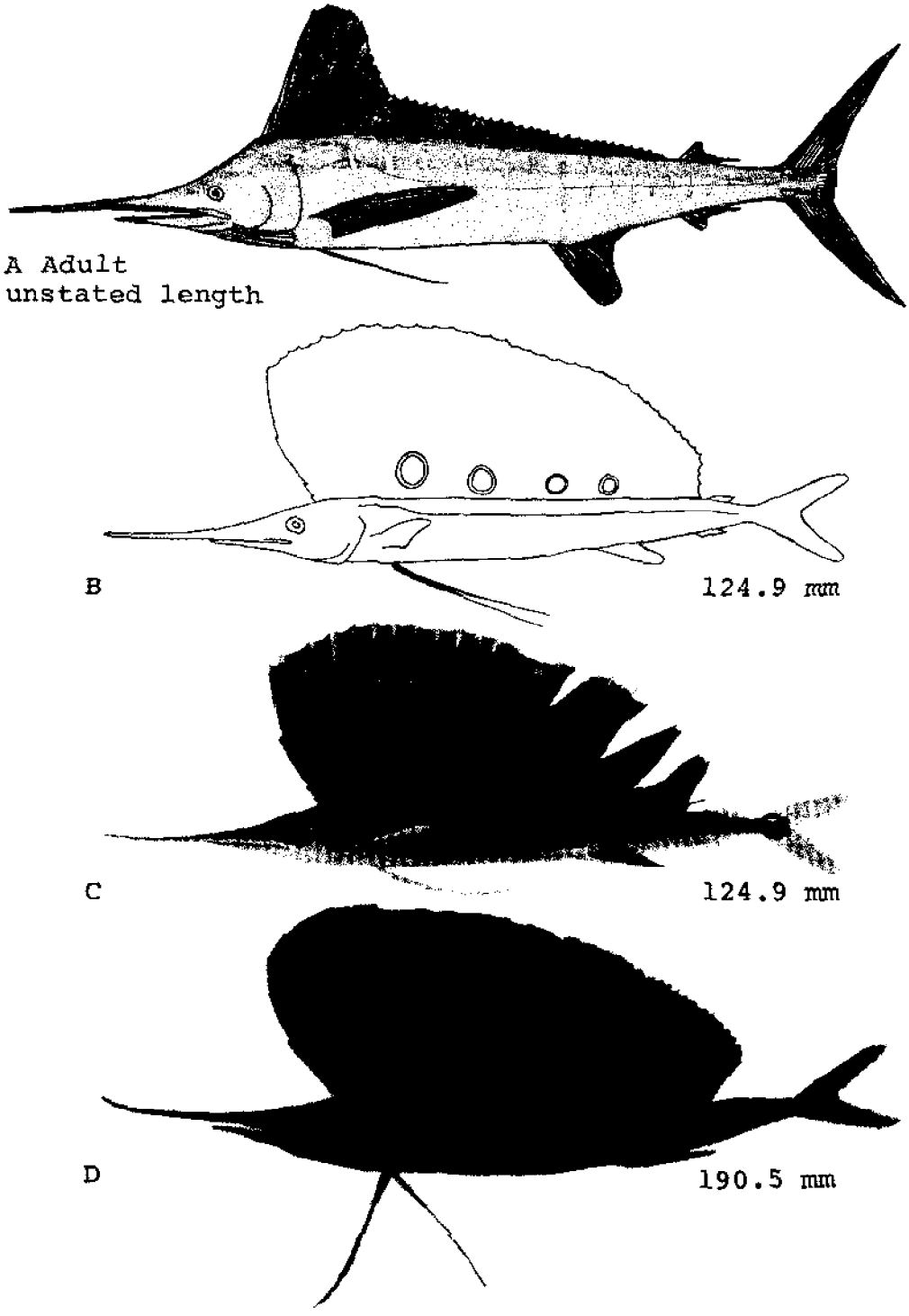

Fig. 112. *Tetrapturus albidus*, White marlin. A. Adult, unstated length. B. Juvenile, 124.9 mm. C. Juvenile, 124.9 mm. D. Juvenile, 190.5 mm. (*A, Nakamura, I., T. Iwai, and K. Matsubara, 1968: fig. 19. B, C, de Sylva, D. P., 1963: figs. 1, 3b; Florida Bd. Conserv., 1968: 5.*)

well developed, with mandible well formed and shorter than bill.[2]

Pigmentation: Brownish olive in formalin. Dorsal part of body darkest midway between dorsum and lateral line, becoming somewhat paler along the sides and silvery white along the ventral surface; four or five diffuse dusky bands along the sides alternating with much narrower, obscure silvery bands. Head colored like body, except maxillary pale. Dorsal fin uniformly dusky, spine tips and edge of interradial membrane immediately bordering spine tips translucent, giving a spotted effect to the fin edge; four distinct dark ocelli with light borders; the first ocellus begins between spines 14 and 15 and extends just past spine 16; second ocellus begins between spines 20 and 21 and ends on spine 23; third ocellus begins between spine 27–28 and ends between spine 29 and 30; fourth ocellus begins between spine 32 and 33 and ends between spines 34 and 35. Caudal fin dusky, dark adjacent to caudal peduncle, and with a translucent region at base of each lobe; pectoral and pelvic fins pale; first four rays of first anal fin translucent, becoming abruptly dark olive on middle rays, the last few rays translucent; second anal and dorsal fins pale.[2]

GROWTH

No information.

AGE AND SIZE AT MATURITY

Matures at 130 cm measured from orbit to fork of tail.[9]

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Tetrapturus pfluegeri Robins and de Sylva, Longbill spearfish

ADULTS

D. 44 [3–53],[1] 6–7; [1,3] A. 12 [1–17],[3] 6–7; [1,3] C. 9+8 (RAF); P. 17–21; [3] V. 3 (RAF); vertebrae 12+12=24.[1,3]

Measurements expressed in thousandths of body length: Body depth 91–128; bill length 213–274; head 227–276; maxillary 135–158; orbit 25–30; caudal keels 23–34; first predorsal length 196–212; height anterior dorsal fin 141–201; height first anal fin 83–120; first preanal length 595–640; pectoral fin length 97–233; pelvic fin length 184–233.[2]

Body slender, its dorsal and anal profiles nearly parallel over the trunk, profile of dorsum anterior to dorsal fin origin flattened, without marked rise at occiput. First dorsal fin with high profile,[1] anterior lobe rounded; pectoral fin long,[2] becoming proportionately longer with growth; [1] anterior lobe of anal fin rounded.[2] Anus far anterior to anal-fin origin; [1,2,6] orbit small; [2] bill long,[1] equal to pelvic and pectoral fin lengths.[6]

Pigmentation: Blue-black above,[4,6] this pigment extending anteriorly on head and posteriorly on caudal base; light spot over pineal area; white [4] to silvery [6] below; bars or stripes lacking on adults.[4,6] Dorsal fin unspotted; [1,4] remainder of fins blue-black without conspicuous markings.[4]

Maximum size: To 179.1 cm and 30.8 kg.[6]

DISTRIBUTION AND ECOLOGY

Range: Western Atlantic from off southern New Jersey to Venezuela and from Texas to Puerto Rico.[1]

Area distribution: Entire Mid-Atlantic Bight.[1]

Habitat and movements: Adults—pelagic.[7]

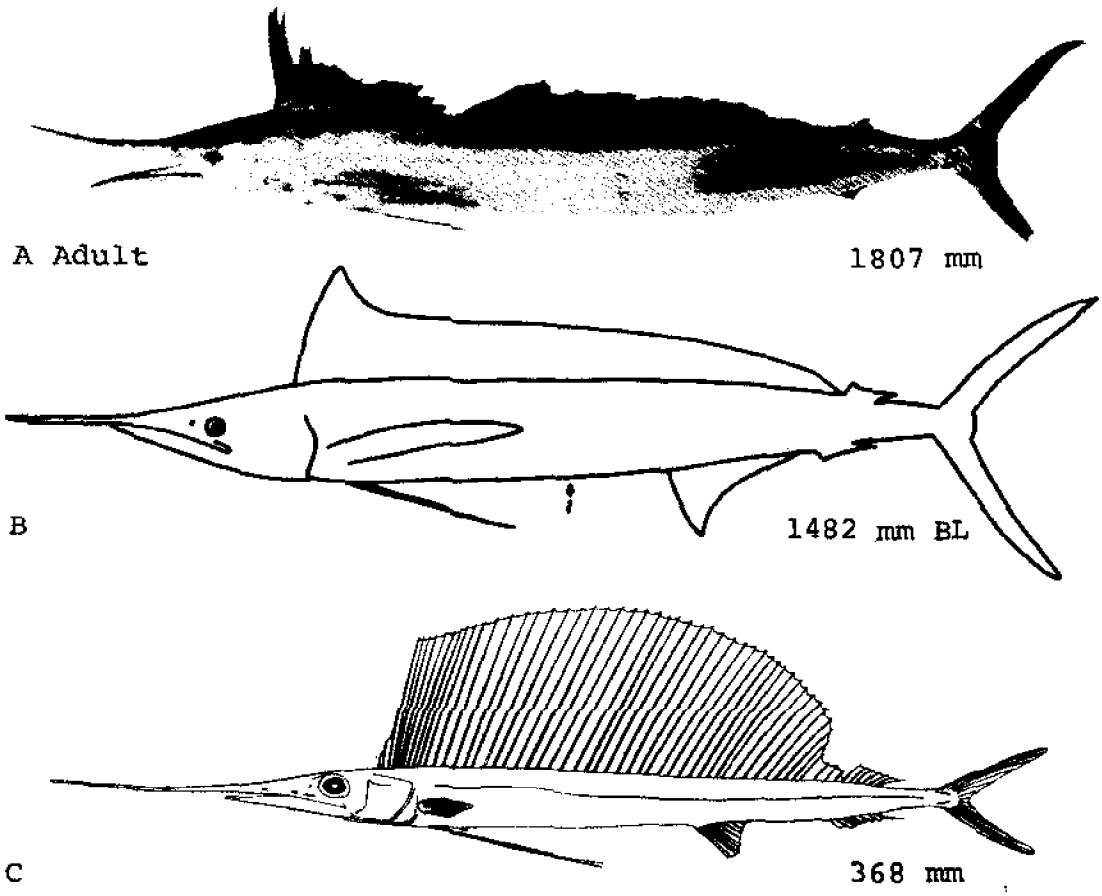

Fig. 113. *Tetrapturus pfluegeri*, Longbill spearfish. A. Adult female, 1807 mm from tip lower jaw to fork of tail. B. Adult, 1482 mm body length. C. Juvenile, 368 mm body length. (*A, C, Robins, C. R., and D. P. de Sylva, 1963: figs. 1–2. B, Robins, C. R., 1975: fig. 2.*)

Larvae—pelagic.[5]

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Xiphias gladius

swordfishes
Xiphiidae

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FAMILY XIPHIIDAE

The swordfish, *Xiphias gladius*, is the most easily characterized of the billfishes and is the only member of this monotypic family. The family is characterized by having the bill flattened in cross-section rather than rounded, and the lack of both pelvic fins and scales in the adults.

The swordfish is found worldwide in tropical and temperate seas entering estuaries and, rarely, in rivers.

The early life history of this species is fairly well known, especially compared to that of the other billfishes. The wide distribution, uniqueness, and commercial value of the swordfish have undoubtedly played a role in the amount of research that has been concentrated on this species.

Definitions and methods of measuring and counting swordfish follow Rivas (1956b).

Xiphias gladius Linnaeus, Swordfish

ADULTS

D. 38–49,[7] 4 [7,20,22]–5; A. 12 [7]–18,[20] 3 [7]–4; [7,20,22] P. 17–19; [7] V. absent; [7,10,22] scales absent; [10,20] vertebrae 10–11 + 15–16 = 26.[7]

Head 2.25,[20] depth 5.5–8.0,[20,22] bill 3 [20] in TL; eye 2–3.5 in postocular head.[6]

Body fusiform,[22] stout,[20] tapering uniformly from head to tail; [20] one median keel on caudal peduncle; [10,20] snout long, broad, flat; [10,20] mouth large, terminal, except upper jaw produced into flat bill, wider than deep; angle of jaw behind posterior part of eye.[22] First dorsal very high, falcate, its height being as great as body depth; second dorsal and second anal fins small, similar, opposite; first anal fin similar to first dorsal fin, but small; caudal fin lobes long,[20] lunate; [22] pectoral fins inserted very low,[20] scyth-shaped.[22]

Pigmentation: Body gunmetal, bronze,[10] blue-black,[20] or dark metallic purplish [22] above; white,[10,20] silvery,[10] or dusky [22] below; head and upper side of bill purplish blue [20] to almost black,[22] lighter on underside; [20,22] fins dark,[10] dark bluish,[20] or dark with silvery sheen; [22] eyes bright blue.[10]

Maximum size: To 488 cm [20,21] and 536 kg.[2,10]

DISTRIBUTION AND ECOLOGY

Range: Occurs in tropical and subtropical waters, but more densely distributed in temperate waters [9] of the Atlantic, Pacific and Indian Oceans,[2,10,20] and in the Red Sea and Mediterranean.[2] Found along both coasts of the Atlantic Ocean,[20] from Newfoundland [2,10,11] and Nova Scotia [11] south to 35° S,[2] and from Scandinavia to the Cape of Good Hope.[23]

Area distribution: Throughout the Mid-Atlantic Bight [10,11] and in Chesapeake Bay.[20]

Habitat and movements: Adults—prefer cooler waters.[19] Reported to winter in deep water,[13] or to be confined to the Gulf Stream where temperatures exceed 18 C.[24] Migrate far north or south in summer to feed when temperatures are 12–13 C; during breeding season, migration is to areas where temperatures are not lower than 23.5 C. Associated with salinities from 6 to 39 ppt [12] and temperatures between 12–13 C and 24 C depending on the time of the year (see above). Found from the surface (RAF) to 500 m.[24]

Larvae—found between 35° N and 35° S with numbers increasing south of the Equator between 160° E and 140° W.[5] Associated with salinities between 33.8 [12] and 36.4 ppt and temperatures above 22.4 C, with a range from 22.4 [15,18]–30.7 C.[23] Yolk-sac larvae live deeper (10–15 m) than larvae (near surface, no deeper than 1–2 m).[5]

Juveniles—no information.

SPAWNING

Location: Most concentrated in northwest Atlantic, eastern Indian, and central Pacific south of equator.[5] Spawning reported in the Atlantic from off Cuba; [10] Gulf Stream off the Carolinas; [11,18] north and northeast of the lesser Antilles; and southern part of Sargasso Sea.[12]

Season: Reported to be in the spring and summer.[11] In the Atlantic from January to October [4] with the season being April to July in the Gulf Stream, May to June in the Gulf of Mexico, and end of December to end of September in the lower Caribbean to South Carolina.[2]

Temperature and salinity: Spawning occurs when the temperature is above 23 [5,18]–24 C [5,9,18] and the salinity is above 25.4 ppt.[18]

EGGS

Location: Buoyant [17] and pelagic.[5]

Unfertilized eggs: 1.60 mm in diameter with 0.44 mm oil globule.[17]

Fertilized eggs: Transparent,[16,17] becoming dirty white; [16] 1.60 [17]–1.87 mm in diameter; oil globule single,[17] 0.50 [16,17]–0.52 [16] mm diameter.

EGG DEVELOPMENT

Forty-five minutes after closure of blastopore numerous black pigmented mesoblastic elements appear over the surface of the body and vitellus. Three–five hours later these chromatophores are more numerous and spinulose and have surrounded the oil globule. The next day light straw colored pigmentation appears on the body, and secondary otic and auditory capsules are formed. After 1 1/2 days in incubation the chromatophores on the yolk mass are strongly ramified and the tail tip has passed the anterior end of the oil globule. Some hours later the heart shows first contractions. On the third day of incubation the tail tip reaches almost to the head and the embryo is more strongly pigmented. Hatches several hours later.[16]

YOLK-SAC LARVAE

Specimens described 4.0–5.0 mm; hatching at 4.0 [5]–4.45 [16] mm.

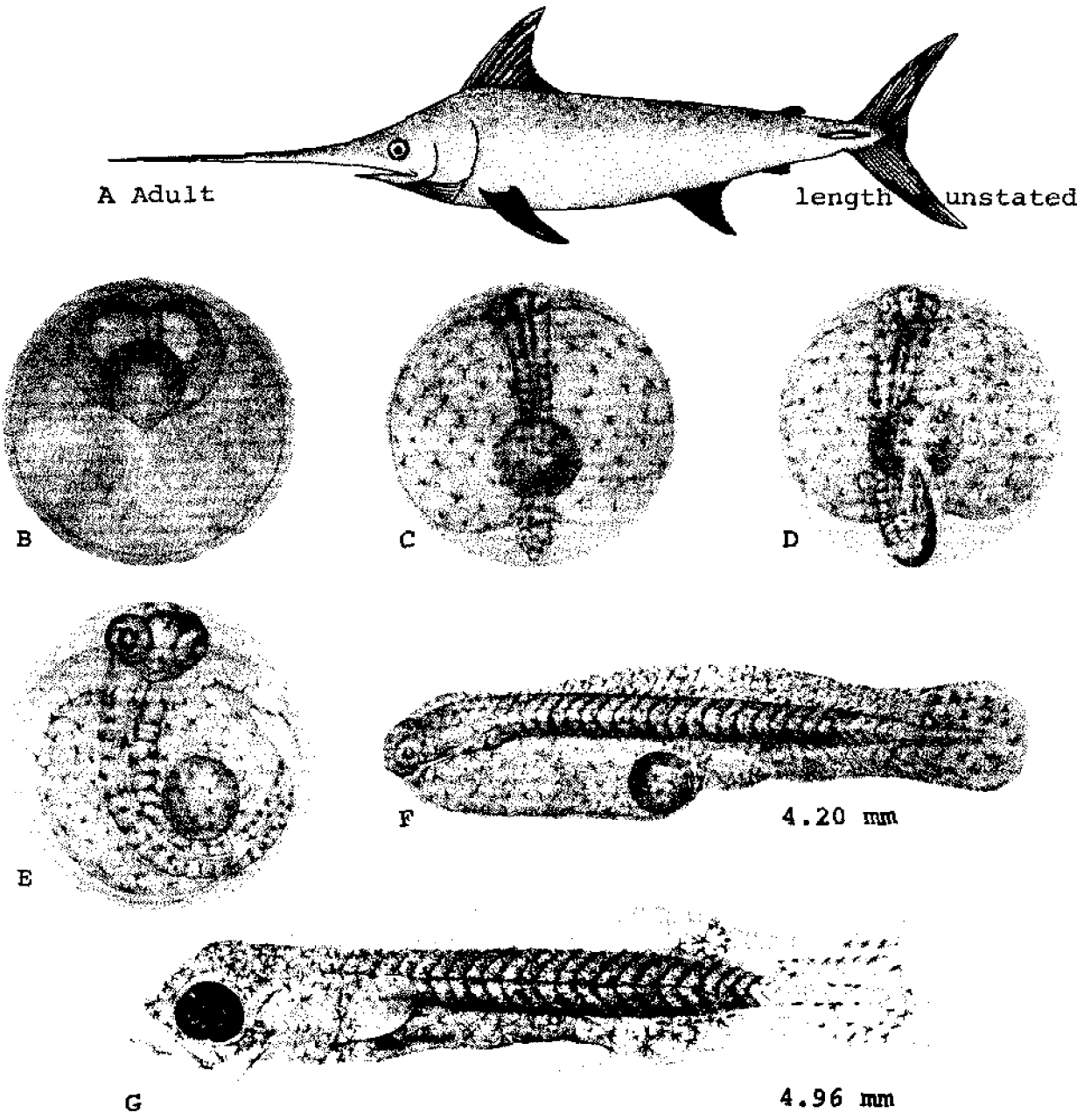

Fig. 114. *Xiphias gladius*, Swordfish. A. Adult, length unstated. B. Egg, just prior to blastopore closure. C. Same egg in the ninth hour of the second day. D. Same egg in the seventeenth hour of the second day. E. Egg on third day of development. F. Yolk-sac larva, just hatched, 4.20 mm. G. Larva, 4.96 mm. (*A, Nakamura, I., T. Iwai, and K. Matsubara, 1968: fig. 10. B-G, Sanzo, L., 1922: figs. 1–6.*)

Total myomeres, 24 at 4.45 mm [16] to 26 at 4.96 mm.[27] Body squat; yolk mass absorbed by 4.5–5.0 mm; [5] oil globule at posterior extremity of yolk,[16] reduced from 0.5 to 0.44 mm at hatching; [27] mouth not open at 4.4 mm,[16] opens on fourth day,[27] jaws equal; [5] pectoral fin distinct at 4.0 mm,[17] membranous and oval at 4.96 mm; [27] finfold originates behind head, rather wide and narrow, ending before end of caudal; [16] scales absent.[5]

Pigmentation: Some pigmentation along myosepta at 4.0 mm.[17] At 4.45 mm, pigmentation heavy on trunk region along myosepta; black ramified chromatophores on finfold except tip of caudal; some yellow pigment on finfold. At 4.96 mm, dorsal finfold becomes transparent except for short zone before caudal constriction; some yellow pigment along margin of dorsal finfold and dorsal border of ventral finfold.[16]

LARVAE

Specimens described 4.8 mm [5]–192.1 mm SL.[2]

D. 36 elements at 13.24 mm; [27] 43 elements at 14.5 mm; [2] 43 elements at 16.27 mm; [4] posterior elements true rays at 18.2 mm. A. 15 at 12.1 mm; [2] 16 at 13.24 mm; [27] 16 at 14.5 mm; [2] 16 at 16.27 mm.[4] C. 15 at 13.24; [27] 16 at 16.25 mm.[4] P. 14 at 13.24 mm; [27] 17 at 14.5 mm.[2] V. absent.[4] Total myomeres 27 at 5.56 mm.[27]

Scales spinous, arranged in rows; appear at 16.27 mm; two prominent rows on each side which run entire length of body, one dorsally and one ventrally; immediately below dorsal and above ventral rows are two shorter rows and between them a number of interrupted rows; scales with 2–3 conical spines.[4] Body short, stumpy at 9.0 mm; [2] depth begins decreasing at 10 mm; [5] becoming relatively more elongate with growth.[2] Snout increases in length 20–25% between 6–8 mm.[5] Teeth increase in number with growth, 11 on premaxillary and 12 on mandible at 6.1 mm TL, increasing to 137 on premaxillary and 214 on mandible at 68.8 mm SL. Maxillary reaches to nostril at 9.0 mm. Eye with dorsal and ventral constrictions at 6.1 mm.[2] At 16.27 mm TL, three interrupted groups of spines on snout dorsally; preorbital ridge with four spines and supraorbital ridge with eight spines; preopercle with two closely-set rows of spines, anterior with three and posterior with two, of which one long and conspicuous; keeled ridge of five spines below angle of jaws; conspicuous spinous projection with two spines dorsolaterally on cranium and another smaller one bearing two spines in temporal region; small spinous projection below and posterior to cranial spines; two very small spinous projections present immediately below postcranial spine.[4] Head spination tends to increase with growth and then becomes very much reduced by 192.1 mm.[2] Dorsal fin single and with supporting structures in posterior two-thirds at 9.0 mm; [2,4] all true rays developed at 68.8 mm.[2] Anal fin slightly narrower than dorsal.[4] Caudal not flexed at 6.1 mm; rays visible at 9.0 mm; flexion at 12.1 mm. Pectoral fins short with base high on body at 6.1 mm; [2] rounded at 16.27 mm; [4] becoming slightly falcate at 68.8 mm; all rays formed by 192.1 mm.[2] Scales appear at 8.0 mm; [5] develop as single spines at 9.0 mm SL to large keeled structures bearing five spines at 192.1 mm SL. Anus becoming more anterior in position by 20.2 mm.[2]

Pigmentation: Tan with sprinkling of chromatophores, darkest on snout, cranial region and lateral midline at 6.1–9.0 mm. Barred color pattern becoming evident at 12.1 mm, well developed by 14.5 mm.[2] At 16.27 mm, general color brown in formalin; pigmentation absent from spiny ridges and pectoral fins; snout heavily pigmented on dorsal side and also interorbital and cranium; body fairly heavily pigmented with ventral side comparatively lighter in color; chromatophores concentrated at posterior end of dorsal and anal fins.[4] Coloration in life at 68.8 mm, overall dorsal surface royal blue marked alternately with seven vertical bands of light blue from head to caudal fin; bands not uniform in width and do not become silver until ventral-most one-fifth of lateral aspect reached; first band located behind head and last band reached from midway on caudal peduncle onto caudal fin; lower edge of anal and posterior edge of dorsal hyaline; distal fourth of premaxillary white and extreme tip of mandible colorless; dorsal fin dark blue with light blue areas corresponding to bars on body; dark blue line running obliquely from gape through middle of eye and across three-fourths of opercle.[2]

JUVENILES

Size range described 200–1200 mm.[2]

Scales present until 580 mm; scales when present smaller in median two rows, most smooth as spines now deciduous; [26] first 8–10 rays of dorsal and anal fins elongate and fins become triangular in shape between 200–400 mm; [2] caudal fin widely forked; keel on caudal peduncle formed by 454 mm; dorsal and anal fins separated into two bases by 580 mm; anus opening just anterior to anal fin; lateral line disappears by 580 mm.[26]

Pigmentation: Coloration at 454 mm approximates that of adult, except for fine thread-like transverse black bands in row along center of side of body.[26]

GROWTH

Reported to reach 80 [12]–400 mm [6] by first year.

AGE AND SIZE AT MATURITY

Over 122 cm.[2]

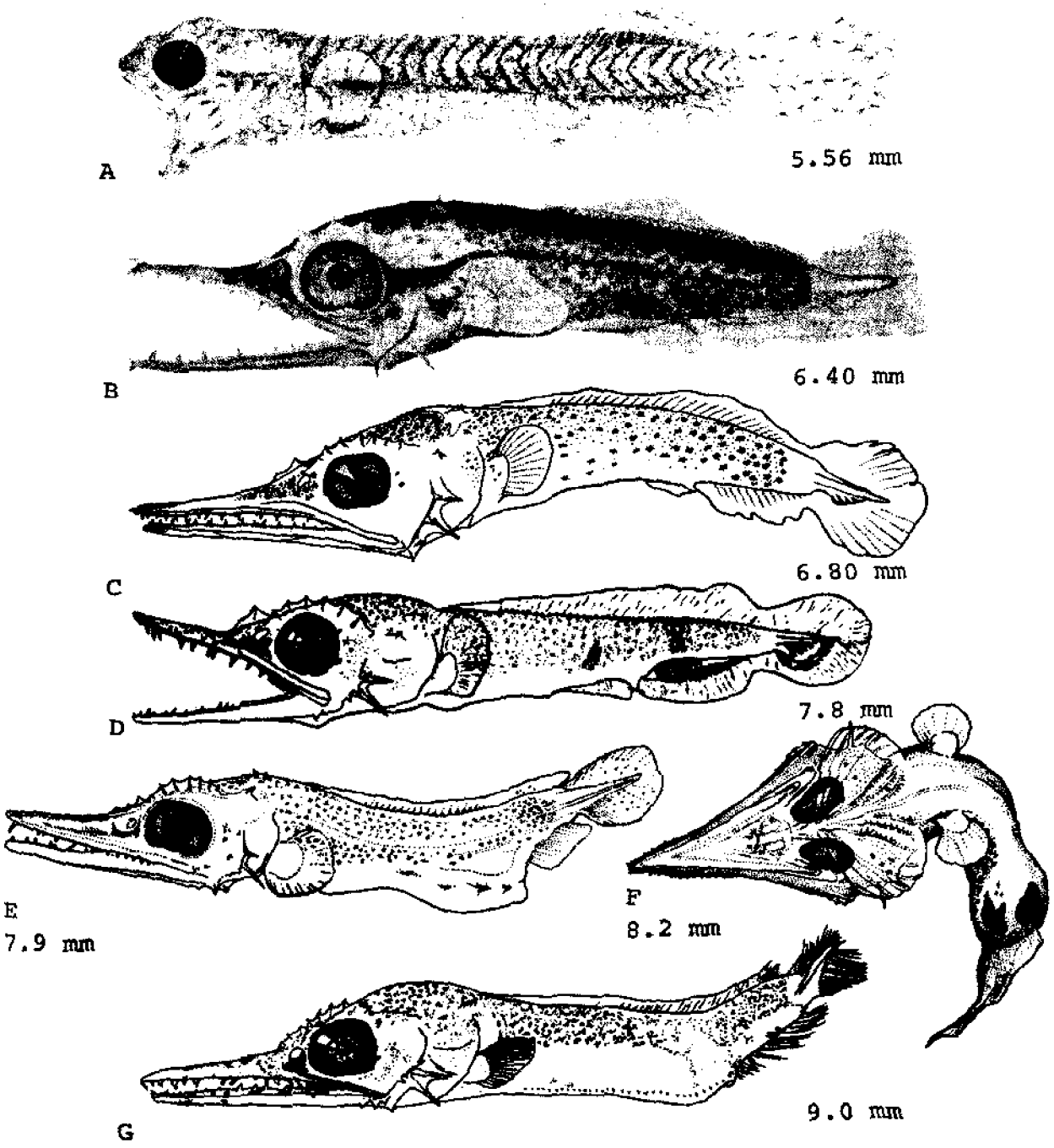

Fig. 115. *Xiphias gladius*, Swordfish. A. Larva, 5.56 mm. B. Larva, 6.40 mm. C. Larva, 6.80 mm. D. Larva, 7.8 mm. E. Larva, 7.9 mm. F. Larva, 8.2 mm, ventral view. G. Larva, 9.0 mm. (*A, Sanzo, L., 1922: fig. 7. B, Sanzo, L., 1930: fig. 1. C, Jones, S., 1962: fig. 2. D, G, Arata, G. F., Jr., 1954: figs. 2, 3. E, F, Tåning, A. V., 1955: fig. 1, one figure reversed.*)

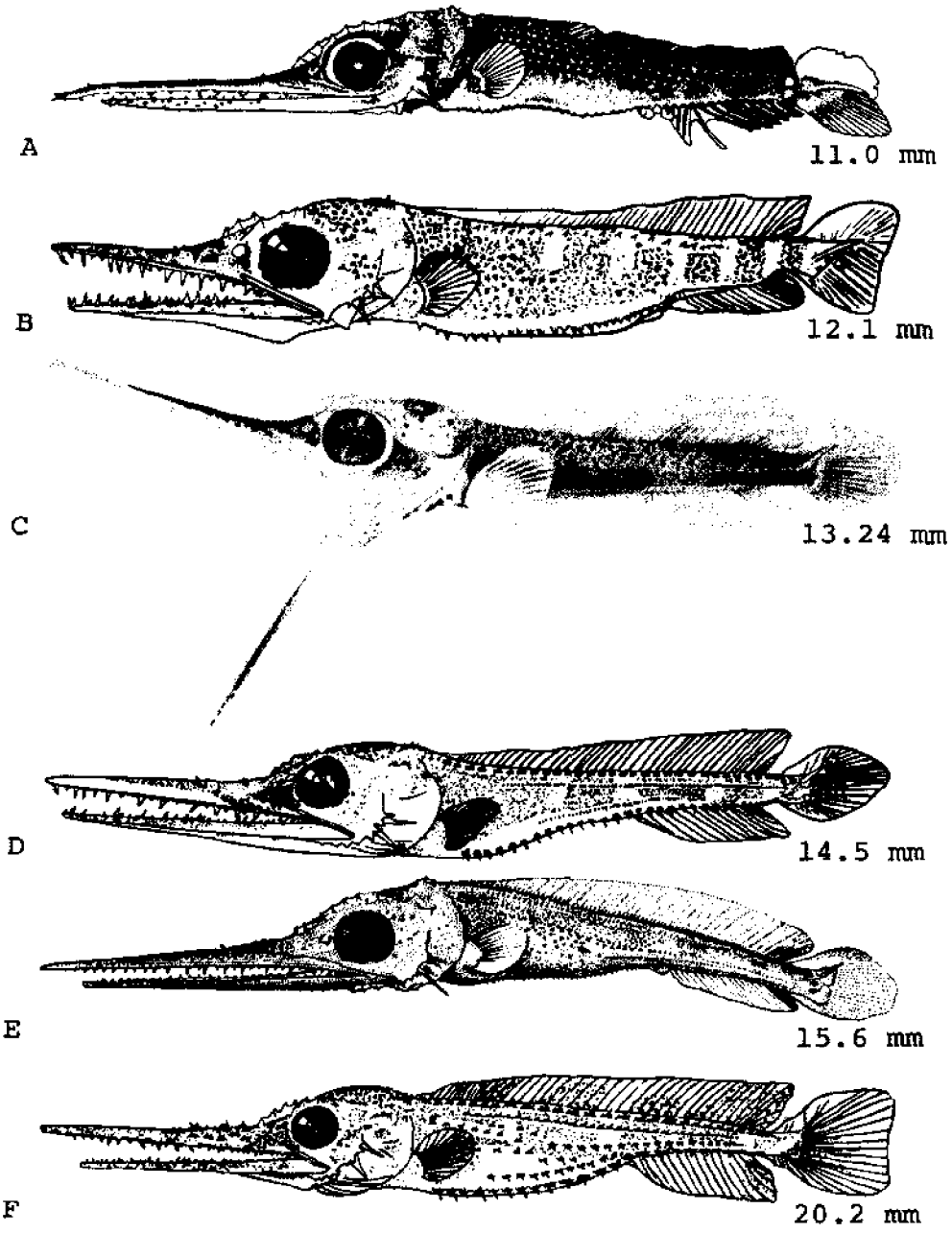

Fig. 116. *Xiphias gladius*, Swordfish. A. Larva, 11.0 mm. B. Larva, 12.1 mm. C. Larva, 13.24 mm. D. Larva, 14.5 mm. E. Larva, 15.6 mm. F. Larva, 20.2 mm. (*A, Yabe, H., 1951: fig. 1. B, D, Arata, G. F., Jr., 1954: figs. 4, 5, 6. C, Sanzo, L., 1922: fig. 7. E, Tåning, A. V., 1955: fig. 1. F*)

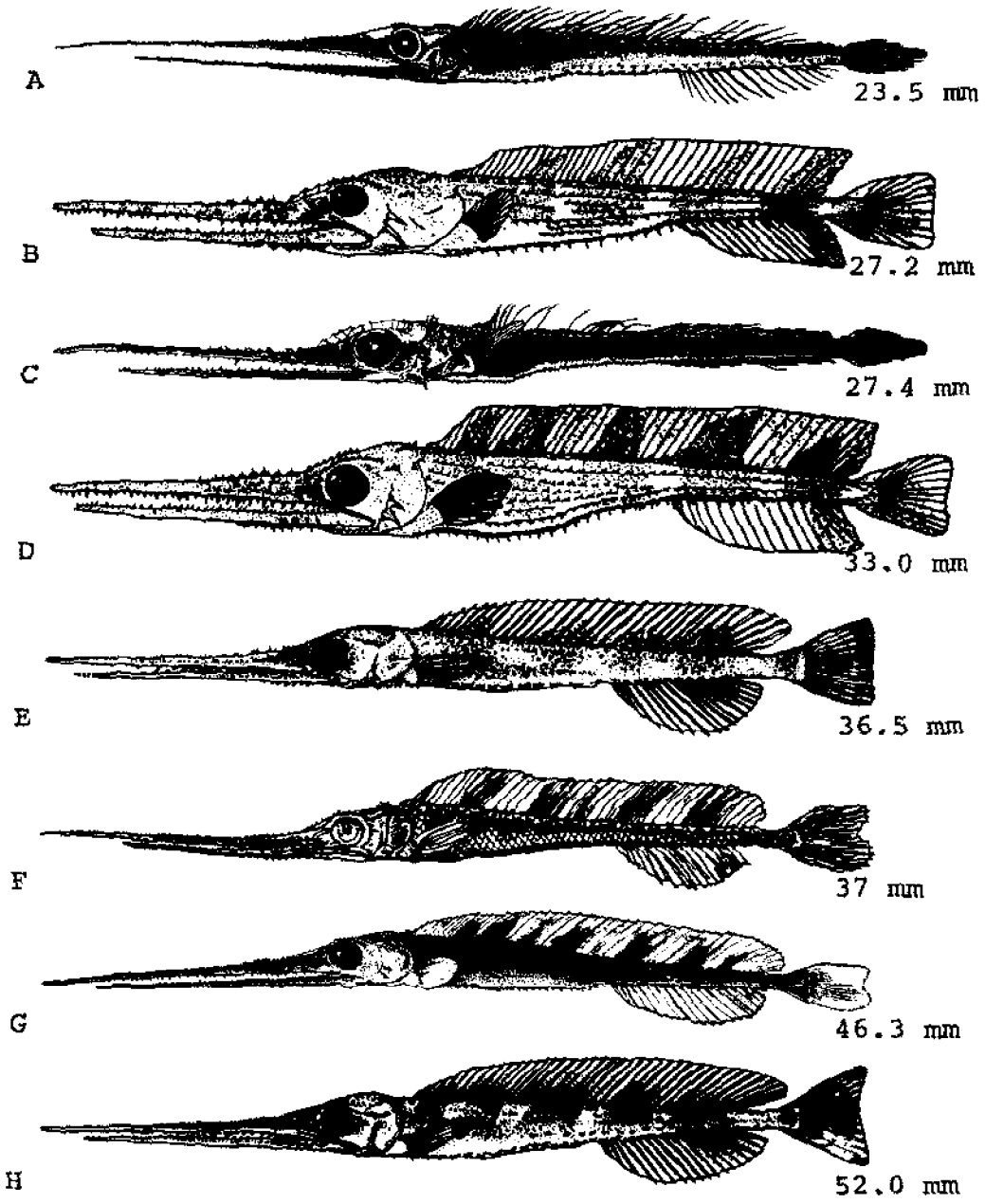

Fig. 117. *Xiphias gladius*, Swordfish. A. Larva, 23.5 mm. B. Larva, 27.2 mm. C. Larva, 27.4 mm. D. Larva, 33.0 mm. E. Larva, 36.5 mm. F. Larva, 37 mm. G. Larva, 46.3 mm. H. Larva, 52.0 mm. (*A, Nakamura, H., et al., 1951: fig. 1. B, D, Arata, G. F., Jr., 1954: figs. 7–8. C, Yabe, H., 1951: fig. 1. E, H, Tibbo, S. N., and L. M. Lauzier, 1969: fig. 6. F, Ehrenbaum, E., 1905: fig. 16. G, Tåning, A. V., 1955: fig. 1.*)

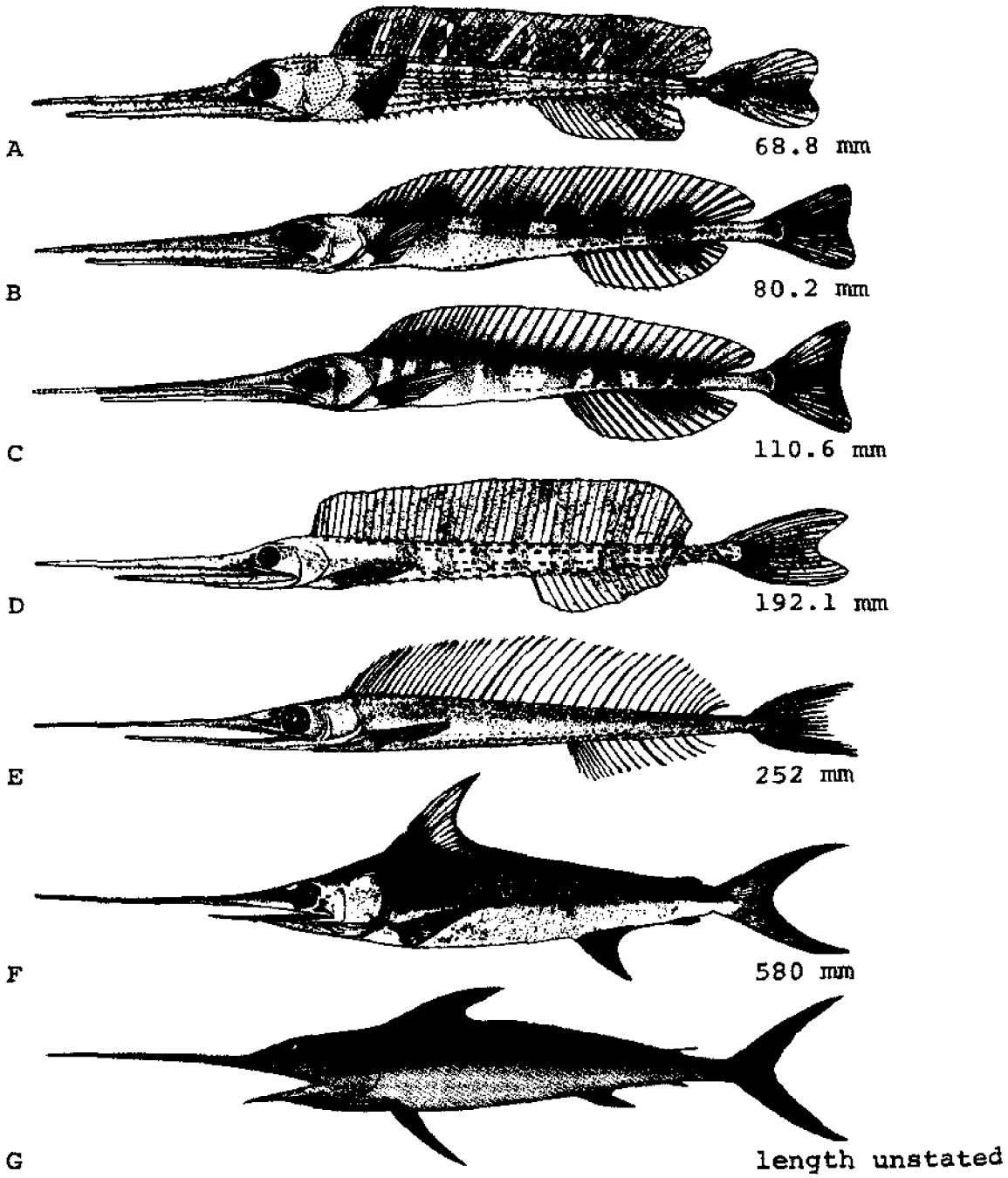

Fig. 118. *Xiphias gladius*, Swordfish. A. Larva, 68.8 mm. B. Larva, 80.2 mm. C. Larva, 110.6 mm. D. Juvenile, 192.1 mm. E. Juvenile, 252 mm. F. Juvenile, 580 mm. G. Juvenile, length unstated. (*A, D, Arata, G. F., Jr., 1954: figs. 9–10. B, C, Tibbo, S. N., and L. M. Lauzier, 1969: fig. 6. E, F, Nakamura, H.*, et al., *1951: figs. 2–3. G, Manday, A. G., 1964: pl. 1.*)

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Evorthodus lyricus
Gobionellus boleosoma
Gobiosoma bosc
Gobiosoma ginsburgi
Gobiosoma robustum
Microgobius gulosus
Microgobius thalassinus

gobies
Gobiidae

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FAMILY GOBIIDAE

The gobies constitute one of the largest groups of fishes, with more than 700 species in the world. They are marine and freshwater fishes of the tropics and temperate regions. Most species have the pelvic fins united to form a sucking disc and separate dorsal fins.

Most gobies lay a few large, elliptical eggs that are attached to shells, stones, coral, or the sides of their burrows. Parental care occurs in many species.

Larvae are small to moderate in size and transparent. The head is round and the mouth usually inferior to oblique. The spinous dorsal is the last fin to form.

Evorthodus lyricus (Girard), Lyre goby

ADULTS

D. VI, 11; A. 12;[2] C. probably 8+7 (RAF); P. 15–17;[4] 30–35 lateral line scales; vertebrae 10+16; teeth in upper jaw uniserial, incisiform in females, conical or caniniform in males; lower jaw teeth, in part, biserial in adults, outer row similar to uppers.[2]

Measurements given as percent SL: Body depth 20; length caudal fin in males 47; length pelvic disc 19–24; eye length 19–27.[2]

Body moderately elongate; mouth inferior; jaws weak; *posterior angle of gape in advance of rear margin of* pupil. Scales cycloid on opercle and predorsal, ctenoid posteriorly. Dorsal fins adjacent, frequently joined by basal membrane; when depressed, longest first dorsal ray of females reaches second dorsal, may reach caudal peduncle in mature males; caudal fin moderate, pointed in large males, narrowly rounded in females; pectoral fin reaches to or slightly beyond anal fin origin; pelvic disc broad. Eye moderate.[2]

Pigmentation: Head and body with varying shades of brown and gray; lateral body markings irregular but usually with some indication of five to six vertical bars and faint median blotches. Caudal fin base with distinctive and characteristic upper and lower dark blotches separated by a median lighter area; dorsal and caudal fin marked with narrow brown lines (vertical, RAF) in females and young males; basal third of dorsal fins lined with brown in large males; first dorsal fin with several median rows of black spots margined with white; two elongate black spots on upper caudal fin and frequently with narrow, pale (rose-pink in life) longitudinal bands on upper and lower caudal fin; anal fin dusky, but lighter in females; pelvic disc dusky and narrowly margined with white in males, pale in females; pectoral fins with *narrow vertical brown bars.*[2]

Maximum size: To about 77 mm.[2]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast and Gulf of Mexico from Chesapeake Bay to Surinam and in the West Indies.[2]

Area distribution: Lower Chesapeake Bay.[3]

Habitat and movements: Adults—frequent muddy estuarine environments, locally abundant in tidal marshes and ponds.[2] Collected at salinities from 13.3 to 31.7 ppt, temperatures from 14.5[6] to 30 C (FDM), and depths less than 3 m.[2]

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Specimens described 25–30 mm TL.[1]

D. VI, 11; A. 12; *scales about 30.*[5]

Head length 4, body depth 5.25, caudal fin length 3.5 in SL; caudal peduncle 2.4; snout length 6, eye 2.9, interorbital 10.6, maxillary 2.65, pelvic disc 1.25 in HL.[5]

Body very elongate, compressed, tapering gradually toward tail; head moderate, somewhat deeper than broad; snout very short; mouth rather large, oblique; lower jaw slightly in advance of upper, without evident lips; maxillary very narrow, reaching to middle of eye. Teeth simple, movable,[5] in single series;[1,5] teeth distinctly notched at lengths above 25–30 mm TL.[1] Interorbital narrow; gill membranes narrowly attached to isthmus. Caudal fin somewhat pointed; pectoral fin moderately large, middle rays longest, about as long as head. Scales large, ctenoid at least posteriorly.[5]

Pigmentation: Coloration *in alcohol* brownish above, somewhat paler below; sides with irregular, large brown blotches, darker than ground color. Base of caudal with two quadrate black spots, one on upper half of base and other on lower half; fins otherwise dusky to colorless.[5]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

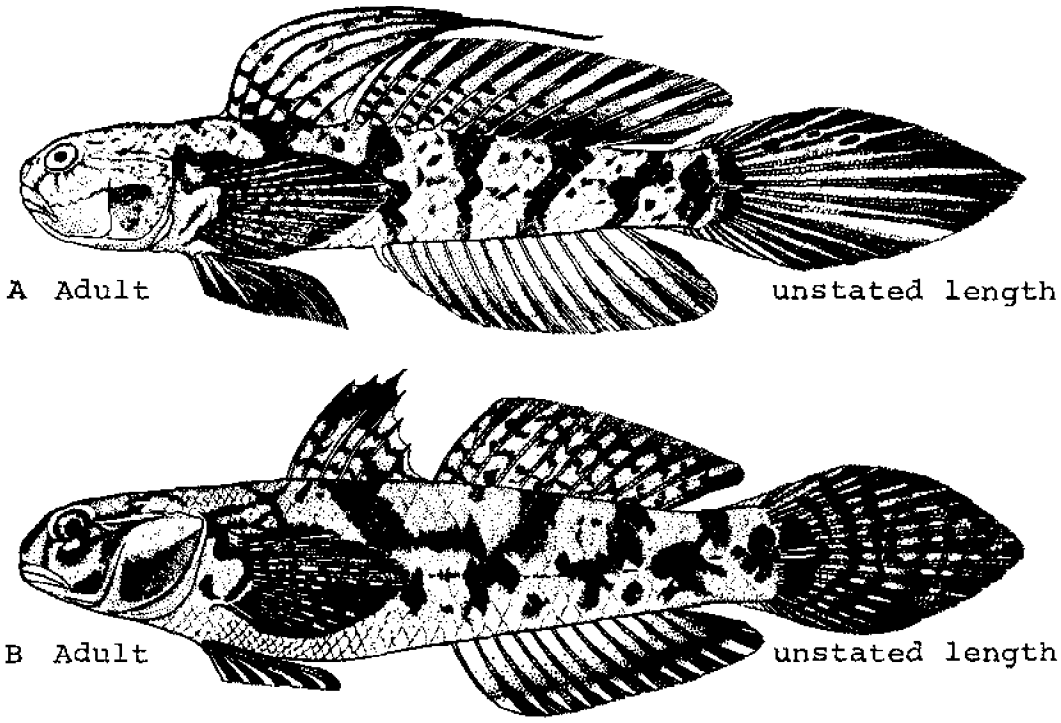

Fig. 119. *Evorthodus lyricus*, Lyre goby. A. Mature male, unstated length. B. Mature female, unstated length. (*A, B, Ginsburg, I., 1935: fig. 1.*)

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Gobionellus boleosoma (Jordan and Gilbert), Darter goby

ADULTS

D. VI, 11;[3,4,6,8] A. 11–13;[8] C. 8+7;[4] P. 16;[6] 29–33 scale rows between base of pectorals and base of caudal fin;[8] 10+16 vertebrae.[4,6] Teeth in several series in each jaw, largest near symphyses; outer teeth somewhat enlarged in females; large males with anterior row of 7 or 8 large, recurved, separated caniniform teeth in outer series of upper jaw and innermost teeth still larger and slightly recurved.[8]

Measurements given as percent SL: Body depth 15–16, caudal fin 28–41, pelvic disc 21–27, pectoral fin 22–27, head length 24–27, eye diameter 7–11.[8]

Body moderately elongate, slender, and compressed; mouth small, placed low, nearly horizontal,[8] lower jaw included;[6,8] maxillary in males which are longer than 40 mm reaches vertical through anterior margin to middle of eye.[8] Scales cycloid on anterior body, larger and

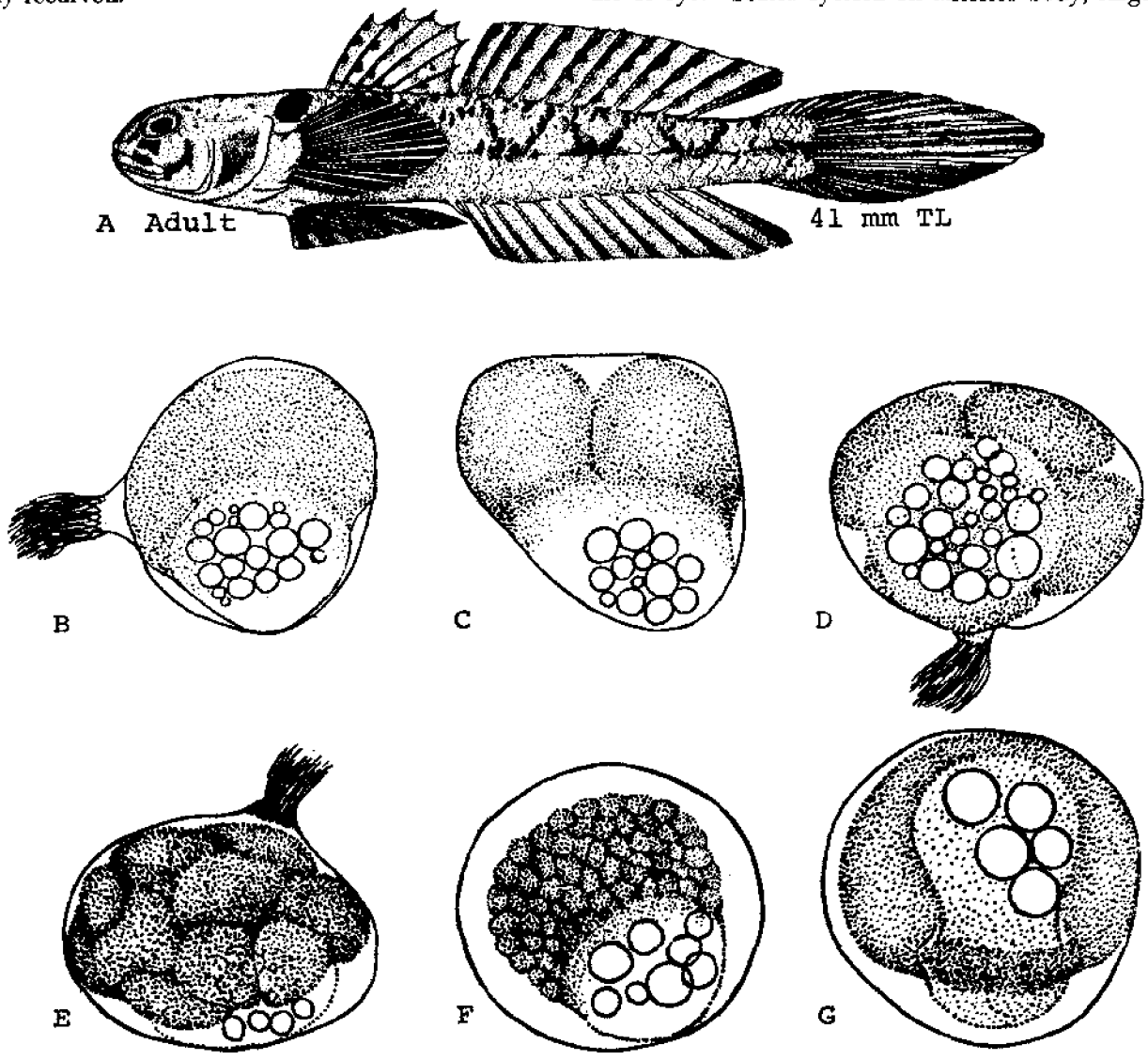

Fig. 120. *Gobionellus boleosoma,* Darter goby. A. Adult male, 41 mm TL. B. Egg with undivided blastodisc. C. Egg with 2-cell blastoderm. D. Egg with 4-cell blastoderm. E. Egg with 16-cell blastoderm. F. Egg with blastoderm of many cells. G. Egg with blastoderm growing around yolk shortly before closing. *(A, Ginsburg, I., 1932: fig. 4. B-G, Hildebrand, S. F., and L. E. Cable, 1938: figs. 56–61.)*

finely ctenoid posteriad; predorsal naked, rarely with 1 or 2 embedded scales,[6] chest and midline of belly naked.[6] Caudal fin centrally elongate; [3] pelvic disc reaches anus or anal origin in males, shorter in females; pectoral fin may reach vertical through anal fin origin in large males; dorsal spines not exceptionally prolonged in either sex, reaching interspace between third and fourth dorsal fin rays in large males and may fail to reach second dorsal fin in females.[6]

Pigmentation: Color predominantly light tan, occasionally dusky in largest males; lateral body usually with 4 or 5 narrow longitudinal brown spots or bars more or less evenly spaced along midline, those under second dorsal fin with diffuse bars diverging upward so as to form a distinct V; V-shaped markings most distinct in larger fish; upper body variously flecked with brown and with small scattered melanophores below; [6] large brown spot above upper opercular angle; [3,6] small brown spot or V-shaped mark on midline in advance of first dorsal fin; diffuse dusky bar between eye and upper lip. Dorsal and caudal fins streaked with small brown spots on pale to dusky background; large males frequently with pale band and streak on caudal fin; anal fin dusky in larger fish; pectoral and pelvic fins usually pale in females, dusky in large males.[6]

Maximum size: To 62 mm TL.[6]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast, Gulf of Mexico, and Caribbean [6,8] from Delaware Bay [5] to Brazil.[6,8]

Area distribution: Delaware Bay [5] and lower Chesapeake Bay.[7]

Habitat and movements: Adults—shallow water over muddy bottoms [1] in lower estuaries and sounds. Recorded from salinities between 0.3 and 34 ppt and temperatures betwen 21.4 [8]–30 C (FDM).

Larvae—no information.

Juveniles—no information.

SPAWNING

Recorded as spawning inside Beaufort Harbor to 20 km offshore. Spawns from mid-March [8] to July or August.[1,8]

EGGS

Ovarian eggs: Each ovum attached to ovary by slender peduncle composed of very minute threads inserted in egg membrane [2] (possibly an artifact of rupturing the egg membranes by handling, EBB).

Fertilized eggs: Demersal; [1,3] attached to submerged objects; [5] shape irregular; [1,2] characterized by enormous amount of protoplasm and little yolk; [2] yellow, highly translucent; [1,2] 0.3 mm in diameter; [1,2,3] egg membrane thin and delicate; [1,2] slightly adhesive; [2] attached by threads; [1] yolk transparent.[2]

EGG DEVELOPMENT

Blastodisc forms immediately upon fertilization and covers half yolk surface. First cleavage occurs 30 minutes after fertilization. Early blastoderm usually spreads widely over surface of yolk, with the blastomeres arranged in a single series. Until 16-cell stage blastoderm cells remain in single series and yolk sinks deeply into concavity of its inner surface. After 16-cell stage cells become heaped up on sides of yolk. Further cleavage produces dome-shaped blastoderm. Blastoderm thickest at periphery. Blastopore closes 6 hours after fertilization. At this time blastoderm thickens distinctly, first anteriad from blastopore. No distinct embryonic shield forms. Anterior end of this region becomes distinctly broader than posterior. Embryo well formed at 11 hours after fertilization, with 10–12 myomeres. At 12 hours after fertilization, embryo makes almost complete turn within egg membrane. Embryo unpigmented, highly transparent. At hatching, embryo marked by small areas of delicate pigment and makes more than one complete turn within egg membrane.[1,2]

Incubation period 18 hours at unstated laboratory temperature.[1,2]

YOLK-SAC LARVAE

Larvae 1.2 mm long at hatching.[1,2]

Finfold continuous and as deep as or greater than depth of body posterior to vent. Anus located little less than half length of body from anterior end.[2]

Pigmentation: Yolk-sac larvae remain highly transparent but are marked by small areas of delicate yellow pigment on dorsum of head, just over vent, and in a vertical band approximately half distance from vent to tail tip.[2]

LARVAE

Specimens described 2.5–10 mm long.

At 2.5 mm, body slender, caudal portion especially slender and notably longer than remainder of body; body deeper by 7.5 mm; head rather broad, width as great as depth; mouth almost vertical in smallest larvae and close to large protruding eyes, becoming less vertical at 3.5 mm. Dorsal and anal fin bases and rayless pectoral fins appear at 3.5 mm. Dorsal and anal fins begin ray development and caudal fin fully formed at 5.0 mm. Soft dorsal and anal fins fully developed, pectoral rays and pelvic fin bases becoming evident at 7.5 mm. All fins except spinous dorsal fully developed at 10 mm. Noto-

chord flexion occurs by 5.0 mm. Swim bladder plainly visible at 2.5 mm.[1]

Pigmentation: Dark peritoneum appears above swim bladder at 2.5 mm. By 3.5 mm, some very small darker spots along ventral outline of body and tail; black peritoneum over swim bladder crescent-shaped. By 5.0 mm, two or three short, narrow, dark lines on chest; very small dark spot at vent and slightly larger one near end of anal base. Coloration remains the same through 10 mm.[1]

JUVENILES

Specimens described 11–22 mm long.

Head slightly broader and somewhat depressed; mouth small, oblique, terminal; maxilla reaches anterior margin of eye.[1]

Pigmentation: Black crescent over swim bladder indistinct by 13 mm. Some dark markings on head visible by 11–12 mm, including indications of a dark oblique bar between eye and mouth; scattered dark spots on dor-

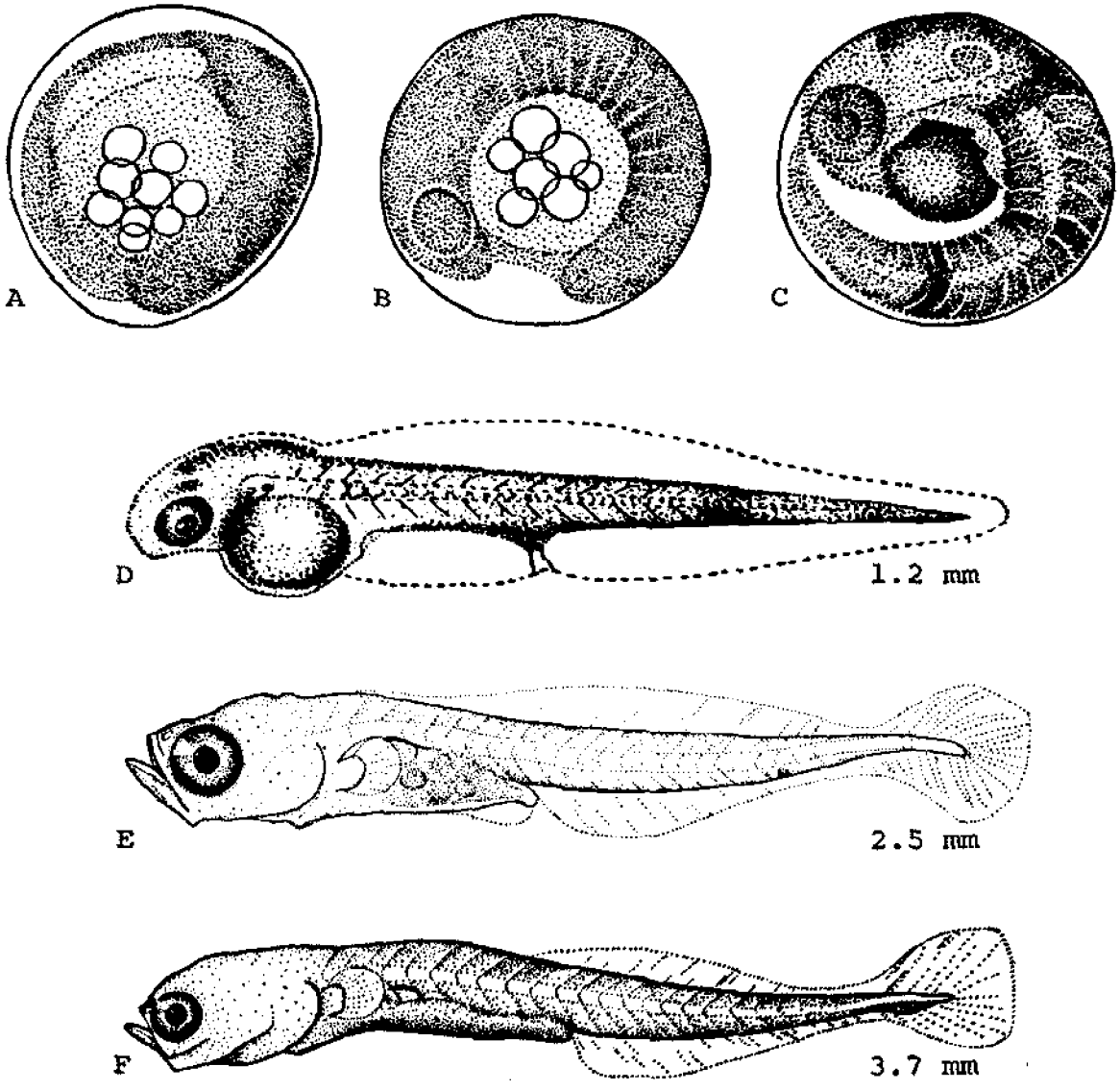

Fig. 121. *Gobionellus boleosoma*, Darter goby. A. Egg showing an early stage in the differentiation of the embryo. B. Egg with well differentiated embryo. C. Egg with large embryo, just before hatching. D. Yolk-sac larva, newly hatched, 1.2 mm. E. Larva, 2.5 mm. F. Larva, 3.7 mm. (*A-F, Hildebrand, S. F., and L. E. Cable, 1938: figs. 62–67.*)

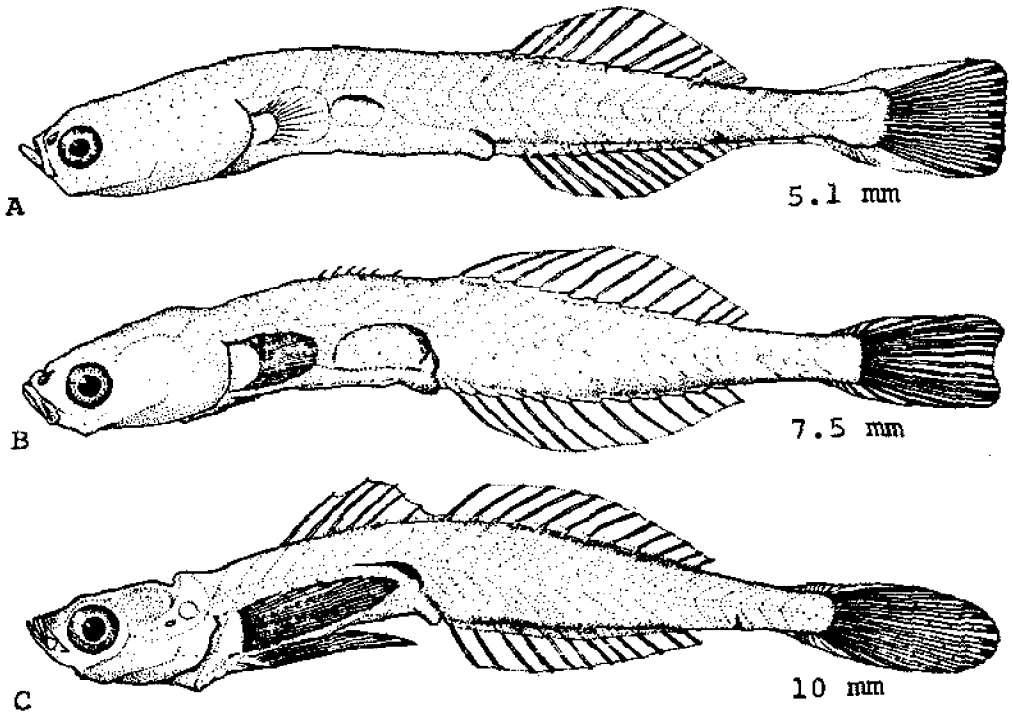

Fig. 122. *Gobionellus boleosoma*, Darter goby. A. Larva, 5.1 mm. B. Larva, 7.5 mm. C. Juvenile, 10 mm. (*A-C, Hildebrand, S. F., and L. E. Cable, 1938: figs. 68–70.*)

sum and along ventral edge of abdomen, a more definite series of black spots on base of anal fin, indication of wavy dusky bars on caudal fin.[1]

GROWTH

No information.

AGE AND SIZE AT MATURITY

Gravid females as small as 18 mm,[6] maturity definitely reached by 25–30 mm.[1]

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Gobiosoma bosc (Lacépède), Naked goby

ADULTS

D. VI to VIII (usually VII),[11] 13 (rarely 12 or 14);[2,4] A. 10–12 (usually 11);[11] C. 8+7;[9] P. 16–19;[11] vertebrae 11+16;[9] teeth pointed, in bands on each jaw, with some of outer teeth enlarged; gill openings mostly lateral, the membranes joined to isthmus;[4] opercular pores 2, preopercular pores 3.[11]

Depth 3.95–4.8,[2,4] head 3.15–3.5, pectoral fin 3.25–4.7 in SL; snout length 3.45–4.25, eye 3.25–4.67, upper jaw 2.25–2.4, pelvic disc 1.65–2.4 in head.[4]

Body robust;[2,4] head depressed, broader than deep; snout short, tapering; mouth terminal;[4] maxillary reaching opposite middle of eye.[2,4] Scales wanting. First dorsal fin consisting of slender spines, the margin convex; second dorsal and anal fins similarly shaped and oppo-

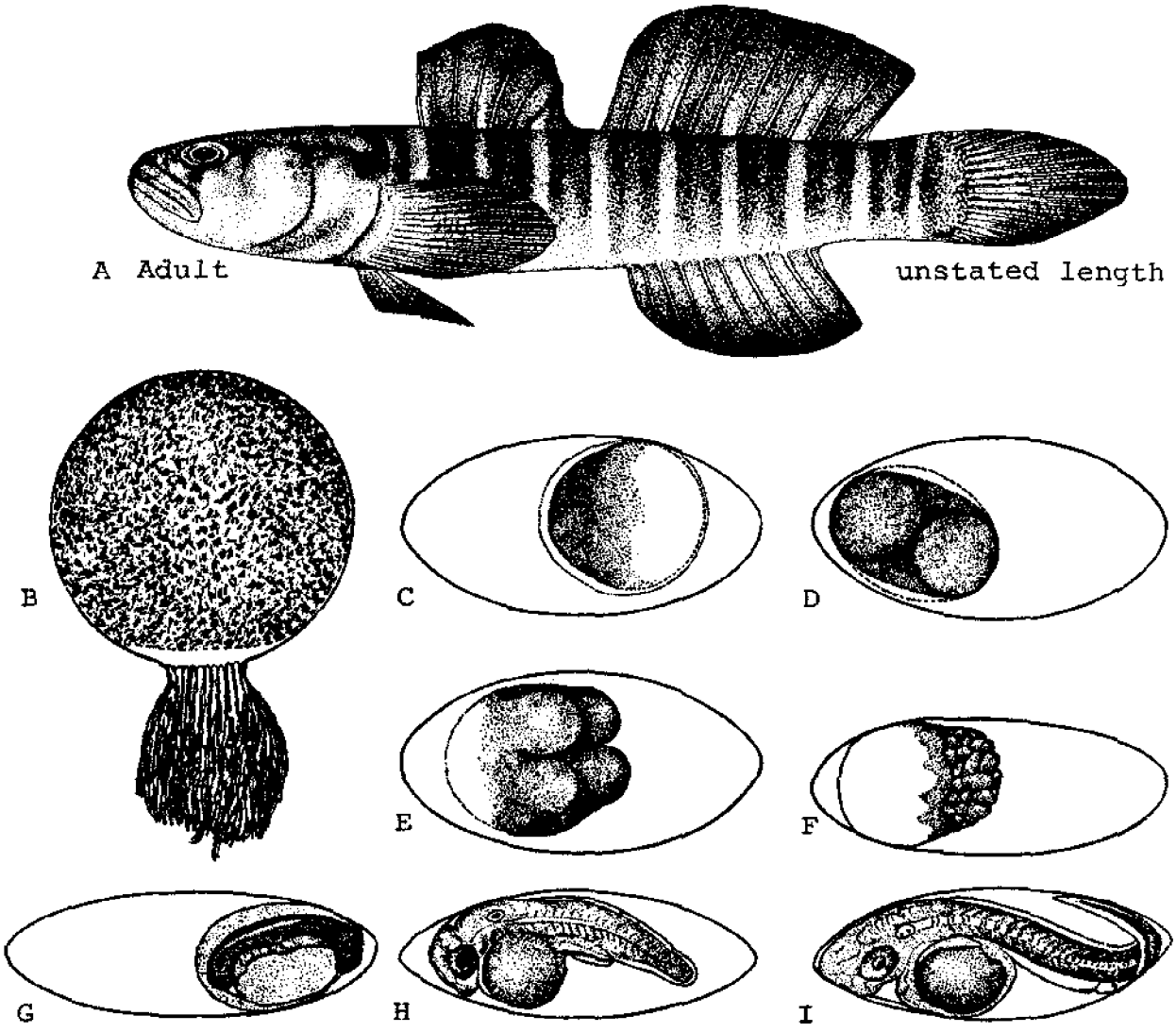

Fig. 123. *Gobiosoma bosc*, Naked goby. A. Adult, unstated length. B. Mature unfertilized egg. C. Egg with fully developed blastodisc. D. Egg with 2-cell blastoderm. E. Egg with 4-cell blastoderm. F. Egg with blastoderm of many cells. G. Egg with recently differentiated embryo. H. Egg with well formed embryo. I. Egg with large embryo. (*A, Fowler, H. W., 1906: pl. 111. B-I, Hildebrand, S. F., and L. E. Cable, 1938: figs. 32–39, after Kuntz, A., 1916.*)

site, the rays of the dorsal fin reaching to or beyond base of caudal procurrent rays; caudal fin short, round, shorter than head;[4] pelvic disc short;[2,4] pectoral fins broad, shorter than head.[4]

Pigmentation: Color in life greenish to dusky above, pale underneath, nape and sides with very narrow pale crossbars. Pectoral fin mostly greenish; other fins blackish, but with caudal fin slightly lighter than dorsal fins. Coloration highly variable. Males generally darker than females.[4]

Maximum size: To about 64 mm in length.[4]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast from Long Island Sound[21] to Cape Canaveral, Florida; Gulf of Mexico from Pearl Bay, Florida[11] to Campeche, Mexico;[21] absent from the Florida Keys.[11]

Area distribution: Throughout the Chesapeake Bight;[4] abundant in Chesapeake Bay and its tributary creeks and rivers.[7]

Habitat and movements: Adults—on oyster bars[6,7] and shallow grass flats;[4,7] moving to deeper channel edges and channels of higher salinity in the winter.[6] Found in salinities which range from 0.04–45 ppt[21] and temperatures from 13–33.2 C;[10] found as shallow as 10 cm (FDM).

Larvae—found upriver,[7] or at least in waters less than 18.5 ppt[5] and in waters between 22–29 C. Typically at mid-depth and near bottom during the day and nearer surface at night.[7]

Juveniles—no information.

SPAWNING

Spawning takes place in clam and oyster shells,[8] in estuarine waters; during May through mid-November; and at temperatures between 18.9 and 29 C in upper Chesapeake Bay.[2]

EGGS

Unfertilized egg: About 0.5 mm in diameter, spherical, yellow and opaque.[8]

Fertilized egg: Demersal;[2] elliptical with the major axis 1.2[2,5]–1.4[5] mm, and the minor axis 0.5[2,5]–0.7.[5] Egg attached by fibrous bundles which form an attachment disc; yolk opposite the pole of attachment.[2]

EGG DEVELOPMENT

The fully differentiated blastodisc is thick and covers a large area of the yolk surface. After the second cleavage division is completed, the first four blastomeres stand out as more or less rounded elevations. As cleavage advances the blastomeres exhibit a greater degree of irregularity than normally observed. At 48 hours after fertilization the embryo is well formed and has 6–8 somites. At 60 hours the length of the embryo exceeds three-fourths the length of the egg capsule. Yolk mass remains opaque, but embryo highly transparent. At hatching a few pigment spots appear near vent.[5]

The egg hatches in 4–5 days at 24–28 C.[3]

YOLK-SAC LARVAE

Reported to hatch at 2.0[7]–2.6[12] mm.

Specimens described 2.0[2,5,7]–3.2 mm TL. Total myomeres 26, 13 preanal and 13 postanal. Head blunt; snout abbreviated. Yolk mass opaque at hatching.[2] Dorsal and ventral finfold depth less than half body length at hatching.[5] Swim bladder conspicuous at hatching.[2,5]

Pigmentation: Color transparent; few melanophores along ventral midline of abdomen, in region of vent, and along ventral half of tail; network of melanophores over dorsal surface of swim bladder in earliest larvae.[2]

LARVAE

Yolk absorbed by 3 mm[6] and fins complete by 10[2]–15 mm.[7]

Body slender and compressed.[2,3] Head elongate;[2] snout pointed by 7.5 mm.[3] Soft dorsal fin rays formed by 5.0[3]–6.8 mm; spinous dorsal forming by 6.8 mm, fin complete by 10 mm.[2] Anal fin rays developed by 5.0[3]–6.8[2] mm. Caudal fin rays developed by 5.0[3]–6.8[2] mm. Pectoral fins without rays at 5.0 mm,[3] well developed by 10 mm.[5] Pelvic fin buds evident at 6.8[2,8]–7.5[3] mm, completed by 10 mm.[2,5] Finfold no longer continuous and notochord flexion completed by 4.0 mm.[3]

Pigmentation: Color remains transparent,[5] however, at 4.0 mm few dark chromatophores on ventral midline and large dark spot near end of anal base. By 7.5 mm two dark, short lines on ventral midline under head and chest, ventral spots still present with last one largest and vertically elongate.[3]

JUVENILES

All fins complete development by 10[2]–15[2,12] mm.

Body more robust, eyes more superior.[2]

Pigmentation: By 10 mm indefinite crossbars present on upper sides of head and back; oblique bar reaches from eye to mouth and another bar occupies base of caudal fin.[3]

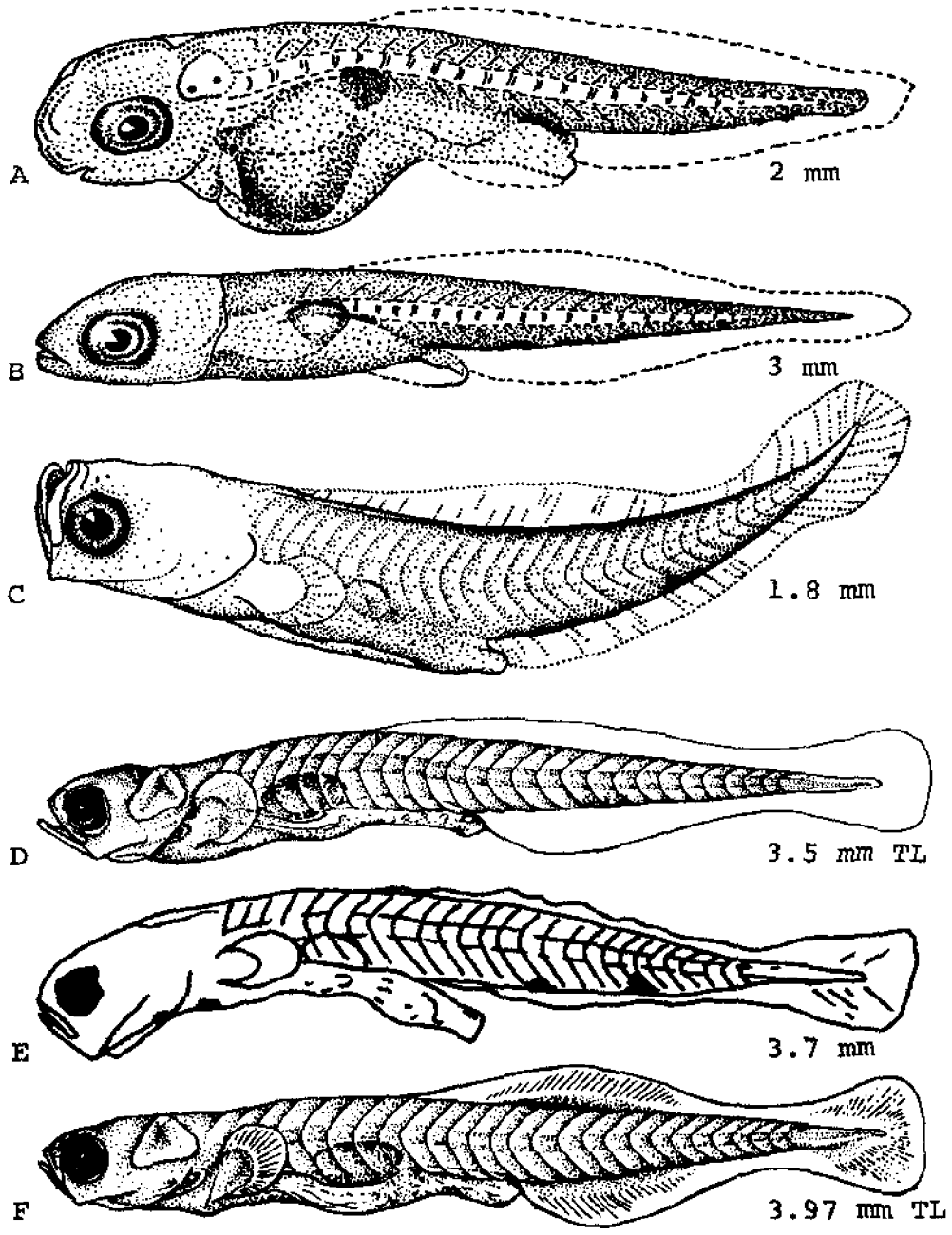

Fig. 124. *Gobiosoma bosc*, Naked goby. A. Yolk-sac larva, 2 mm. B. Larva, 3 mm. C. Larva, 1.8 mm. D. Larva, 3.5 mm TL. E. Larva, 3.7 mm. F. Larva, 3.97 mm TL. (A-C, *Hildebrand, S. F., and L. E. Cable, 1938: figs. 40–42. D, F, Lippson, A. J., and R. L. Moran, 1974: 247. E, Richardson, S. L., and E. B. Joseph, 1975: fig. 1.)*

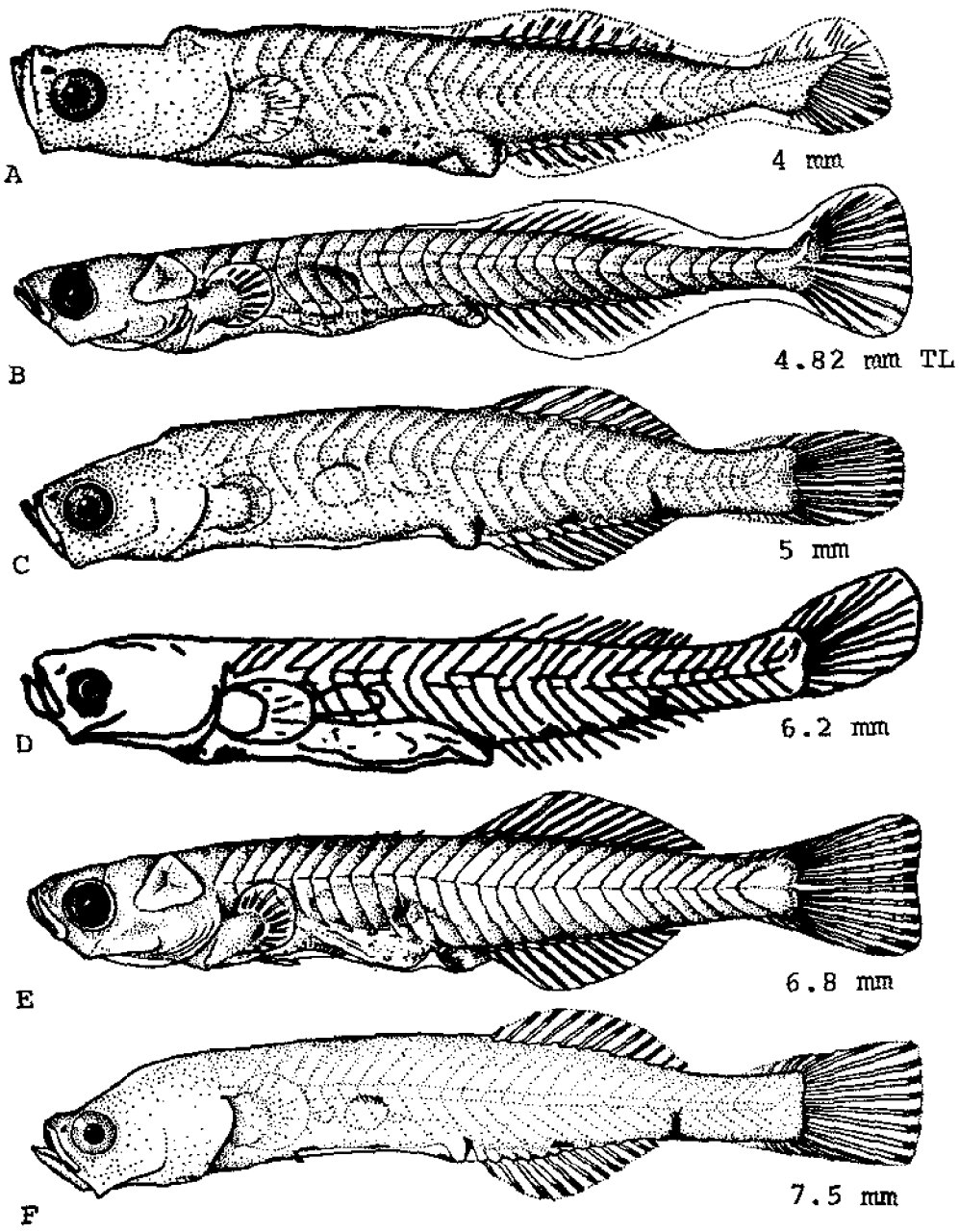

Fig. 125. *Gobiosoma bosc*, Naked goby. A. Larva, 4 mm. B. Larva, 4.82 mm TL. C. Larva, 5 mm. D. Larva, 6.2 mm. E. Larva, 6.8 mm TL. F. Larva, 7.5 mm. (*A, C, F, Hildebrand, S. F., and L. E. Cable, 1938: figs. 43–45. C, E, Lippson, A. J., and R. L. Moran, 1974: 247. D, Richardson, S. L., and E. B. Joseph, 1975: fig. 1.*)

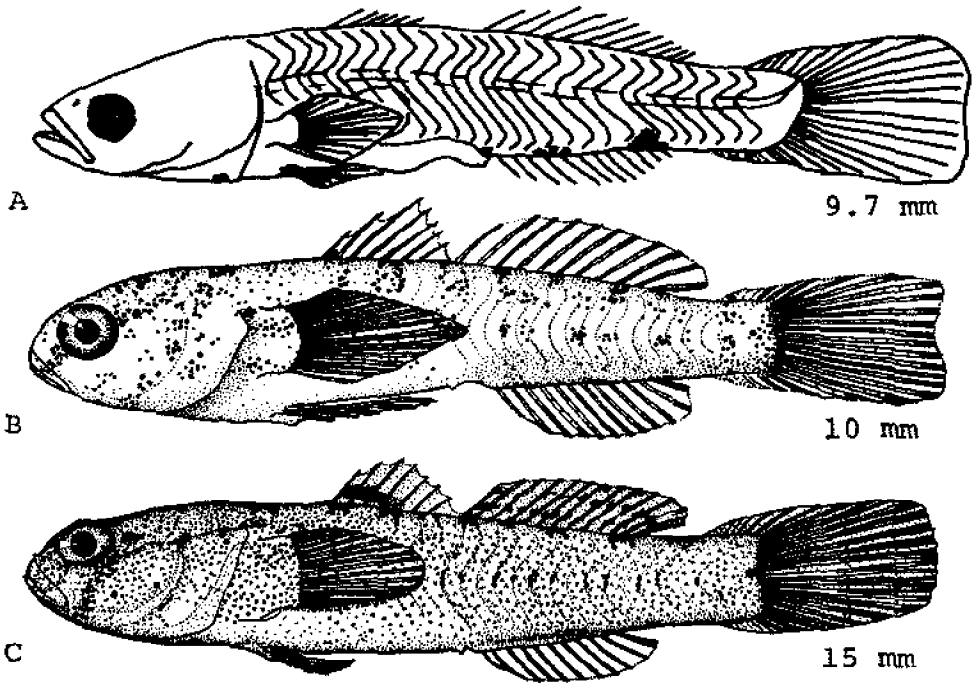

Fig. 126. *Gobiosoma bosc*, Naked goby. A. Larva, 9.7 mm. B. Larva, 10 mm. C. Juvenile, 15 mm. *(A, Richardson, S. L., and E. B. Joseph, 1975: fig. 1. B, C, Hildebrand, S. F., and L. E. Cable, 1938: figs. 46, 48.)*

GROWTH

Juveniles reach 18 mm by August of their first year.[3]

AGE AND SIZE AT MATURITY

Possibly mature by first summer (a few months after hatching), but unlikely to be reached until second summer. Smallest mature female 23 mm, usually 25–30 mm.[3]

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Gobiosoma ginsburgi Hildebrand and Schroeder, Seaboard goby

ADULTS

D. VII,[4,5,11] 11–13 [5] (usually 12 [10]); A. 10 [2]–12 (usually 11); [10] C. 8+7; [5] P. 17–20; [2] distinguished from G. *bosc* by its 2 basicaudal scales; [10] vertebrae 11+16; [4] teeth in jaws pointed, in bands, some outer teeth enlarged; [5] opercular pores 2, preopercular pores 3.[10]

Measurements given as percent SL: Caudal fin length 22–29; predorsal 32–40; body depth 12–18; head length 26–34; pelvic disc length 18–25; pelvic-anal distance 24–34. Measurements given as percent HL: Postorbital length 53–62, snout length 18–23; eye diameter 17–29.[2]

Body rather slender; head somewhat depressed, broader than deep; snout short, tapering; mouth terminal, slightly oblique; maxilla reaching little beyond middle of eye. Dorsal fins separate, first rather short; first dorsal with slender spines and convex margin; second dorsal and anal fins similar and opposite; rays of dorsal fin barely reaching caudal procurrent rays; caudal fin moderate, round, about as long as head; pelvic disc reaching about two-thirds distance to vent; pectoral fin moderately broad, equal or very slightly shorter than head. Interorbital about width of pupil; gill membrane joined to isthmus; pores present in series on cheeks.[9]

Pigmentation: Color brownish; body with about six or seven ill-defined whitish crossbars; lateral line usually with longitudinally elongated dark spots; a few similar spots on median line of back in advance of dorsal fin; lower surface of head spotted with black; a black bar on mandible. Pelvic disc dusky, at least at base; other fins pale to slightly dusky; dorsal and caudal fins sometimes with indications of dark spots or bars; anal fin with dark margin.[5]

Maximum size: To about 53 mm.[3]

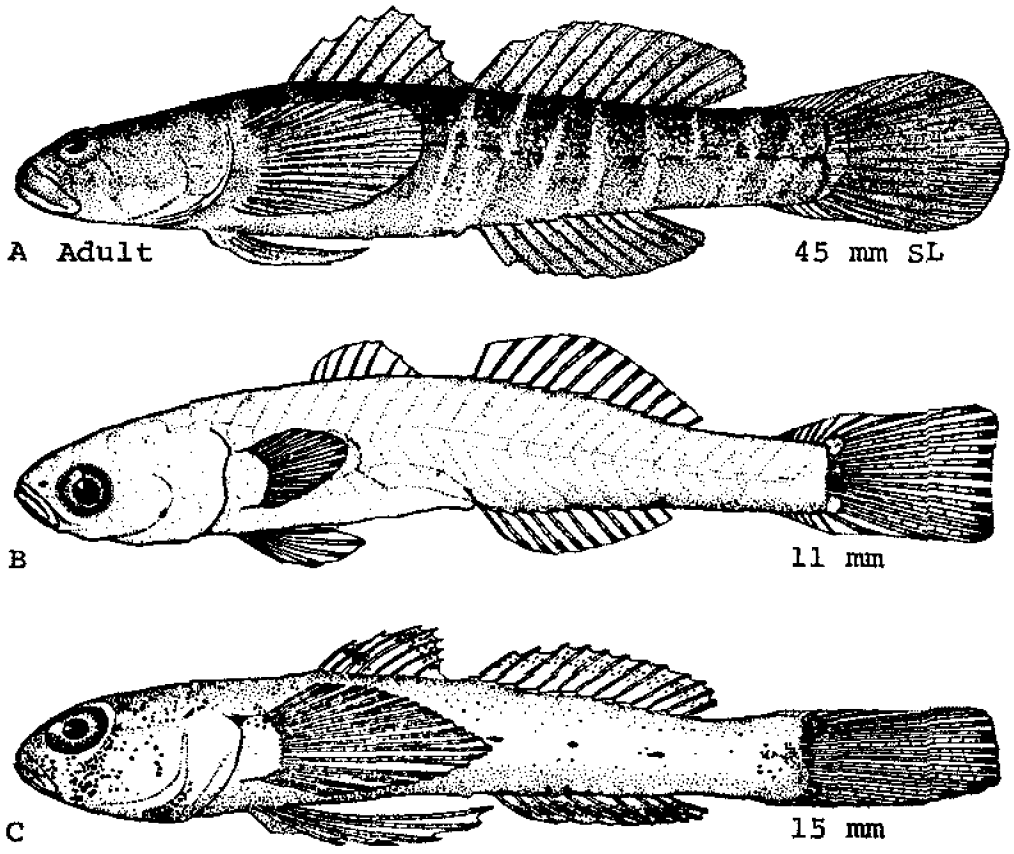

Fig. 127. *Gobiosoma ginsburgi*, Seaboard goby. A. Adult, holotype, 45 mm SL. B. Juvenile, 11 mm. C. Juvenile, 15 mm. (*A, Hildebrand, S. F., and W. C. Schroeder, 1928: fig. 195. B-C, Hildebrand, S. F., and L. E. Cable, 1938: figs. 47, 49.*)

DISTRIBUTION AND ECOLOGY

Range: Wareham River, Massachusetts to Jekyll Island, Georgia.[2]

Area distribution: Chesapeake Bight [2] including the entire Chesapeake Bay.[1]

Habitat and movements: Adults—associated with deeper flats [1,6] and oyster reefs from spring through fall, channels [6] in higher salinity [1,6] during winter. Found in salinities of 15–31 ppt [1] and temperatures between 22–25 C.[3]

Larvae—no information.

Juveniles—no information.

SPAWNING

Larvae present from June through December in Chesapeake Bay.[9]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Conspicuous horizontally elongate pigment spot, located halfway between the vent and base of the caudal fin.[8]

JUVENILES

Specimens described 10–15 mm.

First dorsal fin present by 10 mm, but spines weak and slender; pelvics developed as disc by 10 mm. Two scales at base of caudal fin present at 10 mm.[7]

Pigmentation: Posteriormost of the two short dark lines on the midline of chest now situated at base of pelvic disc. Dark-shaped marks along base of anal fin and on ventral outline of body.[7]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Gobiosoma robustum Ginsburg, Code goby

ADULTS

D. VI to VIII (usually VII),[3] 11[2,4]–14 (usually 13);[8] A. 9[4]–12[2] (usually 11[9]); C. 8+7;[2] P. 15[4]–18;[9] vertebrae 11+16;[2,6] opercular pores 0, preopercular pores 3.[9]

Measurements given as percent SL: Caudal fin length 24–30, predorsal 34–44,[4] body depth 16–23, head length 28–36, pelvic disc length 18–28, pelvic-anal distance 24–34.[4,6] Measurements given as percent HL: Postorbital 49–60, snout 16–23, eye diameter 18–30.[4]

Body robust; short and chunky in lateral aspect; deep, moderately compressed posteriad; head not exceptionally broadened; maxilla reaches vertical through posterior margin of pupil. Body naked. Caudal fin rounded; pelvic disc usually reaches anus or anal fin origin; pectoral fin rounded, reaches vertical through origin of soft dorsal fin.[6]

Pigmentation: Color pale tan to dusky; body markings variable; usually with 10–12 irregular, interrupted, narrow vertical bars which may be well pigmented or practically invisible against pale ground color; usually with a median series of short, melanistic dots and dashes; predorsal and head variously marked with irregular network of faint streaks and lines, sometimes pale; ventrally pale, streaked with melanophores. Fins variously dusky, sometimes streaked darker; pelvic disc usually dark.[6]

Maximum size: Males to 34 mm;[8] females to 45 mm.[6]

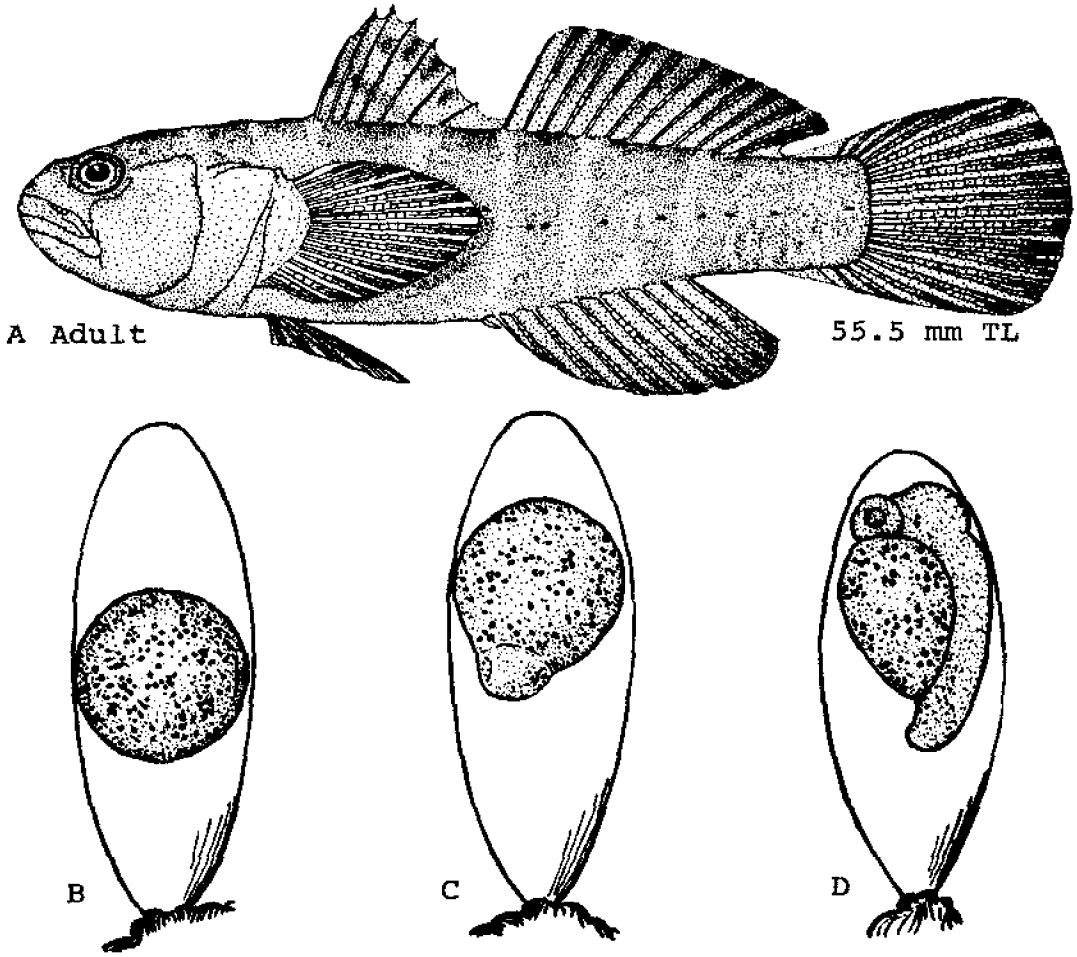

Fig. 128. *Gobiosoma robustum*, Code goby. A. Adult, holotype, 55.5 mm TL. B. Early egg. C. Egg 22 1/4 hours older than B. D. Egg 48 1/2 hours older than B, with tail reaching well beyond yolk. (A, Ginsburg, I., 1933: *fig. 1. B-D, Breder, C. M., Jr., 1942: fig. 1, A-C.*)

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast and Gulf of Mexico [6,9] from Patuxent River, Maryland [1] to Yucatan, Mexico.[6]

Area distribution: Recorded from Green Holly Bar, Patuxent River, Maryland.[1]

Habitat and movements: Adults—recorded as common among mangrove roots and along sandy beaches,[8] flats covered with vegetation,[7] and in bays; [8] also in beach ponds in Texas (FDM). Usually at salinities between 7–37.6 ppt at Cedar Key, Florida, temperatures between 10 [5]–34.8 C,[4] and at depths of a few centimeters [7] to about 6 m.[8]

Larvae—no information.

Juveniles—no information.

SPAWNING

Occurs from early spring to late summer and again from late summer to early fall in Tampa Bay, Florida.[7] Young appear from July through September or October in Mississippi.[4]

EGGS

Location: Attached to shells or sponges.[8]

Unfertilized eggs: Transparent until diameter of .102–.136 mm is attained, then become more opaque; .476–.782 mm when ripe.[7]

Fertilized eggs: Elliptical, opaque, slightly yellowish with clear envelope; length varying from 1.30–1.40 mm in June to 1.55–1.70 mm in March; width varying from 0.50 mm in June to 0.60–0.70 mm in March; [8] attached by filaments attached to chorion at germinal end; [7,8] yolk opaque, slightly yellowish; [8] oil droplets widely variable,[7] scattered over surface of yolk.[8]

EGG DEVELOPMENT

Eggs of unknown age collected on March 14: 22 1/4 hours after collection, head large, prominent; after another 26 1/4 hours, embryo formed; after another 41 1/4 hours, somites visible; after another 27 1/2 hours, heart visible and beating. Observations covered 117 1/4 hours at temperatures fluctuating between 15 5 and 18.5 C. Embryos died before hatching.[6]

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Specimens described 5.6 [7]–8.78 [10] mm SL.

All fin elements present by 5.6–8.5 mm SL.[7]

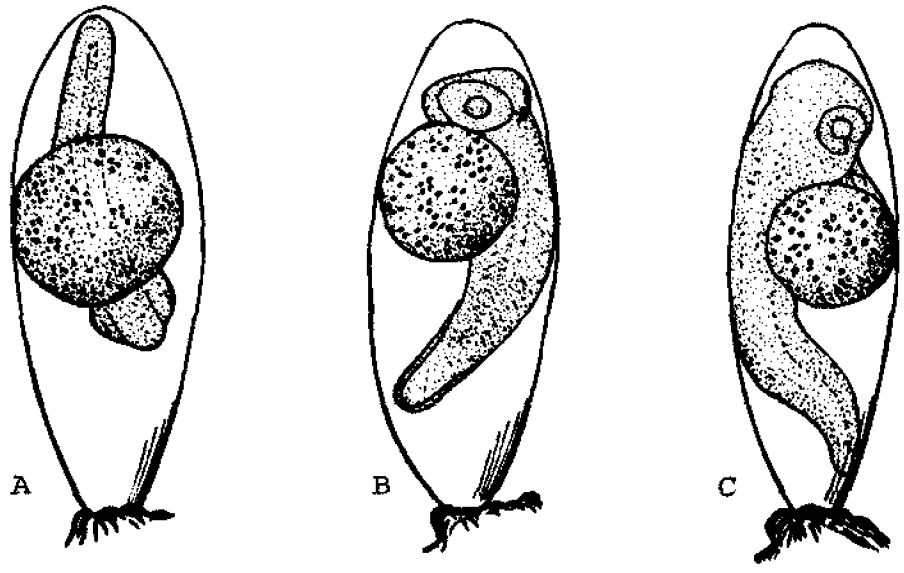

Fig. 129. *Cobiosoma robustum*, Code goby. A. Egg 68 3/4 hours older than fig. 128B. B. Egg 89 3/4 hours older than fig. 128B. C. Egg 117 1/4 hours older than fig. 128B. (*A-C, Breder, C. M., Jr., 1942: fig. 1, D-F.*)

GROWTH

Few, if any, individuals live more than one year, at least in Tampa Bay area.[7]

AGE AND SIZE AT MATURITY

Females reported to mature at 13.1 mm [4] and at 14.6 mm SL (few months old).[7] Smallest ripe male 16.5 mm.[8]

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10. Shropshire, R. F., 1932:28–29.

Microgobius gulosus (Girard), Clown goby

ADULTS

D. VI [1] to VIII [1,4] (usually VII), 15 [1]–17 [1,4] (modally 16); A. 16 [1]–18 [1,4] (modally 17 [1]); C. 8+7; [4] *P.* 22; [2] scales 45–52 in lateral series; [1,2] 11+16 vertebrae; [2,4] teeth in upper jaw biserial, inner row close-set, conical, pointed; outer row caniniform, enlarged, separated and somewhat recurved; lower jaw teeth in 2–3 rows anteriad, outer row enlarged and separate; inner teeth smaller, recurved, more closely spaced.[2]

Measurements given as percent SL: Body depth 13–19, caudal fin length 29–36, pelvic disc length 24; head length 30–32. Measurements given as percent HL: Maxillary of males 48–72 for 27–51 mm fish, females 44–48 for 27–42 mm fish.[2]

Body moderately elongate,[2] with broad, low keel in advance of dorsal fin; [1] head long, not notably broadened; eyes prominent; mouth large,[2] moderately oblique; [1,2] maxilla extends well beyond eye in males,[1,2] to posterior margin of eye in females. Scales cycloid to weakly ctenoid, predorsal, head and chest naked; [2] small patch of larger ctenoid scales under pectoral fin.[1] Caudal fin pointed; second to fifth dorsal spines, which are elongate on large fish, may reach twelfth ray of second dorsal fin in males, fourth to fifth ray in females; [2] pelvic disc reaches anal fin origin; [1,2] pectoral fin pointed, about equal in length to pelvic disc. Interorbital narrow, about one-third of eye diameter; tongue emarginate.[2]

Pigmentation: Body spotted with dark brown markings, these usually most distinct in females and juveniles, frequently faint in large males; 2–3 dark vertical bars on sides below first and second dorsal fins; usually with distinctive pale longitudinal bar below eye. First dorsal fin of large males dusky; second dorsal with submarginal hyaline band, dark above, dusky below; caudal fin dusky, with darker posterior margin and rather broad submarginal hyaline band; anal fin dusky, margined with dark band and hyaline edging; pelvic disc pale to almost black. Females with blotched first dorsal fin; second dorsal fin spotted below, with broad submarginal hyaline band along posterodorsal margin; anal fin dusky or faintly spotted; pelvic disc dusky, with broad, dark submarginal band and hyaline edging. Males under 35 mm TL with coloration similar to females.[2]

Coloration in life includes blue (metallic luster with greenish iridescence) band under eye; a similarly transverse bar behind pectoral base, bordered anteriorly with a silvery bar and posteriorly with a bar of diffuse pigment; second dorsal fin of male with lengthwise blue band above a median row of orange or reddish spots; caudal fin with reddish tinge.[1]

Maximum size: To about 72 mm TL for males; [1,2] 62 mm TL for females.[1]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast and Gulf of Mexico from Chesapeake Bay to Corpus Christi, Texas.[2]

Area distribution: Lower Chesapeake Bay.[5]

Habitat and movements: Adults—frequent muddy, estuarine localities and habitats protected by marine vegetation,[2] also common on bottoms of shell and blue-black muck in Texas (FDM). Associated with salinities ranging from 10–35 ppt and temperatures from 29–35 C in Texas; [3] common at depths from 2 cm to 1 m (FDM).

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

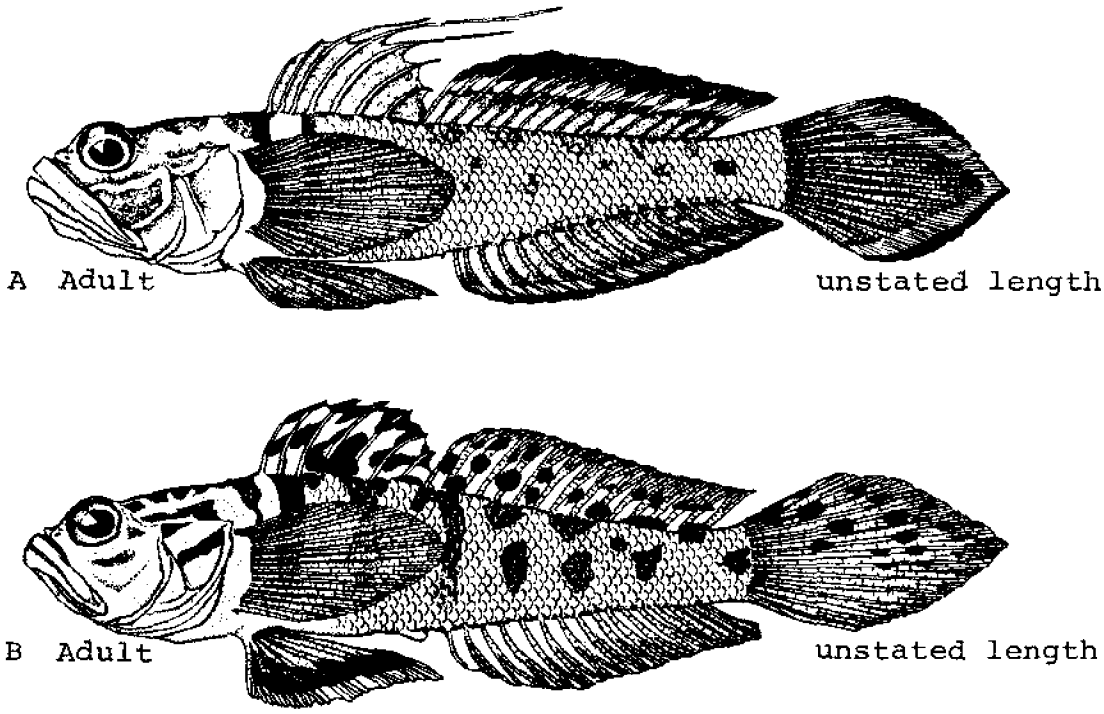

Fig. 130. *Microgobius gulosus*, Clown goby. A. Adult male, unstated length. B. Adult female, unstated length. *(A-B, Baird, R. C., 1965: fig. 3.)*

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5. Musick, J. A., 1972:192.

Microgobius thalassinus (Jordan and Gilbert), Green goby

ADULTS

D. VII [1,4,6] to VIII, 15–17; [6] A. 16–17; [1,6] C. 8+7 (RAF); P. 21; [4] lateral line scales 45–51; [1,6] vertebrae 11 + 16.[1]

Measurements as percent SL: Body depth 20–22, head length 25–28, maxillary 13–14, caudal fin 34–39, pelvic disc 24–28, pectoral fin 27–28 for 4 males between 45 and 50 mm TL; body depth 18–23, head length 26–27, maxillary 11–13, caudal fin 35–40, pelvic disc 24–29, pectoral fin 27–32 for 7 females between 42 and 47 mm TL.[1]

Body moderately elongate,[4] with broad low keel in advance of dorsal fin; [1] mouth large,[4] strongly inclined, maxilla subequal in both sexes, reaching a vertical through anterior margin of pupil. Scales cycloid,[1,4] except those under pectoral fins which are unusually deep and weakly ctenoid; scales extending on midline to point under origin of second ray of spinous dorsal; a variable number of large scales on posterior part of body having a few spinules on posterior margin; [1] head and chest naked.[4] Fourth and fifth dorsal spines moderately long

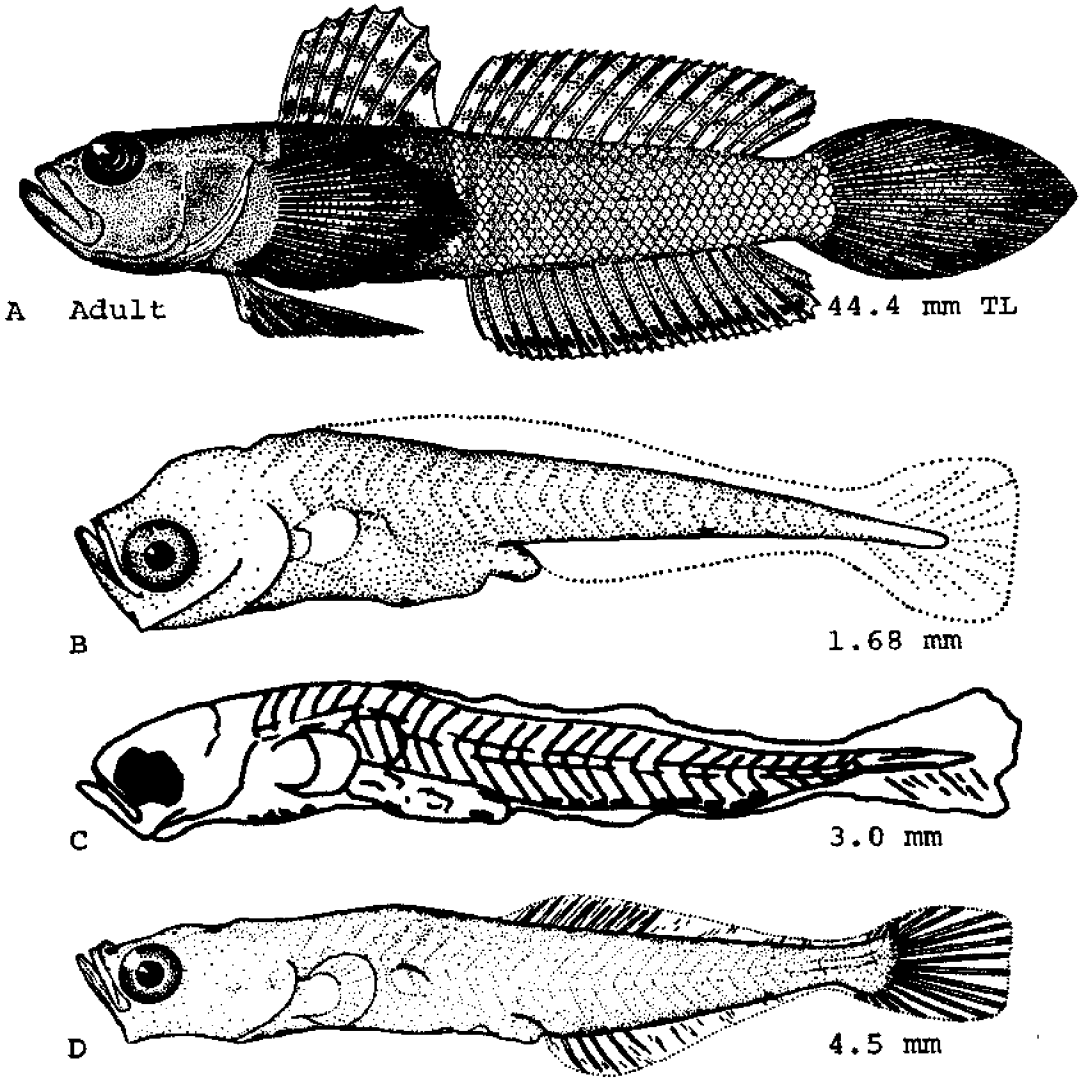

Fig. 131. *Microgobius thalassinus*, Green goby. A. Adult, 44.4 mm TL. B. Larva, 1.68 mm. C. Larva, 3.0 mm. D. Larva, 4.5 mm. (*A, Smith, H. M., 1907: fig. 168. B, D, Hildebrand, S. F., and L. E. Cable, 1938: figs. 50, 51. C, Richardson, S. L., and E. B. Joseph, 1975: fig. 1.*)

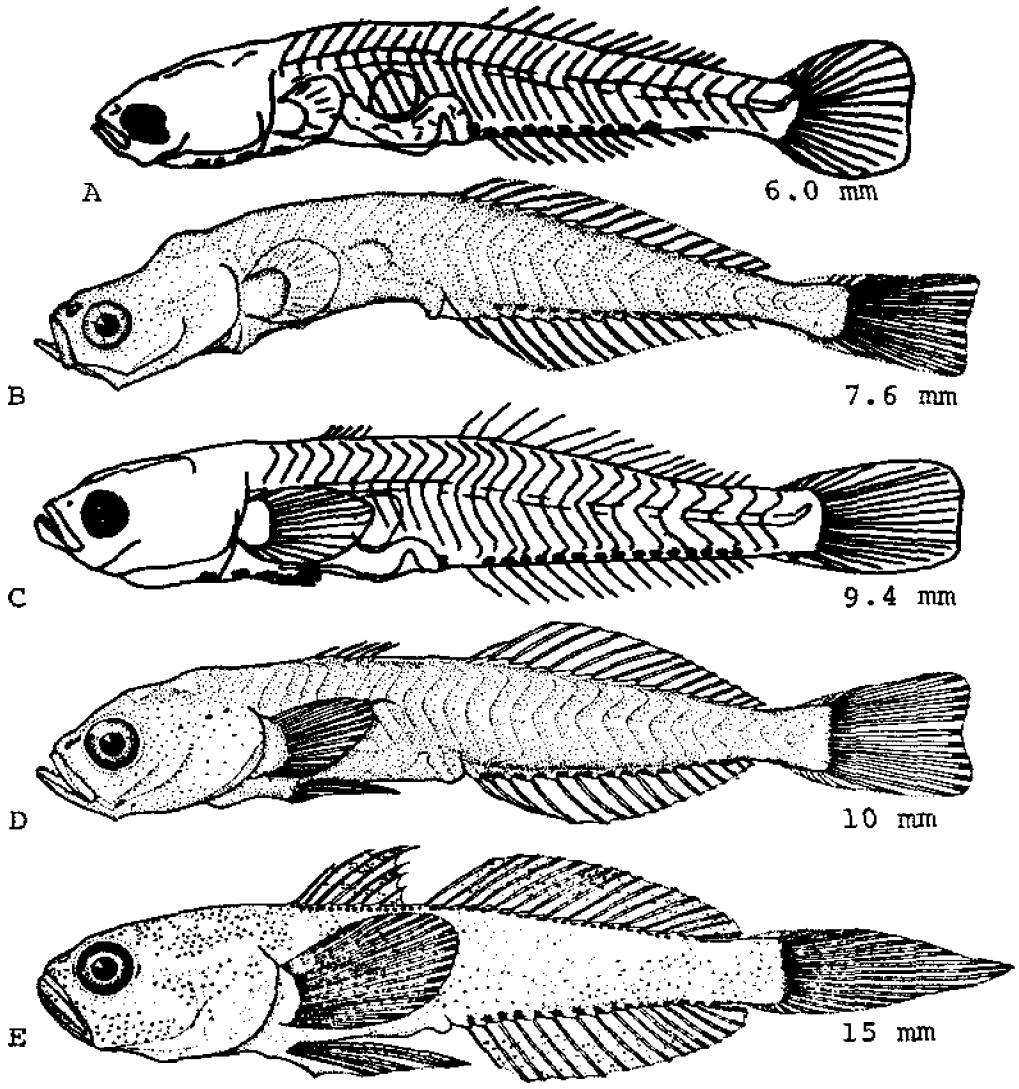

Fig. 132. *Microgobius thalassinus*, Green goby. A. Larva, 6.0 mm. B. Larva, 7.6 mm. C. Larva, 9.4 mm. D. Larva, 10 mm. E. Juvenile, 15 mm. (*A, C, Richardson, S. L., and E. B. Joseph, 1975: fig. 1. B, D, E, Hildebrand, S. F., and L. E. Cable, 1938: figs. 52–54.*)

in males, reaching to base of fourth or fifth ray of second dorsal fin; fourth and fifth dorsal spines to second or third ray in females;[1] caudal fin pointed.[4]

Pigmentation: Coloration in alcohol uniform dusky; 1–4 light-colored bars behind pectoral fin, especially in smaller specimens; scales with dark, curved marginal streak. Males with marginal row of small black spots on anal fin membrane, the rest of fin uniform dusky, margin whitish; similar row of spots sometimes present along lower margin of caudal fin; both dorsal fins with rather large smoke-colored spots; lengthwise hyaline band across both dorsal fins, nearer to base than outer margin, absent in larger specimens. Females without row of spots on anal fin; first dorsal fin with large black spot at distal margin, longitudinal hyaline band present in large as well as small individuals; rest of dorsal fin uniform dusky, occasionally with smoke-colored spots as in males.[1]

Coloration in life (no sex given) uniform light green, iridescent with metallic blue luster; blue color especially developed on middle of sides; behind pectoral fin deeper, metallic green, iridescent with blue; a lengthwise, nearly median row of orange or reddish spots on dorsal fin.[1]

Maximum size: Males to 50 mm TL; females to 51 mm TL.[3]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast and Gulf of Mexico [4] from Indian River, Delaware [6] to Corpus Christi, Texas.[4,6]

Area distribution: Entire Chesapeake Bay.[3]

Habitat and movements: Adults—inhabit the sponge *Microciona prolifera* [6] in deeper oyster reefs during spring, summer, and fall, and in channels and channel edges during winter.[3] Associated with salinities between 10 and 33 ppt [4] and temperatures above 0.5 C. Common at depths of 3 to 6 m during warmer months and 10 m during winter.[6]

Larvae—occur at salinities above 16.5 ppt [2] and at depths up to about 24 m.[5]

Juveniles—no information.

SPAWNING

Larvae collected from Beaufort Harbor, North Carolina and as far as 20 km offshore.[1] Spawning occurs from June through October,[2] with young taken as early as March and as late as November.[1]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Specimens described 1.6–10.0 mm.

Maxilla reaches anterior margin of pupil by 10.0 mm. Second dorsal fin developed by 5.0 mm except for posteriormost rays, fully developed by 7.5 mm; first four or five dorsal spines developed by 10 mm. Anal fin except for posteriormost two rays developed by 7.5 mm, fully developed by 10.0 mm.[5]

Pigmentation: At 4.0 mm there are numerous dark spots on ventral outline of body and a double row of dark spots extending from vent to end of tail, or to base of developing caudal. Dark spot at vent typically forms a short black line lying parallel with upper margin of loosely attached hindgut. By 7.5 mm the two rows of dark spots along either side of base of anal fin are more distant and each spot is horizontally elongate. By 10 mm a few dark markings about mouth, few on side of head, and indication of slight dark bar at base of caudal fin. Some specimens also have some black spots along bases of dorsal fins.[5]

JUVENILES

Specimens described 15–23 mm.

Scales first evident on caudal peduncle at 18 mm; scales develop anteriorly, and are complete at 23 mm; body robust; mouth terminal to slightly superior, oblique; dorsal spines long and slender, longest ones slightly longer than eye and snout; caudal fin variable, rounded to pointed, as long as head; ventral disc reaches slightly beyond anal fin.[5]

Pigmentation: Entire body covered with minute dark points.[5]

GROWTH

Males and females live for one year, spawn and die.[6]

AGE AND SIZE AT MATURITY

Mature by second summer at a length of 40–50 mm.[5]

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Peristedion miniatum
Prionotus carolinus
Prionotus evolans
Prionotus scitulus
Prionotus tribulus

searobins
Triglidae

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FAMILY TRIGLIDAE

The searobins are fishes of moderate size found on the bottom of tropical and temperate seas at shallow to moderate depths. They are characterized by their hard, bony heads armed with spines and the separation of the lower rays of the large pectoral fins into feelers which are used for locomotion over the bottom.

A number of investigators consider the Peristediidae to be distinct from the Triglidae, however, for the purposes of this study the peristediids are included in the family Triglidae. The development of the Mediterranean *Peristedion cataphactum* has been described by Lo Bianco (1909) and is quite distinct.

Prionotus carolinus is the only member of the family found in the study area that has had a study made of its early stages.

Triglids do produce sounds when captured but it is not known if the sound producing capacity is related to reproductive behavior.

Peristedion miniatum Goode, Armored searobin

ADULTS

D. VII [1,3] or VIII, 17 [1]–18; [1,3] A. 17 [1,3]–19; [1] C. 16; [3] P. 12–13 + 2; [1] V. 6; [3] 16–18 gill rakers on lower limb of first arch.[2]

Body depth 4.6–5.7, 4.7–5.5, head 2.7–3.0, pectoral fin length 4.9–5.4, pelvic fin length 5.0–5.7 in SL. Snout length 2.0–2.1, maxillary length 2.6–2.8, orbital width 4.5–5.2, interorbital 4.6–5.6 in HL.[1]

Body moderately low, very broad; head very short, somewhat depressed; snout very long, narrow; mouth very small. Pectoral fins and free rays short; pelvic fins short; spinous dorsal fin high; soft dorsal fin low; anal fin very long. Eye very small; interorbital narrow; nape short and broad. Rostral and nasal spines strongly elevated, retrorse; second suborbitals with 2–3 elevated, retrorse lateral spines; preocular with spiny ridge; supraoculars sometimes with keeled spine; postocular stout, elevated; pterotic elevated, serrate ridge; parietal stout, elevated; posttemporal ridge terminating in small, depressed spine; rostral exsertions short, stout, moderately broad and divergent; pericranial rim widens conspicuously below fourth suborbital and terminates in broad right-angled wing; opercular spine extremely long; [1] about 10 small tentacles on each side of lower jaw, those near symphysis smallest; long tentacles at angle of mouth fringed, extending to bases of pectoral fins.[4]

Pigmentation: Coloration in life—bright crimson.[2,3]

Coloration in alcohol—yellow, with diffuse black markings on head and with vestiges of four or five dark bars across dorsum; pectoral fin with diffuse black bar travers-

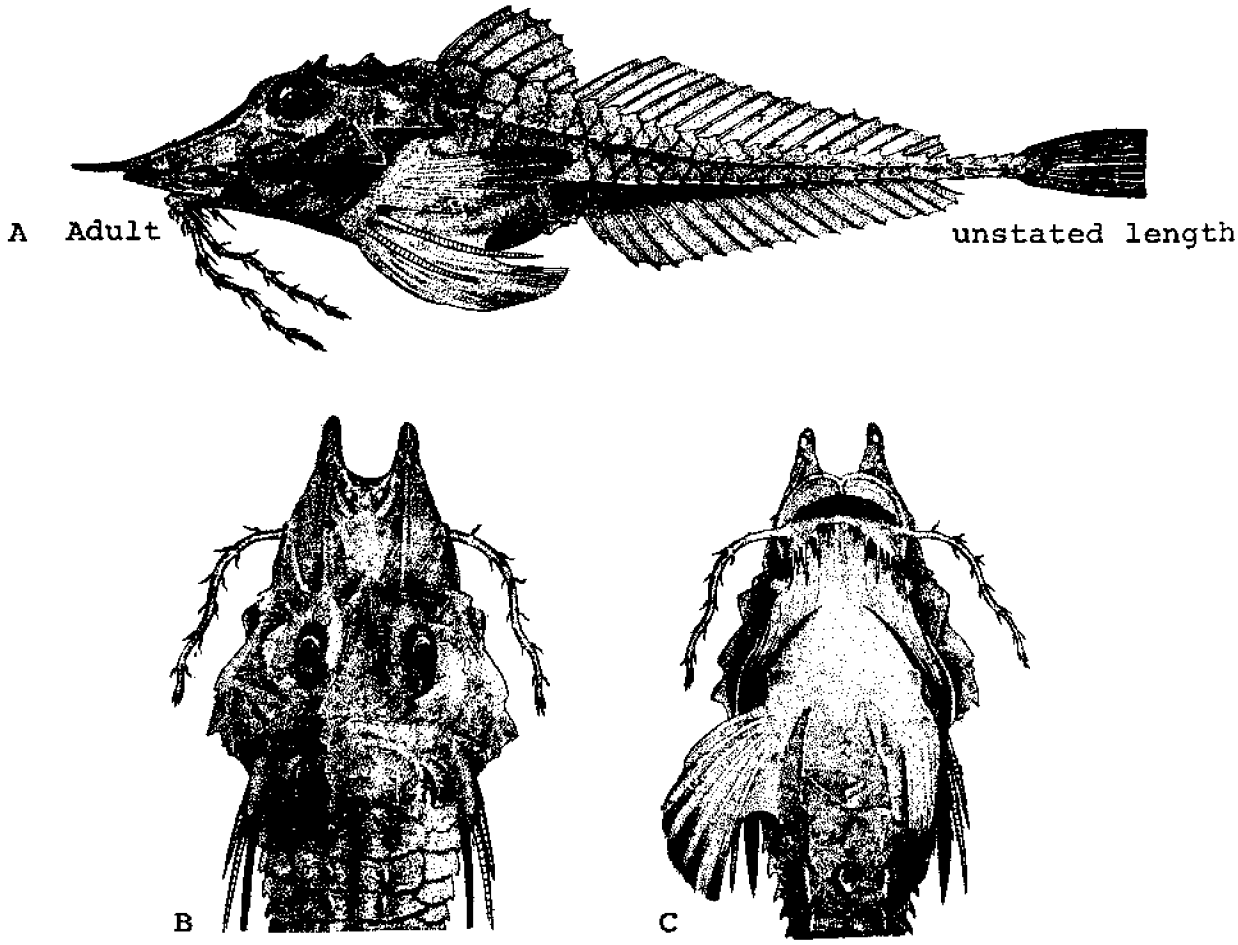

Fig. 133. *Peristedion miniatum*, Armored searobin. A. Adult, unstated length. B. Dorsal view of head. C. Ventral view of head. (*A-C, Goode, G. B., and T. H. Bean, 1895: figs. 385, 385a, b.*)

ing upper half of base, distal two-thirds black; caudal fin with distal third nearly black, excepting lower lobe, dark bar crossing upper two-thirds of fin base; some dark transverse markings between base and distal third; anal and pelvic fins nearly plain.[1]

Maximum size: To 330–355 mm.[2]

DISTRIBUTION AND ECOLOGY

Range: Outer part of continental shelf and upper continental slope from southwestern face of Georges Bank to Charleston, South Carolina.[2]

Area distribution: Several unpublished records from east of Cape Henry, Virginia. Specimens housed at Academy of Natural Sciences, Philadelphia (FDM).

Habitat and movements: Adults—associated with edge of continental shelf at temperatures between 6.7 and 7.2 C and at depths from 90 to 421 m.[2]

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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2. Bigelow, H. B., and W. C. Schroeder, 1953:471–472.
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Prionotus carolinus (Linnaeus), Northern searobin

ADULTS

D. X,[2,6,7] 12 1/2–13 1/2; A. 11 1/2–12 1/2; C. 11; P. 13 + 3; [7] V. I, 5; [2] 52 + 2–7 pored lateral-line scales; [7] 10 + 16 vertebrae; [10] 10 [6,7]–13 [6] gill rakers on lower limb of first arch; teeth small, in villiform bands in each jaw.[4]

Body width 4.9–5.8, body depth 4.6–6.3, head 2.8–3.2, pectoral fin 2.0–2.4, pelvic fin 3.6–4.0 in SL. Snout 1.9–2.2, maxillary 2.4–3.0, orbit 4.2–6.0, interorbital 6.5–8.4, first dorsal spine 3.1–3.2, second dorsal soft ray 2.5–2.7, longest anal ray 2.5–2.8, opercular spine 3.1–3.7, preopercular spine 5.4–7.5, humeral spine 4.3–4.9 in HL.[7]

Body robust, little broader than deep under spinous dorsal fin, round or slightly compressed posteriorly; head moderately large, depressed; snout broad; [4] maxilla ending nearer posterior nostril than eye. Chest fully scaled. First three dorsal fin spines graduated, third spine longest, fourth spine slightly shorter than third; first three dorsal fin spines and first ray serrate; first dorsal fin ray unbranched; fourth pectoral fin ray longest, rays decreasing in length both ways, fin reaching over base of fifth to sixth anal fin ray; caudal fin emarginate. Spines on head moderately developed, disappearing with growth; lachrymal plate moderately projecting, moderately serrate; only small terminal part of occipital groove present.[6]

Pigmentation: Reddish brown above; body irregularly *banded or blotched with pale and dark*; belly dirty white to pale yellow; [2] spinous dorsal fin with spot between fourth and fifth [2,6] spines, surrounded by narrow hyaline or whitish area; [6] soft dorsal fin more or less striped or marbled with pale and dark; pectoral fins reddish brown [2] to black [6] above, slaty [2] to whitish [6] below; free pectoral rays brown at base with white or orange tips; pelvic fins white.[2]

Maximum size: Reported to *reach a length of 406 mm* and a weight of 0.79 kg.[1]

DISTRIBUTION AND ECOLOGY

Range: Bay of Fundy [1] to South Carolina,[1,7,8] but rarely as far south as Charleston.[7]

Area distribution: Recorded from several New Jersey [12] localities; and common in upper Chesapeake Bay and abundant in lower Chesapeake Bay.[11]

Habitat and movements: Adults—associated with the bottom along the coast in shallow and deeper water [1] (see below) and deeper flats and channel edges in Chesapeake Bay. Migrate offshore and south in winter.[11] Recorded as leaving the New England coast in October and returning in April.[2,8] Associated with salinities between 5 ppt [11] and 32.3 ppt, temperatures between 9 and 26 C,[12] and depths to 41 m.[4]

Larvae—no information.

Juveniles—no information.

SPAWNING

Spawning reported as early as May in Long Island Sound [5] and as late as August throughout range.[1,3,5,11] Spawning temperatures between 12.8 and 24.4 C were reported for Long Island Sound.[5]

EGGS

Buoyant; [1] spherical; slightly yellowish [1,3] to bright orange; [1,4] highly transparent; [1,3] 0.94 [9]–1.15 mm in diameter; egg membrane thick and horny; [3] oil droplets 10 [1,3]–20 [1] or 25, unequal in size, scattered over surface of yolk.[3]

EGG DEVELOPMENT

First cleavage 1.5 hours after fertilization.[3]

Within 20 hours after fertilization the embryo is well differentiated and extends halfway around circumference of the yolk; blastopore not yet closed; embryo with *10–12 somites, numerous yellow and black pigment* cells present over its surface and in adjacent areas of blastoderm. Yellow pigment arises earlier than black pigment.[3]

42 hours after fertilization both black and yellow chromatophores larger and less numerous, sparsely distributed over surface of embryo and throughout the extraembryonic blastoderm.[3]

Incubation period: Reported to be 60 hours at 14 C [1] and 22 C,[3] and 89 hours at 20–21 C.[9]

YOLK-SAC LARVAE

Size at hatching 2.6 [1]–2.8 mm long.

Body deepens anteriorly by 4 mm. Head not markedly deflected at hatching, large at 3.1–3.4 mm. Yolk mass small at hatching and still contains oil globules. Dorsal, anal, and caudal fins well differentiated by 8–10 mm; pectoral fins prominent at hatching, large and prominent at 3.1–3.4 mm (5 days), free rays present by 8–10 mm. Depth of finfold greater than depth of body posterior to vent. Anus just posterior to yolk sac.[3]

Pigmentation: At hatching, black and yellow chromatophores sparsely scattered over the head, anterior region

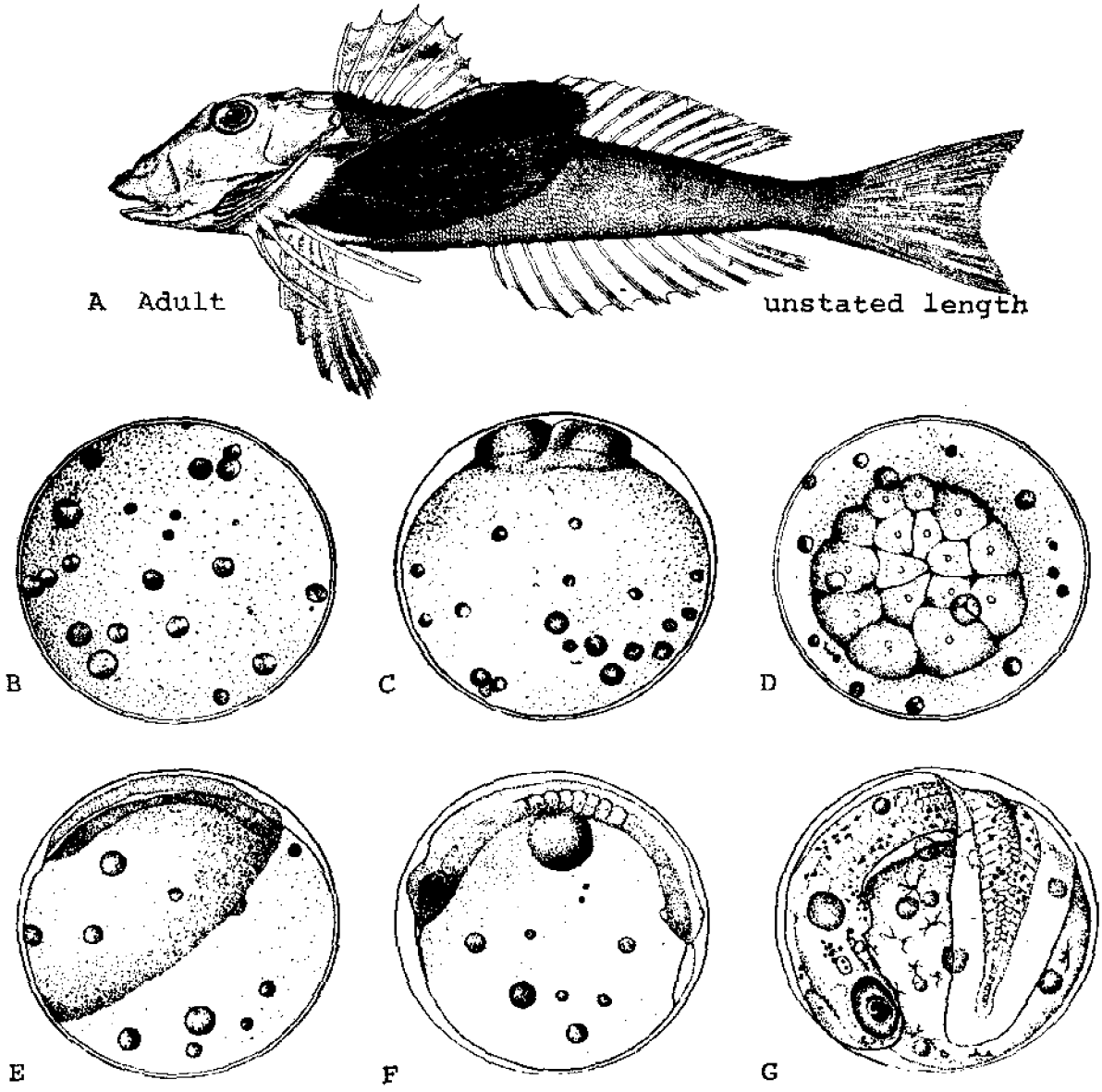

Fig. 134. *Prionotus carolinus*, Northern searobin. A. Adult, unstated length. B. Mature unfertilized egg. C. Egg, 2-cell stage. D. Egg, 16-cell stage. E. Egg showing early differentiation of the embryo. F. Egg with well differentiated embryo, blastopore closed. G. Egg with advanced embryo. (*A, Goode, G. B., 1884: pl. 71. B-G, Kuntz, A., and L. Radcliffe, 1917: figs. 38–43.*)

of trunk, and dorsolateral and ventrolateral aspects of trunk farther posteriorly; two yellow transverse bands present on body, one posterior to pectoral fins, the other approximately halfway between anus and tail tip, these bands extending onto finfolds. Five days (3.1–3.4 mm) after hatching, yellow transverse bands no longer apparent, head, pectoral fins and anus still with yellow pigment; black chromatophores sparsely scattered over body and a few appear on finfolds; posterior caudal region is practically free from pigment. At 4 mm, body remains yellowish; black chromatophores occur sparsely over dorsal and lateral aspects of body and in a series along ventrolateral aspect near base of ventral finfold.[8]

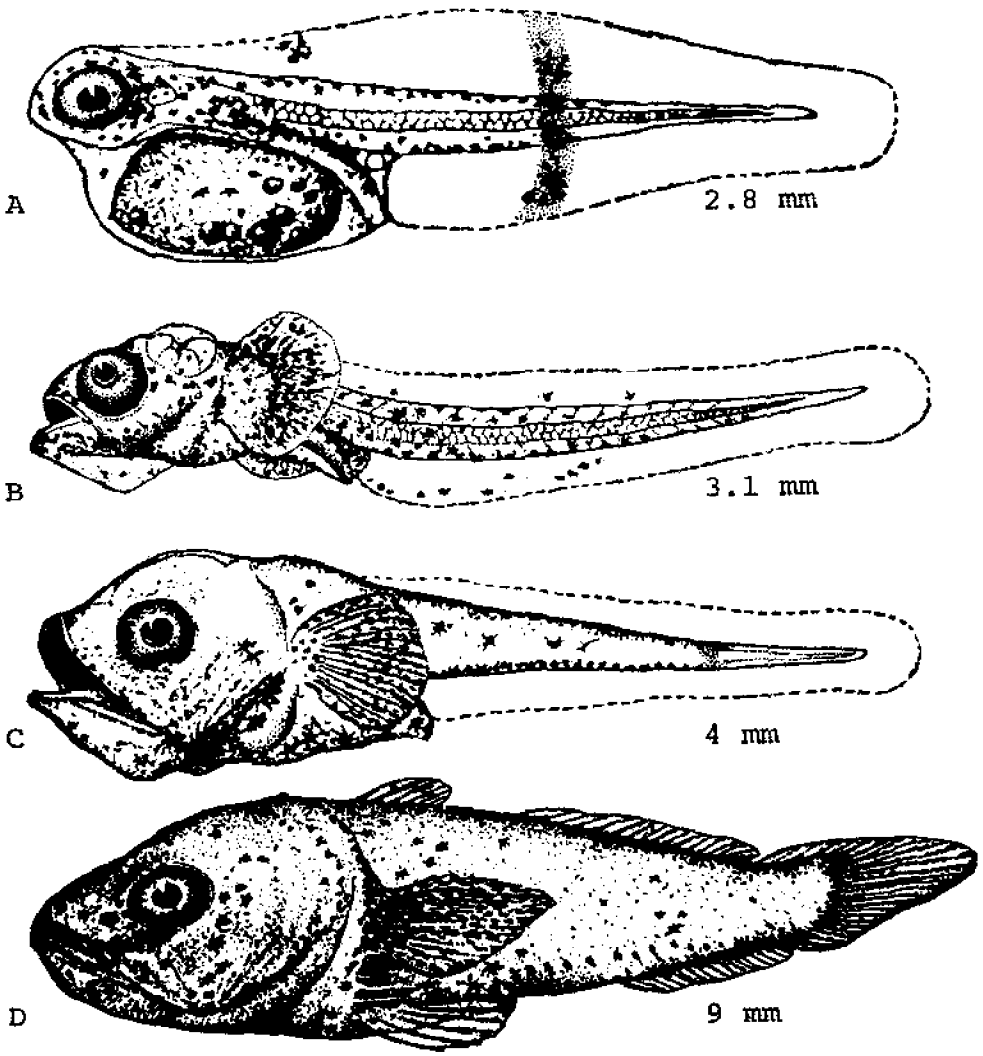

Fig. 135. *Prionotus carolinus*, Northern searobin. A. Yolk-sac larva, newly hatched, 2.8 mm. B. Larva, 5 days after hatching, 3.1 mm. C. Larva, 4 mm. D. Larva, 9 mm. (*A-D, Kuntz, A., and L. Radcliffe, 1918: figs. 44-47.*)

LARVAE

No information.

JUVENILES

Specimens described 25–30 mm.

Head long and pointed;[3] buccal, rostral, and supplemental preopercular spines disappearing at about 70, 150, and 170 mm, respectively; postorbital groove fairly marked in the smaller specimen.[6]

Pigmentation: Body typically with a transverse banded pattern,[3,6] one dark area under spinous dorsal fin, two under soft dorsal fin, and a narrow one at caudal base; banded pattern disappearing with growth.[6]

GROWTH

Young 40–80 mm long by the end of summer in Long Island Sound;[5] 140 mm at one year; and at least 230 mm at two years.[9]

AGE AND SIZE AT MATURITY

A female one year old and 140 mm SL was ripe.[9]

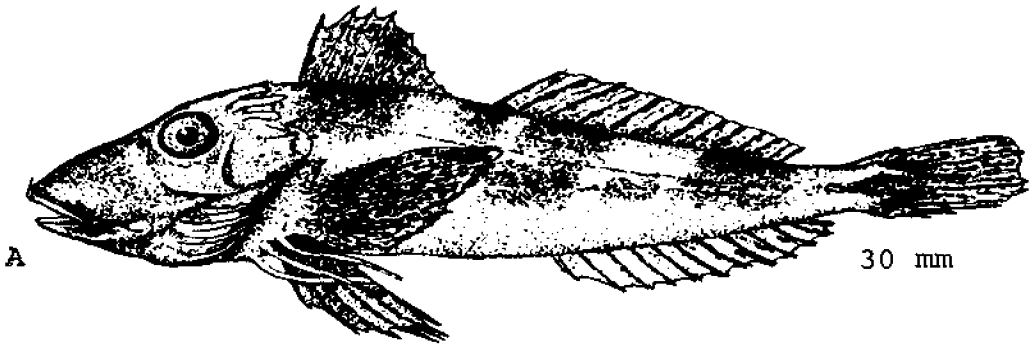

Fig. 136. *Prionotus carolinus*, Northern searobin. A. Juvenile, 30 mm. (*A, Kuntz, A., and L. Radcliffe, 1918: fig. 48.*)

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Prionotus evolans (Linnaeus), Striped searobin

ADULTS

D. IX to XI,[4] 11 1/2–12 1/2; A. 11 1/2; C. 11; P. 13+3; pored lateral line scales 52+2–3; 13[5]–20[4] gill rakers on lower limb of first arch; teeth in jaws in broad villiform bands.[8]

Body depth 4.4–4.9, head 2.4–2.6, pectoral fin length 1.8–2.2, pelvic fin length 3.4–4.0 in SL. Snout length 2.1, maxillary 2.2–2.4, orbit width 5.2–6.2, interorbital 4.8–5.8, first dorsal fin spine 3.7–4.0, second dorsal fin ray 2.3–3.0, longest anal fin ray 2.8–3.2, opercular spine 3.1–3.7, preopercular spine 5.6–8.0, humeral spine 4.6–7.8 in HL.[5]

Body moderately robust, compressed posteriorly; head large, depressed, broader than deep; snout broad;[8] mouth large,[5,8] horizontal, lower jaw included;[8] maxilla reaching anterior margin of eye.[4,8] Scales small, ctenoid,[8] most of chest scaled. First spine and ray of dorsal fin slightly serrate, second ray usually branched; pectoral fin slightly rounded or nearly truncate, reaching over base of sixth anal fin ray; caudal fin slightly to moderately emarginate.[4] Interorbital wide; orbit small;[5] spines generally becoming obsolete with growth.[4]

Pigmentation: Body dark yellowish brown above, lighter below;[5] lateral line pores much darkened; a black or brown streak below lateral line from humeral spine backward to caudal base, breaking up into a row of small spots; body often with five transverse cross streaks, closely crowded, nearly continuous or more or less interrupted;[4] dorsal fin ocellus large, between fourth and sixth spines;[4,5] caudal fin plain, excepting dark blotch at base; anal fin translucent, with opaque fringe; pectoral fin plain brown or transversed by 25 to 30 dark wavy lines; free pectoral fin rays plain or barred with darker.[5]

Maximum size: Reported to attain 421[4]–457[1,8] mm.

DISTRIBUTION AND ECOLOGY

Range: Lower Bay of Fundy[11] to New Smyrna, Florida.[4]

Area distribution: Recorded from New Jersey,[9] and as occasional to common in lower Chesapeake Bay and rare to occasional in upper Chesapeake Bay.[7]

Habitat and movements: Adults—frequent deeper flats and channel edges in Chesapeake Bay, migrates offshore and south in winter.[7] Abundant in New England from late April when temperature reaches 4 C, until late October when temperature falls below 15 C.[3] Reported from salinities of 7 ppt[7]–32.8 ppt and temperatures between 9.5–28.2 C.[10]

Larvae—no information.

Juveniles—no information.

SPAWNING

Season reported as beginning in May in Long Island Sound[2] and ending in early August in New England.[3] Spawning occurs at temperatures between 13 and 19 C.[3]

EGGS

No information.

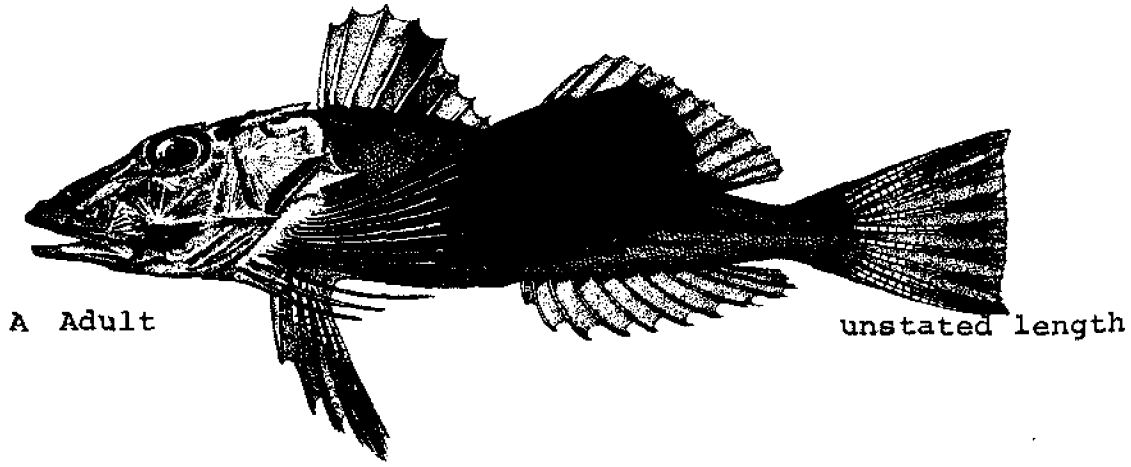

Fig. 137. *Prionotus evolans*, Striped searobin. A. Adult, unstated length. (A, *Goode, G. B., 1884: pl. 71.*)

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Gill rakers longer and more numerous than in adult.[6] Spines on head rather well-developed, disappearing with growth. Approximate length at disappearance as follows: buccal at 150 mm, rostral at 200 mm, and supplemental preopercular present up to 340 mm. Postorbital groove disappearing early in life.[4] Supraocular rim not elevated obliquely.[5]

GROWTH

Young average 55 mm SL at Sandy Hook, New Jersey during August, 70 mm by October 1st,[1] 71–129 mm by October in Long Island Sound; 170 mm is attained by second summer in New England; Chesapeake Bay specimens attained 134–242 mm by 1 year, 208–276 mm by 2 years; and 219–301 mm by 3 years.[12]

AGE AND SIZE AT MATURITY

Reported ripe at one year;[3,12] ripe fish average 260 mm in June;[1] also reported as ripe at greater than 200 mm.[12]

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Prionotus scitulus Jordan and Gilbert, Leopard searobin

ADULTS

D. X,[2,3,4] 13 1/2; A. 12 1/2; C. 11; P. 13+3; [3] V. I, 5; [6] 49–52 + 4–8 pored lateral line scales; [3] 10 + 16 vertebrae; [4] 9–10 gill rakers on lower limb of first arch.[5]

Body depth 5.2–6.4, body width 5.1–6.4, head length 2.8–3.2, pectoral fin length 2.4–2.8, pelvic fin length 3.7–4.4 in SL. Snout length 2.1–2.2, maxillary 2.5–2.8, orbit width 4.8–5.6, interorbital 11.2–12.0, nape length 6.8–9.4, first dorsal fin spine length 2.3–2.6, second dorsal fin ray length 2.3–3.0, longest anal fin ray length 3.0–3.1, opercular spine length 3.8–4.0, preopercular spine length 6.0–6.6, humeral spine length 7.2–8.0 in HL.[3]

Body low and slender; head short; snout rather long, narrow and pointed; mouth moderate; maxillary ending midway between posterior nostril and anterior margin of eye.[3] Scales on dorsum and sides extremely small,[2] chest scaleless for variable area, scalation usually reaching transverse line through base of lowermost pectoral fin ray. First three dorsal fin spines graduated, third longest, fourth slightly shorter or subequal to third; first dorsal fin ray branched or, rarely, unbranched; pectoral fin broadly rounded, reaching over base of third to eighth anal fin ray; caudal fin somewhat emarginate or slightly rounded.[2] Orbit small; interorbital extremely narrow; buccal spinule absent; rostral and supplemental preopercular spinules disappearing with growth; other head spines moderately developed; lachrymal plate hardly projecting, rounded, moderately serrate; occipital groove moderately developed in smaller specimens, its middle and larger part disappearing with growth.

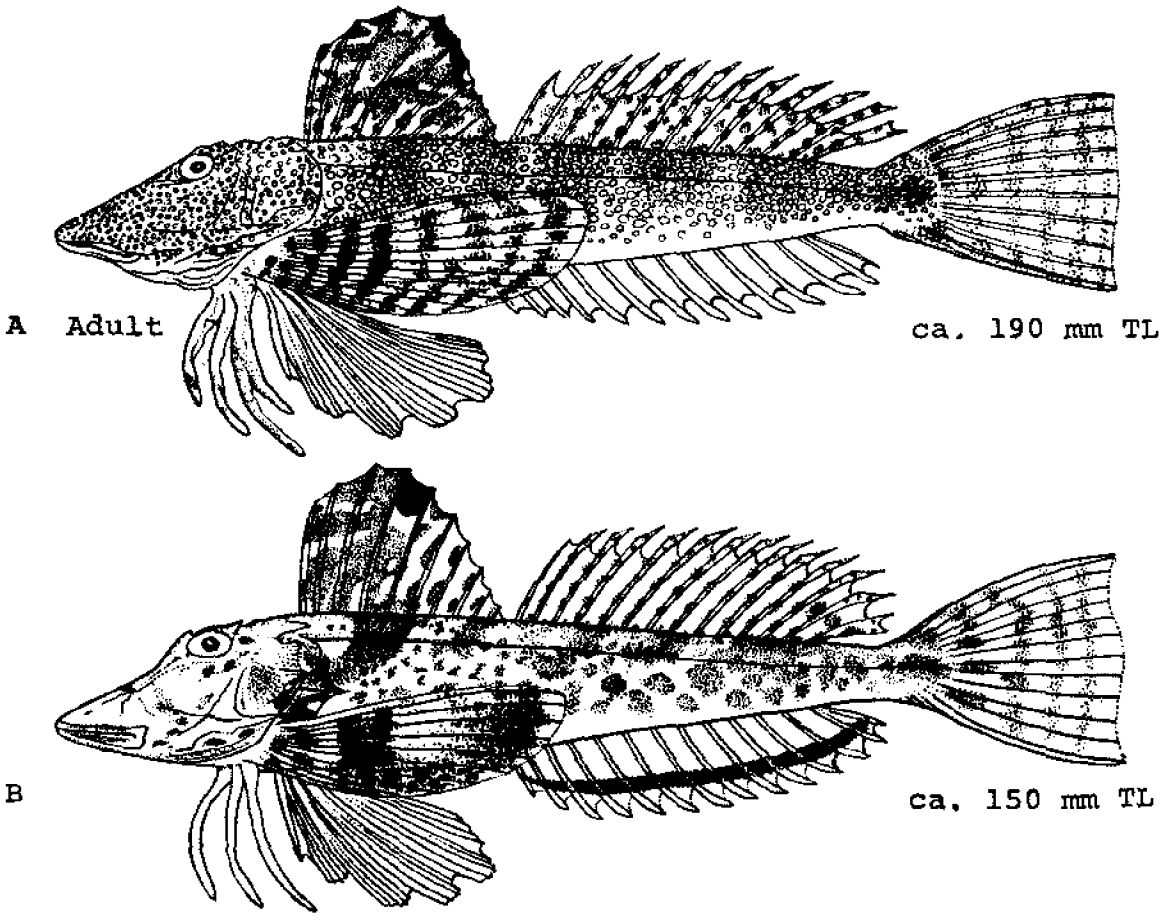

Fig. 138. Prionotus scitulus, Leopard searobin. A. Adult female, ca. 190 mm TL. B. Adult male, ca. 150 mm TL. (*A-B, Fowler, H. W., 1940: figs. 23–24.*)

Pigmentation: Olive brown above, lighter below; [3] upper two-thirds of body with many closely crowded, rather diffuse spots; [2] dorsum crossed from lateral line to lateral line by seven dark bars; [3] spinous dorsal fin darkish, crossed by two opaque light streaks between first and fourth spines, dark streak between first and second spines, dark ocellus with lighter below between fourth and fifth spines; soft dorsal fin traversed from first to sixth ray by five series of smallish brown spots; pectoral fins dark to black,[2] light brown above; anal fin with broad, dark brown median transverse bar, lighter above and below; caudal fin dark olive brown; pelvic fins light.[3]

Maximum size: Recorded to 116 mm.[3]

DISTRIBUTION AND ECOLOGY

Range: Lower Chesapeake Bay [5] to west coast of Florida.[3]

Area distribution: Recorded from the Potomac River at Gunstons, Virginia [2] and the lower Chesapeake Bay.[5]

Habitat and movements: Adults—associated with salinities between 6.9 and 37.6 ppt [1] and temperatures between 10 and 32.5 C.[1,7]

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Specimens described 19–50 mm. Body scaleless at lengths less than 50 mm; buccal spine slightly developed in specimens 19–21 mm.[3]

Pigmentation: Small specimens with 4 oblique, broad, usually diffuse bands at dorsal profile, one under spinous dorsal fin, two under soft dorsal fin, and one at caudal fin base.[3]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Prionotus tribulus Cuvier, Bighead searobin

ADULTS

D. X,[2,5,6] 11 1/2–12 1/2; A. 10 1/2–11 1/2; C. 11; P. 13 + 3; [3] V. I, 5; [5] 50–51 + 3–7 lateral line scales; [4] vertebrae 10 + 16; [6] 8–12 gill rakers on lower limb of first arch.[3]

Body depth 3.6–4.4; body width 3.9–4.6, head 2.2–2.4, pectoral fin 2.0–2.2, pelvic fin 3.4–3.8 in SL. Snout 2.0–2.1, maxillary 2.0–2.2, orbit 4.6–6.3, interorbital 4.2–5.4, nape length 4.2–5.4; first dorsal fin spine 3.5–4.4, longest anal fin ray 3.0–3.4, opercular spine 3.1–3.5, humeral spine 4.0–5.7 in HL.[3]

Body very deep, broad; head and interorbital notably broad; snout broad, rather long; mouth very large;[3] maxilla reaching vertical just short of anterior margin of eye. Chest and opercular flap scaled. First three dorsal fin spines and first ray slightly to moderately shorter or subequal to third, first ray branched, second branched or unbranched; pectoral fin rounded to nearly truncate, reaches posteriorly to base of sixth to ninth anal fin ray; caudal fin truncate to slightly emarginate.[2] Nostril and preorbital spines elevated, recurved; suborbital spine elevated, recurved; suborbital spine elevated, retrorse; supplementary preopercular spine elevated, recurved; *preocular spine moderate, elevated; supraocular rim* steeply oblique; sphenotic, pterotic, and parietal spines

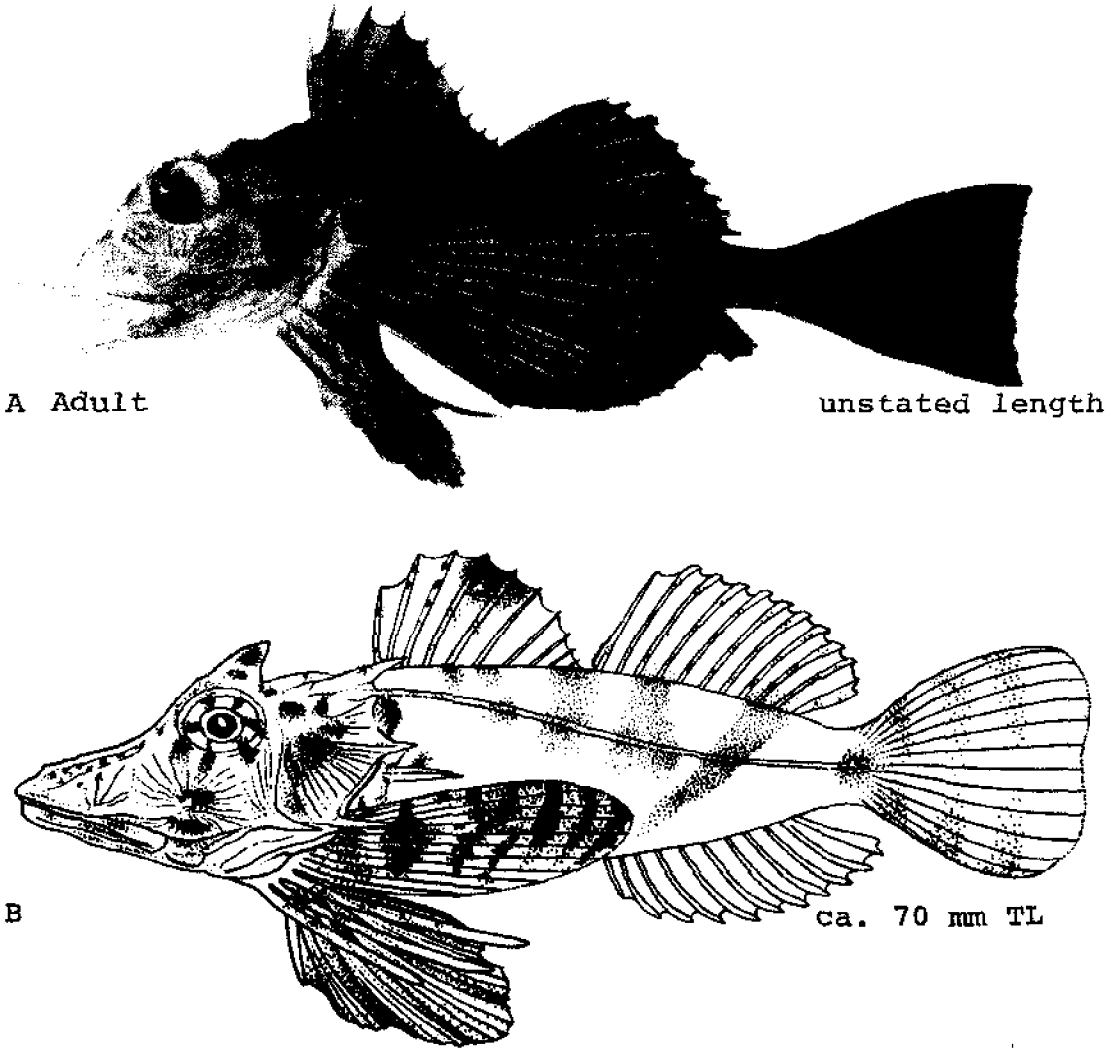

Fig. 139. *Prionotus tribulus*, Bighead searobin. A. Adult, unstated length. B. *Juvenile, ca. 70 mm* TL. (*A, De Kay, J. E., 1842: fig. 226. B, Fowler, H. W., 1940: fig. 25.*)

elevated, recurved; nuchal spine very long, obliquely elevated; postfrontal groove absent; interorbital space concave; rostral plates bluntly serrulate.[3]

Pigmentation: Dark olive brown above, light olive to white below; first dorsal fin with lower half opaque and clouded with darker, upper half translucent except for dark ocellate blotch between third and fifth spines; soft dorsal fin traversed by five to six series of dark spots; caudal and anal fins translucent with opaque border; darkish brown blotch on caudal base; pelvic fins plain; free pectoral fin rays barred with darker; pectoral fin brown, with seven to 18 wavy lines, sometimes alternately broad and narrow; [3] upper body typically with short, oblique bands at dorsal profile, one under spinous dorsal fin, two under soft dorsal fin, one each at some distance from its anterior and posterior ends, one at caudal fin base; bands tending to disappear with growth; occasionally with dusky longitudinal, interrupted band behind humeral spine or series of dark spots along course of lateral line or both; sometimes with few or many very small whitish or pearly spots on upper part of body.[2]

DISTRIBUTION AND ECOLOGY

Range: Long Island, New York to Brazos Santiago, Mexico,[3] and throughout the Gulf of Mexico (WJR).

Area distribution: Recorded from the lower Chesapeake Bay,[4] and Ocean View and Lynnhaven Roads, Virginia.[2]

Habitat and movements: Adults—recorded from salinities between 1.0 and 40.8 ppt and temperatures between 9 and 31 C.[1]

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Young have much larger and more compressed head spines; 3 or 4 strong knife-like spines on each side of snout; larger preopercular spine; fin spines proportionately longer and fins shorter; soft dorsal, caudal, anal and pelvic fins plain.[5]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Hemitripterus americanus
Myoxocephalus octodecemspinosus

sculpins
Cottidae

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FAMILY COTTIDAE

Most sculpins are bottom-oriented marine fishes of northern temperate waters; however, there are a few estuarine, brackish or even freshwater species. Sculpins are characterized by being scaleless or partially scaled, and by having two dorsal fins, either completely separate or with a notch between them, fan-shaped pectoral fins, and pelvic fins having a single spine and two to five rays. There are about 300 species in the family, but only two representatives are found in the Mid-Atlantic Bight.

Khan (1971) has listed the characters useful in identifying cottid larvae:

1. Body more or less pin-shaped, swollen anteriorly, and pointed posteriorly.
2. Intestine forms a loop on the right side and terminates at anus, located just in front of ventral finfold.
3. Pectoral fins are fan-shaped, broad based, and lack pigmentation.
4. Pigmentation consists of cephalic concentrations, peritoneal concentrations, and a medioventral row of melanophores.

The early stages of *Hemitripterus americanus* described by Agassiz and Whitman (1885) are of some other fish.

Key to the Eggs of the Cottidae

1a Egg diameter 3.75–4.09 mm diameter . . . . *Hemitripterus americanus*
1b Egg diameter 1.9–2.3 mm diameter . . *Myoxocephalus octodecemspinosus*

Key to the Larvae of the Cottidae

1a Specimens shorter than 10 mm . . . *Myoxocephalus octodecemspinosus*
1b Specimens longer than 10 mm 2a

2a Lateral pigment dense, meeting head pigment; small melanophores on ventral side of lower jaw . . . . . *Hemitripterus americanus*
2b Lateral pigment not dense, not meeting head pigment; no melanophores on ventral side of lower jaws . . . . *Myoxocephalus octodecemspinosus*

Hemitripterus americanus (Gmelin), Sea raven

ADULTS

D. XVI–I, 12;[2,4] A. 13;[2] V. I, 3;[4] vertebrae 16 + 23;[10] body scaleless, but with prickles everywhere,[6] enlarged near back and lateral line;[2,6] jaws with several rows of stout sharp teeth.[6]

Head 2.7, body depth 3.8 in SL.[2]

Body elongate, heavy forward, mouth terminal oblique,[6] its angle extending slightly beyond eye;[2,6] eye large;[6] lateral line high on body. Pectoral fin nearly reaching anal fin; highest dorsal spine as long as caudal fin; pelvic fins reaching halfway to anal fin;[2] caudal fin largt, regularly rounded.[6] Nasal spines strong; supraocular ridge elevated, with dermal flaps and 2 blunt spines; 3 pairs

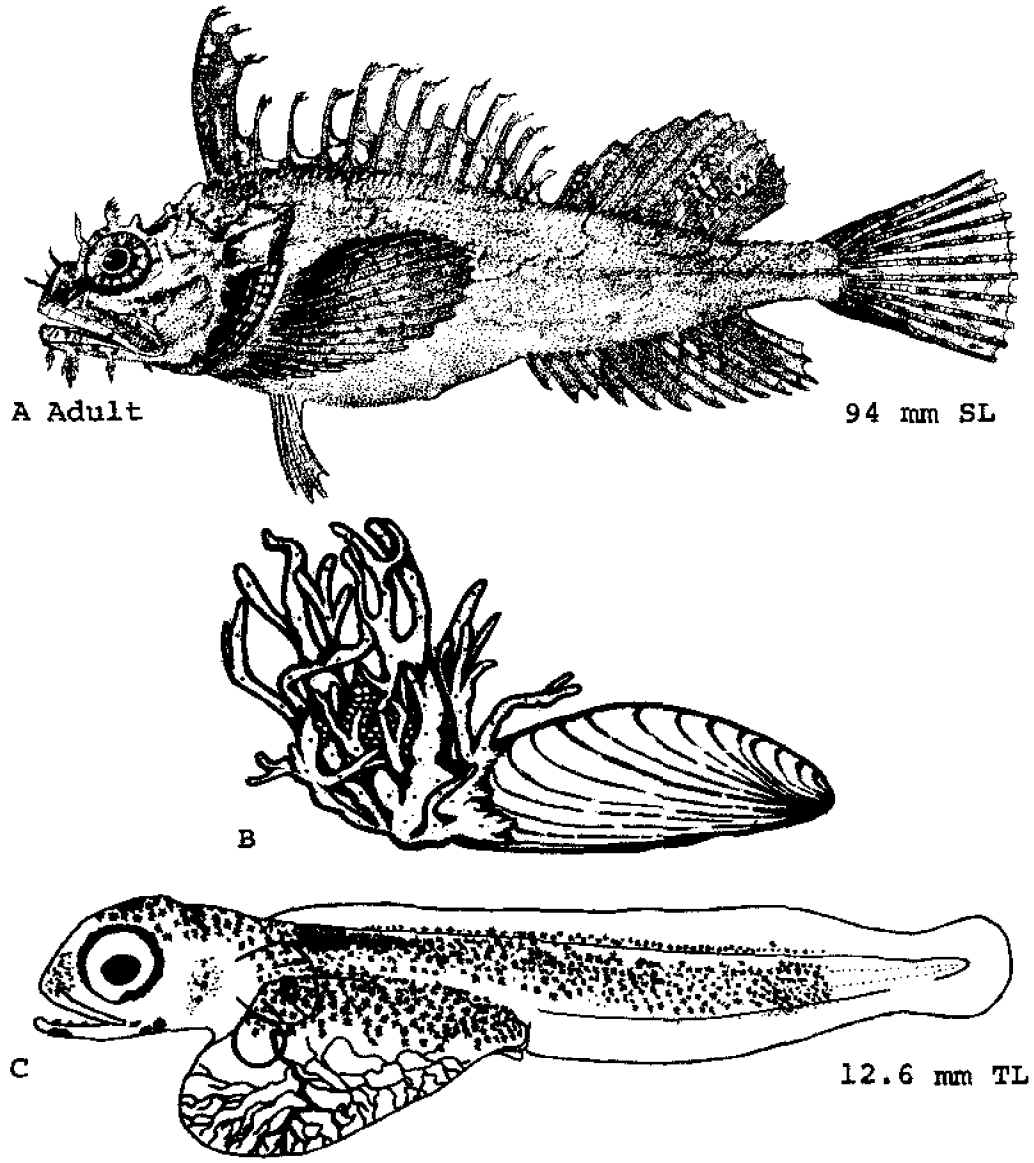

Fig. 140. *Hemitripterus americanus*, Sea raven. A. Adult, 94 mm SL. B. Eggs attached to sponge. C. Newly hatched larva, 12.6 mm TL. (*A, Goode, G. B., 1884: pl. 74a. B, Warfel, H. E., and D. Merriman, 1944: fig. 1. C, Fuiman, L. A., 1976: fig. 1.*)

of fleshy flaps on nasal bones, 2 pairs of supraocular ridges; smaller cirri on maxillary and preorbital, and several on lower jaw; interorbital deeply concave; 2 blunt occipital spines on each side, outside of which are 2 or 3 others; opercle small, with bony ridge; preopercle with 2 blunt spines.[2]

Pigmentation: Reddish brown, marbled with darker brown, and much variegated; yellowish below; fins variegated with light and dark.[2,6]

Maximum size: To 625 mm [4] and a weight of 2.4 kg.[1]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast south to Chesapeake Bay; [4] chiefly northward, from New York to Labrador.[2]

Area distribution: Recorded near the entrance to Chesapeake Bay,[3] and from New Jersey.[7]

Habitat and movements: Adults—associated with rocky ground, pebbles, hard sand, or clay.[4] Found in deep water in summer, moving toward shore in winter.[5] Recorded from temperatures no higher than 14.4–15.6 C and from depths between a few to 189 m.[6]

Larvae—remain on bottom until about 14.5 mm, then pelagic or free-swimming (DJF).

Juveniles—no information.

SPAWNING

Spawn 0.6–1.8 km from shore at 18–27 m depth, during mid-October to late December off Rhode Island,[1] November off New York.[9] Spawning temperatures recorded to be 2.9–14 C.[1]

EGGS

Located on the bottom attached to the sponge *Haliclona* sp. or *Halichrondria panicea*. The eggs are pale yellow, amber or light orange with a mean diameter of 3.9 mm (range 3.75–4.09 mm); egg membrane 0.1 mm thick; highly adhesive; yolk color clear-amber.[1]

EGG DEVELOPMENT

Pigmentation on body of embryo consisting of melanophores arranged in vertical bars corresponding to location of somites; retina black and iris silvery; median finfold and pectoral buds formed. About 37 days later, large melanophore on hindbrain and dorsal half of yolk sac; body pigmentation ending abruptly on caudal peduncle; mouth formed and open; oil globule (ca. 0.8 mm diameter) inside yolk sac located near anterior confluence of abdomen and yolk sac.[9]

YOLK-SAC LARVAE

Size at hatching 9.9–14.1 mm.[1]

Total myomeres 38–39; [1,9] head not flexed over anterior of yolk sac at hatching; no gas bladder developed; mouth very large; maxillary extending to or slightly beyond middle of eye; lower jaw with four sharply pointed, conical teeth on each side at hatching, the fourth tooth smaller and located lower on dentary; [9] caudal fin rays develop few hours after hatching, ventral rays first; pectoral fin well-developed at hatching; [1] yolk sac extends forward to or beyond posterior margin of eye.[9]

Pigmentation: Body of living specimens light olive green, underlain with silvery guanin. Chromatophores abundant on dorsum under dorsal fin [1] and in base of dorsal fin fold,[9] also scattered on top and sides of head, surface of opercle and proximally on dorsal and pelvic fins; few chromatophores on upper edge of lower jaw, anterior half of circumorbital ridge and on ventral surface of head; [1] pigmentation lacking over forebrain, ventral half of yolk sac,[9] and posterior one-fourth of body; [1,9] median and paired fins, part of eye, head, and body wall characterized by small, closely spaced, papilliform white dots.[1]

LARVAE

Specimens described 14.5–18.8 mm.

D. XVII, 13 at 18.8 mm; [8] XIV, 13 at ca. 20 mm TL. A. 10 at ca. 20 mm TL.[9] C. 13 at 18.8 mm,[8] 12 at ca. 20 mm TL.[9] Total myomeres 39. Opercular spines 2 by 18.8 mm.[8] Dentary and premaxillary with 15 teeth on each side at ca. 20 mm TL.[9]

At ca. 20 mm TL ratio of head length to total length 3.6, predorsal length to total length 3.8, and eye diameter to head length 2.7.[9]

Over 16.1 mm TL rudimentary caudal fin rays developed; rays begin to develop in second, then first, dorsal fins followed by pectoral fins at about 3 months after hatching; [9] pectoral fins broad based and fan shaped; caudal flexion complete at 18.8 mm; [8] hypural plate begins forming at ca. 20 mm TL; spines on preopercle begin forming at ca. 3 months after hatching and become more prominent by ca. 20 mm TL; [9] anus just anterior to ventral finfold.[8]

Pigmentation: At 15.5 mm TL pigmentation uniform olive gray over body.[9] At 18.8 mm small melanophores appear on both dorsal fins and anal fin.[8] At ca. 20 mm TL iris less silvery; dense pigmentation develops on interradial membrane of first dorsal fin between elements 1 through 4 and 8 through 12; similar pigmentation develops in second dorsal fin between elements 3 and 7 and in anal fin between elements 3 and 6; few melano-

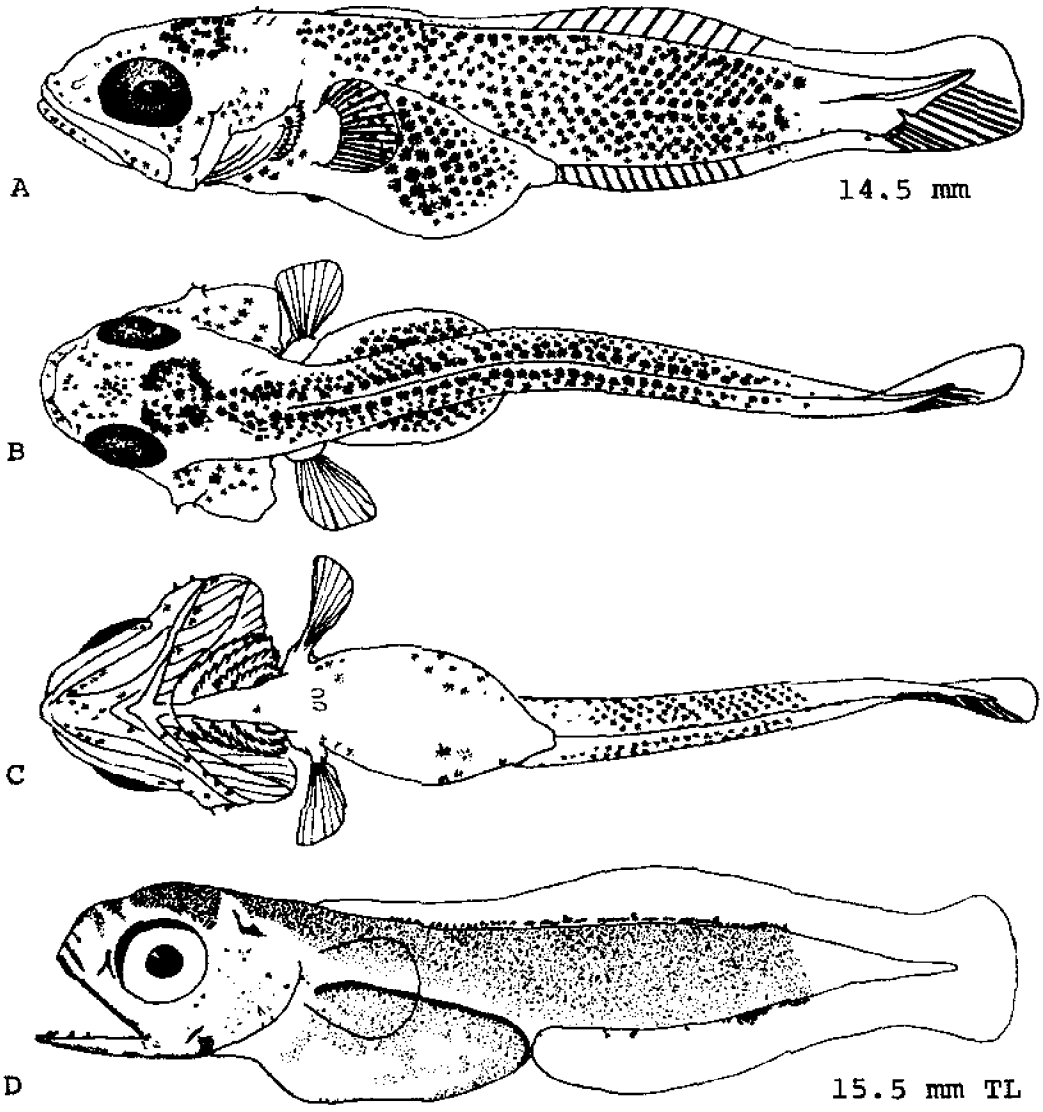

Fig. 141. Hemitripterus americanus, Sea raven. A. Larva, 14.5 mm. B. Dorsal view of A. C. Ventral view of A. D. Larva, 15.5 mm TL. *(A-C, Khan, N. Y., 1971: fig. 13, used with the author's permission. D, Fuiman, L. A., 1976: fig. 2.)*

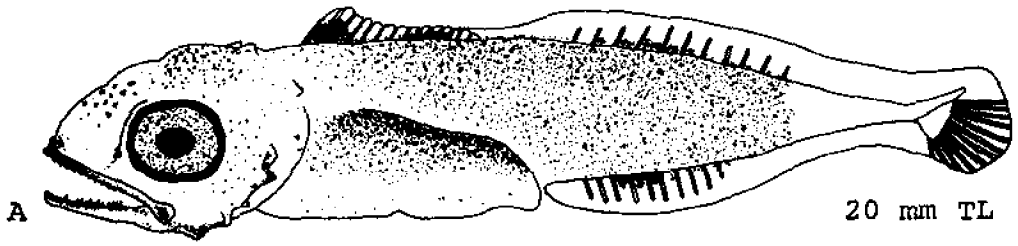

Fig. 142. *Hemitripterus americanus*, Sea raven. A. Larva, ca. 20 mm TL. (A, *Fuiman, L. A., 1976: fig. 3.*)

phores scattered between the dense areas on dorsal and anal fins.[9]

JUVENILES

No information.

GROWTH

Reach 61–102 mm by middle of first summer (6–8 months old), and 152 mm by the following April (1.5 years old) in the Gulf of Maine.[4]

AGE AND SIZE AT MATURITY

No information.

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Myoxocephalus octodecemspinosus (Mitchill), Longhorn sculpin

ADULTS

D. VIII [1,10] to X,[1] 15–16; [1,5,10] A. 12 [6]–15; P. 16–19; V. I, 3; [10] vertebrae 34–37; [12] naked,[1,10] but sometimes with prickly plates and tubercles; [1] small teeth present on jaws and vomer.[1,10]

Head 2.5–3.0, depth 4.5–5.8 in SL. Maxillary 2.1–3.1, upper preopercular spine 2.6–3.6, eye 3.2–5.1, longest dorsal spine 1.8–3.3 in head.[1]

Body slender, tapering,[1,10] elongate and ending in small caudal peduncle; head blunt, heavy,[10] large,[1] flattened; [10] mouth rather large, terminal, lower jaw included; [1] max-

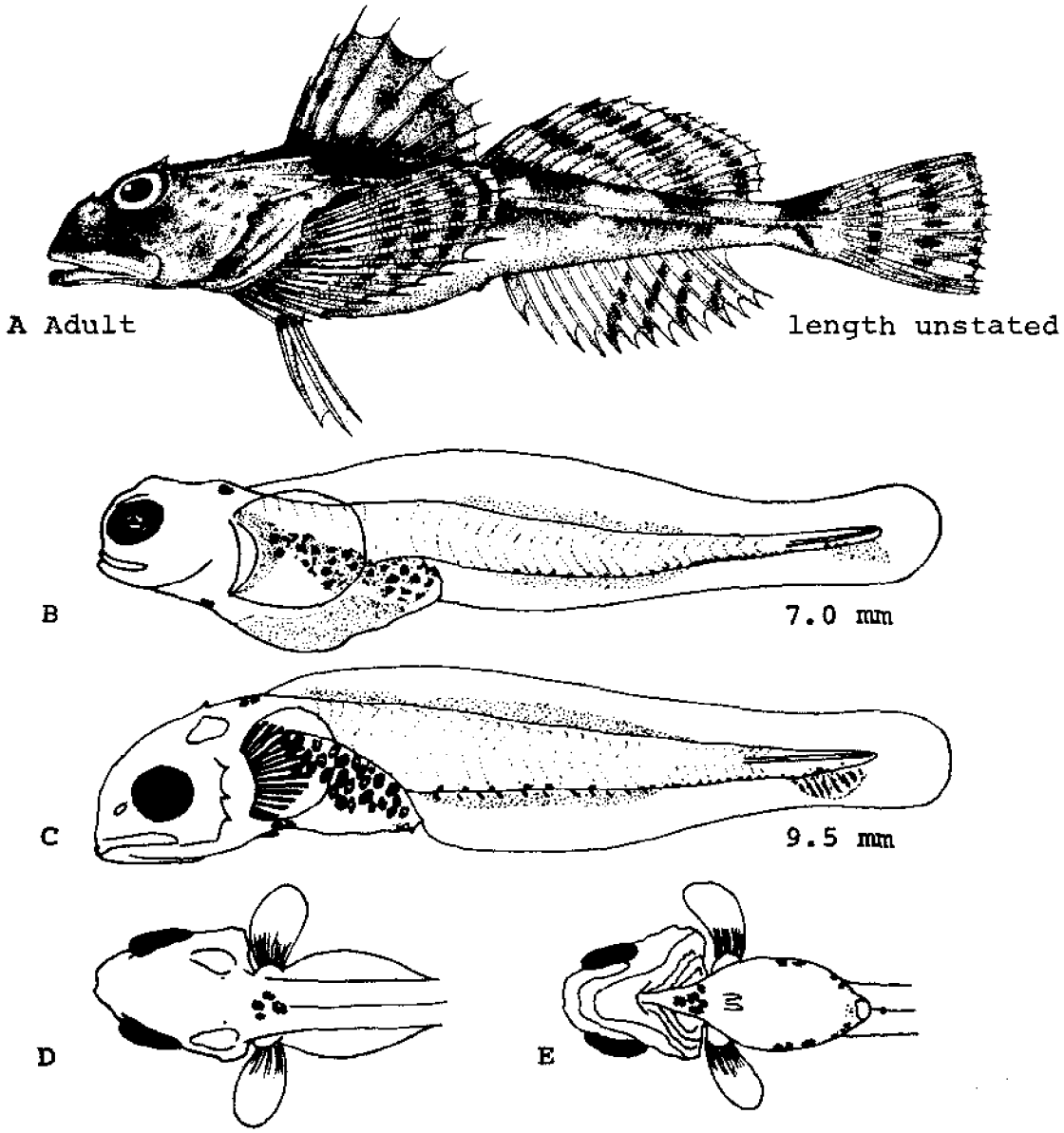

Fig. 143. *Myoxocephalus octodecemspinosus*, Longhorn sculpin. A. Adult, length unstated. B. Yolk-sac larva, 7.0 mm. C. Larva, 9.5 mm. D. Dorsal view of C. E. Ventral view of C. (*A, Leim, A. H., and W. B. Scott, 1966: 356. B-D, Khan, N. Y., 1971: fig. 7, used with the author's permission.*)

illary not extending past eye.[1,10] Lateral line marked by smooth cartilaginous plates.[1,5,10] Dorsal fins separate, first short and with sharp slender spines,[1] second rounded; [10] anal fin slightly lower and shorter than second dorsal fin; pectoral fins large, fan-like; [10] pelvic fins not reaching vent.[1] Upper preopercular spine long, reaching posterior edge of gill cover, third preopercular spine turned downwards; nasal spines strong; spine at upper posterior margin of orbit, another at end of each occipital ridge, sharp spine on cleithrum just behind and below opercular spine; supracleithral spine sharp; short spine on subopercle below base of second and third opercular spines; eye large, wider than interorbital.[1]

Pigmentation: Coloration varies with surroundings; back and sides range from dark olive to pale yellowish green or gray; 4 irregular dark crossbars, often broken into indistinct blotches; first dorsal fin generally dark with irregular mottlings or spots; second dorsal fin paler with three or four irregular dark crossbands; caudal fin pale gray; pectoral fins yellowish; anal fin yellowish with dark mottlings; belly white.[1,5]

Maximum size: To 450 mm.[10]

DISTRIBUTION AND ECOLOGY

Range: Coastal waters of western North Atlantic Ocean from eastern Newfoundland [7,8,10] and Labrador [5,6] south to New Jersey,[7] and occasionally to Virginia.[7,10]

Area distribution: Recorded from Atlantic, Cape May, and Ocean counties, New Jersey [4] and Virginia.[7,10]

Habitat and movements: Adults—demersal; [1] approach shore in spring and retreat to deeper water in fall.[1,3,5,6] Associated with temperatures of 0.5–19 C [11] and tidal flats [5] to 192 m.[8]

Larvae—prefer shallow and enclosed estuarine areas,[11] also found off the coast considerable distances from shore (DJF); migrate diurnally, most abundant at surface during night; found from 18–146 mm.[11]

Juveniles—no information.

SPAWNING

Location: In estuaries, and in shallow and enclosed areas where bottom is rocky; [11] along coasts of Massachusetts and Maine, probably along western Nova Scotia as well.[7]

Season: Late November–January or possibly into February in Block Island Sound,[1] November–December in New England.[5,6]

Salinity: At about 32 ppt in Block Island Sound.[1]

Fecundity: Average female produces about 8000 eggs/year.[11]

EGGS

Demersal; [9] deposited in clusters on shells, stones,[1,9] or among branches of finger sponge (*Haliclona*).[1,2,9]

Unfertilized eggs: 0.85 mm diameter, chocolate brown.[7]

Fertilized eggs: Coppery green, to reddish brown, brown, orange,[1,9] purple, or dirty white; 1.9–2.3 mm ($\bar{x}$=2.1 mm) in diameter; chorion thick and rather opaque, strongly adhesive; yolk colored like egg; one or more oil droplets of varying sizes.[9]

EGG DEVELOPMENT

Hatching in about 3 months.[11]

YOLK-SAC LARVAE

6.8 mm at hatching; specimens described 6.8 [9]–7.99 mm.

Total myomeres 37–40; 2–3 preopercular spines at about 7.5 mm, 1 parietal spine at 8 mm,[11] opercular spines develop during end of third week.[9] No oil globule apparent; nostril single; caudal hypurals appear after 7.5 mm; pelvic fins appear as buds at about 7.99 mm; finfold complete; anus on midventral line just anterior to ventral finfold.[11]

Pigmentation: Large melanophores on dorsolateral aspect of peritoneum; very small melanophores ventrally at posterior end of intestine, just anterior to anus; 3–4 large melanophores on isthmus, usually clustered; series of 16–30 medioventral melanophores at base of ventral finfold starting at 15th–16th myomere and extending almost to hypurals; few melanophores just behind head.[11]

LARVAE

Specimens described 8.5–14 mm.[11]

D. V–IX, 13–12 at 12–14 mm; A. 10–12 at 9.5 mm, 13–14 at 12–14 mm; C. 8–11 at 9.5 mm; V. 3 at 12–14; 5 preopercular, 2 parietal and 1 otic spine at 12–14 mm.[11]

Nostril begins to constrict at 10.5 mm, divided at 12.5 mm; dorsal fin rays appear at 13 mm, first and second dorsal fins almost separated by 12–14 mm; first anal fin rays appear at 9.5 [11]–13 [5] mm; finfold complete.[1]

Pigmentation: Medioventral melanophores gradually move up and away from surface during growth, as anal fin develops surface melanophores obscured by tissue development (DJF).

JUVENILES

Specimens described 14.5–15.1 mm.

D. VIII or IX, 15–16; A. 14–15; P. 17–18; V. I, 3; 4 well

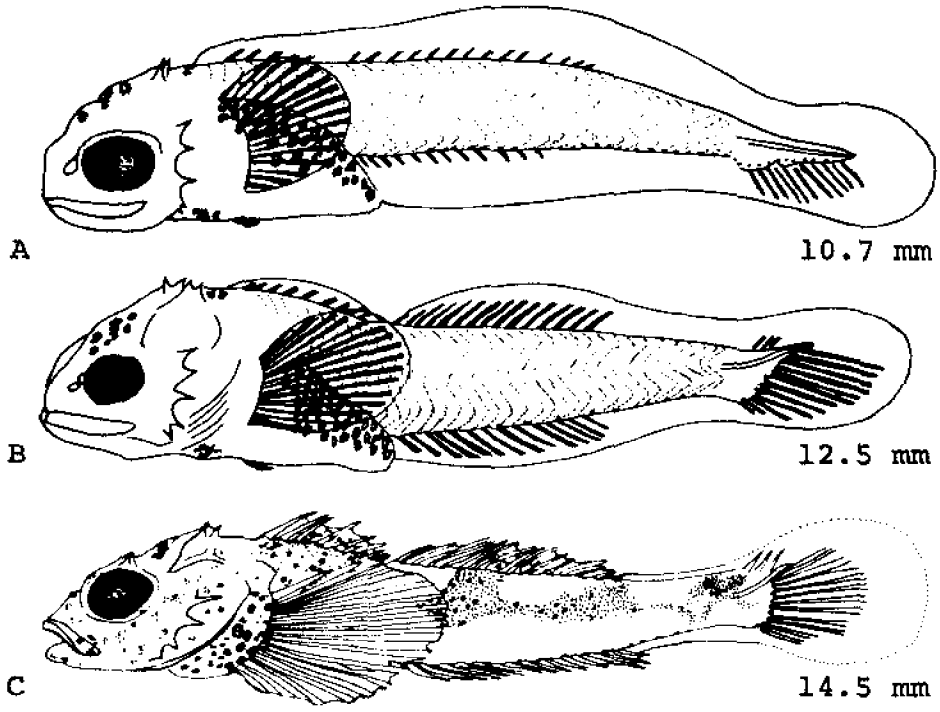

Fig. 144. *Myoxocephalus octodecemspinosus*, Longhorn sculpin. A. Larva, 10.7 mm. B. Larva, 12.5 mm. C. Juvenile, 14.5 mm. (*A-C, Khan, N. Y., 1971: fig. 7, used with the author's permission.*)

developed preopercular, 2 parietal, and 1 supraorbital spine.[1]

All fins assume adult shape; finfold remnants still visible.[1]

Pigmentation: Adult pigmentation begins to appear; small melanophores of various sizes appear laterally to form saddle bars, extending to first and second dorsal fins; peritoneal melanophores still present; few medio-*ventral melanophores still* present; small melanophores line edges of both hypurals; large melanophores appear at base of pectoral fins; some melanophores on pectorals and sides of head.[1]

GROWTH

Reaching 55 mm at end of first year, 180 mm at 2 years, and 210 mm at 3 years.[1]

AGE AND SIZE AT MATURITY

Matures in third year (2+ age-group).[1]

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Cyclopterus lumpus
Liparis inquilinus

lumpfishes and snailfishes
Cyclopteridae

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FAMILY CYCLOPTERIDAE

The snailfishes and lumpsuckers are generally cold-water fishes found in the northern hemisphere. They are characterized by the presence of a sucking disc formed by a modification of the pelvic fins.

The family is often divided into the families Liparidae (snailfishes) and Cyclopteridae (lumpsuckers). The snailfishes have a long dorsal fin bearing a few spines at its anterior end and are small flabby fishes without scales. The lumpsuckers' dorsal fin is divided by a notch into two sections and the sides bear tubercles. This account treats the two families together. As recognized, the family Cyclopteridae contains over 100 species, two of which are found in the Mid-Atlantic Bight.

Khan (1971) has listed the characters useful in distinguishing young snailfish from other closely related groups:

1. Small melanophores on the pectoral fins.
2. Pelvic fins modified into a sucker.
3. Pigmentation diffuse.

Cyclopterus lumpus Linnaeus, Lumpfish

ADULTS

D. VI to VIII,[5,6,8,9] 9[5,8]–11; [5,6,8,9] A. 9[5,6,8,9]–11; [5,8] C. 3+5+5+2; [21] P. 20; V. 6; [6,9] body covered with conical, rough, bony tubercles; [9] vertebrae 11+18=29; [6,9] teeth small,[5,9] simple,[9] arranged in bands; [5,9] branchiostegals 6.[6,8]

Head 5, depth 2 in TL.[5]

Body massive,[5,6] triangular in transverse section at first dorsal, more or less compressed posteriorly.[5,6,9] Body with seven longitudinal ridges: one on median line of back as cartilaginous flap enclosing the first dorsal fin and dividing into two ridges between dorsal fins; one on each side over eye; one from posterior point of opercle to lower edge of caudal; and one at side of belly.[5] Head

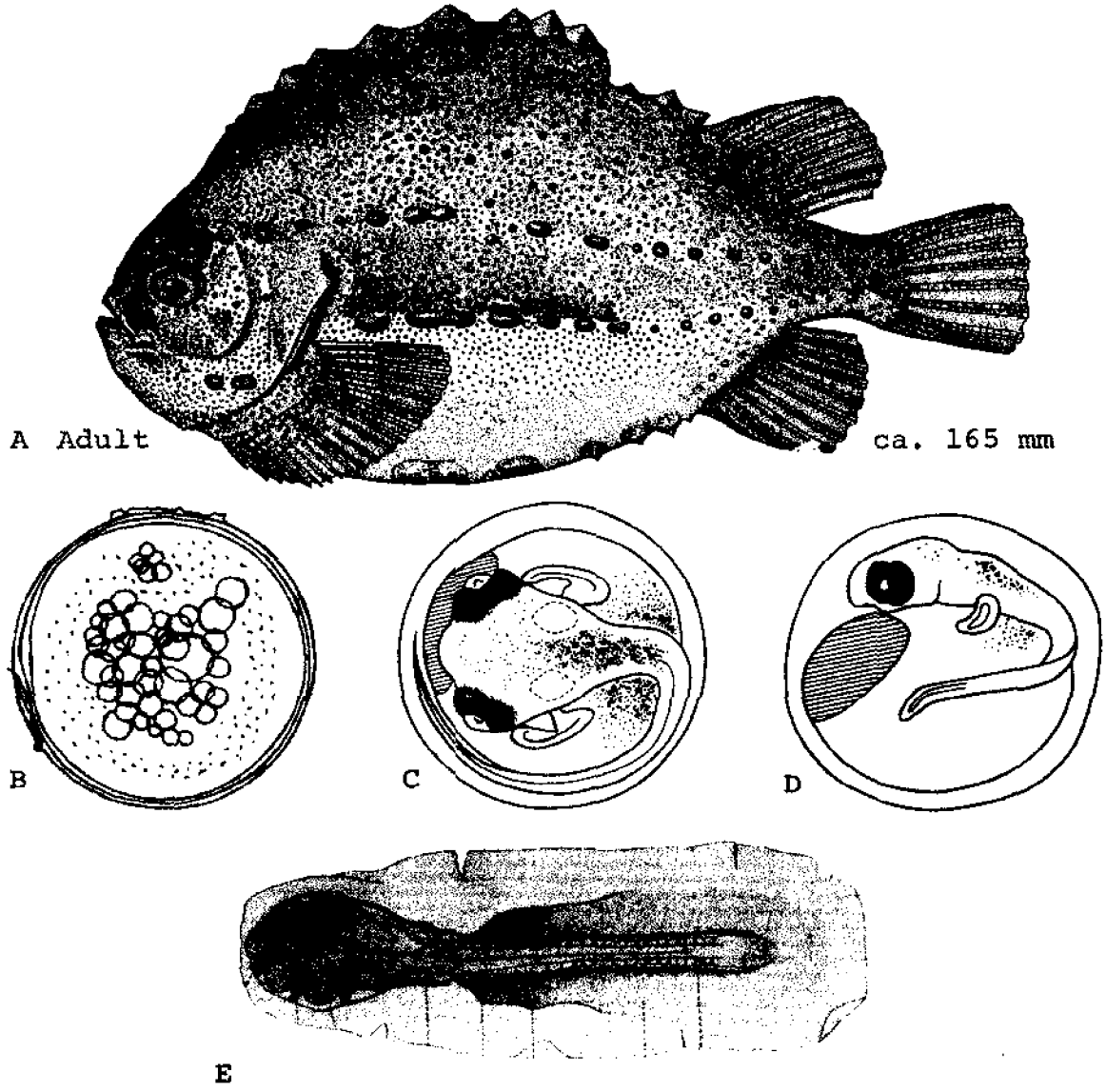

Fig. 145. *Cyclopterus lumpus*, Lumpfish. A. Adult, ca. 165 mm SL. B. Egg. C. Egg, with developing embryo. D. Egg, with developing embryo. E. Embryo with 22 myomeres. (*A, Gill, T. N., 1907: fig. 36 after Goode. B, McIntosh, W. C., and A. T. Masterman, 1897: pl. 2, fig. 1. C, D, Zhitenev, A. N., 1970: fig. 4. E, Guitel, F., 1896: pl. VI, figs. 1–2.*)

short, broad, blunt;[6] snout short;[5] mouth terminal,[5,6,9] opening slightly upward; gape almost vertical from front margin of eye.[6,9] Second dorsal and anal fins similar and opposite; caudal fin square to slightly rounded; pelvic fins modified into six pairs of fleshy knobs in center of sucking disc, surrounded by circular flap of skin; pectoral fins large, broadbased, nearly meeting below.[5] Gill openopenings moderately wide;[5,6] eye lateral,[9] small[5,8] to moderate.[9]

Pigmentation: Color variable;[5] males reddish; females bluish to brown;[5,6,9] spots, blotches, cloudings, and other marks not infrequent.[5]

Maximum size: To 600 mm and 6–7 kg,[17] 700 mm on English coast.[2]

DISTRIBUTION AND ECOLOGY

Range: Both sides of North Atlantic;[5,8] south in Europe to 45° N;[1,2] in western Atlantic north to Isle Disko (off Greenland)[2,8] and south to New Jersey,[1,2,8] and rarely to Chesapeake Bay.[2,5,8]

Area distribution: Recorded from Buckroe Beach and Wolf Trap Light, Virginia;[5] Worcester County, Maryland;[6] Atlantic and Cape May counties, New Jersey.[7]

Habitat and movements: Adults—primarily a bottom fish[8] along rocky shores,[4] but also semipelagic, drifting on floating seaweed.[2,8] Migrate offshore during spawning;[8] present in Bay of Fundy during spring–autumn, but disappear in winter.[1] Associated with water of fairly high salinity and low temperature;[2] recorded from tidal limits[10] and surface to 80 m.[18]

Larvae—associated with drifting seaweed,[1,2,5] and in littoral pools;[12,13] also from eelgrass at Nahant, Massachusetts.[14] Leave surface in winter[8] and at night;[1,2] found from surface to 92 m and to 2.5 km offshore.[1]

Juveniles—float among drifting seaweed,[2,5] and in eelgrass at Nahant, Massachusetts.[14]

SPAWNING

Location: Usually recorded as nearshore,[3,4,8] but also reported to occur at 27–46 m.[8]

Season: Late winter to spring,[5] April[2]–June in Nova Scotia,[1] January–April in Rhode Island,[4] February–May in Scotland,[11,12,13] and January–May in Europe.[2]

Time: Night.[20]

Fecundity: 15,000–200,000 eggs;[20] a 457 mm female produces 136,000 eggs.[8]

EGGS

Location: Deposited in mass on suitable substrate,[10] often in corners and holes in rocks between tide marks.[12,13]

Unfertilized eggs: Reddish, salmon, lilac, pale violet, pale brown, pink,[11] or amethystine through various shades of dull yellow to greenish[11,12,13] or yellowish.[3,11,17]

Fertilized egg: 2.2–2.6 mm in diameter;[2,3,4,5,8,11] adhesive;[15] several oil droplets;[1,2] 0.72–0.88 mm in diameter,[3] fusing into single one early in development,[2] golden.[4]

EGG DEVELOPMENT

Vascular system of yolk sac formed at time of embryo segmentation, and heart soon begins to function; erythrocytes found at beginning of stage of eye pigmentation.[20] Embryonic paired fin development described in detail.[15]

Hatching occurs in 43 days in eggs at surface of egg mass at 5.27–8.33 C, 60 days for eggs deep inside egg mass,[11] 70 days maximum;[1] takes 10 days or more.[22]

YOLK-SAC LARVAE

Size at hatching, 4[14]–7.4 mm,[4,8] depending on size of egg and length of incubation.[1] Yolk sac absorbed at about 10 mm (12 days).[8]

Oil globule 0.72–0.88 mm in diameter.[3] Dorsal fins connected by finfold at 6–7 mm, first dorsal fin first to form; anal and caudal fins visible in finfold at 6–7 mm; pectoral fins small and rudimentary at 5.5 mm,[1] indication of rays at 6 mm;[12,13] dorsal, anal, caudal, and pectoral fins formed by 9 mm, 10–12 mm in Europe; ventral disc present at hatching.[1]

Pigmentation: Yellowish green, with slight brassy luster and with scattered lighter streaks and patches with silvery sheen; head, pectoral fins and caudal fin base dotted with dark spots; as fins grow, coloring increases; unpigmented band between eyes and another between snout and gill opening.[1,2]

LARVAE

Specimens described 10[8]–23 mm[12,13] or to 32 mm.[14] D. VI, 11; A. 10; C. 10.[12,13] Tubercles appear at 18 mm, few behind and above eye; 22 mm, two side rows reach mid-body, ventral rows consisting of flattened papillae; 25 mm, upper lateral series complete and numerous small tubercles scattered thickly over body.[1,2]

Pigmentation: Head light chocolate brown, with darker band extending from nostrils above eye to base of first dorsal; light blue band extends from rear of orbit to top of operculum, and in front of eye to nostrils; blue spot at posterior base of dorsal and at posterior part of base of second dorsal; remainder of body straw colored. At later stage, usually bright olive green, darkest toward dorsal side; blue band extending to operculum from rear of orbit; one or two round blue spots above level of pec-

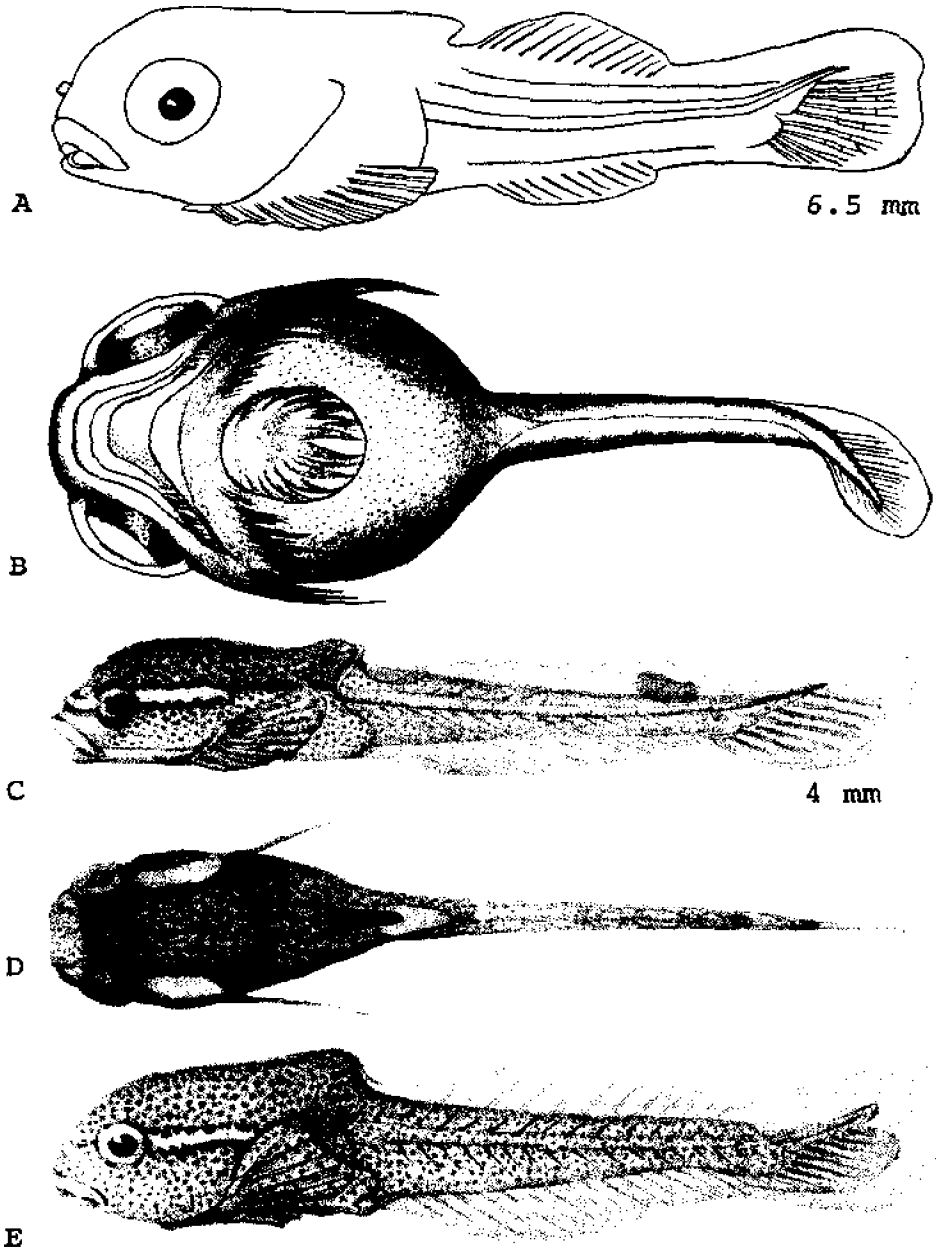

Fig. 146. Cyclopterus lumpus, Lumpfish. A. Embryo just before hatching, 6.5 mm. B. Newly hatched larva. C. Yolk-sac larva, 4 mm. D. Same from above. E. Yolk-sac larva, somewhat older. (*A, Guitel, F., 1896: fig. 7. B, Cunningham, J., 1886: pl. VII, fig. 1. C-E, Agassiz, A., 1882: pl. IV, fig. 1-3.*)

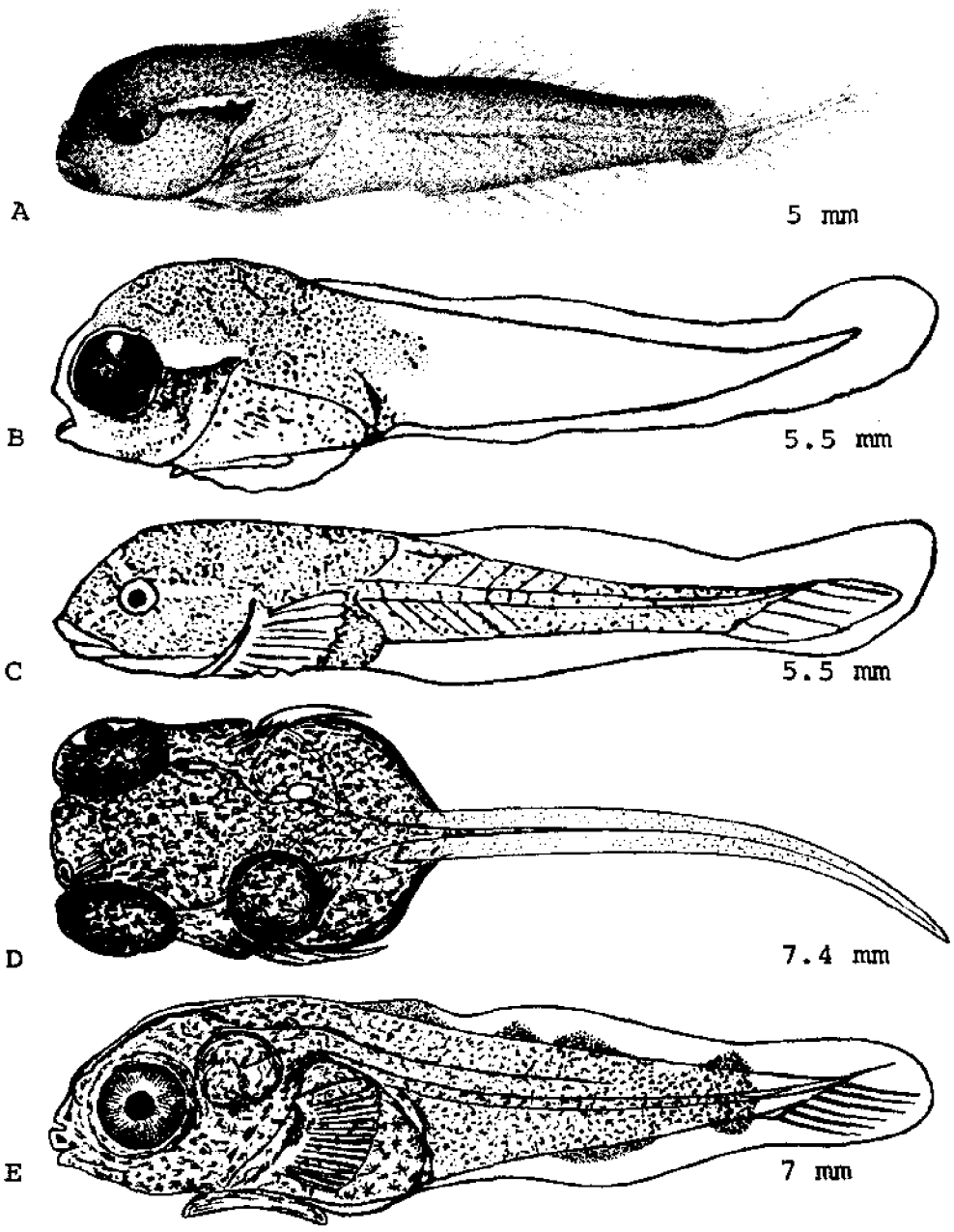

Fig. 147. *Cyclopterus lumpus*, Lumpfish. A. Yolk-sac larva, 5 mm. B. Yolk-sac larva, 5.5 mm. C. Yolk-sac larva, 5.5 mm. D. Yolk-sac larva, 7.4 mm. E. Yolk-sac larva, 7 mm. (*A, Agassiz, A., 1882: pl. IV, fig. 4. B, Rass, T. S., 1949: fig. 19. C, Cox, P., 1920: fig. 6. D, E, Ehrenbaum, E., 1905: fig. 51 a and b.*)

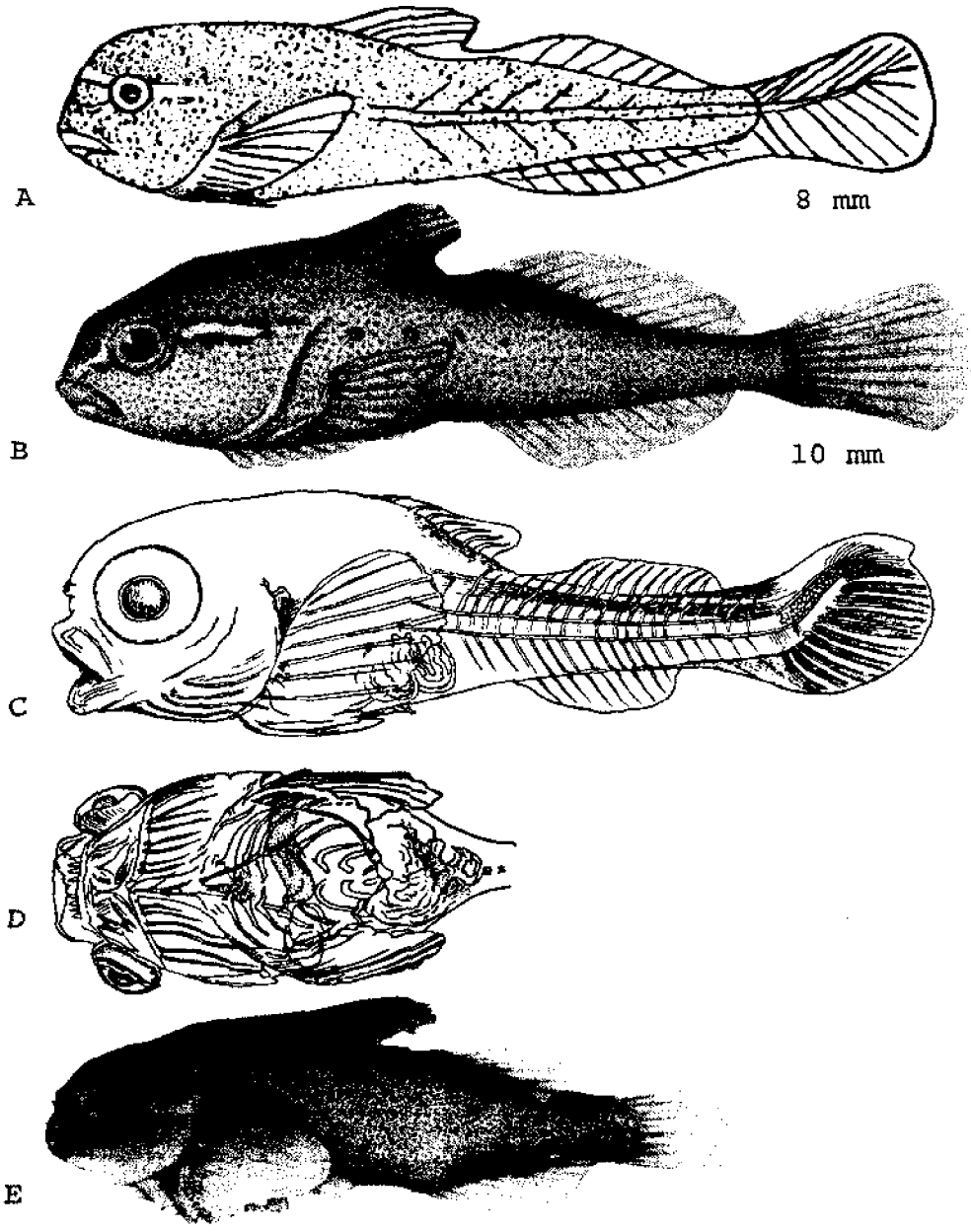

Fig. 148. *Cyclopterus lumpus*, Lumpfish. A. Larva, 8 mm. B. Larva, 10 mm. C. Larva, length unstated. D. Same from below. E. Larva, length unstated. *(A, Cox, P., 1920: fig. 6a, reversed. B, Agassiz, A., 1882: pl. IV, fig. 4. C, E, Ehrenbaum, E., 1905: fig. 51c, reversed, and d after McIntosh and Prince. E, O. Sette, original drawing.)*

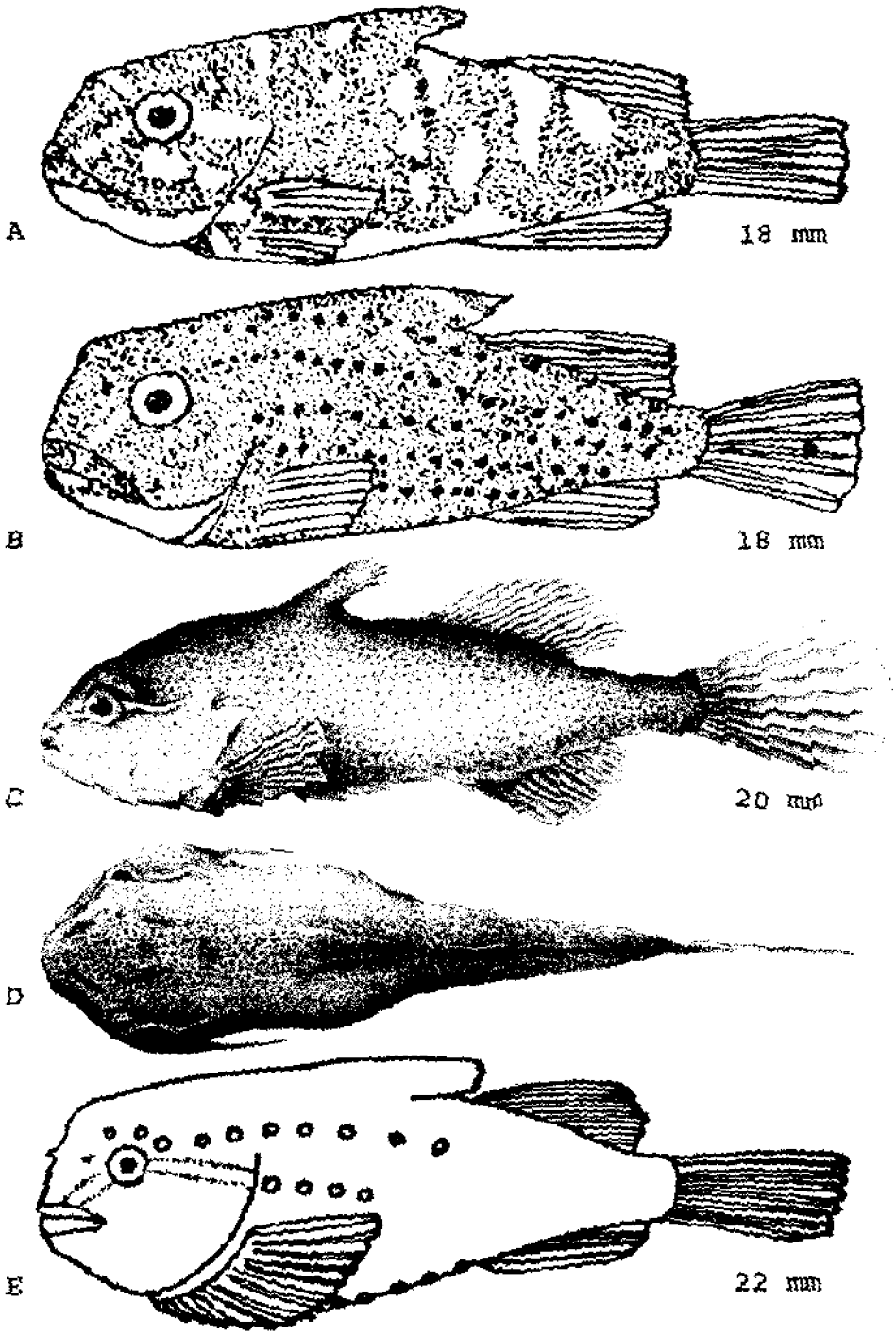

Fig. 148. *Cyclopterus lumpus*, Lumpfish. A. Larva, 18 mm. B. Larva, 18 mm. C. Larva, 20 mm. D. Same from above. E. Larva, 22 mm. (*A, B, E, Coz, P., 1920: figs. 7–8. C, D, Agassiz, A., 1882: pl. V, figs. 1–2.*)

toral fins along lateral line. Other specimens bluish neutral slate tint, uniformly spotted with darker pigment cells, with same blue band between eyes, above nostrils, and behind eyes.[14] Specimens from Scotland similarly colored.[12,13]

JUVENILES

Specimens described 23 [12,13]–34 mm.[14]

D. VI, 11; A. 10; C. 11; P. 21. Tubercles developed to

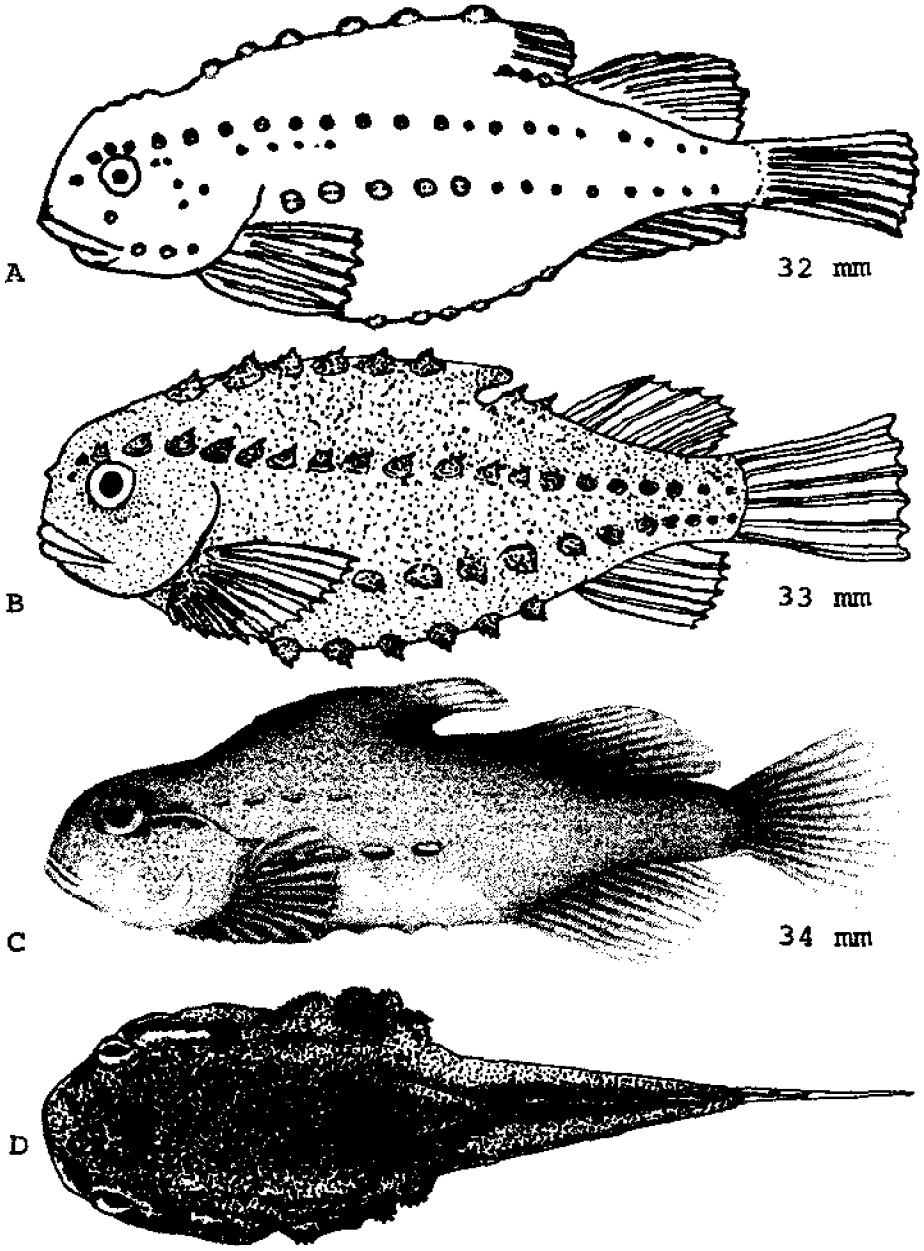

Fig. 150. *Cyclopterus lumpus*, Lumpfish. A. Juvenile, 32 mm. B. Juvenile, 33 mm. C. Juvenile, 34 mm. D. Same from above. *(A, B, Cox, P., 1920: figs. 9–10, fig. 9 reversed. C, D, Agassiz, A., 1882: pl. V, figs. 3–4, fig. 4 reversed.)*

slight extent at 34 mm,[14] 18 mm in Scotland,[12,13] and 20 mm in Trondheim.[19] Anterior part of body assumes angular outline, but more elongate than adult.[14]

Pigmentation: Green, olive, brown,[3] or yellowish, often colored like surroundings.[5]

GROWTH

Reported to grow to 7.6 mm in July, 17 mm in August; [1,2] also 23 mm in August, 43 mm in December, and 55 mm following June in Bay of Fundy; [1] 11–30 mm in July of second year in British waters; [4] increasing by .9 mm per month over 20 mm.[16]

AGE AND SIZE AT MATURITY

Mature at 127 mm in Bay of Fundy; [1] males at 229 mm and .3 kg, and females at 356 mm and .3–.36 kg in Scotland; [11] spawning fish 300–340 mm in length.[2]

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Liparis inquilinus Able, Inquiline snailfish

ADULTS

D. VII to X, 25–30; A. 28–31; C. 10–11; P. 30–35; head pores 2–6–7–2; vertebrae 8–10 + 28–32; upper pharyngeal teeth on pad, weakly trilobed; lower pharyngeal teeth reduced, simple; teeth in jaws trilobed, in regular oblique rows, 8–12 rows on upper jaw, 8–11 on lower; 6–10 teeth *per row on upper jaw, 5–9 on lower jaw;* 14–21 *pyloric* caeca.[1]

Measurements given as percent SL: snout to disc 11.4–29.0; snout to anal fin origin 39.8–53.8; snout to vent 31.9–48.3; height above disc 16.9–33.4; disc length 12.2–17.7; pectoral fin length 19.3–27.4; caudal fin length 14.9–23.7; width at anal fin origin 4.5–15.2; head length 23.0–35.1; disc to vent 4.0–13.4; disc to anal fin 12.3–26.5. Measurements given as percent HL: disc length 43.3–67.3; eye length 18.6–30.0; interorbital 26.1–49.5.[1]

Body tadpole-shaped, compressed behind origin of anal fin; greatest body depth in region of disc; head broader

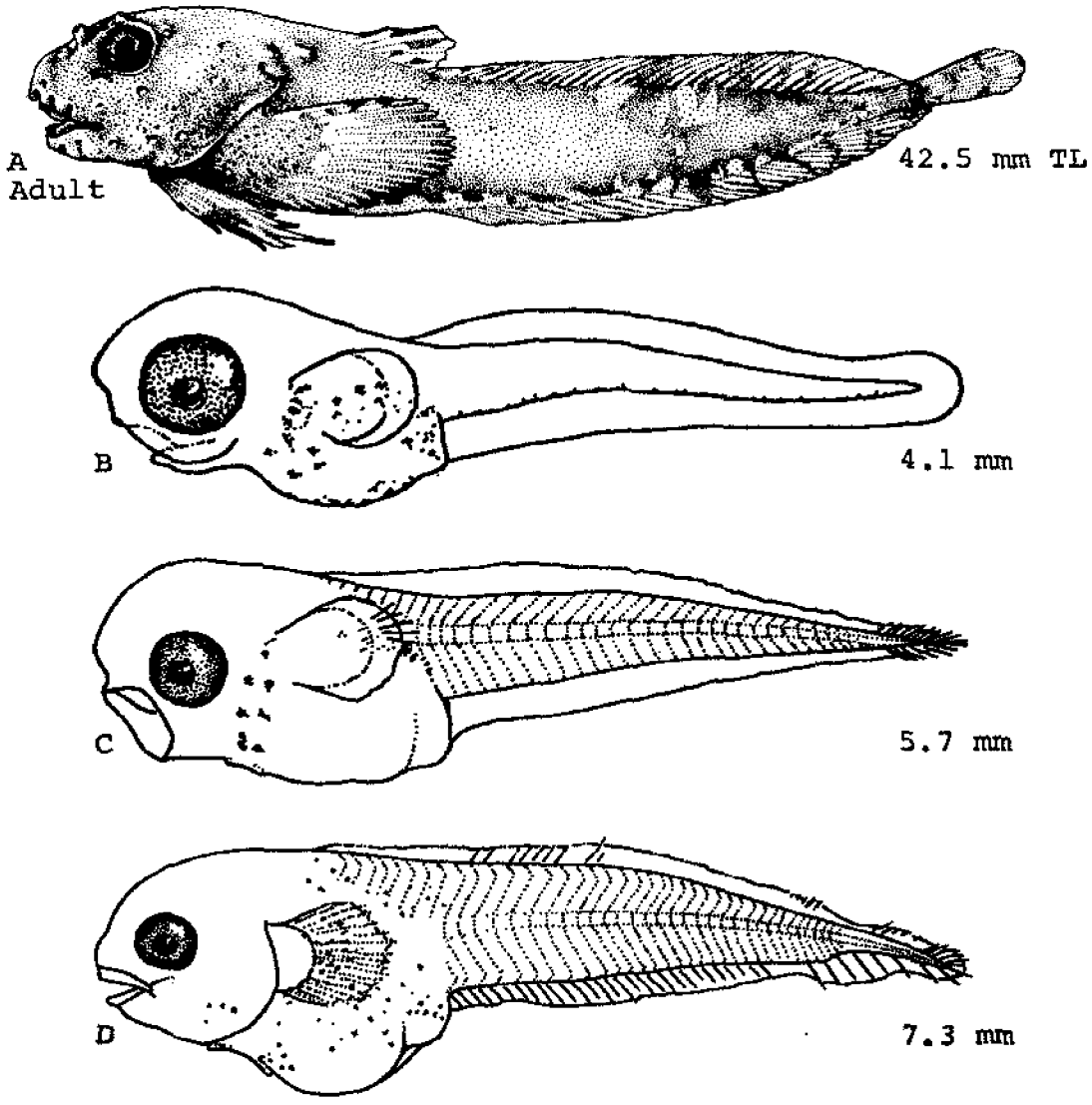

Fig. 151. Liparis inquilinus, Inquiline snailfish. A. Adult, 42.5 mm TL. B. Yolk-sac larva, 4.1 mm. C. Yolk-sac larva, 5.7 mm. D. Yolk-sac larva, 7.3 mm TL. (A, Able, K. W., 1973: fig. 1. B-D, Able, K. W., 1974.)

than high, sloping to snout, then rounded; two pairs nostrils, anterior in tubes, posterior in raised pores; mouth extends laterally to front of eye; lips fleshy, with recessed pores, those of upper jaw extending over those of lower jaw. Skin loose with small thumb-like prickles; disc longer than wide, with 13 papillae.[1]

Pigmentation: Extremely variable. Four basic color patterns: spotted, striped, mottled, and plain. Patterned individuals usually light brown to reddish brown. White often present on striped form; plain patterned individuals usually brownish to black, with white ventral surface. Areas of fins without patterns, usually clear or white; caudal fin usually barred. Peritoneum with a few brown spots.[1]

Maximum size: 72 mm TL.[3]

DISTRIBUTION AND ECOLOGY

Range: Southern Gulf of St. Lawrence to Cape Hatteras, North Carolina.

Area distribution: Mouth of Delaware Bay, on continental shelf of the Mid-Atlantic Bight.

Habitat and movements: Adults—collected at depths from 5 to 97 m[1] (November–April) while migrating inshore to spawn; 4.0–14.5 C.[3]

Larvae—planktonic during spring (April–June).[3]

Juveniles—found in the mantle cavity of sea scallops (*Placopecten magellanicus*)[2,3] from July–December.[3]

SPAWNING

Near shore and away from scallop beds in winter; peaking in March and April.[3]

Fecundity: Mean number of eggs per female 342.[3]

EGGS

Demersal; adhesive; in pinkish masses of 20–80 in laboratory; attached to hydroids in nature; 1.02–1.12 ($\bar{x}$=1.07) mm preserved and 1.15–1.24 mm in diameter when fresh; 3–8 oil globules in preserved eggs from laboratory, single oil globule 0.24–0.25 mm in diameter in eggs collected in nature.[4]

EGG DEVELOPMENT

Embryo with large melanophores on abdominal region, usually on anterior portion behind base of pectoral fin, and on dorsolateral and ventral surfaces. Smaller melanophores on inner surface of pectoral fin base and in line along entire ventral midline above anal finfold. Xanthophores present on pectoral fins. Eyes large, black.[4]

YOLK-SAC LARVAE

Specimens described 2.9 to 6–7 mm SL.

Newborn with large eyes and short gut.[1] Pectoral fin well formed at hatching; pectoral and caudal fins develop incipient rays at about 5 mm; sucking disc formation begins at 4–5 mm; fin rays present in pectoral fin and ventral primary caudal rays developing by 7 mm. Single pair of nares present at hatching; anus located immediately anterior to ventral finfold.[4]

Pigmentation: Coloration of recently hatched individuals identical to that of embryos.[4]

LARVAE

Specimens described 6–7 to 10 mm.

Eye diameter relative to head length decreases from 40% prior to notochord flexion to 28% during flexion and 21% after; relative head length increases from 20%, to 24% and 28%; ventral disc relative to head length increases from 16% to 25% and 36%; snout anus distance decreases from 42% to 39%.

Dorsal and anal rays forming by 6–7 mm and by 8–9 mm dorsal fin notched at fifth to seventh rays; full ray complement in all fins by 10 mm; nares elongate and split into two distinct openings by about 9 mm.[4]

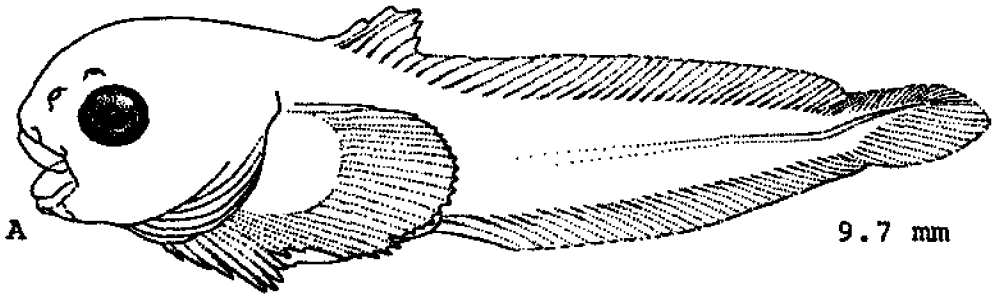

Fig. 152. *Liparis inquilinus*, Inquiline snailfish. A. Larva, 9.7 mm. (*A, Able, K. W., 1974.*)

Pigmentation: At about 6–7 mm consists of small melanophores in irregular pattern on body above gut and on dorsal, lateral, and ventral surface of head and on disc and tail; melanophores on ventral midline occasionally lengthen and occupy dorsal portion of individual anal fin rays. Larvae longer than 9 mm have melanophores densely scattered over entire body.[4]

JUVENILES

Specimens described 10 mm[4]–45 mm TL.[3]

Notochord flexion complete by 12 mm but notochord comprises portion of caudal fin in some up to 14 mm.[4]

Pigmentation: By 12–14 mm some develop patterns on posterior portion of dorsal and anal fins characteristic of some adults. Juveniles longer than 14 mm develop individual variation in pigmentation characteristic of adults.[4]

GROWTH

Specimens 3–13 mm TL in April–June; 14–45 mm TL in July–December; greater than 33 mm TL in November–January; 41–72 mm TL in February–April.[3]

AGE AND SIZE AT MATURITY

Mature at 1 year and from 41 mm TL.[3]

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Cephalacanthus volitans

flying gurnards
Cephalacanthidae

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FAMILY CEPHALACANTHIDAE

The flying gurnards are marine fishes confined to warmer seas. They bear some resemblance to the searobins (Triglidae) and are characterized by enlarged pectoral fins with the inner rays free, large bony head, and single isolated spine on the nape. Although reported able to fly, no concrete evidence of this has been produced.

The early development of the only species included in this volume has been extensively studied by Sanzo (1933).

Cephalacanthus volitans (Linnaeus), Flying gurnard

ADULTS

D. VI–I,[2,5,6,7] 8; A. 6;[2,3,5,6,7] C. 3+5+5+2;[3] P. 26[7]–30[7,8]+5[8]–6;[5,8] V. I, 4;[6] 59[2]–69[7] lateral scale rows; vertebrae 8+14=22;[3] teeth in jaws granular,[6] blunt, in bands.

Head 4.0[2]–4.3,[5] body depth 5.5[2,5]–6.5,[7] pectoral fins 1.4 in SL. Snout 2.6, eye 3, interorbital 1.8, maxillary 2.6 in head.[2]

Body elongate,[2,6] depressed, broader than deep,[2] head blunt,[2,6] depressed,[2] quadrangular;[6] snout short;[2] mouth small,[6,7] low on head,[7] lower jaw included; maxillary reaching to anterior margin of orbit.[6] Scales with sharp keels;[2,7] no lateral line.[9] First two dorsal fin spines separate;[2,5,7] second dorsal and anal fins similar in shape; caudal fin deeply concave; pelvic fins inserted under posterior part of pectoral fins, rather narrow, pointed;[2] pectoral fins in two sections,[2,5,7] upper short, lower long, broad,[2] reaching caudal base.[2,5,7] Interorbital concave, broad;[2] preopercle with long spine;[2,5,7] long keeled spine extending posteriorly from bony shield on nape.[7]

Pigmentation: Color variable;[5,6] back and sides shades of green, brown,[2,5,6] and red;[2] pale[5,6] to white[2] below; spinous dorsal fin barred and spotted with purple, brown, and yellow; soft dorsal fin plain, the rays alternately spotted with yellow and red; caudal fin with two[2] or three[2,5,6] reddish[6] to brownish red[5] bars, with yellow interspaces; anal fin with three pale reddish bars, outer edge yellowish; pelvic fins deep orange; pectoral fins mostly black,[2] with blue streaks, spots, and bars,[2,5,6] and obscure reddish blotches.[2]

Maximum size: To 457 mm SL.[10]

DISTRIBUTION AND ECOLOGY

Range: Both sides of the Atlantic Ocean;[2,5,7] on American coast from Bermuda[7] and Cape Cod, Massachusetts[2] to Argentina;[7] common southward; rare north of North Carolina, only occasionally straying northward to Cape Cod.[2]

Area distribution: Recorded from Atlantic and Cape May counties, New Jersey,[4] from Worcester County, Maryland[5] and lower Chesapeake Bay.[2,5]

Habitat and movements: Adults—associated with sandy or muddy bottoms, usually around 10–30 m,[11] occasionally as shallow as 2 m (FDM).

Larvae—pelagic.[1]

Juveniles—attracted to submerged lights.[8]

SPAWNING

Ripe females collected in June and July in the Mediterranean.[1]

EGGS

Pelagic; rosy coral or bright coralline when unfertilized; slightly oval; transparent; small, 0.8 x 0.76 mm; without sculpturing; yolk vesiculated; oil droplet 0.14 mm in diameter, reddish coral; no obvious perivitelline space.[1]

EGG DEVELOPMENT

Development rapid. Six hours after fertilization—embryo reaches halfway around egg, some segmentation, otic diverticulum forming. 23 hours after fertilization—embryo almost encircling egg, tiny otoliths present, 22 myomeres visible. Eggs hatch in about one day.[1]

YOLK-SAC LARVAE

Specimens described 1.8[1]–1.86 mm.[12]

Total myomeres 22,[1,12] 7–8[1,12] preanal, 14[1]–15[12] postanal. Head deeper on second day; yolk mass reaching under head, very small by third day; oil globule posterior and coralline; mouth opens third day after hatching;[1] pectoral fins round and membranous;[1,12] anus migrates forward,[12] in advance of midpoint of body by third day after hatching;[1] length decreasing as yolk sac absorbed; spine at inferior angle of preopercle at 1.86 mm.[12]

Pigmentation: No pigmentation at hatching, takes on some pigment during second day, by third day some pigment appears on head and posteriorly on body;[1,12] eyes pigmented, intense black pigment on abdomen, spot at base of pectoral fin and on opercle, yellowish tinge on nape at 1.86 mm.[12]

LARVAE

Specimens described 2.40–9.12 mm.

Total myomeres 22, 6 preanal, 16 postanal. Body high, greatest height one-third of TL; snout short; mouth narrow, small; eye large; elevated orbital crest; three large spines on head and a preopercular spine; crests and spines smaller at 2.48 mm than 2.40 mm;[12] second dorsal fin, anal fin, hypurals forming by 3.48 mm. Second dorsal with 8 unbranched, unsegmented rays at 7.48 mm. Anal fin with 6 unsegmented, unbranched rays at 7.48 mm; 10 rays formed by 9.12 mm. Pectoral fins reach near second dorsal fin by 9.12 mm.[1]

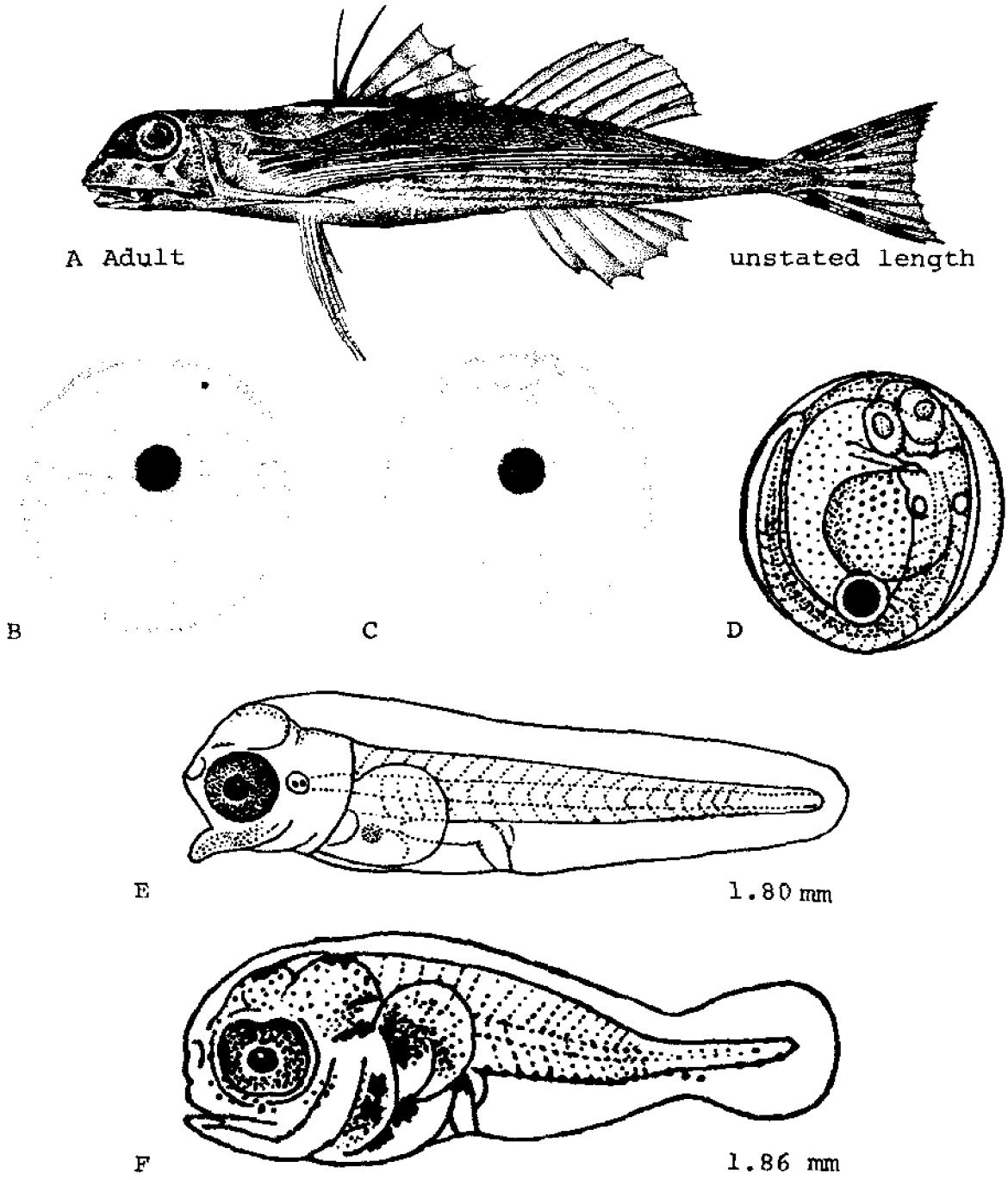

Fig. 153. *Cephalacanthus volitans*, Flying gurnard. A. Adult, unstated length. B. Egg. C. Same egg a few hours later. D. Same egg the next day. E. Yolk-sac larva, recently hatched, 1.80 mm. F. Yolk-sac larva, 1.86 mm. *(A, Smith, H. M., 1907: fig. 165. B-C, Sanzo, L., 1933b: figs. 1–2. D-F, Padoa, E., 1956b: figs. 519–521 redrawn from Sanzo, 1933b and Sanzo, 1939.)*

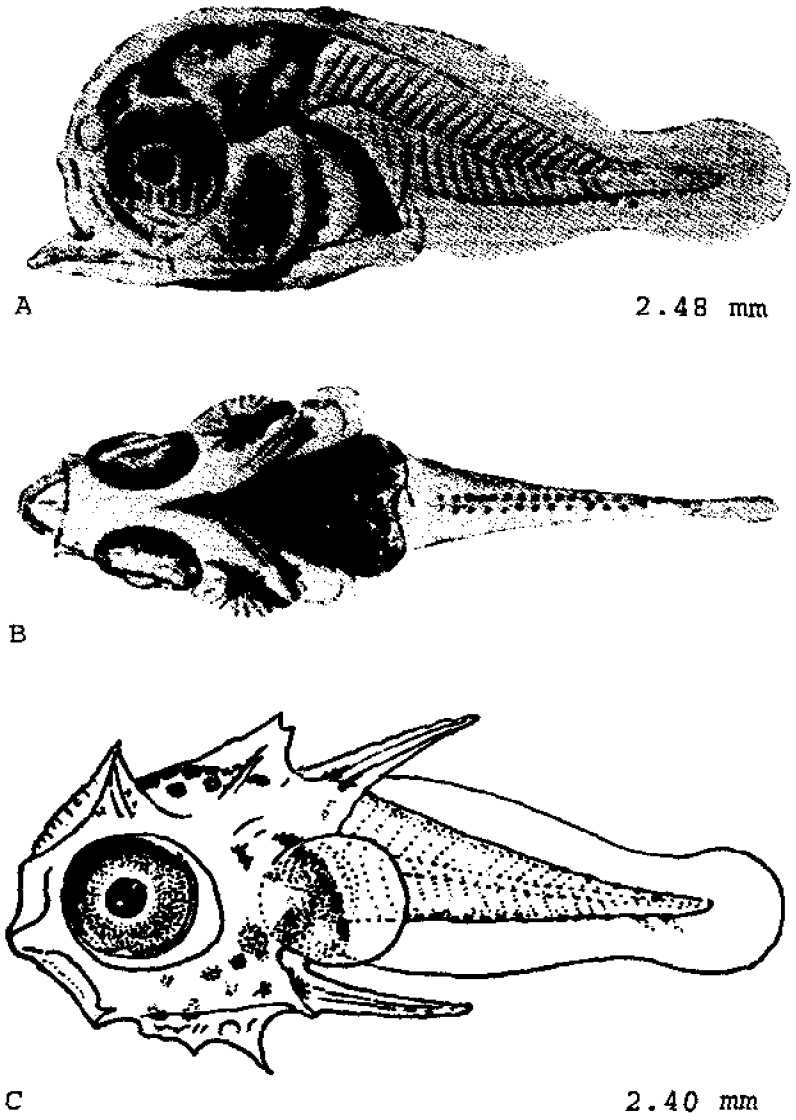

Fig. 154. *Cephalacanthus volitans*, Flying gurnard. A. Larva, 2.48 mm. B. Ventral view of A. C. Larva, 2.40 mm. (*A, B, Sanzo, L., 1939: figs. 13–14. C, Padoa, E., 1956b: fig. 522 redrawn from Sanzo, L., 1933b.*)

Pigmentation: At 2.40 mm pigmentation sparse, present on interorbital, postorbital and sides of body; chromatophores on dorsum evenly spaced; some pigment ventrally on caudal peduncle and behind anus. Pigmentation at 2.48 mm more intense even though spines less developed; peritoneal pigment diffuse; band of pigment at base of pectoral and opercular region.[12] At 3.48 mm pigmentation similar except new chromatophores in advance of and below orbit; pigment absent posteriorly.[1]

Coloration at 7.48 mm similar to 3.48 mm larva; head with large evenly spaced chromatophores, numerous tiny spots; opercle with pigment; trunk goldish with ventral surface spotted; no fin pigment. Pigmentation similar at 9.12 mm but posterior pigment absent.[2]

JUVENILES

Specimens described 16.5–100 mm SL.

Head deep; snout short; mouth small; eye quite large; head spines similar to 3.48 mm larva. First dorsal fin continuous with second dorsal fin; second dorsal fin rays segmented and branched by 32 mm. Anal fin rays seg-

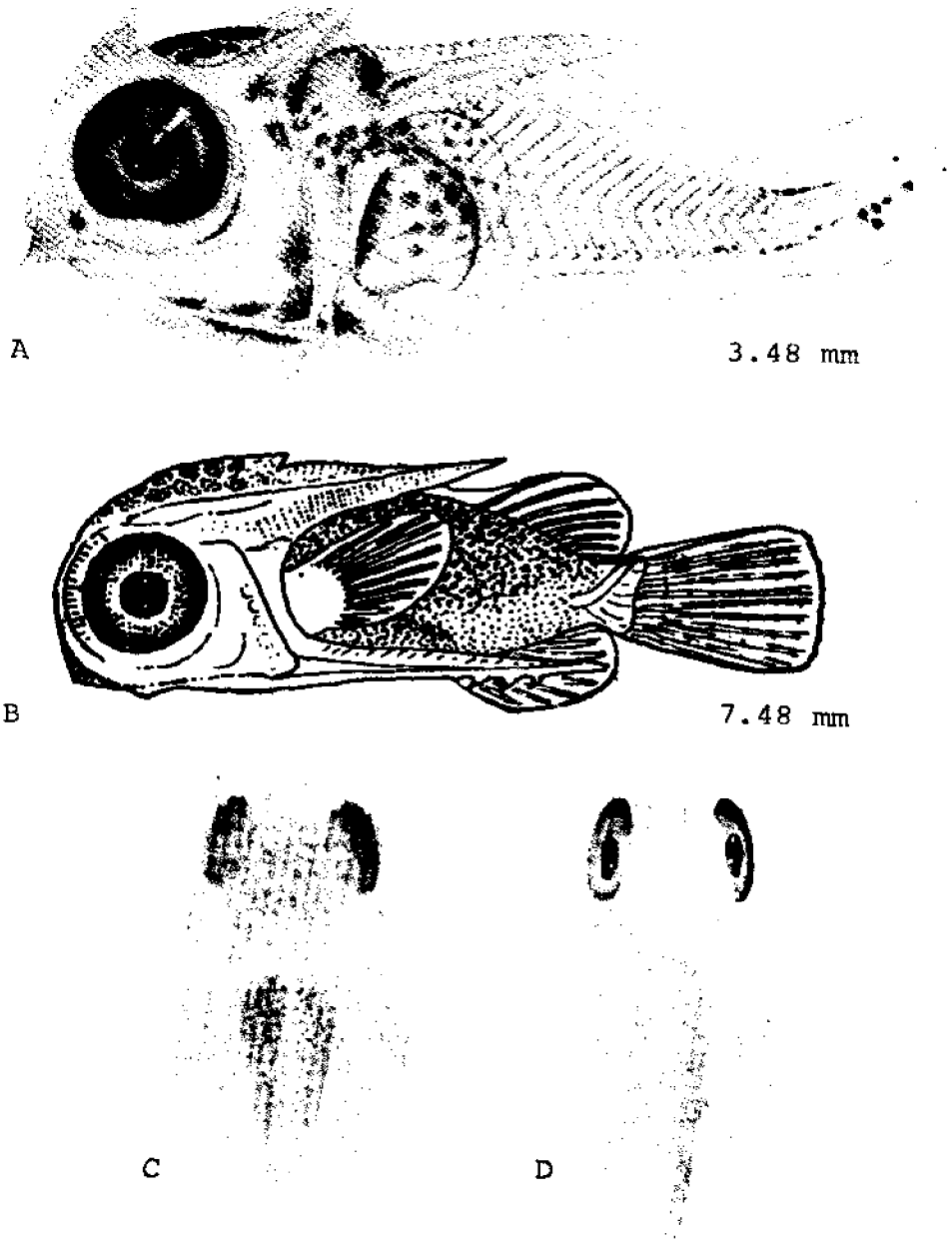

Fig. 155. *Cephalacanthus volitans*, Flying gurnard. A. Larva, 3.48 mm. B. Juvenile, 7.48 mm. C. Dorsal view of B. D. Ventral view of B. *(A, C, D, Sanzo, L., 1933b: figs. 6, 7, 7₁. B, Padoa, E., 1956b: fig. 523 redrawn from Sanzo, L., 1933b.)*

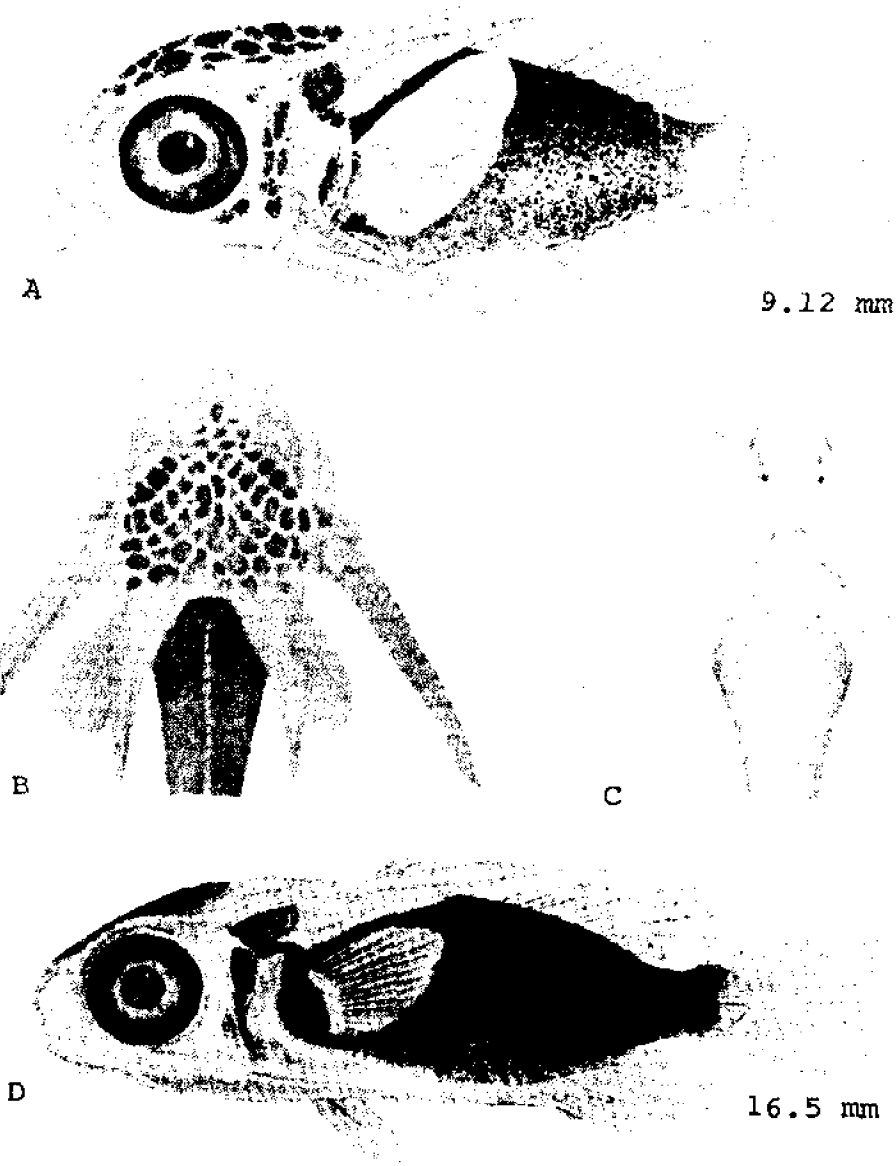

Fig. 156. Cephalacanthus volitans, Flying gurnard. A. Juvenile, 9.12 mm. B. Dorsal view of A. C. Ventral view of A. D. Juvenile, 16.5 mm. *(A-D, Sanzo, L., 1933b: figs. 8–9.)*

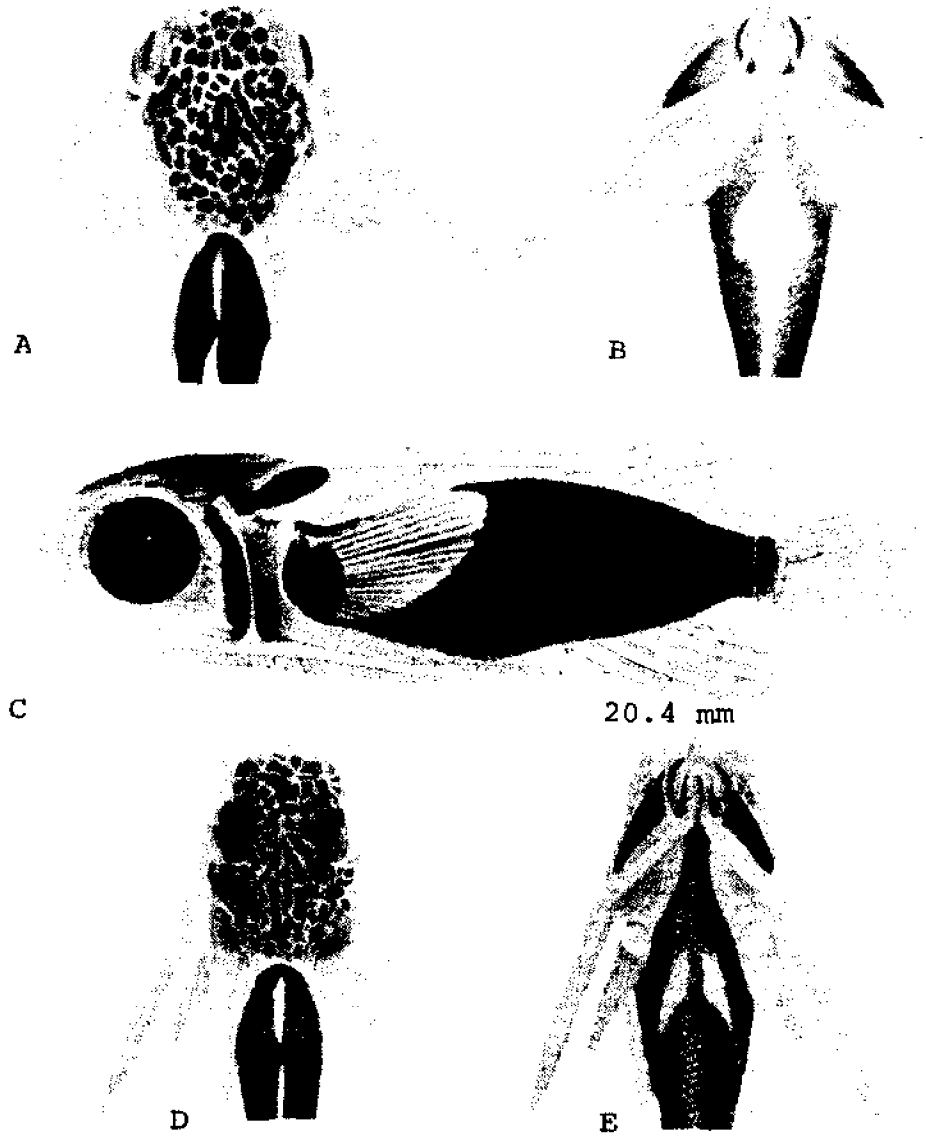

Fig. 157. *Cephalacanthus volitans*, Flying gurnard. A. Dorsal view of 16.5 mm juvenile. B. Ventral view of same. C. Juvenile, 20.4 mm. D. Dorsal view of C. E. Ventral view of C. (*A-E, Sanzo, L., 1933b: figs. 9–10.*)

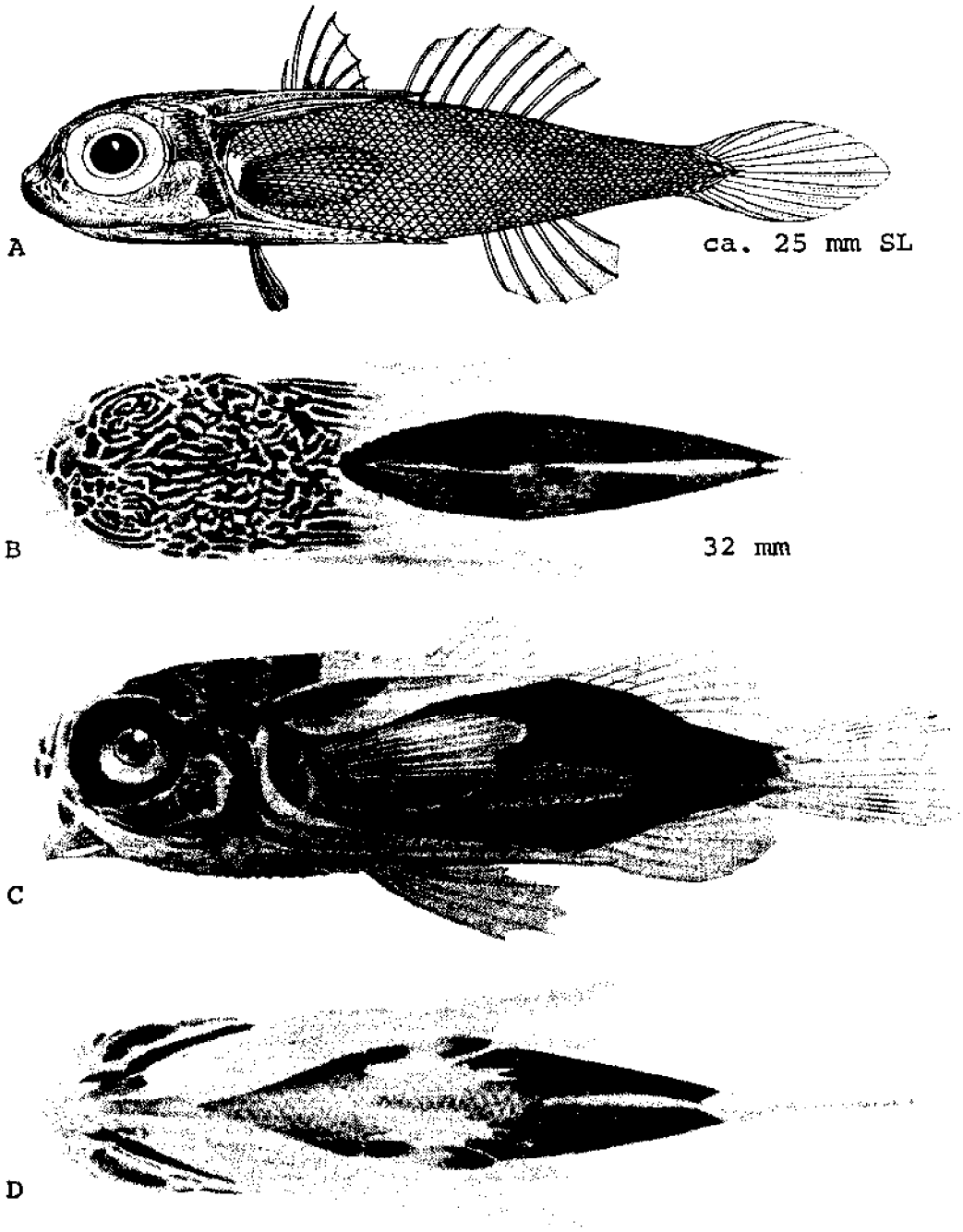

Fig. 158. *Cephalacanthus volitans*, Flying gurnard. A. Juvenile, ca. 25 mm SL. B. Juvenile, dorsal view, 32 mm. C. Lateral view of B. D. Ventral view of B. (*A, Fowler, H. W., 1945: fig. 251. B-D, Sanzo, L., 1933b: figs. 11–12.*)

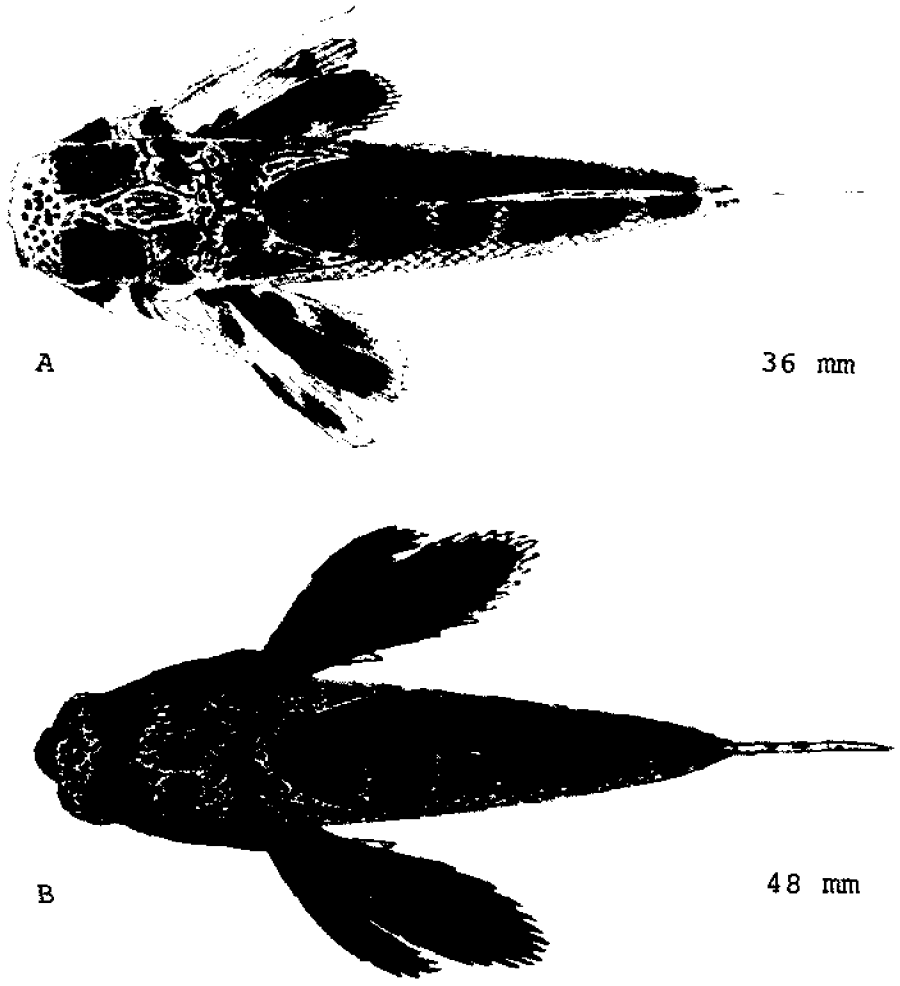

Fig. 159. *Cephalacanthus volitans*, Flying gurnard. A. Juvenile, dorsal view, 36 mm. B. Juvenile, dorsal view, 48 mm. *(A-B, Padoa, E., 1956b: tav. 40, fig. 11 and tav. 41, fig. 1.)*

mented and branched by 32 mm; caudal fin well-developed, long margin rounded, 3 dorsal and 3 ventral procurrent rays by 32 mm; pectoral fins long, reach to caudal base by 100 mm; pelvic fins formed by 16.5 mm.[1]

Pigmentation: By 32 mm, dorsolateral pigment brownish and intense. By 46.5 mm, pectoral and anal fin origins intensely pigmented with black; bases whitish; pelvic fins remain unpigmented; dorsal fin rays with some spots.[1]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

Fig. 160. *Cephalacanthus volitans*, Flying gurnard. A. Juvenile, dorsal view, 63 mm. (*A, Padoa, E., 1956b: tav. 41, fig. 2.*)

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Ammodytes sp.

sand lances
Ammodytidae

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FAMILY AMMODYTIDAE

The sand lances can be locally abundant and are found in northern temperate waters over sand bottoms. They spend a good deal of time buried in the sand.

The number and identity of North American species of *Ammodytes* are still in a state of flux (Richards, Perlmutter, and McAneny, 1963; Richards, 1965; Richards and Kendall, 1973). A resolution of this problem is not within the scope of this volume and as a result a specific name or names have not been assigned to the sand lance covered herein. Information published under all nominal species from the area of interest, i.e., *A. americanus, A. hexapterus, A. dubius*, . . . , has been abstracted; thus, this account may include more than one species.

Ammodytes sp., American sand lance

ADULTS

D. 51–68; A. 25–35; P. 12–16;[4] V. absent;[9] vertebrae 60[4]–80;[6] jaws[9,11] and vomer without teeth; lateral skin folds 125–130, running obliquely downward and backward.[11]

Measurements given as percent SL: Body depth 6.8–9.7; head 18.4–24.2; pectoral length 8.8–13.0. Eye 13–26.2% of head length.[4]

Body very slender,[9,11] elongate, slightly compressed,[11] with a pair of ventrolateral keels (AWK); head long, snout sharply pointed,[9] mouth large, lower jaw projecting;[9,11] angle of mouth slightly in front of eye;[11] scales small, lying in series between lateral skin folds;[9,11] lateral line straight;[11] dorsal fin single, low, soft rayed, originating somewhat in advance of tip of pectoral fin and running back nearly to base of caudal fin; anal fin similar in outline, soft rayed, originating slightly behind middle of dorsal fin and running back nearly to base of caudal fin; caudal fin deeply forked; pectoral fins pointed, set low on body;[9] eye moderate.[11]

Pigmentation: Olive, brownish or bluish green above with lower sides silvery and belly dull white; sides may or may not have longitudinal stripe of steel blue iridescence.[9,11]

Maximum size: To about 216 mm.[11]

DISTRIBUTION AND ECOLOGY

Range: North American coast,[9] Hudson Bay and western Greenland (69° N)[4] south to Cape Hatteras.[9,11]

Area distribution: Recorded from the entire Mid-Atlantic Bight[4,9,11] specifically from Cape Charles, Virginia[5] and lower Chesapeake Bay.[10]

Habitat and movements: Adults—demersal,[7] preferring sandy bottoms[7,10] from the littoral zone to the edge of the continental shelf.[4] Leave shallower bays in midsummer when water is warmest, come in again in early autumn at Woods Hole;[9] associated with salinities from 26.0 ppt to greater than 30.0 ppt and temperatures between 0 and 10 C.[4]

Larvae—most abundant off southern New England and the region off Delaware with declining numbers to the south. Thought to migrate diurnally,[7] however, the evidence is inconclusive;[2] move seaward with increase in size off Chesapeake Bay;[1] tending to drift generally offshore and slightly south; during May, there is a general migration back to the coast or to the bottom on offshore banks.[2] Recorded from waters with salinities between 1.8 ppt[1] and 33.0 ppt and temperatures between 0 and 11 C, generally present seasonally when the water column is thermally homogeneous (AWK). Collected where depth greater than 15 m in Long Island Sound.[7]

Juveniles—no information.

SPAWNING

Location: From Canada to Virginia, on inner half of continental shelf south of Cape Cod;[1,7] at depths from 9 to 21 m;[1] both inshore and offshore.[2]

Season: Winter and spring spawners;[8] late November or early December to late March for 35°–41° N,[2] November to May with a peak in December off Chesapeake Bay.[1]

Temperature and salinity: Occurs when temperatures are lower than 9 C,[1,7] recorded at 8.0 C (November) to −1.7 C (February); and when salinities are 28.5 ppt (November) to 26.9 ppt in Long Island Sound.[8]

EGGS

Probably demersal;[1,7,12] not quite spherical; interior cloudy; 0.67–0.91 mm, $\bar{x}$=0.82 mm in diameter (n=40); membrane pitted; slightly adhesive; yolk dull yellow to white; oil droplets 0, 2, or 3, 0.17–0.33 mm, $\bar{x}$=0.22 mm in diameter (n=34); perivitelline space narrow.[8]

EGG DEVELOPMENT

Embryo colorless until body extends nearly twice around yolk, when the eye turns brown and pigment appears along ventral edge of body.[8]

YOLK-SAC LARVAE

Hatch at 3[3]–6.5 mm,[12] larger to the north,[3] 3.1–7.0 mm specimens described.[1]

Body very slender;[1] oil globule near posterior end of yolk sac,[8] absorbed between 5 and 7.5 mm;[3] lower jaw protrusible;[1] no teeth on jaws at any time during development;[3] anus opens to one side, not at margin of finfold.[1,8,12]

Pigmentation: At hatching—all pigment ventrad; 2 or 3 black chromatophores beneath pectoral fins[8] followed by short dashes of black pigment above intestine;[8,12] 2 black spots appear just above vent; first of a series of round black spots present on tail just posterior to vent;[8] gut pigment always present; caudal pigment present either at hatching or shortly after hatching, changing from horizontal to vertical in position as caudal fin develops; ventral body pigment increases with development; ventral finfold never pigmented.[8]

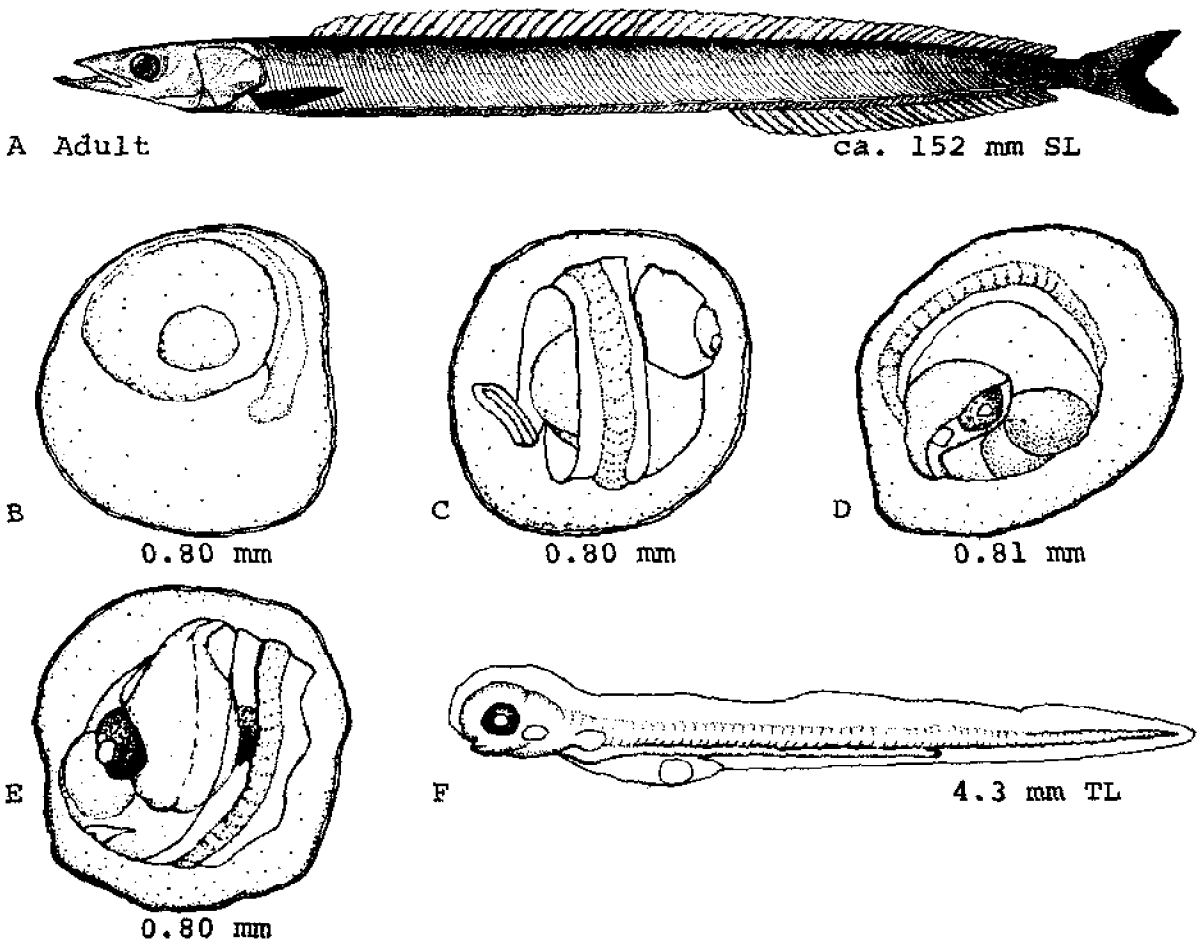

Fig. 161. *Ammodytes* sp., American sand lance. A. Adult, ca. 152 mm SL. B. Developing egg, 0.80 mm diameter. C. Developing egg, 0.80 mm diameter. D. Developing egg, 0.81 mm. E. Developing egg, 0.80 mm diameter. F. Yolk-sac larva, 4.3 mm TL. *(A, Goode, G. B., 1884: pl. 66. B-F, Williams, G. C., et al., 1964: fig. 1.)*

LARVAE

Specimens described 7.0 [12]–33.5 [1] mm.

D. 51–66, increasing with latitude and distance from shore; A. 25 (?)–35, increasing with latitude and distance from shore; myomeres 66–76, increasing with latitude and distance from shore; vertebrae 61–77.[8]

Body very slender; head pointed; [1] dorsal and anal fin rays appear at 9–16 mm depending on area; [3] caudal rays formed by 15 mm; [1,12] caudal fin forked at 22 mm; gut shows internal folds at 8.0 mm; [1] anus opens slightly more than halfway back.[12]

Pigmentation: Dorsal pigment absent at less than 10 mm, between 10–14 mm few chromatophores develop anterior to caudal region simultaneously with one melanophore just posterior to head, continuous line of dorsal melanophores develop between 13–16 mm.[3] Gut pigment variable, some larvae 8–13 mm with a few melanophores,[1] others without pigment until greater than 20 mm; [8] melanophores develop on top of head [3,12] between 9–13 mm; starting as one or two prominent spots and increasing to 6–8 at length of 18–22 mm in Chesapeake Bay and Delaware Bay, 13–19 mm from Long Island Sound to Nova Scotia, and 14–16 mm along west coast of Greenland. Snout pigment present as small dots at 25 mm, and as large dots and streaks in specimens longer than 32 mm. Pectoral melanophores develop in larvae 10–12 mm; [3] usually additional scattered pigmentation more concentrated at caudal end.[12]

JUVENILES

Specimen described 42.6 mm SL.[1]

Body long,[12] slender; [1,12] head pointed; [1] lower jaw pro-

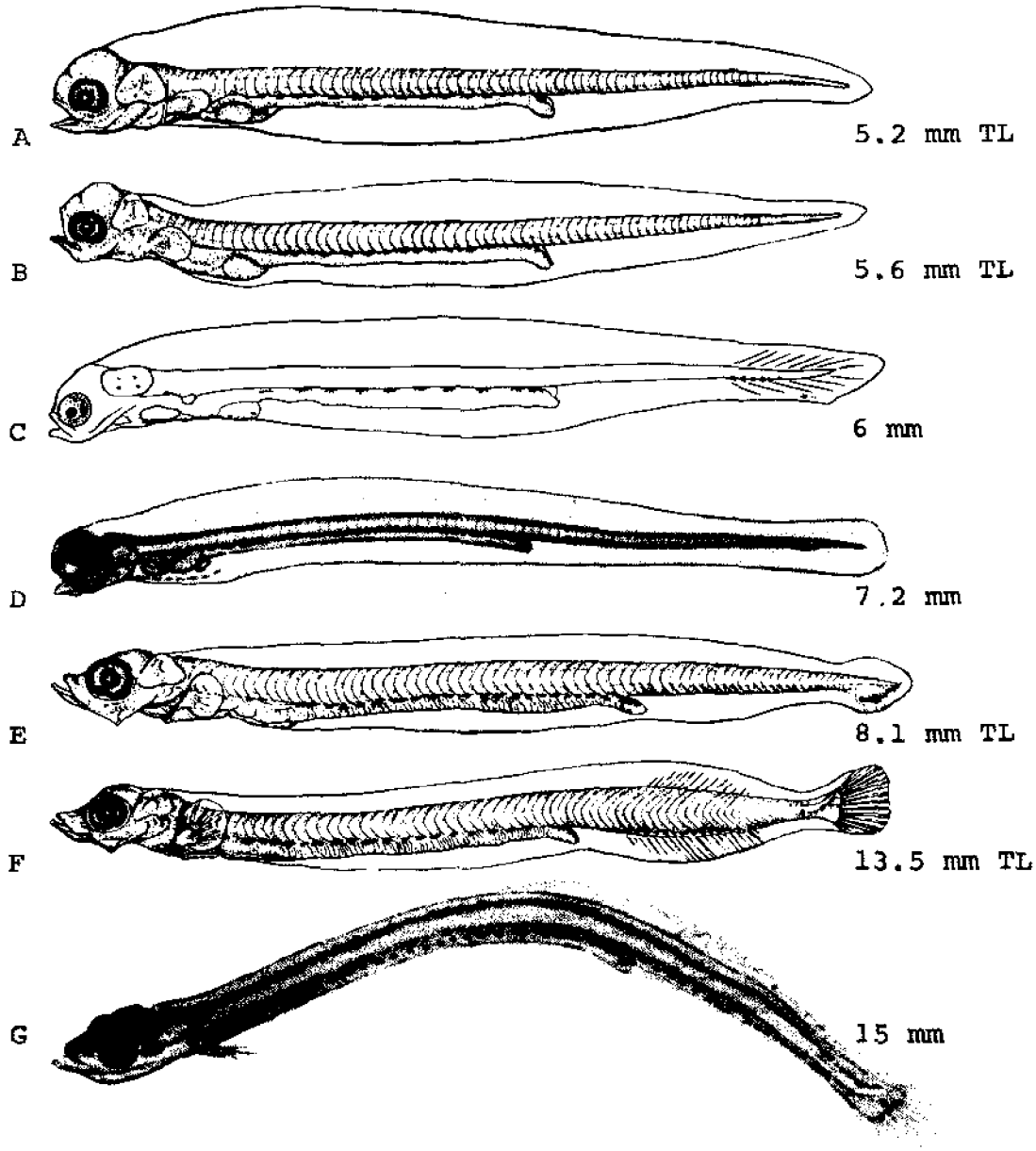

Fig. 162. *Ammodytes* sp., American sand lance. A. Yolk-sac larva, 5.2 mm TL. B. Yolk-sac larva, 5.6 mm TL. C. Yolk-sac larva, 6 mm. D. Larva, 7.2 mm. E. Larva, 8.1 mm TL. F. Larva, 13.5 mm TL. G. Larva, 15 mm. (*A, B, E, F, Norcross, J. J., W. H. Massmann, and E. B. Joseph, 1961: fig. 1 a-d. C, O. Sette, original drawing. D, G, Dannevig, A., 1918: pl. III, fig. 23, 24 reversed.*)

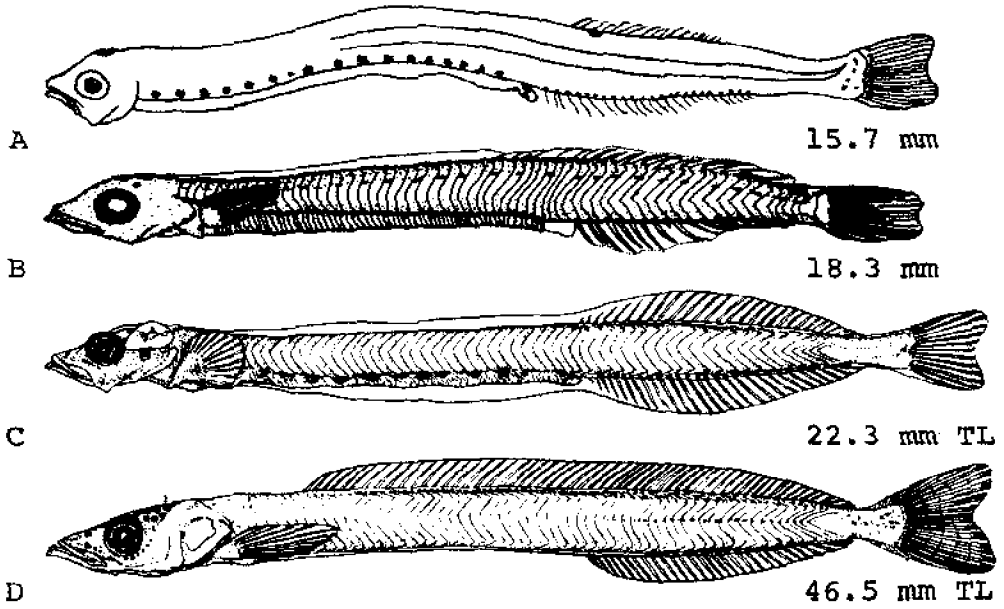

Fig. 163. *Ammodytes* sp., American sand lance. A. Larva, 15.7 mm. B. Larva, 18.3 mm. C. Larva, 22.3 mm TL. D. Juvenile, 46.5 mm TL. *(A, Miller, D., 1958. B, Richards, S., 1965: fig. 1E. C-D, Norcross, J. J., W. H. Massmann, and E. B. Joseph, 1961: figs. 1e-f.)*

jecting far beyond upper; dorsal fin single, long; pelvic fins lacking.[12]

GROWTH

Larvae from Long Island Sound reported to grow 3–5 mm/month;[7] Chesapeake Bay specimens estimated to grow 11.7 mm/month.[1]

AGE AND SIZE AT MATURITY

No information.

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Astroscopus guttatus

stargazers
Uranoscopidae

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FAMILY URANOSCOPIDAE

The stargazer family occurs in both tropical and temperate marine waters around the world. Many species are provided with electrogenic organs located behind the eyes. In addition, a pair of large venomous spines are present just above the pectoral fins. The mouth is nearly vertical in position and the lips are fringed. About 24 species are known. Adults and juveniles are generally benthic, some burrowing into the bottom, and the species variously occur from the littoral zone onto the continental slope. The larvae of all are primarily pelagic.

Astroscopus guttatus Abbott, Northern stargazer

ADULTS

D. IV or V, 13[3,7]–15;[7] A. I, 12;[3] C. 5+7+6+4;[10] P. 19–21;[7] V. I, 5;[3,7] vertebrae 11+14=25;[10] teeth small, in bands on jaws, also on vomer and palatines; branchiostegals 6.[3]

Head 2.4–2.7, depth 2.7–3.55 in SL. Snout 4.5–5.3, eye 5.75–13, maxillary 1.95–2.15, pectoral 1.05–1.3 in head.[3]

Body robust, anteriorly as wide as deep, posteriorly compressed; head broad, flat above; snout very broad and short; mouth broad, lower jaw forming anterior margin of head.[3] Scales present on body and extending onto caudal fin; scales absent from head, area posterior to pectoral fin bases, throat, abdomen, between lateral lines and dorsal fin, and along anal fin base.[7] Exposed frontal bones forming Y on anterior part of head.[3,7] Lateral lines on each side of body extending from head back close to dorsal fin, bending down onto fleshy part of candal fin, then bending anteroventrally to unite at posteroventral

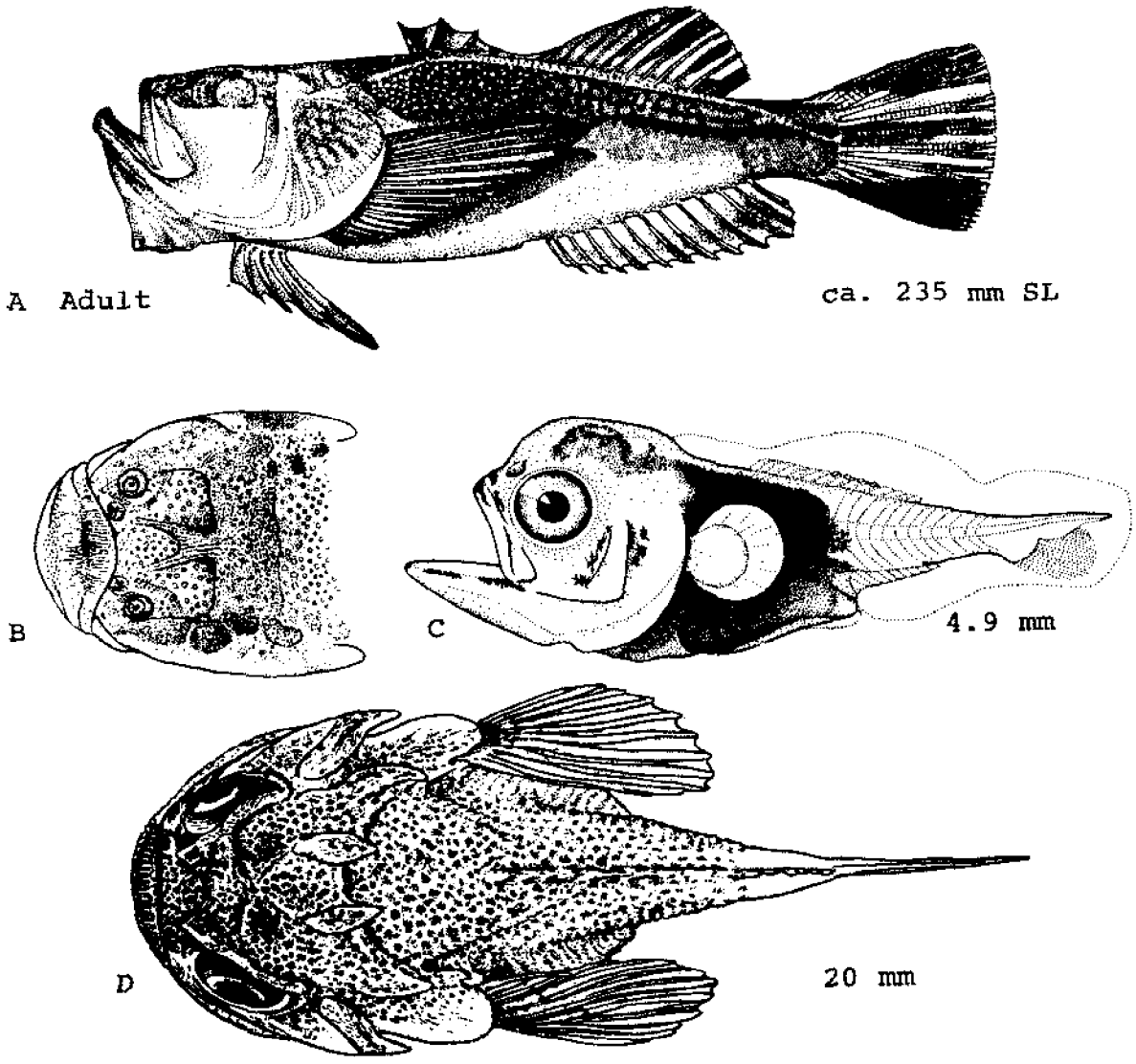

Fig. 164. *Astroscopus guttatus*, Northern stargazer. A. Adult, ca. 235 mm SL. B. Dorsal surface of head. C. Yolk-sac larva, 4.9 mm. D. Larva, 20 mm. (*A, Goode, G. B., 1884: pl. 69. B, Hildebrand, S. F., and W. C. Schroeder, 1928: fig. 200. C, Pearson, J. C., 1941: fig. 24. D, White, G. E., 1918: 149.*)

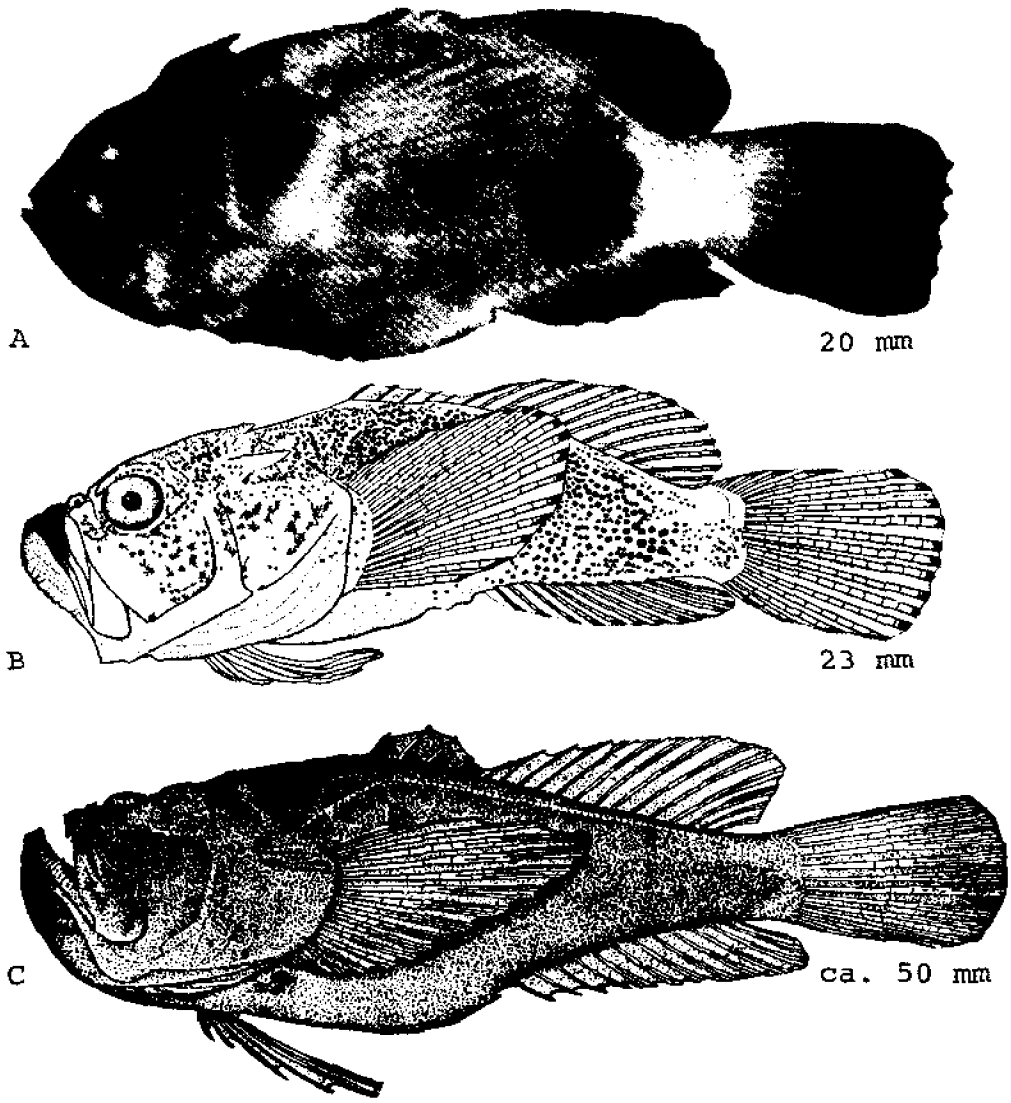

Fig. 165. *Astroscopus guttatus*, Northern stargazer. A. Larva, 20 mm SL. B. Larva, 23 mm. C. Juvenile, ca. 50 mm. (*A, Dahlgren, U., 1927: fig. 8. B, Pearson, J. C., 1941: fig. 25. C, Bean, T. H., 1888: fig. 1.*)

edge of caudal peduncle.[7] Dorsal fins separate, the first composed of short, sharp spines, the second much higher; anal fin more or less enveloped in skin; caudal fin rounded; pelvic fins inserted on throat; pectoral fins large, lower rays short. Eyes small, anterior, superior; interorbital very broad; lips with fringes; nostrils with shorter fringes; elliptical area between and behind eyes with double row of fringes;[3] cleithral spines small, laterally compressed, covered with skin and adpressed to body;[7] edge of snout with two very short, blunt spines in front of each eye.[3,7]

Pigmentation: Body and head generally dusky above; dirty white below; upper surface with many small, irregular white spots,[3,7] increasing in size posteriorly;[3] caudal peduncle with lateral dark stripe;[3,7] lower half of sides with obscure dark blotches;[3] each side of chin with large black blotch; spinous dorsal fin black; soft dorsal with series of about four oblique black bars; anal fin with longitudinal blackish stripe;[3,7] pelvic fins mostly clear[7] to pale,[3] with dark spot between distal ends of last two rays; pectoral fins dusky over most of fin, becoming black near tip, and with narrow light ventral margin extending to tip; caudal with three black stripes.[7]

Maximum size: To about 559 mm (probably TL) and 6.8–9 kg.[8]

DISTRIBUTION AND ECOLOGY

Range: Long Island, New York, south to Cape Lookout, North Carolina.[7]

Area distribution: Throughout the Mid-Atlantic Bight; [7] recorded from Atlantic, Cape May, Monmouth, and Ocean counties, New Jersey; [4] Delaware River estuary; [5] and the entire Chesapeake Bay.[3,6]

Habitat and movements: Adults—primarily inhabit *inshore, shallow, sandy areas;* [7] *smaller adults congregate* at bay mouths during the fall.[8] Recorded from marine salinities to 11 ppt and 22.1 C [1] temperature.

Larvae—pelagic.[7,8]

Juveniles—spend summers near mouths of bays.[8]

SPAWNING

Late spring to early summer, May–June near Norfolk, Virginia; takes place near bottom in 9–65 m.[8]

EGGS

Rise to surface after spawning; transparent; small.[8]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

Specimens described 2.5 [2]–6 or 7 mm.[8]

Pigmentation: Heavy pigment covers body from pectoral fins to vent.[2]

LARVAE

Specimens described 7–ca. 25 mm.[8]

Electric organs develop after 12 mm.[8]

Pigmentation: Black color deepens with growth; a bright yellow spot on chin.[8]

JUVENILES

Specimens described 23 [2,8]–381 [8] mm.

Mouth more vertical, with fringed lips; eye migrates *dorsally, migration completed by 25 mm;* [2] *electric organs* complete development and unite to form one organ at 33–45 mm; [9] pectoral fins much enlarged.[2]

Pigmentation: Becomes more scattered.[2]

GROWTH

Probably to 12–15 mm at end of one month and to 23 mm in 2–3 months.[8]

AGE AND SIZE AT MATURITY

Probably larger than 381 mm.[8]

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Blennius marmoreus
Chasmodes bosquianus
Hypsoblennius hentz

combtooth blennies
Blenniidae

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FAMILY BLENNIIDAE

The combtooth blennies are primarily shallow water, tropical marine fishes. However, some species occur in temperate waters, and some enter estuaries and fresh water. They are characterized by the nonprotractile premaxillary, the absence of scales, and about an equal number of spines and soft rays in the dorsal fin.

Many species lay their eggs in empty shells or other sheltered areas and guard them until hatching. A few species of the tribe *Salariini* go through a pelagic larval stage often known as an "ophioblennius."

Blennius marmoreus Poey, Seaweed blenny

ADULTS

D. XI [8,5] to XII,[1,4,5] 17 [1,3,5]–18; [1,4,5] A. II,[1,4] 19 [1]–20; P. 14; [1,4] V. I, 2 (VGS)–3; 11–13 gill rakers; [1] 24 incisiform teeth in each jaw,[3] with strong canines posteriorly on either side of each jaw.[1,3,4]

Measurements expressed as percent SL: Head 28.5–30.6, depth 21.8–23.2, eye 6.9–8.0, maxillary 12.5–13.6, snout 9.1–10.2.[4]

Head short, steep, profile nearly vertical; [3] lateral line short, ending beneath rear of spinous portion of dorsal fin, with 11–13 pairs of pores; [1] dorsal fin slightly emarginate, free from caudal, spines rather stiff; [8] slender tentacle at edge of anterior nostril, simple or branched; [1] supraorbital cirris long, branched,[5] bifid at tip, fringed at base; gill membranes free from isthmus posteriorly.[3]

Pigmentation: Color variable, often yellowish on back, bluish gray ventrally, numerous small brown spots (orangish on head) which tend to intensify to form broad stripe on upper side; [1,4] small black spot (probably bluish in life, VGS) at front of dorsal fin; [1,3] edge of anal fin pale [1] to white; [4] paired fins yellow.[1,4]

Maximum size: Rarely exceeds 76 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Fire Island, New York [6] south to Venezuela [1,4] and northeastern Gulf of Mexico.[4]

Area distribution: Recorded from Somerset and Worcester counties, Maryland [3] and lower Chesapeake Bay.[2]

Habitat and movements: Adults—in shallow water [1] on rocky reefs and coral heads and on *Thalassia* beds,[4] often in open ocean floating with drifting *Fucus*.[5]

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

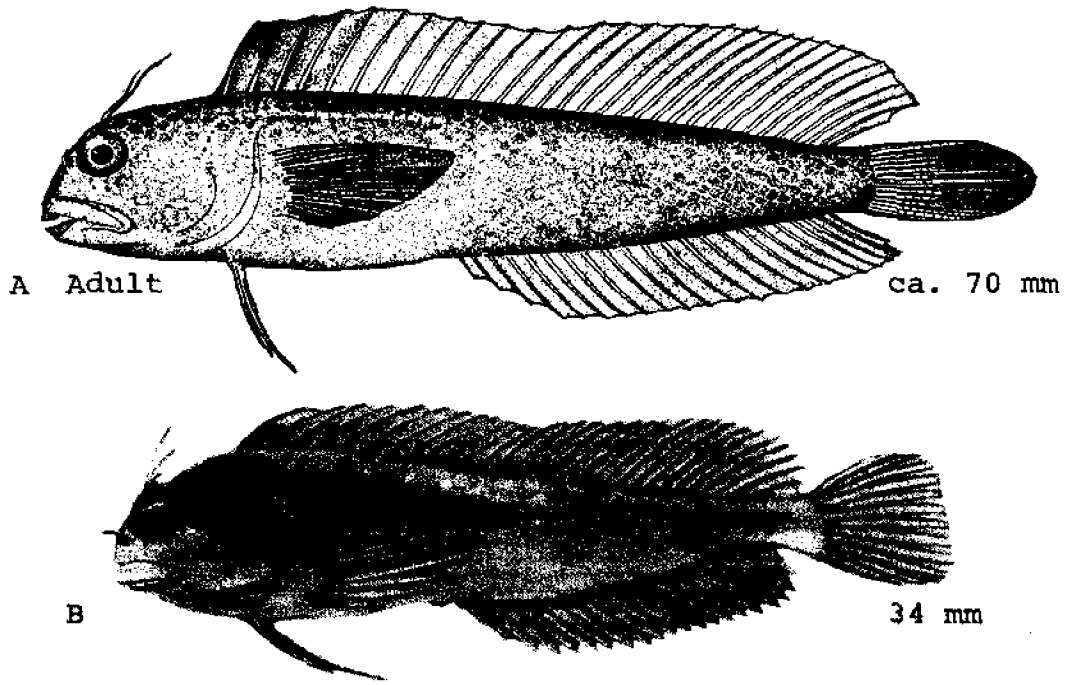

Fig. 166. *Blennius marmoreus*, Seaweed blenny. A. Adult, ca. 70 mm. B. Juvenile, 34 mm. (*A, Jordan, D. S., and B. W. Evermann, 1896–1900: fig. 820. B, Böhlke, J. E., and C. C. G. Chaplin, 1968: 565.* © *Academy of Natural Sciences of Philadelphia. Used with permission of publisher and authors.*)

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Chasmodes bosquianus (Lacépède), Striped blenny

ADULTS

D. X [3] to XII,[3,5] 16–20; [3] A. II [3,5] or III,[5] 17–20; [3] C. 3+7+6+3; [6] P. 11 [1,3]–13; V. I, 3; [3] vertebrae 10+24–25=34–36; [5] teeth in jaws in single close-set row, rarely one or two enlarged teeth anteriorly behind row of teeth in lower jaw, number of teeth increases with SL.[3]

Head 3.25–3.7, depth 2.9–3.8 in SL. Snout 3.15–3.65, maxillary 1.6–2.2, eye 2.55–4.6, interorbital 9.8–11, pectoral 1–1.35 in head.[5]

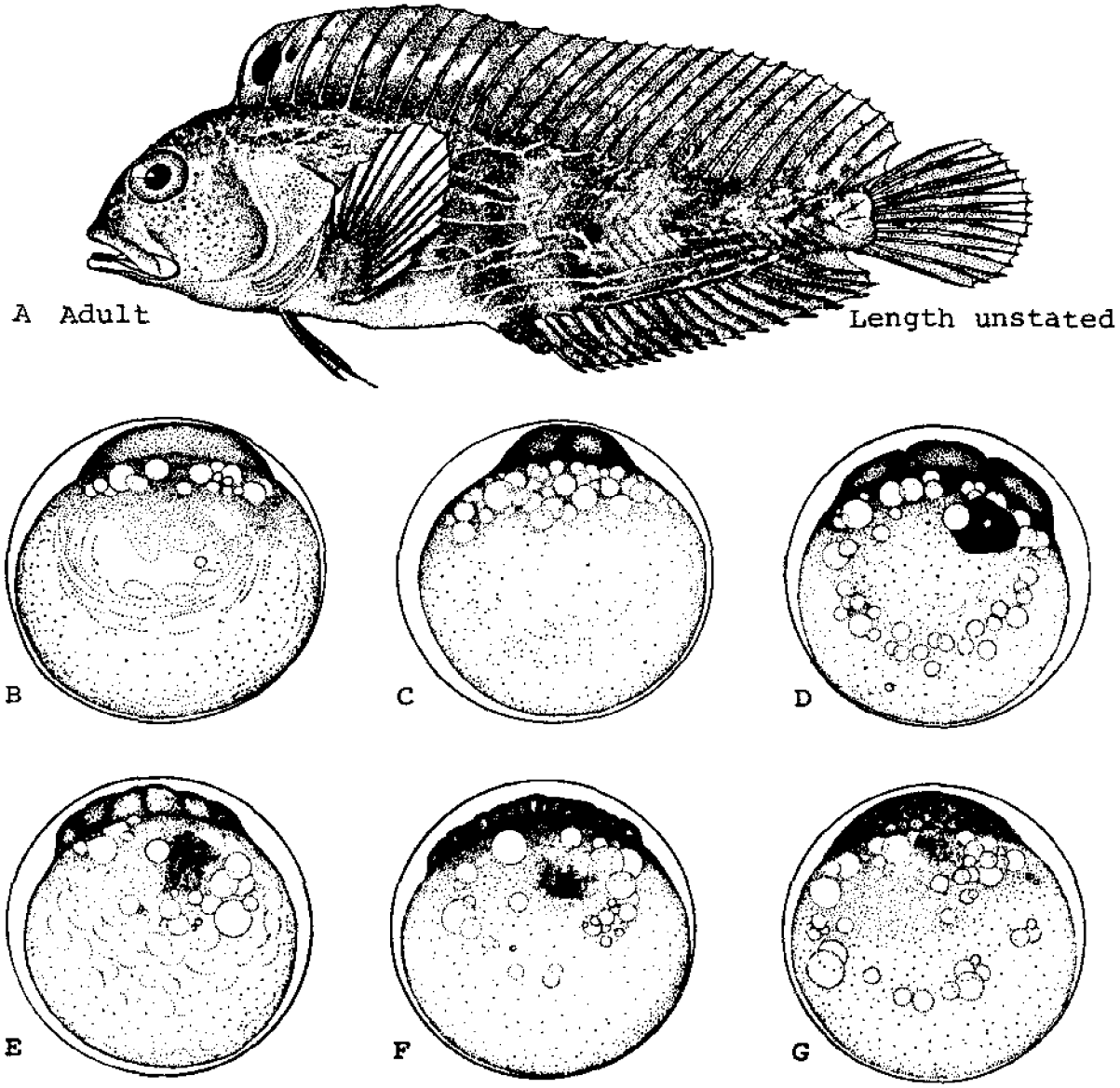

Fig. 167. *Chasmodes bosquianus*, Striped blenny. A. Adult male, length unstated. B. Egg with blastodisc, probably about an hour after fertilization. C. Egg in 2-cell stage, about 2 hours after fertilization. D. Egg in 4-cell stage, about 2 1/2 hours after fertilization. E. Egg in 16-cell stage, about 3 hours after fertilization. F. Egg in about 64-cell stage, about 3 1/2 hours after fertilization. G. Egg in advanced cleavage stage, about 6 or 7 hours after fertilization. (*A-G, Hildebrand, S. F., and L. E. Cable, 1938: figs. 110–116.*)

Body compressed, deepest slightly behind base of pectorals; head compressed, with moderately convex upper profile; snout not very blunt; mouth moderately large, slightly oblique, terminal; maxillary reaching nearly or quite to posterior margin of eye, increasing with standard length; lateral-line pores in longitudinal series, not paired vertically, extending from level of opercle in an arc to above posterior tip of pectoral fin; [5] spinous dorsal fin with flexible spines (VGS); soft dorsal fin higher than spinous, attached to caudal base; first two anal fin spines of males with rugose fleshy knobs, obscured in females by genital papilla; anal fin free from caudal base; caudal fin round; pelvic fins very narrow; pectoral fins broad; eye moderate, lateral; interorbital convex; cirri small, simple, on tube of anterior nostril and above eye; supraorbital cirri decrease in size with increasing SL, usually absent in adults.[4]

Pigmentation: Coloration in life varying from a pattern of light longitudinal lines on dark background to a varied mottling, sometimes giving the effect of irregular bands; head with small spots dorsally and laterally; dorsal fin with anterior blue spot or band anteriorly in males, mottled in females; other fins uniformly dusky in males; spotted in females.[3]

Coloration in alcohol: Females brown, some individuals darker than others; sides with pale crossbars or sometimes simply with whitish blotches; frequently with irregular dark bars or blotches; occasionally with wavy longitudinal lines; head with dark dots above; fins dark, spotted or barred; base of caudal with obscure dark spot. Males usually darker, more uniform; sides with pale, wavy lines; occasionally with roundish pale spots, somewhat broader than lines; upper part of head with small dark dots; fins mostly dark brown with pale dots; spinous dorsal with black dot between first and second spines in males and frequently with smaller dark spots and dots, usually with pale longitudinal stripe; no spot at caudal base.[4]

Maximum size: To about 100 mm.[4]

DISTRIBUTION AND ECOLOGY

Range: Two disjunct populations—Atlantic coast from Banana River Lagoon, Florida (VGS) north to New York; Gulf of Mexico coast from Pensacola, Florida west to southern Texas.[3]

Area distribution: Recorded as numerous [1] from the entire Chesapeake Bay [4,9] and also from Ocean County, New Jersey.[10]

Habitat and movements: Adults—shallow flats,[6,9] and oyster reefs in spring and summer; deeper flats and reefs in fall; channels at higher salinities in winter; recorded from salinities between 12 [9]–28 [8] ppt, but usually above 20 ppt.[8]

Larvae—reported from 18–31 C.[7]

Juveniles—no information.

SPAWNING

Reported from April [4] to August at various places throughout range,[1,4] June to late July at Isle of Wight and Assawoman Bays, Maryland; [8] early morning.[1]

EGGS

Laid in shells,[1,4] usually oysters, but clams and scallops also used; in aggregates, not all the same age; slightly flattened next to adhesive disc; very pale yellow [1] to orange; [8] major axis 0.93–1.1 mm ($\bar{x}$=1.04, n=27), minor axis 0.8–0.9 mm; egg membrane cellular in appearance; yolk granular, becoming more so during development; oil droplets numerous, yellowish.[1]

EGG DEVELOPMENT

Blastodisc near adhesive foot, large and projects prominently beyond yolk; perivitelline space wide at animal pole, narrow or absent at vegetative pole. First blastomeres large, equal in size; second cleavage plane at approximately right angles to first and follows first in 20 min. at 26 C; third and fourth cleavage just as rapid; blastomeres large and prominent until about 16-cell stage, thereafter they get smaller and flatten rather rapidly.

At 24-hours after 1st cleavage—early embryonic stage reached; well formed embryo with eyes 48-hours after fertilization; embryo under yolk in some eggs, others lay mostly above yolk; grayish blotches visible for first time.

At 2 1/2 days after fertilization—embryo well formed, curving about 2/3 distance around egg; head large; eyes partly pigmented; somites just visible; heart beating; black blotches with irregular outlines, variable in size, shape, and number on yolk.

At 4th day of incubation—somites marked anteriorly; eyes with many black pigment dots, most numerous along upper margin; yolk granular and deeply cut by embryo, numerous dark spots on its surface.

At 5th day of incubation—embryo completely encircles egg; eyes prominent, fully pigmented; yolk approximately 2/3 original size and more or less crescent-shaped; central opaque body of yolk disappears; dark markings on yolk smaller and more numerous; dark markings concentrated on trunk.

At 7th day of incubation—tail reaches past head; yolk cut more deeply; black markings on yolk less numerous; trunk darker; irregular dark blotch at each auditory vesicle.

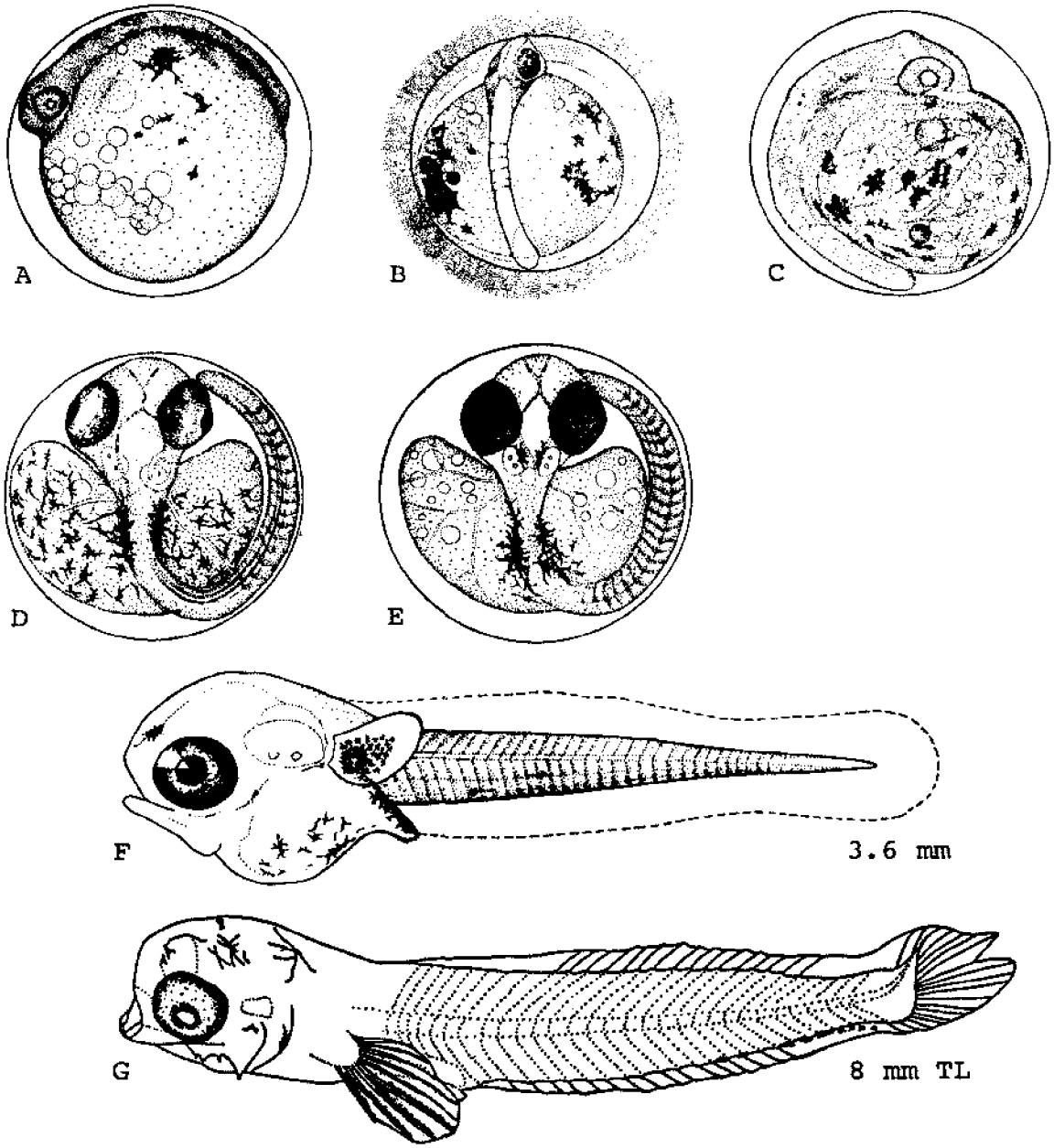

Fig. 168. *Chasmodes bosquianus*, Striped blenny. A. Egg with moderately well-differentiated embryo, about 2 days after fertilization. B. Egg with well-formed embryo, 2 1/2 days after fertilization. C. Egg with developing embryo, 4 days after fertilization. D. Egg with advanced embryo, 5 days after fertilization. E. Egg with large embryo, about 7 days after fertilization. F. Yolk-sac larva, newly hatched, 3.6 mm long. G. Larva, 8 mm TL. (*A-F, Hildebrand, S. F., and L. E. Cable, 1938: figs. 117–122. G, Lippson, A. J., and R. L. Moran, 1974: 238.*)

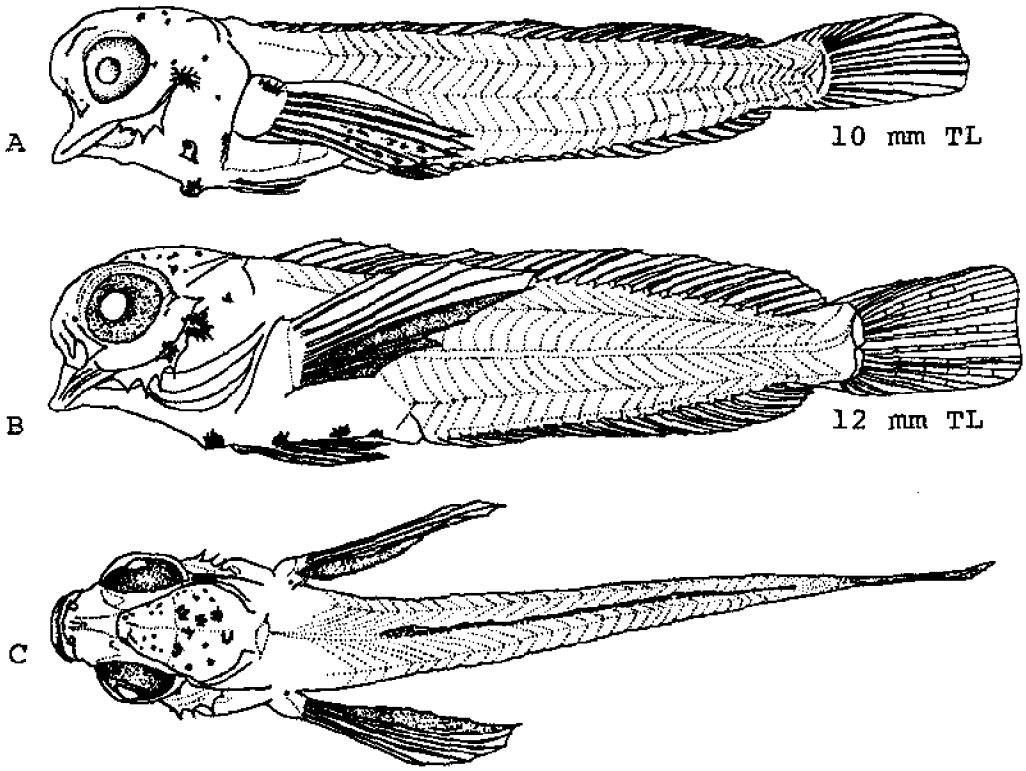

Fig. 169. *Chasmodes bosquianus*, Striped blenny. A. Larva, 10 mm TL. B. Juvenile, 12 mm TL. C. Dorsal view of B. (*A-C, Lippson, A. J., and R. L. Moran, 1974: 238.*)

At 9th day of incubation—some have lost pigmentation on yolk; dark blotch between eyes anteriorly; some with short branching cross-lines on ventral margin of caudal somites; black spots on pectoral membranes.

At 10th day of incubation—dark markings more pronounced.

Hatching in 11 days at 24.5–27 C.[1]

YOLK-SAC LARVAE

Hatch at 3.56–3.78 mm.

Preanal myomeres 8–9, postanal myomeres 28–30.[1]

Body short, robust, tail long and slender; snout short, blunt; yolk mass small; mouth placed rather low, anterior; gape to or little past vertical from anterior margin of eye; eye large, its diameter little greater than depth of body behind vent; pectoral fin membranous, large; finfold rather broad, originating above auditory vesicle and continuing to vent; anus far in advance of mid-body length, snout-vent distance about 1/3 body length.[1]

Pigmentation: Fairly transparent; snout with elongate "twin" blotches anteriorly and in advance of eyes; abdomen largely black along upper margin, reaching from upper pectoral fin base to vent; ventral surface of abdomen with few melanophores; tail with short branching cross-lines on ventral edge, sometimes wanting anteriorly or posteriorly; basal 3/4 of inner surface of pectoral fins with melanophores, the lowermost being very large.[1]

LARVAE

Specimens described 5-10 mm.

Dorsal fin rays differentiating at 5 mm; anal rays noticeable at 8 mm; caudal rays differentiating at 5 mm.[2]

Pigmentation: Lower 3–4 pectoral rays darkly pigmented.[2]

JUVENILES

Specimens described 10–12 mm.

Several opercular spines of equal length.[2]

Pigmentation: Coloration resembles adult females, being somewhat lighter in color and in having pale spots and bars.[4]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Hypsoblennius hentz (Lesueur), Feather blenny

ADULTS

D. XII,[1,2,8] 13 [2]–15; [1,2] A. II, 16 [1,8]–17; C. 5–6+7+6+5; [8] P. 13–15; [1] vertebrae 10+22–24=32–34; [8] all jaw teeth incisiform, no canines.[2]

Head 3.35–3.75, depth 2.95–3.3 in SL. Snout 2.8–3.25, eye 3.15–3.8, interorbital 7.8–10.4, maxillary 2.5–3.05 in HL.[2]

Body compressed, deepest over pectoral fins, tapering gradually to tail; head short and deep, anterior profile very steep; snout short; [2] mouth small,[1] broad, terminal,[2] and horizontal; [1,2] maxillary scarcely reaching under middle of eye; [1,2] dorsal fin long, continuous, spines slender but pungent, not quite as high as soft rays; caudal fin round; anal fin lower than soft dorsal,[2] long and low; males with fleshy expansions on tips of anal fin spines and possibly some anterior rays, fin itself preceded by low elliptical membranous hood, opening backward; [1] pelvic fins well-developed; [2] pectoral fins broad,[1] large; eye placed high, lateral; interorbital deeply concave; each nostril with simple, short, fleshy tentacle; branched tentacle on upper margin of eye,[2] longer branched tentacle on upper margin of eye,[2] longer in males; [1] gill openings restricted to sides.[2]

Pigmentation: Color in alcohol brownish, some specimens darker than others; sides and head with dark spots, largest on lower part of sides and smallest dorsally on head; some individuals less profusely spotted but with indefinite crossbars extending on dorsal fin; chin nearly always with two or three dark bars; pelvic fins nearly black; other fins paler than body, variously spotted; [2] males with dark spot (blue in life) anteriorly in dorsal fin (VGS); caudal usually crossbarred; anal fin with tips of rays pale.[2]

Maximum size: Males attain 104 mm, females 84 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: New Jersey to Yucatan.[3]

Area distribution: Recorded from Atlantic and Cape May counties, New Jersey,[11] Isle of Wight Bay, Maryland,[5] and the entire Chesapeake Bay.[2,7,10]

Habitat and movements: Adults—common on grass flats in Tampa Bay area; [12] abundant in deeper flats and oyster reefs,[10] or shallow water [1] areas in summer; shallow flats in fall; [10] and in deeper channels [1,10] and holes [1] at higher salinities in winter. Salinities in Chesapeake Bay 12–30 ppt; [10] 23.6–35.0 ppt in Tampa Bay area.[12] Recorded from waters from 10 (Cedar Key, Florida) [13] to 32.5 C (Tampa Bay area).[12]

Larvae—surface dwelling in open waters [1] of 11–21 ppt and 11–25 C.[9]

Juveniles—pelagic at 13 mm; on bottom by 24 mm.[1]

SPAWNING

Location: In empty oyster, and possibly clam and scallop shells; several batches of eggs in each clump.[1]

Season: Reported to spawn from May–August near Beaufort, North Carolina [1] and throughout the summer in Chesapeake Bay.[2]

Time: Occurs in early morning.[1]

EGGS

In aggregates in empty mollusk shells; slightly flatttned near adhesive disc; pinkish, due to yolk bodies; large central body grayish and opaque; major axis 0.72–0.8 mm ($\bar{x}$=0.769, n=11), minor axis 0.64–0.68 mm (n=4); adhesive disc greater in diameter than egg; yolk pinkish, granular; oil globules concentrated near blastoderm, golden yellow.[1]

EGG DEVELOPMENT

Blastodisc next to adhesive disc. First blastomeres about equal in size; second cleavage cuts blastodisc at right angles to first. Perivitelline space largest at positive pole. Cleavage rapid, 8- and 16-cell stages following 4-cell stage at intervals of 30 min. at 26 C. Egg becomes more granular with development.

24 hours after fertilization—germ ring more evident.

48 hours after fertilization—embryo well differentiated.

Development slows after embryo formed. Embryo extends 3/4 distance around egg in 3 days at 25–27 C; somites evident in part of body; eyes well formed, punctuated with dark spots; circulation begins; heart under anterior tip of head; dark blotches on yolk.

Six days after fertilization—embryo encircles egg; eyes large, black with greenish sheen; heart beating (200/min.).

After 6th day—embryo increases little in length; yolk absorbed very slowly; dark blotches on yolk disappear 1–2 days before hatching; large branching blotch present on head between eyes; numerous melanophores on pectoral fins; short, branching cross-lines on somites along ventral surface in caudal region.[1]

YOLK-SAC LARVAE

Hatch at 2.6–2.8 mm.

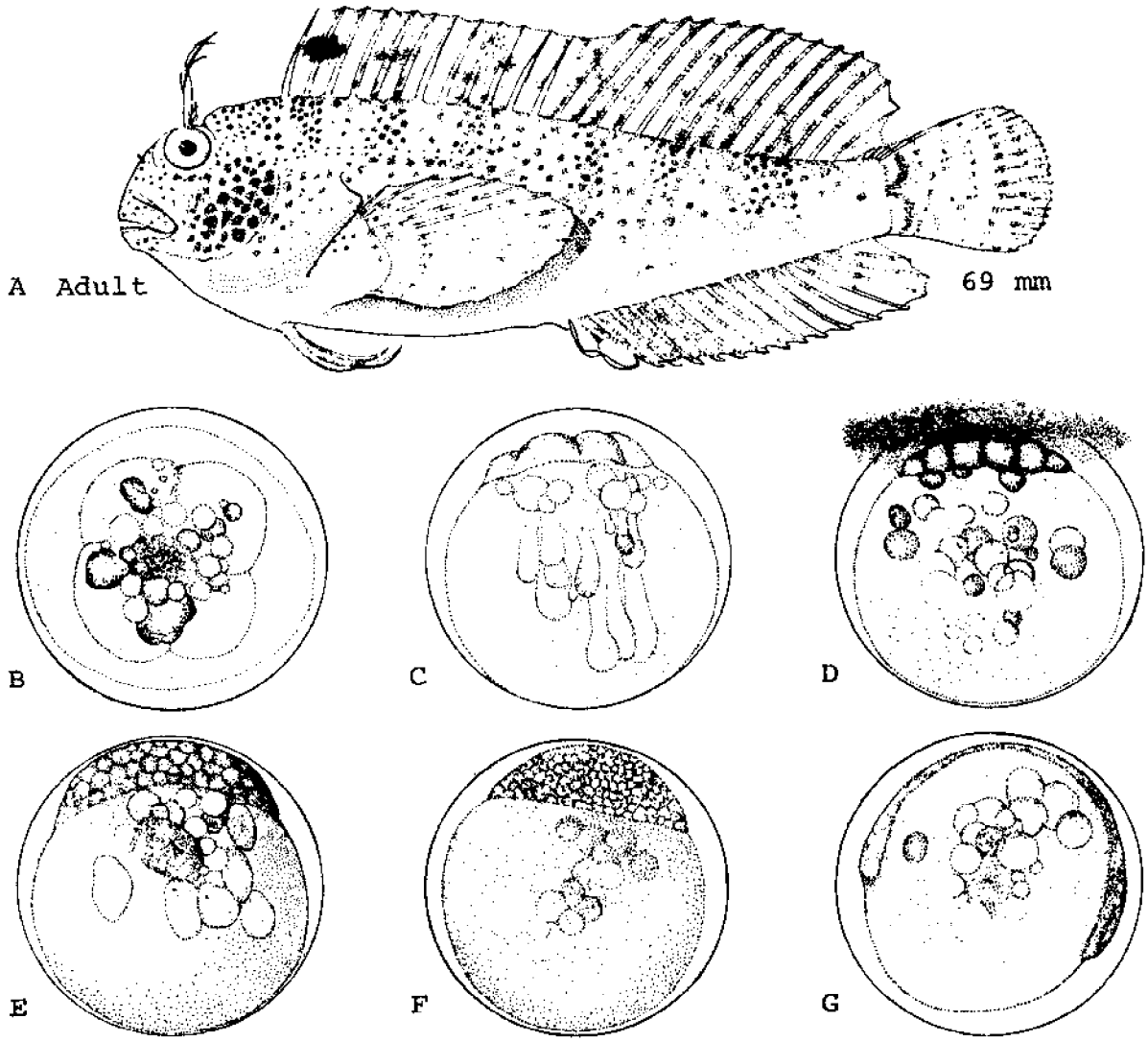

Fig. 170. *Hypsoblennius hentz*, Feather blenny. A. Adult male, 69 mm. B. Egg, 4-cell stage, about 2 to 3 hours after fertilization. C. Eggs, 8-cell stage, about 3 hours after fertilization. D. Egg, about 16-cell stage, about 3 1/2 hours after fertilization. E. Egg, moderately advanced cleavage stage, probably about 6 hours after fertilization. F. Egg, advanced cleavage stage, about 8 hours after fertilization. G. Egg, showing blastoderm growing around egg, about 1 day after fertilization. (*A-G, Hildebrand, S. F., and L. E. Cable, 1938: figs. 74–80.*)

Myomeres 28–30; vertebrae 9 + 24.[1]

Body robust anteriorly, with broad, depressed head; tail long and slender; snout short and very blunt; mouth large; gape reaching to or past middle of eye; eye large; pectoral fins large, rays just becoming evident; anus in advance of mid-body.[1]

Pigmentation: Body fairly transparent, dark markings correspond to those of advanced embryo; eye dark with greenish sheen: irregularly outlined spot on head between anterior part of eyes; melanophores on snout and interorbital in some; auditory vesicle with dark blotch; abdominal region with many melanophores; ventral side of tail with short black cross-lines; pectoral fins with black markings on basal 2/3 of inner surface.[1]

LARVAE

Specimens described 1.5 (preserved)–8.0 mm.

Preanal distance 2.4 in TL.

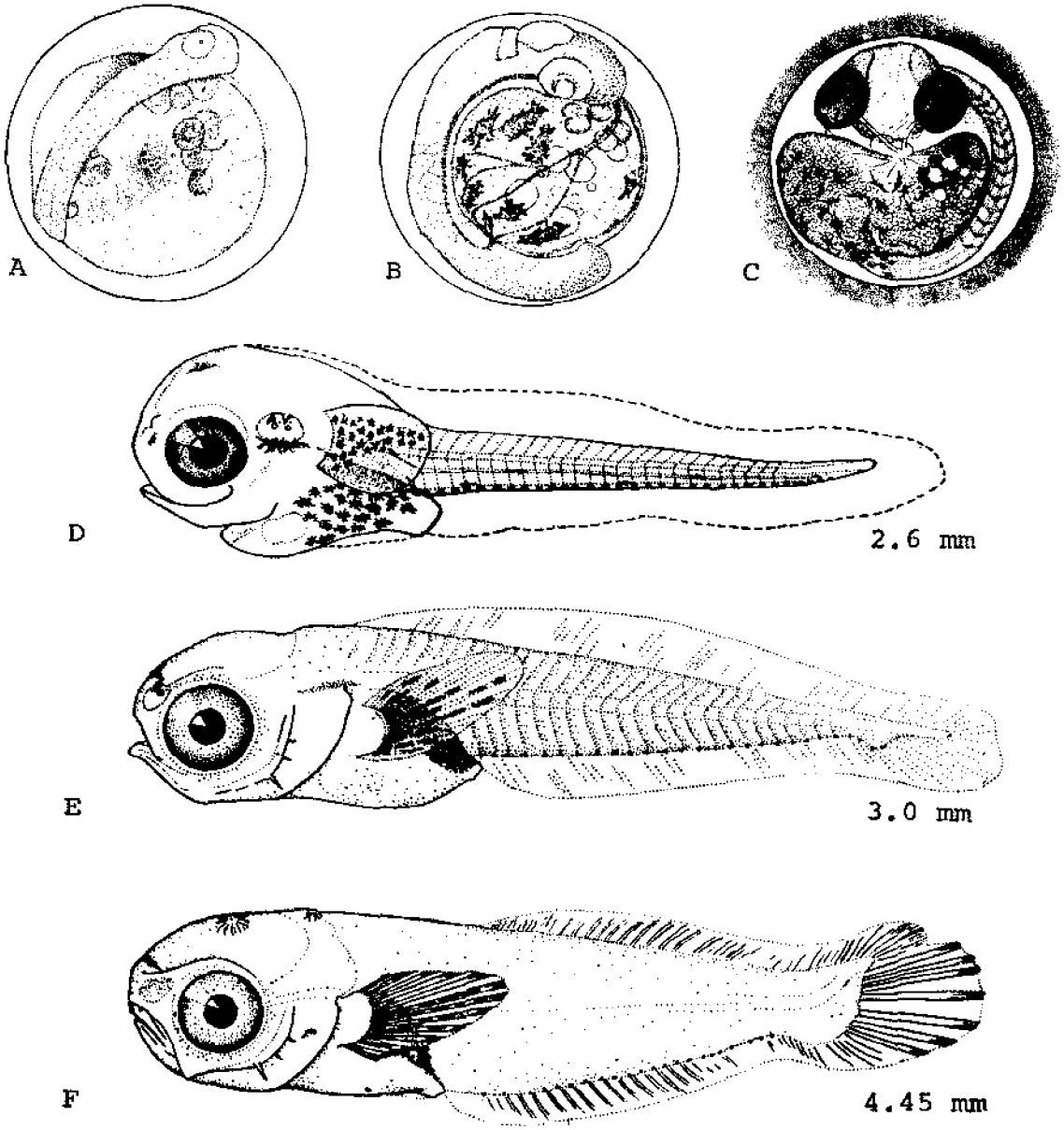

Fig. 171. *Hypsoblennius hentz*, Feather blenny. A. Egg, with an early embryo, about 2 days after fertilization. B. Egg, with well-formed embryo, about 3 days after fertilization. C. Egg, with large embryo, about 6 days after fertilization. D. Yolk-sac larva, newly hatched, 2.6 mm. E. Larva, 3.0 mm. F. Larva, 4.45 mm. (*A-F, Hildebrand, S. F., and L. E. Cable, 1938: figs. 81–86.*)

Body less robust anteriorly, becoming deeper and more compressed with growth; snout short, blunt, scarcely longer than pupil; mouth slightly inferior and moderately oblique; tip of lower jaw little below level of middle of eye; bony ridge evident over and in front of eyes at 5–6.5 mm; five preopercular spines at 5–6.5 mm; dorsal and anal fins partly developed at 4–4.5 mm; caudal flexion and rays become evident at 4–4.5 mm; pectoral fins becoming elongate, definite rays at 2.5–3.0 mm; pelvic fins not evident at 4–4.5 mm.

Pigmentation: Color on abdomen more concentrated along upper margin of abdominal mass; black spots on pectoral surfaces; and cross-lines on ventral edge of caudal region of the finfold.

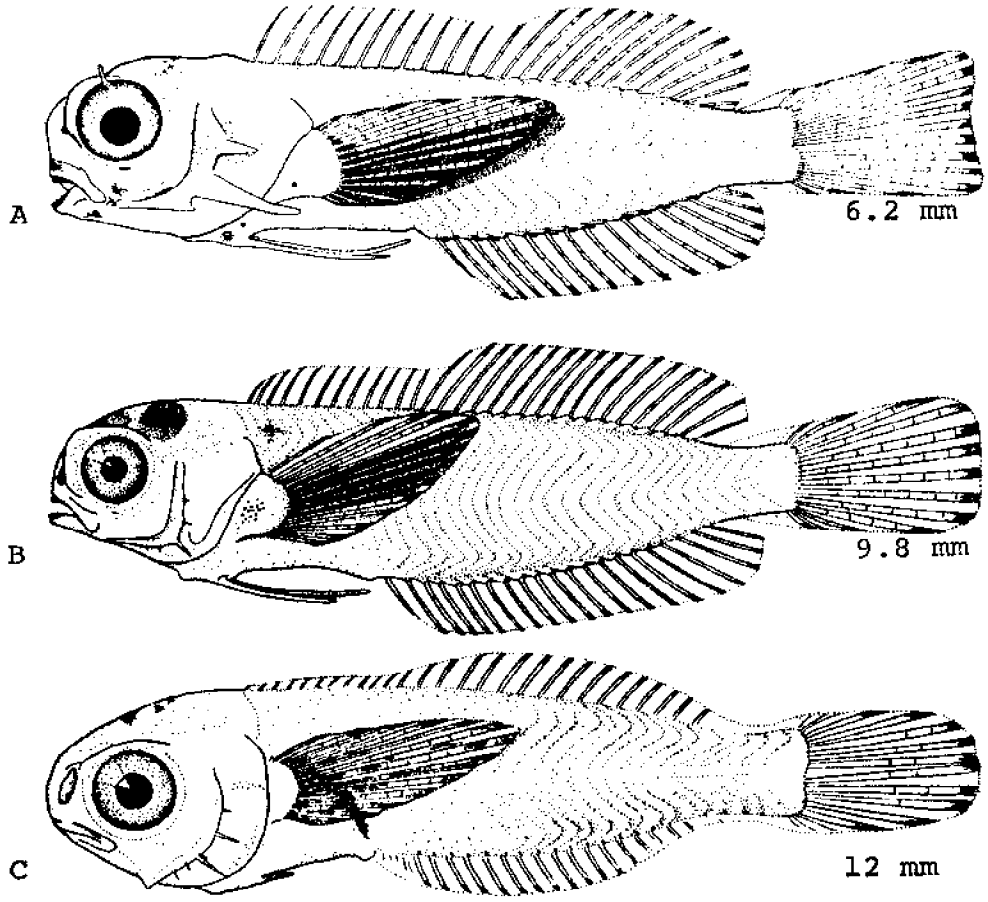

Fig. 172. *Hypsoblennius hentz*, Feather blenny. A. Larva, 6.2 mm. B. Juvenile, 9.8 mm. C. Juvenile, 12 mm. (*A-C, Hildebrand, S. F., and L. E. Cable, 1938: figs. 87–89.*)

At 2.5–3.0 mm—oblique black bar extending from pectoral axil to ventral outline just in front of hindgut; several dark dots on ventral surface in advance of vent; distinct bar crosses forehead between eyes; several chromatophores present on upper surface of head and nape; row of small vertically elongate dark spots situated on ventral outline of tail; dark spots cover most of pectoral rays.

At 4.0–4.5 mm—few obscure dark markings generally present on ventral surface of trunk; dark band extends from pectoral axil to vent; dark band on forehead between eyes; occipital surface of head with one to several dark dots and large median black spot present on nape; pectoral fin densely dotted with black; row of very small black spots begins short distance behind vent and extends to caudal fin base.[1]

JUVENILES

Specimens described 8–25 mm.

Body rather deep, strongly compressed, becoming more robust anteriorly at 12 mm; head deep, snout short, forehead very steep; mouth small, low, almost horizontal, terminal to slightly inferior; level of tip of lower jaw little below lower margin of eye; maxillary reaches to or slightly past anterior margin of eye; preopercular spines become longer with growth but disappear at 25 mm; supraorbital ridge disappearing at 25 mm; dorsal and anal fins fully developed at 8–10 mm, notched at 12 mm; pelvic fins well developed, long and slender.[1]

Pigmentation: Lower surface of head and chest variously dotted with black; few definite dark spots slightly behind articulation of lower jaw; pair of dark spots short distance in advance of ventral fins; another pair in ventral axils; side of head with few indefinite spots or blotches and upper surface bears brownish spots with dark centers and dark outlines; pectoral fins almost wholly black in some, in others 2–4 upper rays pale; oblique dark bar behind pectoral fin obscure by 10 mm; row of fine dark points along anal base present in some.[1]

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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Macrozoarces americanus

eelpouts
Zoarcidae

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FAMILY ZOARCIDAE

The marine eelpouts are bottom-associated fishes of the Northern Hemisphere. They are found in shallow cold water to depths of hundreds of meters. The family is characterized by confluent dorsal and anal fins, pointed tail, small pelvic fins located slightly anterior to the pectoral fins, projecting upper jaw, and large fleshy lips.

The European *Zoarces viviparous* is a live bearer; however, the closely related *Macrozoarces viviparous* lays large eggs that are guarded by one or both parents.

Macrozoarces americanus (Bloch and Schneider), Ocean pout

ADULTS

D. 95–100,[2,4] XVI to XX,[4] 17; A. 105[2,4]–124; [1,2,4] P. 18–21; V. 3; [1] vertebrae 131–144; [1,4] gill rakers 4–6 + 11–13; [1] two series of strong, blunt,[2] conic teeth in front of both jaws; [1,2] and one series on sides,[2] no teeth on vomer or palatines; [1,2] branchiostegals 6.[1]

Depth 7, head 5.5 in TL. Dorsal height 2.7, anal height 5, pelvic fin 6, eye 9 in head.[2]

Body elongate, moderately compressed, tapering to pointed tail; [1,2,4] head broad,[1,2] dorsal profile somewhat angular; [1] snout blunt; [2] mouth terminal,[2,4] large,[1,2,4] almost horizontal,[1] lower jaw included; [2,4] maxillary reaches well behind eye. Scales small,[1,2,4] ovoid, separate, imbedded.[1] Lateral line straight to caudal.[1] Dorsal fin height mostly uniform, last 16–24 rays uniformly very short, continuous with caudal fin; anal rays uniform in height, continuous with caudal; pectoral fins large, rounded, and with scalloped edges, their bases low on sides of body; pelvic fins small, located ventrally before pectoral base.[2,4] Eye small,[1,2] oval, high on head; nares simple, tubular, single on each side; interorbital relatively narrow.[1]

Pigmentation: Coloration variable; [2] muddy yellow [1,2,4] with mottlings of darker gray or olive-green; [1,2] some tinged with brownish, salmon or orange; a few pure, pale green.[4] Top of head darker than body, grading to lighter hues on cheeks; white,[1,2] light lavender,[1] or dull yellow [2] below; lips dirty yellow; [1] anal fin edged with yellow [1,2] or muddy pink; [1] dorsal fin darker than anal fin,[1,2] edged with yellow to darker olive-green at base; [1] pectorals generally red or orange,[1,2] varying from olive-green at base to yellow-orange or reddish in marginal areas; pelvic fins yellow or pink; pupil deep blue; iris orange flecked with brown.[1]

Maximum size: To 107 cm and 5.4 kg.[2,4]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast of North America from Straits of Belle Isle and Gulf of St. Lawrence south to Delaware,[1,2,4] possibly straying to North Carolina.[2]

Area distribution: Common in New Jersey [2] and recorded from Atlantic, Monmouth, and Ocean counties.[3]

Habitat and movements: Adults—bottom fish, on hard and semi-hard bottoms; [2,4] reported to migrate to deeper water in autumn and return to shallower areas in spring,[2,4] or to deeper water in summer and fall; [1] associated with 0–17 C; [4] depth from intertidal zone [2,4] to 189 m.[4]

Larvae—no information.

Juveniles—often found around rocks and in seaweed in Bay of Fundy during ebb tide.[4]

SPAWNING

Season: Recorded as occurring during fall,[6] September–October in southern New England, progressively later from north to south.

Temperature: At temperatures of 10 C and above,[1] eggs collected at 0 C.[5]

Fecundity: 1,306 eggs in 550 mm and 4,161 in 875 mm female.[1,4]

EGGS

Held in gelatinous substance; [4,5] yellow; [4] 6–7 mm in diameter.[4,5]

EGG DEVELOPMENT

Incubation 2 1/2 [4]–3 1/2 [1] months.

YOLK-SAC LARVAE

30 mm at hatching.[5]

LARVAE

30 mm in length, yolk absorbed 20 seconds after hatching.[5]

Checkered along sides and irregularly blotched on back with light and dark brown; prominent black spot on anterior part of dorsal fin.[4]

JUVENILES

Specimens described 74–295 mm.

Gill rakers short; body elongate and slender; head short and notably less heavy than adults; snout blunter.[1]

Pigmentation: Mottled appearance of light and dark brown on sides and back; suggestion of yellow-green on dorsal fin, which bears irregular blotches; dark streak extending across cheek from eye to posteroventral edge of operculum; anal light, suggestion of yellow; belly, pelvic fins, pectoral fins and ventral part of head light; dark spot on anterior dorsal fin disappears with growth.[1]

GROWTH

Reaching 41–60 mm in April, 45–70 mm in May, 54–75

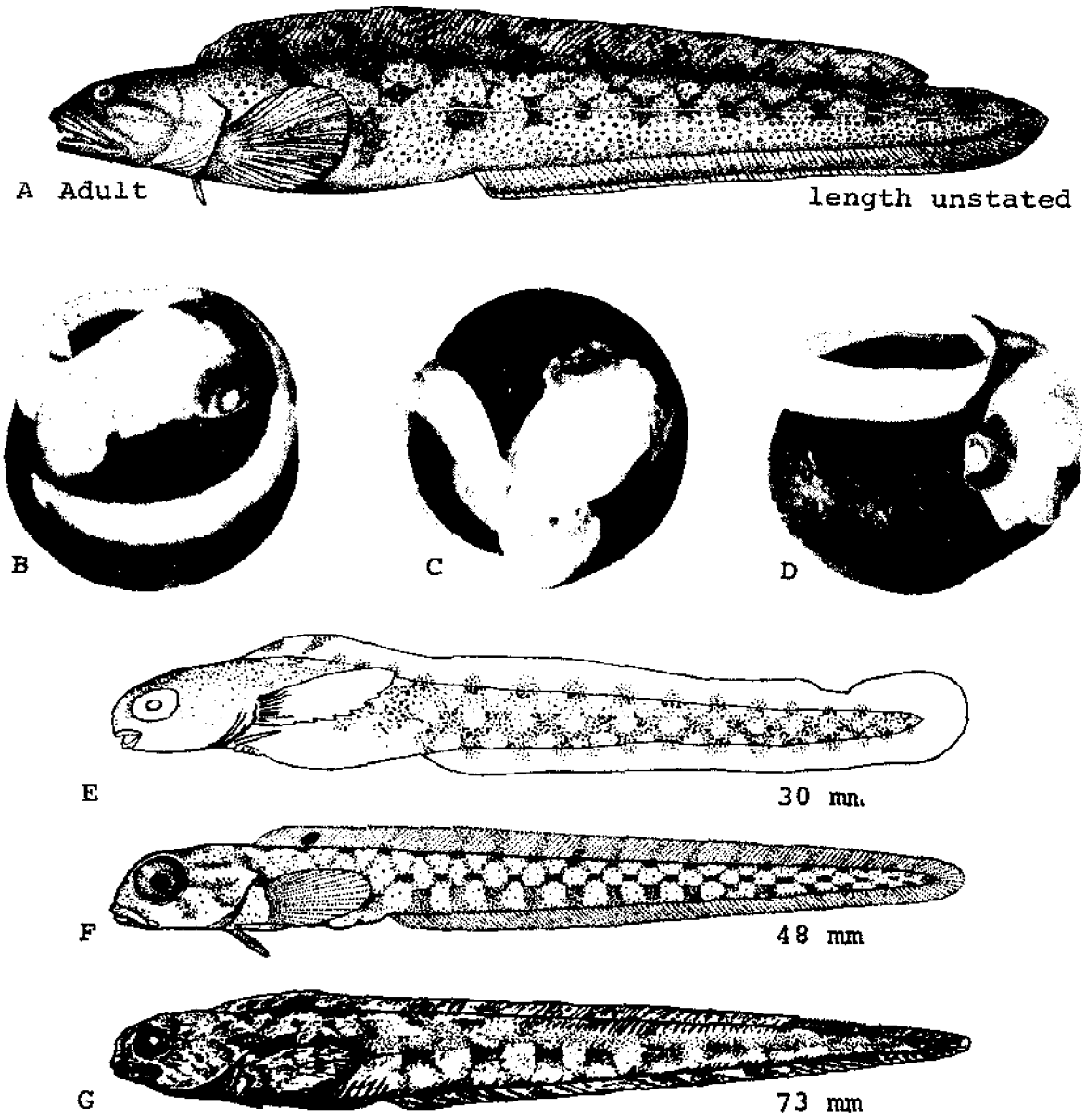

Fig. 173. *Macrozoarces americanus*, Ocean pout. A. Adult, length unstated. B-D. Developing embryos. E. Larva a few minutes after hatching, 30 mm. F. Larva, 48 mm. G. Juvenile, 73 mm. (*A, Leim, A. H., and W. B. Scott, 1966: 326. © Fisheries Research Board of Canada. Used with permission of authors and publisher. B-D, G, Olsen, Y. H., and D. Merriman, 1946: figs. 9–10. E, White, H. C., 1939: fig. 1. F, Bigelow, H. B., and W. C. Schroeder, 1953: fig. 270.*)

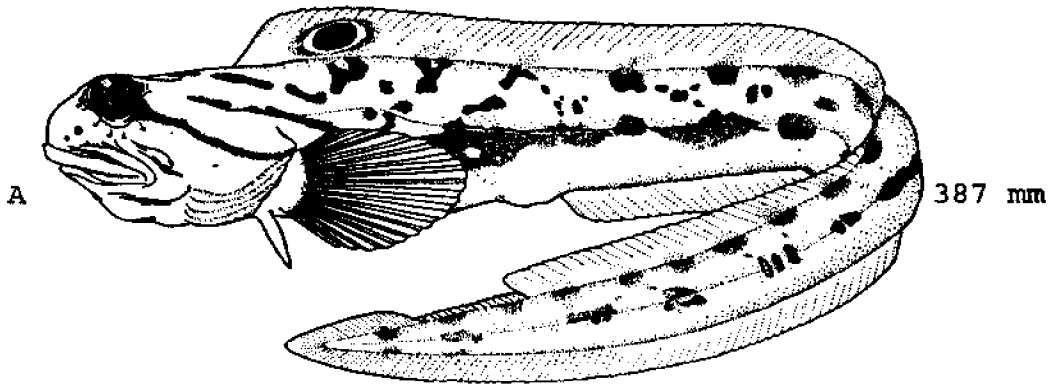

Fig. 174. *Macrozoarces americanus*, Ocean pout. A. Juvenile, 387 mm. (*A, Bigelow, H. B., and W. C. Schroeder, 1953: fig. 270 reversed.*)

mm in June,[1] 37–100 mm in first year, 120–147 mm in second year, 175–210 mm in third year, 218–262 mm in fourth year, and 675 mm in nineteenth year.[6]

AGE AND SIZE AT MATURITY

Some females maturing in 5th or 6th year,[1] all by 8[6] or 9 years [1] at a size of 40–45 cm,[6] all by 69 cm.[1]

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Lepophidium cervinum
Ophidion welshi
Rissola marginata

cusk-eels
Ophidiidae

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FAMILY OPHIDIIDAE

The cusk-eels occur world-wide in tropical and temperate marine waters. They are easily recognized by the peculiar pelvic fins that are reduced to barbel-like structures and are placed on the chin. The Mediterranean *Ophidion barbatum* produces oval pelagic eggs which are contained in floating gelatinous masses (Sparta, 1932). However, the early development of most, if not all, cusk-eels is virtually unknown.

The family is in a very confused state taxonomically and is just now being intensively studied. Several species found in the Mid-Atlantic Bight region are only now being described (R. N. Lea and C. R. Robins pers. com.).

Lepophidium cervinum (Goode and Bean), Fawn cusk-eel

ADULTS

D. 132–134; A. 112–117; C. 0+4+5+0; [4] scales in about 11 rows from origin of dorsal fin to median line of body; [3] vertebrae 15+57–59=72–74; [4] gill rakers short, 7–8 on lower limb of first arch, gill bar black; [2] teeth in narrow bands on jaws, vomer and palatines, villiform, some noticeably enlarged.

Head 6.5, depth 10.5 [3]–13,[1] predorsal length 4.8, preanal 3 into TL. Interorbital 5.67, eye 4, maxillary 2.67, pelvic fin 3, pectoral fin 2 into head.[3]

Body elongate, slender; head slender, somewhat compressed; snout sharp, conical, armed with short, sharp spine; maxillary reaching nearly to vertical through posterior margin of orbit. Scales with radiating striae, covering all parts of body except snout, undersurface of head, and fins; lateral line continued almost to end of tail. Dorsal fin origin far back,[3] soft; dorsal, anal, and caudal fins continuous; pelvic fins on throat.[1] Interorbital broad, convex; eye circular.[3]

Pigmentation: Brownish yellow,[1,3] darker above than below; upper side with 14–23 roundish white or pale brown spots; [1] vertical fins with narrow black [1,3] or dusky [1] margin.

Maximum size: Unknown, type specimen 262 mm.[3]

DISTRIBUTION AND ECOLOGY

Range: George's Bank [2] south to and including Gulf of Mexico [2,6] and Caribbean.[2]

Area distribution: Recorded from Atlantic and Cape May counties, New Jersey.[5]

Habitat and movements: Adults—recorded from 102–186 m.[3]

Larvae—no information.

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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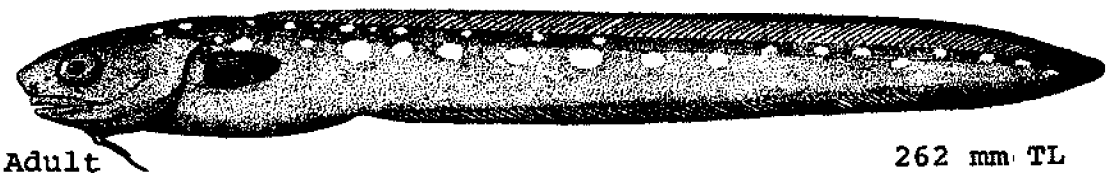

Fig. 175. *Lepophidium cervinum*, Fawn cusk-eel. A. Adult, holotype, 262 mm TL. (*A, Goode, G. B., and T. H. Bean, 1895: fig. 306.*)

Ophidion welshi (Nichols and Breder), Crested cusk-eel

ADULTS

D. 138–146; A. 114–121; C. 0+4+5+0; [1] head scaleless, scales ending on nape, or vertical over opercle; [5] vertebrae 16+50–51=66–67; [1] gill rakers 4 on lower limb of first arch.[5]

Head 5.1–5.2, depth 6.4–6.6 in SL. Pectoral fin 1.6, eye 5.1, snout 4.5, maxillary 2.3, longest pelvic ray 1.5, interorbital 5.1 in head.[5]

Head profile low and slanting to past middle of eye then rising to high gibbous nape [5] in males; [3] scales rudimentary, embedded,[5] in groups, not overlapping; [3] concealed spine on margin of opercle.[5]

Pigmentation: Yellowish, with four narrow brown stripes on each side, one at dorsal fin base, one on lateral line, two on lower sides; [3] stripes commonly broken and irregular; [3,5] preorbital, suborbital and postorbital regions punctulate with dark dots; dark blotch on upper margin of opercle; dorsal fin pale basally, with elongate black marginal spot beginning near its origin, posteriorly edged with narrow dusky margin; anal fin pale basally, but with inconspicuous dark punctulations; pectoral fins pale, punctulate with brown at margin and on base.

Maximum size: To 199 mm SL.[5]

DISTRIBUTION AND ECOLOGY

Range: New Jersey south to Florida and northern Gulf of Mexico.[4]

Area distribution: Recorded from Atlantic, Monmouth, and Ocean counties, New Jersey.[2]

Habitat and movements: Adults—prefer soft bottoms from shore line to at least 18 m.[5]

Larvae—common in bays of low salinity.[3]

Juveniles—no information.

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

Uniformly golden and silvery with only vague indications of stripes.[3]

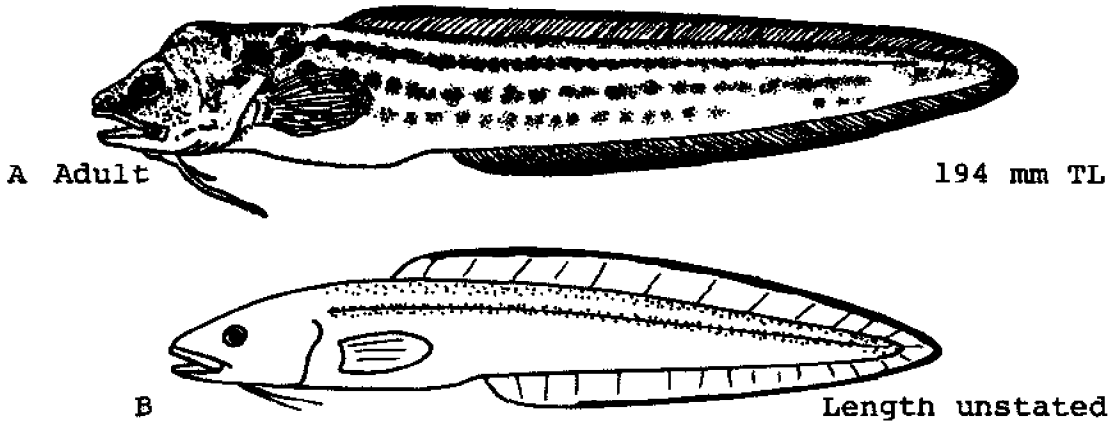

Fig. 176. *Ophidion welshi*, Crested cusk-eel. A. Adult holotype, 194 mm TL. B. Juvenile, length unstated. (*A, Nichols, J. T., and C. M. Breder, Jr., 1922: fig. 3. B, Walls, J. G., 1975: 130.* © *TFH Publications. Used with permission of author and publisher.*)

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

LITERATURE CITED

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Rissola marginata (DeKay), Striped cusk-eel

ADULTS

D. 147–158; A. 118–124; C. 0+4+5+0; [3] P. 21; [5] vertebrae 15+53–54=68–69; [3] gill rakers short, 4–5 on lower limb of first arch; teeth in jaws pointed, in bands; bands of blunt teeth on vomer and palatines.[1]

Head 5.95–6.15, depth 7.3–8.2 in SL. Snout 3.5–4.05, eye 3.05–3.3, interorbital 4.75–6.85, maxillary 2–2.15, pectoral fin 1.2–1.3 in head.[1]

Body elongate, compressed,[1,2] about uniform in depth to anal base, then tapering to tail; head compressed; snout moderately pointed; mouth moderately large, horizontal, lower jaw included; maxillary reaching nearly or quite to posterior margin of eye.[1] Scales minute, inconspicuous; [2] lateral line not quite continuous with caudal fin; [1] dorsal, anal and caudal fins continuous.[2] Dorsal fin origin over or little behind middle of pectoral length; anal fin origin on second third of body; [1] pelvic fins on throat; [2] pectoral fins moderately large.[1]

Pigmentation: Color in life grayish green; sides golden; belly snow white; ventral surface of head mostly golden; sides of head punctulated with brown; lateral line in dark band; dorsal fin pale green with black margin, continued on caudal and posterior part of anal; anterior margin of

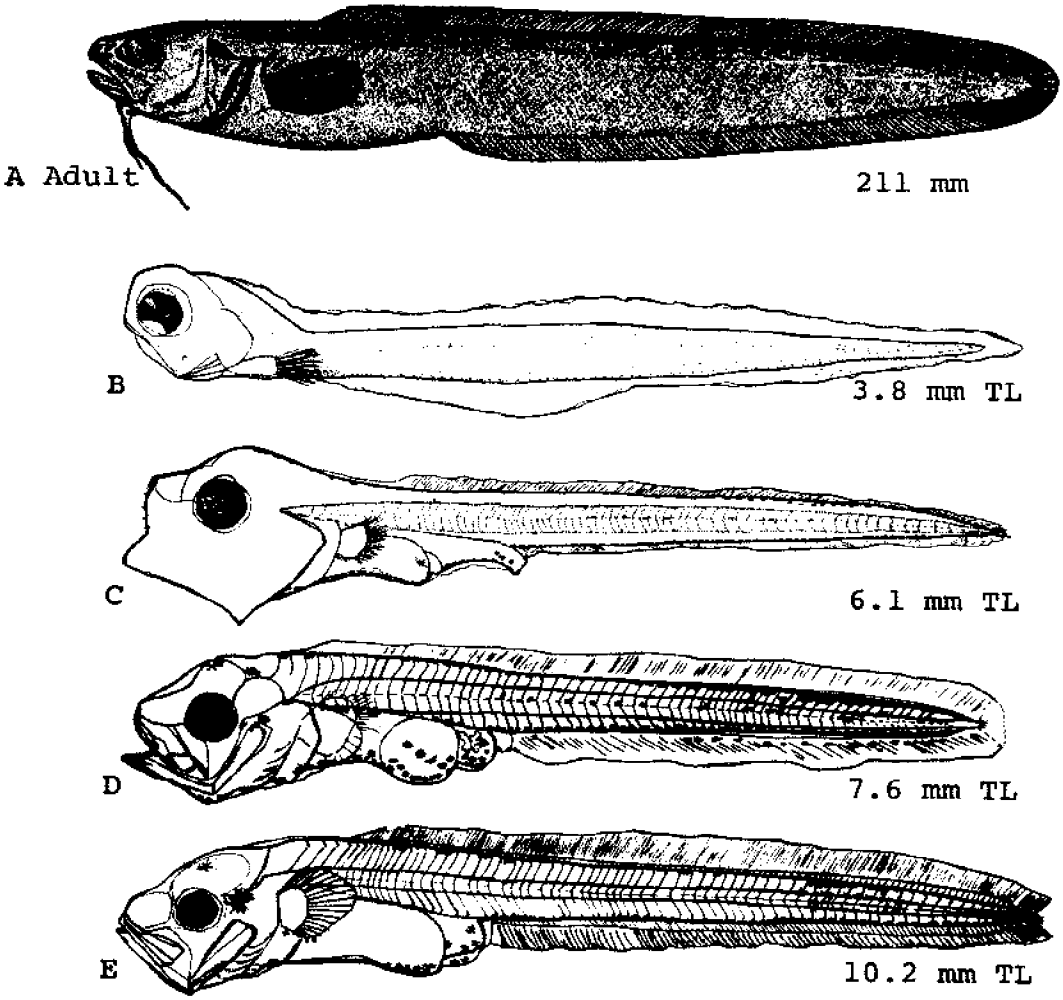

Fig. 177. *Rissola marginata*, Striped cusk-eel. A. Adult, 211 mm. B. Yolk-sac larva, 3.8 mm TL. C. Yolk-sac larva, 6.1 mm TL. D. Yolk-sac larva, 7.6 mm TL. E. Yolk-sac larva, 10.2 mm TL. (*A, Hildebrand, S. F., and W. C. Schroeder, 1928: fig. 202. B-E, Scotton, L. N., et al., 1973: 134.*)

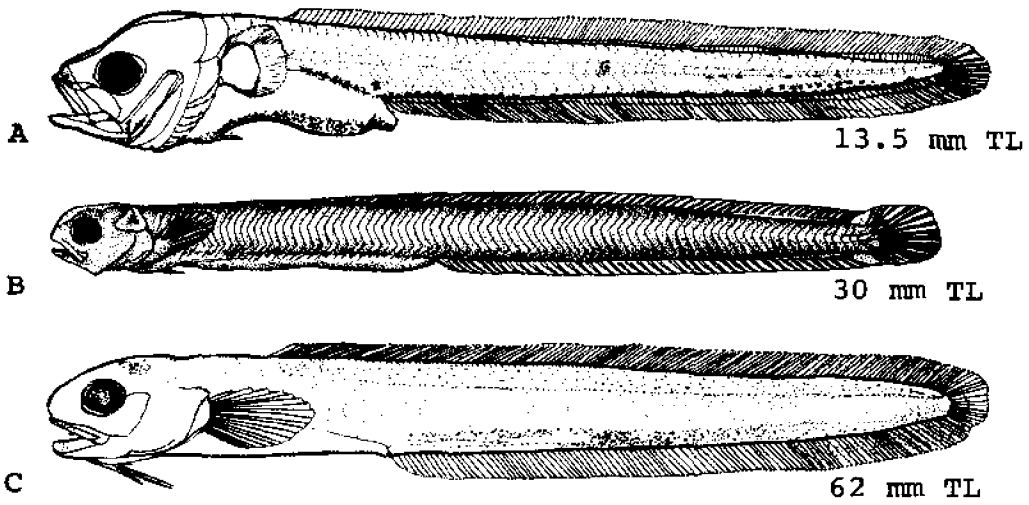

Fig. 178. *Rissola marginata*, Striped cusk-eel. A. Larva, 13.5 mm TL. B. Larva, 30 mm TL. C. Juvenile (?, RAF), 62 mm TL. (*A, Scotton, L. N.*, et al., *B, Alice J. Lippson, original drawing. C, Nancy Schenck Smith, original drawing.*)

anal fin white; pelvic fins white; pectoral fins golden with distal and lower margins white.[1]

Maximum size: To 230 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: New York south to Texas.[1,2]

Area distribution: Recorded from Atlantic County, New Jersey[4] and Cape Charles and Lynnhaven Roads, Virginia.[1]

Habitat and movements: Adults—frequent sandy shores,[1,2] burrowing in sand;[2] nocturnal.[1]

Larvae—no information.

Juveniles—no information.

SPAWNING

Season possibly June–September.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

Extremely elongate body.

Pigmentation: Two narrow, parallel black lines along ventral edge.[6]

JUVENILES

No information.

GROWTH

No information.

AGE AND SIZE AT MATURITY

No information.

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