LARVAL DEVELOPMENT OF *CITHARICHTHYS CORNUTUS*, *C. GYMNORHINUS*, *C. SPILOPTERUS*, AND *ETROPUS CROSSOTUS* (BOTHIDAE), WITH NOTES ON LARVAL OCCURRENCE[1, 2]

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ABSTRACT

Developmental series of 4 of the 12 species of *Citharichthys* and *Etropus* known from the western North Atlantic and Gulf of Mexico are illustrated and described. The series consist of *C. cornutus* (preflexion to nearly transformed, 2.2-17.4 mm body length, BL), *C. gymnorhinus* (preflexion to late transformation, 4.4-12.9 mm BL), *C. spilopterus* (preflexion to juvenile, 3.7-25.4 mm BL), and *E. crossotus* (preflexion to nearly transformed, 4.6-10.8 mm BL).

Data from this study and that for 2 species previously described permit identification of larvae of 6 of the 12 species. For the species investigated, caudal fin formula (4-5-4-4) is the most reliable indicator for the group of genera *Citharichthys*, *Cyclopsetta*, *Etropus*, and *Syacium*. Number of elongate dorsal rays, degree of cephalic spination, and pigmentation are most useful for determining genus for known forms. Number of elongate dorsal rays, number of caudal vertebrae, pigmentation, morphology, and number of gill rakers are most useful for identification of *Citharichthys* and *Etropus* larvae that have been described.

Citharichthys cornutus larvae have no pectoral melanophore, little notochordal pigmentation, heavy lateral pigmentation, 3 elongate dorsal rays, and develop 6 left pelvic rays and 25-26 caudal vertebrae. Flexion is complete at 9-10 mm SL and transformation at about 18 mm SL. Larvae have been collected during all seasons. Caudal fin development in *C. cornutus* is typical of the four species described here. *Citharichthys gymnorhinus* larvae have no pectoral melanophore, little notochordal pigmentation, light lateral pigmentation except for a caudal band, 3 elongate dorsal rays, and develop only 5 left pelvic rays and 23-24 caudal vertebrae. Flexion is complete at 7-8 mm SL and transformation probably at about 18 mm SL. Larvae have been collected during all seasons. *Citharichthys spilopterus* larvae have no pectoral melanophore, little notochordal pigmentation, light lateral pigmentation, a blunt snout, a deep body, 2 elongate dorsal rays, and develop 6 left pelvic rays and 23-24 (rarely 25) caudal vertebrae. Flexion is complete at 7-8 mm SL and transformation at 9-11 mm SL. Larvae have been collected from September through April. *Etropus crossotus* larvae have a melanophore at the base of the pectoral fin, heavy notochordal pigmentation, heavy lateral pigmentation, 2 elongate dorsal rays, and develop 6 left pelvic rays and 25-26 (very rarely 24) caudal vertebrae. Flexion is complete at 9-10 mm SL and transformation at 10-12 mm SL. Larvae have been collected in May and August and probably occur from March to August.

Twelve species of the flatfish genera *Citharichthys* and *Etropus* (subfamily Paralichthyinae, family Bothidae) are recognized from the western North Atlantic (Table 1). Because of their small size at maturity, these fishes are presently used only by the pet food and fish meal industries (Topp and Hoff 1972). However, the abundance of larvae (Richardson and Joseph 1973; Smith et al. 1975; Dowd 1978) and adults (Dawson 1969; Topp and Hoff 1972; Christmas and Waller 1973) indicates that some species may represent significant components of estuarine and marine food webs.

Larvae in the *Citharichthys-Etropus* complex are difficult to distinguish and are often ignored or classified as "unidentified bothids" in species composition analyses (e.g., Fahay 1975). Of the 12 western North Atlantic species, only *C. arctifrons* and *E. microstomus* have been described in detail (Richardson and Joseph 1973). *Citharichthys cornutus*, *C. gymnorhinus*, *C. macrops*, and *E. rimosus* have been briefly described by Dowd (1978). Larvae of the remaining species have not been reported previously. Hsiao (1940) mis-

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takenly described *Bothus* sp. larvae as *E. crossotus*.

In this paper I present descriptions of larvae of *C. cornutus*, *C. gymnorhinus*, *C. spilopterus*, and *E. crossotus* and summarize data useful for identifying *Citharichthys* and *Etropus* larvae.

MATERIALS AND METHODS

Abbreviations

The following institutional abbreviations are used: CP&L = Carolina Power and Light Company, Raleigh, N.C.; GCRL = Gulf Coast Research Laboratory, Ocean Springs, Miss.; GMBL = Grice Marine Biological Laboratory, College of Charleston, S.C.; LSU = Louisiana State University, Baton Rouge; NCSU = North Carolina State University, Raleigh; NMFS = National Marine Fisheries Service, NOAA (four laboratories—Beaufort, Galveston, Panama City, and La Jolla); OSU = Oregon State University, Corvallis; RSMAS = Rosenstiel School of Marine and Atmospheric Science, University of Miami, Fla.; SCMRRI = South Carolina Marine Resources Research Institute, Charleston; Texas A&M = Texas A&M University, College Station; UNC = University of North Carolina, Institute of Marine Sciences, Morehead City; USNM = U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C.; VIMS = Virginia Institute of Marine Science, Gloucester Point.

Specimens

Larval and juvenile specimens used in this study were obtained from several sources. Forty-seven *C. cornutus* specimens from SCMRRI (MARMAP ichthyoplankton survey) collections in the South Atlantic Bight and five specimens from RSMAS collections from the Gulf of Mexico off western Florida were used for morphometrics, counts, and general development. Seven additional RSMAS specimens were used for counts. Other specimens from NMFS (Beaufort) collections in Onslow Bay, off North Carolina, were used for comparison. Twenty-eight *C. gymnorhinus* specimens from SCMRRI collections and 12 from RSMAS collections were used for morphometrics, counts, and general development. Other specimens from NMFS (Beaufort) collections were used for comparison. Fifty-five *C. spilopterus* specimens from NCSU and personal collections in the Cape Fear River estuary, one from a CP&L collection in the ocean just off Cape Fear, and three from Texas A&M collections in the Gulf of Mexico off Texas were used for morphometrics, counts, and general development. Other specimens from Texas A&M, NMFS (Beaufort, Galveston, and Panama City), and RSMAS collections were used for comparison and additional count data. Thirty *E. crossotus* specimens from LSU collections from the Gulf of Mexico off Louisiana and one from a NCSU collection were used for morphometrics, counts, and general development. Other specimens from Texas A&M collections were used for comparison.

Comparative larval material of other species was also examined. *Citharichthys* sp. A (probably *C. abbotti*) specimens came from Texas A&M; *Citharichthys arctifrons* specimens from NMFS (Beaufort), SCMRRI, and VIMS; a *Citharichthys* sp. B (probably *C. dinoceros*) specimen from RSMAS; and *Citharichthys* (*macrops*?) specimens from GCRL, RSMAS, and VIMS. Larvae of the eastern Pacific species *Citharichthys sordidus*, *C. stigmaeus*, and *C. xanthostigma* came from NMFS (La Jolla). Other specimens of Pacific *Citharichthys* spp. came from OSU; *Etropus microstomus* specimens from NMFS (Beaufort) and VIMS; *Etropus* sp. A (probably *E. rimosus*) specimens from CP&L, NMFS (Panama City), and RSMAS; *Cyclopsetta fimbriata* specimens from NMFS (Beaufort), RSMAS, SCMRRI, and Texas A&M; and *Syacium papillosum* specimens from RSMAS and Texas A&M.

Juvenile and adult specimens were examined to determine permanent characters. Specimens of *C. arctifrons*, *C. macrops*, *C. spilopterus*, *E. crossotus*, *E. intermedius* (cf. *E. crossotus*), *E. microstomus*, and *E. rimosus* came from USNM; *Citharichthys cornutus* and *C. gymnorhinus* specimens from GMBL; *Citharichthys macrops* specimens from UNC and a personal collection; and *Citharichthys spilopterus* and *E. crossotus* specimens from NCSU.

Description of caudal skeleton development was based on study of the entire developmental series of *C. cornutus* and comparison with the series of the three other species described. Calcified components of the caudal skeletons of nearly all the specimens could be seen following light staining with Alizarin Red S in 1% aqueous potassium hydroxide solution. Twenty cleared and stained (Taylor 1967) specimens were examined: *C. arctifrons*, (2) 40, 117 mm SL; *C. cornutus*, (1) 51.5 mm SL; *C. spilopterus*, (2) 41.6, ~100 mm SL; *C. macrops*, (2) 45.7, ~100 mm SL; *E. crossotus*, (1) 49.4 mm SL; *E. microstomus*, (12) ~30-100 mm SL. Radiographs of juveniles and adults also were studied: *C. arctifrons*, (1) 100 mm SL; *C. cornutus*, (16) 30-67 mm SL; *C. gymnorhinus*, (3) 23-37 mm SL; *C. macrops*, (75) 47-113 mm SL; *C. spilopterus*, (65) 23-109 mm SL; *E. crossotus*, (62) 29-92 mm SL; *E. intermedius* (cf. *E. crossotus*), (2) 80, 92 mm SL; *E. microstomus*, (1) 66 mm SL; *E. rimosus*, (1) 104 mm SL.

Counts

All larvae were lightly stained with Alizarin Red S in 1% aqueous potassium hydroxide solution for making counts and observing the sequence of ossification. Most specimens were fairly transparent and internal structures were visible without clearing. The following counts were taken from larvae and juveniles with a stereomicroscope: precaudal neural spines, caudal neural spines, hemal spines, precaudal centra, caudal centra (including urostyle), caudal fin rays supported by each hypural element, dorsal fin rays, anal fin rays, left and right pelvic fin rays, left and right preopercular spines, left and right frontal-sphenotic spines, and left and right upper (premaxillary) and lower (dentary) larval teeth.

Morphometrics

Measurements of various body parts of representative specimens were made on the left side with an ocular micrometer in a stereomicroscope. The only exceptions were standard and total lengths of the six longest *C. spilopterus* (19.4-25.4 mm SL), which were made with dividers and a millimeter scale. Measurements are defined as follows:

Body length (BL) = snout tip to notochord tip for preflexion and flexion larvae (notochord length, NL); snout tip to posterior margin of hypurals for postflexion larvae and juveniles (SL).

Upper jaw length = snout tip to posterior margin of maxillary.

Lower jaw length = anterior tip of dentary to posterior margin of articular just above the angular.

Snout length = horizontal distance from snout tip to anterior margin of left pigmented eye.

Eye diameter = horizontal diameter of left pigmented eye.

Head length (HL) = horizontal distance from snout tip to anterior margin of cleithrum at the body midline.

Snout to anus length = horizontal distance from snout tip through midline of body to vertical line through anus.

Total length = snout tip to posterior margin of finfold prior to caudal fin ray development, then to posterior tip of longest caudal ray.

Head depth = greatest vertical depth of head; in preflexion larvae, this is near or just behind the posterior half of the eye, but with development the greatest depth is progressively more posterior.

Body depth at pelvic fin = vertical distance from dorsal to ventral body margin at base of second pelvic ray.

Body depth at loop of gut = vertical distance from dorsal to ventral body margin at the deepest part of the gut (*C. cornutus* and *C. gymnorhinus* only).

Body depth at anus = vertical distance from dorsal to ventral body margin at anus.

Body depth at third hemal spine = vertical distance from dorsal to ventral body margin at third hemal spine.

Caudal peduncle depth = prior to dorsal and anal fin formation, the vertical distance from dorsal to ventral body margin at the shallowest part of the caudal peduncle; after dorsal and anal fin formation, at the posterior edge of dorsal and anal fins.

Developmental Terminology

Body length is a useful basis for linking characters of unidentified specimens with those in larval descriptions. However, body length may not be the most appropriate basis for comparing larvae of different species, especially bothids, which undergo notochord flexion and transformation at different sizes, usually within a narrow range for a single species but over a wide range for the family or even within a genus (e.g., *Citharichthys*). In this paper, both body length and stage of development are indicated for developmental events. Stage of development is defined by degree of notochord flexion or degree of transformation. Terminology is similar to that of

Moser et al. (1977) and Sumida et al. (1979), with slight modification because of the peculiarities of bothid development.

Preflexion stage = notochord is straight.
Early caudal formation = a substage of preflexion in which the notochord is still straight, but the caudal fin has begun to form.
Flexion stage = notochord is turning upward. There are three substages: Early flexion = notochord is slightly flexed; midflexion = notochord is S-shaped and flexed about 30°-60°; late flexion = notochord is turned up and is no longer S-shaped but is not yet in final position.
Postflexion stage = notochord is in final position, but transformation is not complete.
Transforming larvae = those in which dorsal migration of the right eye can be detected with low magnification. The period of transformation is divided into thirds, depending on the position of the right eye.
Juveniles = those specimens in which the right eye has reached its final position on the left side of the head and in which all fin rays have formed. Reported size ranges at transformation are based on available specimens and might not encompass the full possible size ranges. Environmental stimuli inducing transformation may be encountered at different sizes.

Terminology of components of the caudal skeleton follows Amaoka (1969), except as noted. The caudal fin formula was described by Gutherz (1971) as the number of caudal rays supported by each caudal element, dorsal to ventral.

Gutherz (1971) described certain cranial spines of *Cyclopsetta fimbriata* larvae as originating from the sphenotic bones. Futch and Hoff (1971) described similar spines of *Syacium papillosum* larvae as originating from the frontal bones. In the *Citharichthys* and *Etropus* larvae I have examined, similar spines are at the suture between frontal and sphenotic bones. The origin of these could not be determined with certainty, and therefore they are called "frontal-sphenotic" spines.

For the larvae described here, the first elongate dorsal ray is actually the second ray of that fin.

Larval Identification

Four developmental series were assembled, primarily on the basis of similar meristics, shape, and pigmentation. Transforming larvae and juveniles were identified first by the presence of known adult characters. Additional larval characters observed in those specimens were then used to aid in identification of the smaller specimens.

Because all transformed specimens were sinistral and the right eye of all transforming specimens was migrating, it was decided that the four larval series belonged to one or more of the flatfish families Bothidae, Scophthalmidae, or Cynoglossidae. Morphological characters exhibited in the larval series and shared by larvae of these three families are lateral compression, deep head, deep abdomen, and looped gut, and in early larvae a raised and rounded dorsal profile of the head and slender caudal region. Only one scophthalmid species, *Scophthalmus aquosus*, is known from the western North Atlantic (Gutherz 1967; Hensley 1977). The distinctive rhomboid shape, long-based pelvic fins, and dense pigmentation of *S. aquosus* larvae were lacking in my series of larvae. The small eyes, small head, and confluent dorsal, caudal, and anal fins of cynoglossids were also lacking. In addition, cynoglossids from this region have fewer caudal (usually 9-14) and pelvic (usually 4 left, 0 right) rays than the specimens in my series. Therefore, Scophthalmidae and Cynoglossidae were eliminated from consideration.

Gutherz (1971) summarized known characters most useful for identifying bothid larvae. Futch (1977) summarized subfamilial larval characters and tentatively recognized two subfamilies, Paralichthyinae and Bothinae. The following discussion is limited to western North Atlantic species. Four paralichthyine genera—*Citharichthys*, *Cyclopsetta*, *Etropus*, and *Syacium*—have a similar combination of transitory (larval) and permanent characters that distinguish them from other bothid genera. These include: 1) adult caudal fin ray formula of 4-5-4-4; 2) placement of the left pelvic fin on the ventral midline and the right above the ventral midline, both originating behind the cleithra (Gutherz 1971); 3) the same basic larval shape; 4) similar larval pigmentation—on the gas bladder, in dorsal and anal lines, and in the caudal region; 5) larval preopercular spines (at least in *Citharichthys cornutus*, *C. gymnorhinus*, *C. spilopterus*, *Cyclopsetta fimbriata*, *C. chittendeni*, *Etropus crossotus*, *E. microstomus*, and *Syacium papillosum*); 6) larval frontal-sphenotic spines (at least *Cith-*

arichthys arctifrons, C. cornutus, C. gymnorhinus, C. spilopterus, Cyclopsetta fimbriata, C. chittendeni, E. crossotus, E. microstomus, and *S. papillosum*). Caudal formula, pelvic fin placement, shape, and pigmentation of larvae in the four series corresponded to this group.

Cyclopsetta spp. have 26-28 caudal vertebrae (Gutherz 1967). Larvae of *C. fimbriata, C. chittendeni,* and *S. papillosum* have 5-10 elongate dorsal rays and well-developed preopercular and frontal-sphenotic spines (Gutherz 1971; Futch and Hoff 1971; Evseenko 1979). Futch and Hoff (1971) listed *Syacium* generic larval characters. Other *Cyclopsetta* and *Syacium* larvae are probably similar. Larvae in the four developmental series had lower caudal vertebral count ranges than *Cyclopsetta* spp., only 2-3 elongate dorsal rays, and relatively small preopercular and frontal-sphenotic spines. Therefore, these two genera were ruled out, leaving *Citharichthys* and *Etropus.* Identification to species is described in the individual species accounts.

For aid in determining species of *Citharichthys* and *Etropus,* frequency distributions of caudal vertebral, anal ray, and dorsal ray counts were tabulated from the literature, and from radiographs of juveniles and adults from the Atlantic off the southeastern United States (Append. Tables 1-3). Ranges of gill raker counts were tabulated from the literature (Append. Table 4). Number of caudal vertebrae (Append. Table 1) was the count most useful for distinguishing larvae. Vertebral counts can be made before ossification during early or midflexion, and overlap is not excessive. However, care is necessary to avoid inaccurate counts because of fused centra. Caudal neural spines and hemal spines, both of which number one less than caudal vertebrae, will stain with alizarin and sometimes can be counted before caudal vertebrae, during early or midflexion. The number of gill rakers on the lower limb of the first arch (Append. Table 4) can be counted in most specimens during transformation and can be very useful for identification of older larvae. The number of anal rays (Append. Table 2) is next in usefulness, followed by the number of dorsal rays (Append. Table 3); however, the overlaps for these counts are great. Efficiency can be gained by plotting individual anal versus dorsal counts on a graph, so that the counts can be used simultaneously. The adult complements of anal and dorsal rays are present by the end of transformation.

After the largest specimens in each series were identified, the identities of successively smaller larvae were verified. The most useful characters for untransformed specimens were lateral, pectoral, and notochordal pigment; number of elongate dorsal rays; number of caudal vertebrae; number and size of left pelvic rays; and head shape.

DESCRIPTION OF DEVELOPMENTAL STAGES

Citharichthys cornutus (Figs. 1-5)

Identification

Larvae approaching transformation had complete complements of countable characters. Those specimens were identified by comparing the following larval counts with known adult counts. Number of specimens is given in parentheses.

Caudal fin formula = 4-5-4-4 (27)
Caudal vertebrae = 25(11)-26(16)
Gill rakers (lower limb, first left) = 12 (1)
Left pelvic rays = 6 (17)
Anal rays = 60-66 (11)
Dorsal rays = 78-84 (11)

Of the potential species listed in Table 1, only *C. cornutus* has counts that agree with these. In addition, larvae were captured over the outer shelf, slightly farther offshore than *C. gymnorhinus* (Fig. 1). This is consistent with bathymetric distribution of adults.

Distinguishing Characters

Citharichthys cornutus larvae have no pectoral melanophore, and notochordal pigment is restricted to the caudal region. Three elongate dorsal rays are present from preflexion (about 4 mm) through transformation. Caudal vertebrae (25-26) can be counted by early flexion (6 mm). Lateral pigment is relatively heavy. Flexion is complete at 9-10 mm SL. The larval mouth and eye are large. Morphology is similar to that of *C. gymnorhinus.* However, the left pelvic fin of *C. cornutus* has a full complement of six rays, and in larvae the first ray is not reduced in size. The left pelvic fin of *C. gymnorhinus* has only five rays, and in larvae the first ray is much reduced compared with that of *C. cornutus.* Length of *C.*

TABLE 1.—Distribution of adults of *Citharichthys* and *Etropus* species known from the western North Atlantic and status of knowledge of their larvae.[1]

Species	Geographic range of adults	Depth range of adults (m)	Larval descriptions
C. arctifrons	Georges Bank to Yucatan	22-682	Richardson and Joseph 1973
E. microstomus	New York to South Carolina	5-91	Richardson and Joseph 1973
C. cornutus	Georgia to Brazil	27-366	This paper
C. gymnorhinus	Florida to Guyana	37-201	This paper
C. spilopterus	New Jersey to Brazil (rare north of Virginia)	1-73	This paper
E. crossotus	Chesapeake Bay to French Guiana	1-86	This paper
C. macrops	Southern Atlantic and Gulf coasts of the United States	1-91	Brief description in Dowd 1978
E. rimosus	North Carolina to Mississippi River	5-190	Brief description in Dowd 1978
C. abbotti	Veracruz to Campeche, Mexico	0-2	Unknown
C. amblybregmatus	Western Caribbean off Nicaragua	139-197	Unknown
C. arenaceus	West Indies to Brazil	Shallow	Unknown
C. dinoceros	Florida to Nicaragua	183-1829	Unknown
C. uhleri[2]	Haiti		Unknown
E. intermedius[3]	Trinidad to Rio de Janeiro	27	Unknown

[1]Distributions compiled from Goode and Bean 1896; Gutherz 1967; Dawson 1969; Gutherz and Blackman 1970; Topp and Hoff 1972; Leslie 1977; Wenner et al. 1979; and original data for *C. spilopterus*, *E. crossotus*, and *C. macrops* (i.e., 1 m depths).
[2]cf. *C. arenaceus*, Dawson 1969.
[3]cf. *E. crossotus*, Gutherz 1967.

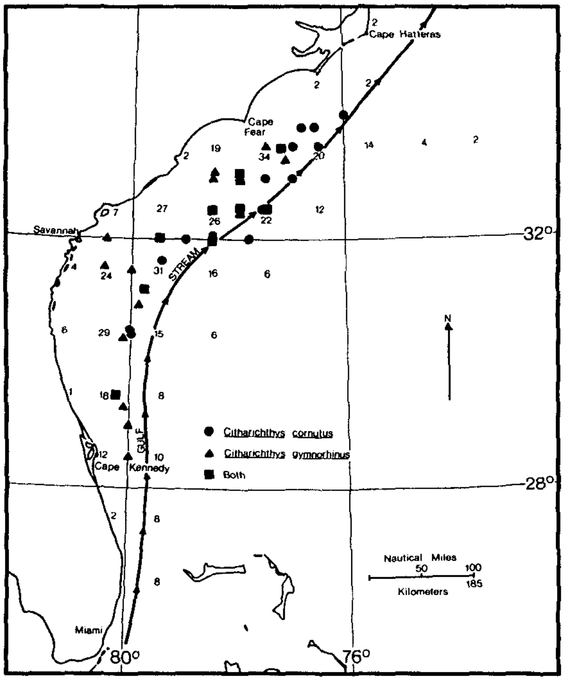


FIGURE 1.—Occurrence of *Citharichthys cornutus* and *C. gymnorhinus* larvae off the southeastern United States. Numbers are the sums of bongo and neuston tows made per 1° quadrangle during four RV *Dolphin* fall, winter, and spring cruises in 1973 and 1974. Symbols indicate positive tows.

cornutus at transformation is about 18 mm. Larvae may appear in collections year-round.

Pigmentation

Pigmentation of *C. cornutus* larvae is relatively heavy. Gas bladder, gut, and lateral tail pigment are the most striking. By 2.2 mm NL and throughout larval development, the dorsal one-third of the left side of the gas bladder is fairly heavily pigmented. This pigment may be diffuse or in the form of stellate or punctate melanophores. With growth, the number of melanophores increases. The maximum number in a preflexion specimen was five (4.8 mm). The right side of the gas bladder is usually unpigmented.

During preflexion (2.2 mm, see Fig. 4A), two or three melanophores are present on both the dorsal and the ventral body margins about halfway between the anus and the notochord tip. Another one or two melanophores are present between these two clusters near the lateral midline. Later in development, pigment in this area forms a band. One or two small melanophores may be present on the ventral finfold just posterior to the hindgut. Three or four melanophores are on the caudal finfold near the ventral body margin just anterior to the notochord tip. Two melanophores are on the ventral surface of the gut loop; additional melanophores appear there during development. A small melanophore appears along the posterodorsal surface of the midgut at about 3 mm. Melanophores begin appearing on the ventral body margin anterior to the cleithrum at about 3 mm. At about 4.7 mm, one or two melanophores appear along the posterior margin of the articular.

Flexion larvae (see Fig. 4B) usually have four or five melanophores on the dorsal one-third of the left side of the gas bladder. Midlateral caudal pigmentation consists of up to six dashlike melanophores. Additional, dashlike clusters of pigment appear along the dorsal and ventral body margins between the anus and the caudal fin base.

During midflexion (6 mm, see Fig. 4B), internal pigment appears along the dorsal notch between the midbrain and hindbrain, and one or two round melanophores appear below the notch. Visible internal notochordal pigment is restricted to the vicinity of the external caudal band. The dorsal surfaces of one to three forming centra are darkened by about 6 mm. Several melanophores are present along the ventral body margin from just above the tip of the urohyal to just behind the cleithrum. Internal pigment appears between the hindgut and anal fin origin by midflexion.

By late flexion (8 mm, see Fig. 4C), both sides of the gas bladder are obscured by body musculature, and pigment appears diffuse. Notochordal pigment appears as fine dashes along the dorsal surfaces of three to six centra of caudal vertebrae 15-21. As many as 30 or more melanophores may be present along the ventral surface of the gut loop. Pigment along the posterodorsal surface of the midgut extends to the gas bladder and appears as a black lining over the gut. One or more melanophores appear on or just behind the posterodorsal margin of the preopercle. Melanophores have developed along the elongate second left pelvic ray and begin to develop along the elongate dorsal rays at 8-9 mm. Some larvae have small melanophores near the distal tips of rays at the middle of both dorsal and anal fins. By 8 mm, a group of melanophores has appeared along the middle of the caudal fin. The posterior margin of the articular is covered with a stellate melanophore.

By postflexion (9 mm), myoseptal pigment is present in the caudal band as well as adjacent to dorsal and ventral lines. Internal pigment along the brain surface looks diffuse. Pigment appears on the dorsal fin membrane adjacent to the first dorsal ray at about 11 mm. Body musculature tends to obscure dorsal notochordal pigment in larvae longer than 12 mm. Additional midlateral dashlike melanophores appear near the caudal fin base at 13-14 mm (see Fig. 5A). By about 14 mm, all five dorsal and four ventral pigment lines have formed, and myoseptal pigment is well developed. A small amount of pigment is present along the anteroventral edge of the maxillary by about 14 mm. Late transforming larvae have about three small internal melanophores near the pectoral fin base and just forward of the cleithrum beneath the angle of the last gill arch (barely visible through the opercle); these probably develop by about 14 mm. Ventral pigment from the urohyal to the cleithrum persists until late transformation. By late transformation (see Fig. 5B), midlateral dashlike melanophores are present anterior to the caudal band.

Morphology (Figs. 4, 5; Tables 2, 3)

General morphological features include lateral compression, a deep head, a deep abdomen, and a looped gut. In early larvae the dorsal profile of the head is raised and rounded and the caudal region is slender. The eye is nearly spherical during early development but becomes ellipsoidal in transforming larvae. A ventral choroid fissure is visible from 3-4 mm NL until about the end of the postflexion stage. The nasal capsule is visible by about 3 mm NL. The gas bladder is prominent just above the foregut until the end of postflexion. It bulges slightly on the left side of the body and is not as obvious on the right. A loop forms in the gut by 2 mm NL. The liver occupies a large portion of the anteroventral region of the abdomen. Adult morphometrics given in the following discussion were derived from Topp and Hoff (1972).

The mouth is relatively large in larvae and adults. Larval upper jaw length/BL increases slightly from 10.3% (preflexion) to 11.0% (flexion) and then decreases to 9.8% (postflexion). Adult upper jaw length/BL is 12.8%, range 11.8-13.7%. Larval upper law length/HL decreases from 37% to 34%. Adult upper jaw length/HL is 45%. Larval lower jaw length/BL increases slightly from 13.3% (preflexion) to 13.9% (flexion) and then decreases slightly to 13.0% (postflexion). Larval lower jaw length/HL decreases slightly from 48% to 46% and is only slightly greater than that of *C. gymnorhinus*.

Larval snout length is moderate. Larval snout length/BL increases slightly from 6.2% (preflexion) to 7.1% (flexion) and then decreases slightly to 6.3% (postflexion). Adult snout length/BL is 5.5%, range 4.8-6.2%. Larval snout length/HL is constant at about 22-23%. Adult snout length/HL is 19.5%.

The larval eye is large, and the relative size of the adult eye is greater than that of any other western North Atlantic *Citharichthys* or *Etropus* species except *C. amblybregmatus*. Larval eye diameter/BL is constant at 9.8% during preflexion and flexion and then decreases to 8.5% (postflexion). Adult orbit length/BL is 10.0%, range

TABLE 2.—Measurements (mm) of larvae of *Citharichthys cornutus*. Pref = preflexion, ECF = early caudal formation, Early = early flexion, Mid = midflexion, Late = late flexion, Post = postflexion. S = symmetrical, 1 = 0 to one-third of the way to the dorsal ridge, 2 = one-third to two-thirds of the way to the dorsal ridge, 3 = two-thirds to all the way to the dorsal ridge, R = on the dorsal ridge.

Body length	Upper jaw length	Lower jaw length	Snout length	Eye diameter	Head length	Snout to anus length	Total length	Head depth	Body depth at pelvic fin	Body depth at loop of gut	Body depth at anus	Body depth at third hemal spine	Caudal peduncle depth	Flexion stage	Right eye position
2.2		0.33	0.12	0.27	0.62	1.1		[1]0.76	[1]0.61	[1]0.61	[1]0.53	[1]0.26		Pref	S
3.2	0.35	0.41	0.21	0.31	1.0	1.7		1.2	[1]1.1	[1]1.0	[1]0.79	[1]0.36		Pref	S
3.7	0.40	0.47	0.25	0.37	1.1	1.9	3.8	1.2	[1]1.2	[1]1.2	[1]0.88	[1]0.47		Pref	S
4.0		0.56	0.28	0.44	1.1	1.9		1.4	[1]1.4	[1]1.5	[1]1.2	[1]0.64		Pref	S
4.1		0.59	0.27	0.43	1.2	2.1	4.2		[1]1.3			[1]0.57		Pref	S
4.5	0.47	0.57	0.27	0.43	1.2	1.8	4.6	1.4		[1]1.4	[1]1.1	[1]0.65		Pref	S
4.5	0.44	0.61	0.23	0.40	1.1	1.9	4.6	1.5	[1]1.4	[1]1.5	[1]1.2	[1]0.63		Pref	S
4.6	0.50	0.71	0.29	0.47	1.3	2.2	4.7	1.8	1.7		1.5	0.83		ECF	S
4.8	0.51	0.66	0.26	0.48	1.3	2.2	5.0	1.6	[1]1.6	[1]1.6	[1]1.4	[1]0.82		ECF	S
4.9			0.28	0.47	1.3	2.1	5.0		[1]1.6	[1]1.8	[1]1.5	[1]0.83		ECF	S
5.0	0.58	0.73	0.37	0.53	1.5	2.2		1.7	1.9					ECF	S
5.7	0.48	0.63	0.32	0.50	1.5	2.3	5.8		1.9	1.9	1.9	1.1		ECF	S
5.7	0.53	0.65	0.35	0.52	1.5	2.5		2.0	1.9	2.0		1.0		ECF	S
5.8	0.65	0.81	0.33	0.63	1.7	2.7		2.2	2.5	2.6	2.5	1.6	0.57	Mid	S
6.0	0.63	0.78	0.40	0.53	1.7	2.4		2.1	2.2	2.4	2.2	1.4		Early	S
6.1	0.69	0.86	0.37	0.63	1.8	3.1		2.4	2.7	3.0	2.6	1.8	0.61	Mid	S
6.3	0.66	0.84			1.8	2.6	7.4	2.4	2.5			1.7	0.59	Mid	S
6.3	0.75	0.96	0.46	0.65		3.0		2.5	2.8	3.1	2.7	1.8	0.64	Mid	S
6.4	0.70	0.92	0.41	0.63	1.8	2.9	7.5	2.5	2.8	3.0	2.7	1.8	0.64	Mid	1
6.4	0.70	0.89	0.44	0.63	1.8	3.0	7.2	2.4	2.6	2.8	2.5	1.6	0.54	Mid	S
6.4	0.77	0.90	0.55	0.63		3.0		2.5	2.8	3.1	2.7	1.9	0.65	Late	1
6.9	0.87	1.1	0.53	0.73	2.3	3.2	8.6	2.8	3.2	3.6	3.3	2.3	0.88	Late	1
7.2	0.76	0.96	0.46	0.74	2.2	3.2		2.8	3.0	3.4	3.1	2.1	0.84	Late	S
7.2	0.77	1.0	0.47	0.75	2.2	3.2	8.7	2.7	3.0	3.5	3.3	2.2	0.80	Late	S
7.6	0.90	1.2	0.60	0.77	2.5	3.6		3.2	3.7	4.2	4.0	3.0	1.0	Late	S
7.6	0.77	0.99	0.51	0.73	2.2	3.6	9.2		3.0	3.2	3.0	2.3	0.82	Late	S
7.6	0.83	1.0	0.50	0.77	2.3	3.3		2.8	3.2	3.6	3.3	2.3	0.88	Late	2
7.6	0.84	1.1	0.50		2.3	3.7	9.3	3.0	3.6	4.0	3.5	2.6	0.90	Late	S
7.7	0.90	1.1	0.65	0.73	2.4	3.4		3.2	3.5	3.7	3.5	2.6	0.94	Late	S
7.9	0.81	1.0	0.54	0.74	2.4	3.9	9.5		3.5	3.8	3.6	2.5	0.90	Late	1
8.2	0.91	1.2	0.64	0.81	2.6	3.6			3.7	4.1	4.0	3.0	1.1	Late	1
8.2	0.87	1.1	0.62	0.76	2.5	3.6		3.1	3.4	3.5	3.3	2.5	0.87	Late	1
8.3	0.97	1.3	0.71	0.81	2.7	4.1		3.5	4.0	4.8	4.3	3.0	1.1	Late	1
8.3	0.96	1.2	0.51	0.85	2.6		10.5		4.0	4.6	4.1	3.0	1.1	Late	S
8.4	0.90	1.1	0.61	0.80	2.7	4.2	10.2	3.4	3.8	4.4	3.9	2.8	0.94	Late	1
8.6	0.90	1.1	0.66	0.81	2.7	4.1	10.7	3.2	3.7	4.4	4.1	3.0	1.0	Late	2
8.8	0.95	1.2	0.61	0.80	2.6	3.7		3.2	3.8	3.9	3.9	2.9	1.0	Late	2
8.9	0.90	1.1	0.62	0.80	2.6	3.9		3.4	3.8	4.1	3.8	2.9	1.0	Late	2
10.4	1.1	1.4	0.74	0.93	3.2	4.6	12.9	4.0	4.6	5.3	5.1	4.0	1.4	Post	3
10.6	1.1	1.5	0.77	1.0	3.2	4.8	13.2	4.1	4.8	5.8	5.6	4.1	1.5	Post	3
10.6	1.2	1.5	0.73	0.94	3.2	4.6		3.9	4.6	5.3	5.1	4.1	1.4	Post	1
10.9	1.2	1.5	0.79	0.99	3.2	4.3		4.0	4.7	5.7	5.3	4.1	1.4	Post	3
11.5	1.2	1.6	0.74	1.1	3.4	4.9	14.1	4.0	4.6	5.5	5.3	4.1	1.4	Post	3
12.0	1.1	1.6	0.89	0.99	3.5	4.6	14.7	4.3	4.9	5.1	5.2	4.3	1.4	Post	3
12.1	1.3	1.6	0.73	1.1	3.6	5.0		4.6	5.1	6.1	6.0	4.9	1.6	Post	2
12.8	1.1	1.6	0.64	1.1	3.5	5.0		4.4	4.9	5.8	5.5	4.6	1.6	Post	3
12.9	1.2	1.6	0.73	1.0	3.5	5.1		4.8	5.2	6.1	5.9	4.8	1.6	Post	3
13.0	1.2	1.6	0.72	1.0	3.5	4.8	15.9	4.5	5.4	5.9	5.9	5.3	1.6	Post	3
13.8	1.2	1.7	0.70	1.2	3.7	5.2		5.4	5.9	6.7	6.5	5.5	1.8	Post	3
15.4	1.4	1.8	0.95	1.2	4.0	5.6	18.5	5.1	6.1	6.9	6.8	6.1	1.9	Post	3
17.4	1.6	2.2	1.2	1.2	4.8	5.6	21.2	5.7	6.6	7.5	7.6	7.2	2.2	Post	3
17.4	1.7	2.1	1.0	1.5	4.8	5.6		6.3	6.5		7.7	6.8	2.0	Post	R

[1]Measurement does not include dorsal or anal pterygiophores.

9.2-11.1%. Larval eye diameter/HL decreases from 36% to 30% and is similar to that of *C. gymnorhinus*. Adult orbit length/HL is 35.5%.

The head is relatively large in larvae and moderate in adults. Larval head length/BL increases from 28% (preflexion) to 30% (flexion) and then decreases to 28% (postflexion). Postflexion head length/BL is similar to those of *C. arctifrons* and *C. gymnorhinus*. Adult head length/BL is 28%, range 27-30%. Larval head depth/BL increases from 34% (preflexion) to 39% (flexion) and then decreases slightly to 36% (postflexion).

Larval snout to anus length is relatively great until postflexion. Snout to anus length/BL is 46% during preflexion and flexion and then decreases greatly to 39% (postflexion).

The body is relatively deep in larvae and moderate in adults. Larval body depth at pelvic fin/

TABLE 3.—Body proportions of larvae and juveniles of three species of *Citharichthys* and one species of *Etropus*. Except for body length, values are in percentage of body length (BL) or of head length (HL) and are given as: mean ± standard deviation (range). (Values derived from Tables 2, 5, 6, 7.)

Measurement	C. cornutus	C. gymnorhinus	C. spilopterus	E. crossotus
Body length (mm)				
Preflexion	4.6 (3.2-5.7)	4.6 (4.4-5.0)	3.7	4.6
Flexion	7.4 (5.8-8.9)	6.7 (5.3-7.7)	6.4 (5.7-6.8)	6.8 (4.9-9.5)
Postflexion	12.9 (10.4-17.4)	10.4 (7.9-12.9)	9.4 (8.3-10.6)	10.2 (9.3-10.8)
Early juvenile			10.0 (8.7-11.6)	
Midjuvenile			20.5 (14.3-25.4)	
Upper jaw length/BL				
Preflexion	10.3±1.0(8.4-11.6)	9.5±0.7(8.3-10.3)	9.9	7.0
Flexion	11.0±0.6(10.1-12.5)	9.3±0.4(8.3-10.0)	7.2±0.8(6.3-7.9)	7.2±0.7(5.9-8.4)
Postflexion	9.8±0.8(8.6-10.8)	9.3±0.7(8.1-11.3)	6.7±0.6(5.6-7.9)	7.1±0.5(6.4-7.8)
Early juvenile			7.3±0.4(6.1-8.1)	
Midjuvenile			9.0±0.4(8.4-9.7)	
Lower jaw length/BL				
Preflexion	13.3±1.3(11.0-15.3)	11.5±1.0(10.2-12.9)	12.1	9.6
Flexion	13.9±0.9(12.4-15.5)	12.7±0.6(11.6-13.6)	9.9±0.7(9.1-10.4)	9.6±1.0(8.5-12.3)
Postflexion	13.0±0.8(11.9-14.4)	12.7±0.6(11.6-14.2)	9.1±0.5(8.2-10.2)	9.8±0.5(9.2-10.6)
Early juvenile			10.3±0.5(8.9-11.5)	
Midjuvenile			13.1±0.4(12.5-13.8)	
Snout length/BL				
Preflexion	6.2±0.7(5.1-7.4)	5.2±1.1(3.7-6.7)	7.5	5.2
Flexion	7.1±0.8(5.7-8.6)	5.8±0.6(4.9-7.0)	7.6±0.8(6.8-8.1)	6.4±0.7(5.1-7.5)
Postflexion	6.3±0.8(5.0-7.4)	6.1±0.6(4.8-7.6)	6.4±0.6(5.6-7.4)	6.8±0.9(5.4-7.6)
Early juvenile			5.8±0.6(4.4-7.2)	
Midjuvenile			5.0±0.5(4.3-5.5)	
Eye diameter/BL				
Preflexion	9.8±0.7(8.8-11.0)	8.8±0.5(8.1-9.5)	9.7	7.4
Flexion	9.8±0.5(8.8-10.8)	8.9±0.8(6.9-10.0)	7.9±0.2(7.6-8.1)	6.9±0.4(6.1-7.7)
Postflexion	8.5±0.6(7.2-9.4)	8.8±0.5(7.9-9.8)	6.5±0.6(5.5-7.6)	6.3±0.3(6.1-6.9)
Early juvenile			6.8±0.5(5.9-7.7)	
Midjuvenile			7.0±0.6(6.5-8.2)	
Head length/BL				
Preflexion	27.6±2.2(23.8-31.2)	24.8±1.0(23.8-26.6)	28.0	23.4
Flexion	30.4±1.5(28.0-33.1)	27.9±1.9(25.0-31.1)	26.4±0.8(25.5-27.0)	26.4±1.3(24.2-28.7)
Postflexion	28.4±1.6(25.9-30.5)	28.6±1.7(26.8-33.8)	23.9±1.0(22.4-25.7)	26.4±1.5(24.4-28.8)
Early juvenile			25.4±0.8(23.9-27.1)	
Midjuvenile			25.0±0.7(24.2-26.2)	
Snout to anus length/BL				
Preflexion	45.8±4.7(39.4-54.1)	43.0±1.2(42.0-45.1)	40.0	39.1
Flexion	45.9±2.9(40.1-51.2)	44.2±2.0(40.2-46.6)	39.0±1.4(37.5-40.2)	44.2±2.0(39.8-48.0)
Postflexion	39.3±4.1(32.1-45.8)	39.7±2.9(34.6-46.2)	31.8±1.2(29.7-33.5)	38.8±3.2(33.5-42.2)
Early juvenile			31.0±1.3(28.8-34.0)	
Midjuvenile			31.6±1.2(29.8-34.3)	
Total length/BL				
Preflexion	102.3±0.7(101.6-103.5)	102.0±0.6(101.5-102.9)	102.2	101.5
Flexion	121.0±3.9(112.3-126.5)	116.0±12.6(102.0-126.2)	128.0	115.0±8.8(100.7-127.4)
Postflexion	123.0±1.4(120.6-124.9)	121.3±1.0(119.8-122.5)	123.1±1.2(121.4-125.0)	122.3±1.3(119.7-123.4)
Early juvenile			123.9±2.0(119.4-129.4)	
Midjuvenile			125.4±1.6(123.4-128.0)	
Head depth/BL				
Preflexion	34.5±2.3(31.4-38.8)	29.0±1.8(26.7-31.4)	36.6	28.6
Flexion	38.7±2.0(34.3-42.5)	33.3±2.3(28.3-36.2)	39.4±2.0(38.1-41.7)	33.8±1.6(30.7-36.4)
Postflexion	36.2±1.9(32.9-38.8)	33.3±1.6(31.0-36.3)	32.8±1.1(31.0-34.9)	33.1±1.6(31.5-35.8)
Early juvenile			32.0±1.1(29.8-34.9)	
Midjuvenile			31.0±1.0(29.6-33.0)	
Depth at pelvic fin/BL				
Preflexion	33.6±2.0(31.2-37.6)	29.8±2.6(27.0-33.5)	40.3	26.2
Flexion	43.6±2.9(37.1-49.1)	37.5±3.1(31.9-42.7)	46.7±0.9(45.9-47.7)	39.0±4.0(32.7-49.7)
Postflexion	41.3±2.4(37.4-45.8)	39.0±1.7(36.4-43.9)	39.0±1.1(36.9-40.8)	40.2±2.4(36.2-43.6)
Early juvenile			37.2±1.2(34.7-40.3)	
Midjuvenile			35.0±0.9(33.3-36.4)	
Depth at loop of gut/BL				
Preflexion	33.7±1.9(31.0-37.0)	29.2±2.9(25.5-33.9)		
Flexion	48.4±4.4(39.6-57.4)	39.1±4.3(32.7-45.0)		
Postflexion	48.0±3.6(42.6-54.7)	43.9±2.2(41.5-50.2)		
Depth at anus/BL				
Preflexion	28.4±3.6(23.8-33.7)	24.9±2.5(22.4-29.2)	38.7	21.4
Flexion	44.5±4.0(36.1-52.4)	36.9±4.4(30.3-44.2)	50.6±1.2(49.2-51.4)	37.8±5.6(29.3-45.7)
Postflexion	46.6±2.8(43.0-52.9)	42.2±1.7(39.7-47.0)	42.9±1.6(39.9-44.9)	43.1±3.5(36.3-46.2)
Early juvenile			39.5±1.4(35.9-43.3)	
Midjuvenile			38.7±0.7(37.2-39.7)	
Depth at third hemal spine/BL				
Preflexion	15.6±2.5(11.2-19.5)	14.2±2.3(11.9-18.2)	22.6	11.6
Flexion	31.4±3.9(22.8-39.8)	26.6±4.3(19.7-33.2)	40.8±2.9(38.7-44.0)	28.2±7.3(18.2-39.1)
Postflexion	38.6±1.9(35.6-41.8)	34.8±2.8(28.6-42.0)	38.0±1.4(35.3-39.8)	37.7±1.5(36.2-40.2)
Early juvenile			37.0±1.4(34.6-40.0)	
Midjuvenile			40.2±1.0(39.0-42.3)	

TABLE 3.—*Continued.*

Measurement	C. cornutus	C. gymnorhinus	C. spilopterus	E. crossotus
Caudal peduncle depth/BL				
Flexion	11.4±1.4(8.4-13.8)	11.6±1.6(9.3-14.4)	14.4±1.6(13.1-16.2)	9.6±3.0(4.7-13.4)
Postflexion	12.7±0.6(11.6-13.8)	13.2±0.7(12.2-14.7)	13.5±0.5(12.7-14.3)	12.6±0.6(11.8-13.4)
Early juvenile			13.6±0.6(12.2-14.6)	
Midjuvenile			11.4±0.6(10.0-12.3)	
Upper jaw length/HL				
Preflexion	37.4±2.7(32.6-40.7)	38.3±2.0(34.9-40.9)	35.6	29.9
Flexion	36.0±1.8(33.2-39.1)	33.3±2.1(29.2-37.6)	27.2±2.4(24.7-29.4)	27.2±2.4(21.6-30.5)
Postflexion	34.4±1.6(31.6-36.6)	32.6±1.9(29.4-37.5)	28.1±2.2(24.0-33.8)	26.9±1.1(24.7-27.6)
Early juvenile			28.7±1.5(25.4-31.3)	
Midjuvenile			36.2±1.4(33.9-38.4)	
Lower jaw length/HL				
Preflexion	48.0±4.9(41.0-56.5)	46.5±3.2(42.7-51.2)	43.3	41.1
Flexion	45.5±2.9(39.5-51.4)	45.6±2.2(42.5-49.6)	37.5±1.4(35.9-38.6)	36.3±3.2(30.8-46.8)
Postflexion	45.9±1.1(43.6-47.7)	44.5±1.8(40.2-46.8)	38.2±1.7(35.9-41.5)	37.2±1.5(35.4-39.0)
Early juvenile			40.5±2.1(36.9-44.1)	
Midjuvenile			52.6±1.5(50.9-55.9)	
Snout length/HL				
Preflexion	22.4±1.5(20.2-25.2)	20.8±4.1(15.4-26.8)	26.9	22.4
Flexion	23.0±2.0(19.3-27.2)	20.9±1.6(19.0-24.6)	28.8±3.3(25.0-31.2)	24.3±1.9(21.0-28.0)
Postflexion	22.3±2.3(18.4-25.5)	21.3±1.9(17.6-24.0)	27.0±2.5(23.2-31.4)	25.9±2.7(22.3-29.1)
Early juvenile			23.0±2.3(18.3-27.1)	
Midjuvenile			19.9±1.7(17.5-22.5)	
Eye diameter/HL				
Preflexion	35.6±2.1(31.0-39.6)	35.4±2.2(32.3-38.2)	34.6	31.8
Flexion	32.2±2.1(29.6-37.5)	31.9±2.7(27.8-39.1)	29.9±0.5(29.4-30.3)	26.0±1.8(22.0-30.6)
Postflexion	29.9±1.5(26.3-31.7)	30.6±1.6(27.4-33.9)	27.1±2.0(23.4-31.1)	23.6±0.4(23.3-24.3)
Early juvenile			26.8±2.0(23.1-30.0)	
Midjuvenile			27.8±1.6(26.4-31.2)	

BL increases from 34% (preflexion) to 44% (flexion) and then decreases slightly to 41% (postflexion). Larval body depth at loop of gut/BL increases from 34% (preflexion) to 48% (flexion and postflexion). Larval body depth at anus/BL increases greatly from 28% to 47%. Larval body depth at third hemal spine/BL increases greatly from 16% to 39%. Adult body depth/BL is 46%, range 43-50%. Larval caudal peduncle depth/BL increases from 11.4% (flexion) to 12.7% (postflexion). Adult caudal peduncle depth/BL is 10.5%, range 9.7-11.4%.

Fin and Axial Skeleton Formation

Development of the caudal skeleton of *C. cornutus* from larva to juvenile (Fig. 2A-E) is typical of the four species described in this paper. The major difference among them is the rate of development. Flexion is complete at about 7-8 mm in *C. gymnorhinus* and *C. spilopterus* and at about 9-10 mm in *C. cornutus* and *E. crossotus.*

During preflexion, before caudal formation (2.2-4.5 mm NL), the notochord is straight and there is no evidence of hypural formation. During early caudal formation (4.6-5.7 mm NL, Fig. 2A) the notochord is straight and the outline of incipient hypurals 2+3 and 4+5 are visible, but neither hypurals nor incipient caudal rays are calcified.

During early flexion (6.0 mm NL, Fig. 2B) the notochord begins to turn upward. Hypurals 2+3 and 4+5 (sometimes hypural 1) and caudal rays begin to stain with alizarin, and the last neural and hemal spines stain with alizarin. Caudal rays form in about equal numbers dorsally and ventrally during flexion, beginning at the posteroventral corner of hypural 4+5 and the posterodorsal corner of hypural 2+3. The 6.0 mm specimen (Fig. 2B) was the smallest in which calcification of caudal rays had begun. During midflexion (6.1-6.4 mm NL, Fig. 2C) the notochord is S-shaped and hypurals 1 and 6 and the epural begin to stain with alizarin. During late flexion (6.4-8.9 mm NL, Fig. 2D) the notochord tip points upward and is nearly flexed but is still in contact with hypural 6 and the epural; all hypurals stain with alizarin and the last neural spine touches hypural 6. All rays are formed by about 7.5 mm NL.

When flexion is complete (10.4-17.4 mm SL, Fig. 2E) the urostyle is separate from hypural 6 and the epural, and all caudal rays stain with alizarin. Fusion of the epural with hypural 6, and fusion of hypural 4+5 with the urostyle occur at about the time of transformation. The terminology of Amaoka (1969) is followed here; however, actual fusion of hypurals 2 with 3 and 4 with 5 was not observed.

The adult caudal skeleton of *C. cornutus* (Fig. 3A) is composed of a urostyle, or terminal half

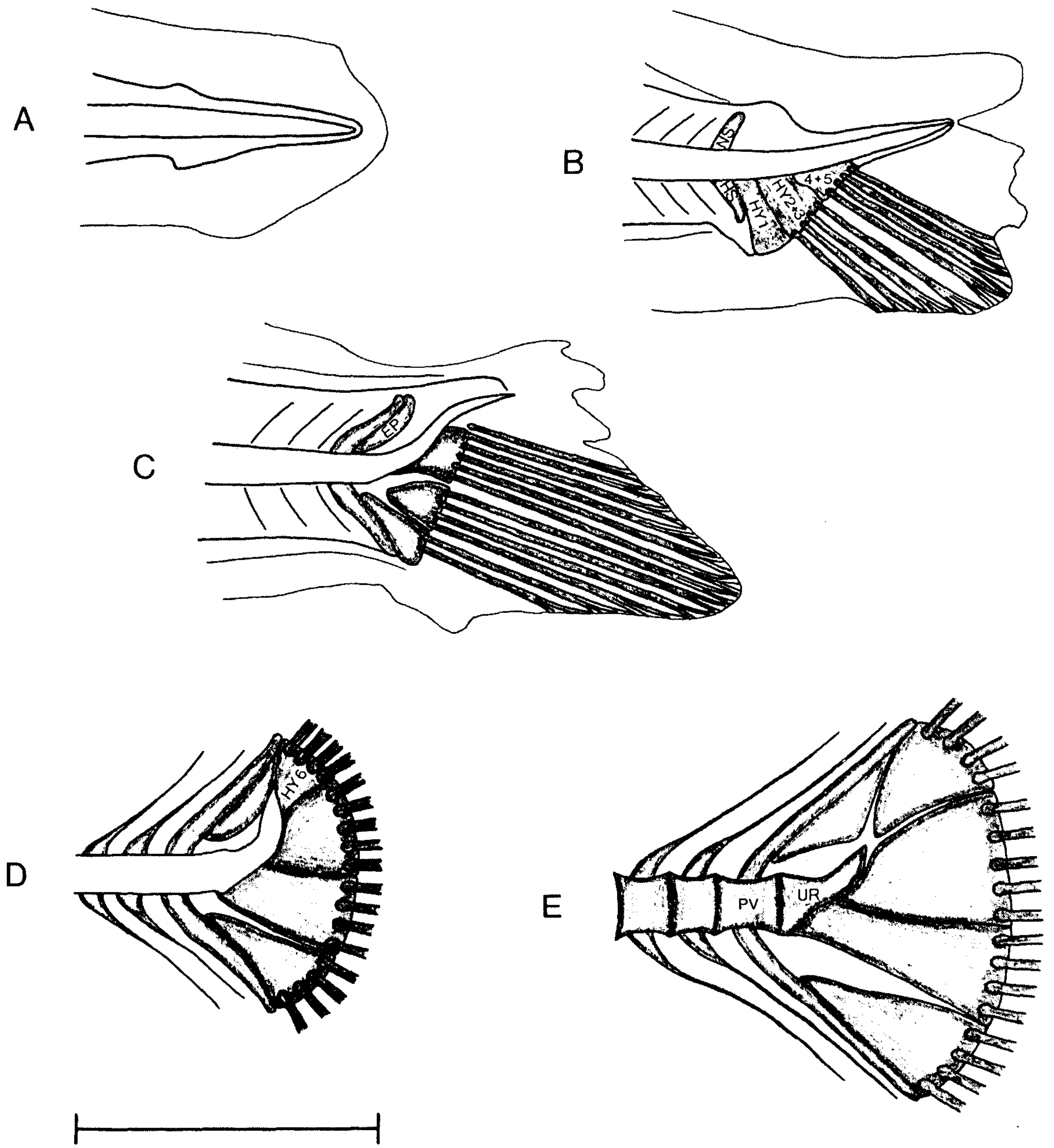


FIGURE 2.—Development of the caudal skeleton of *Citharichthys cornutus*: A. Preflexion (early caudal formation), 5.7 mm NL; B. Early flexion, 6.0 mm NL; C. Midflexion, 6.4 mm NL; D. Late flexion, 8.2 mm NL; E. Postflexion, 13.7 mm SL. NS = neural spine, HS = hemal spine, HY1 = hypural 1, HY2+3 = hypurals 2 and 3, 4+5 = hypurals 4 and 5, HY6 = hypural 6, EP = epural, PV = penultimate centrum, UR = urostyle. Scale = 1 mm.

centrum (according to Hensley 1977, in the bothid *Engyophrys senta* this bone consists of the first and second ural centra and the first preural centrum); a penultimate, or second preural, centrum (see Hensley 1977); an enlarged hemal spine from the second preural centrum supporting hypural 1; autogenous, proximally free, hypural 1 which supports three unbranched and one branched ray (equivalent to "parhypural" of some authors—e.g., Futch 1977; Hensley 1977—

see Sumida et al. 1979); autogenous, fused hypurals 2 and 3, articulating ventrally with the urostyle and supporting four branched rays; fused hypurals 4 and 5, fused with the tip of the urostyle and supporting five branched rays; an autogenous, proximally free element consisting of hypural 6 fused anteriorly with the single epural, one branched and three unbranched rays supported by hypural 6; no evidence of a uroneural; an enlarged neural spine from the second preural centrum supporting the epural. The caudal skeletons of the four species described here are similar to Amaoka's (1969) type 4, except for the lack of a uroneural.

Dendritic splitting of hypurals 2+3 and 4+5 occurs in *Etropus crossotus* by about 40 mm SL (Fig. 3B). The hypurals of adult specimens of *Citharichthys* spp. examined were sometimes grooved but never split as in *E. crossotus*. Hypurals 2+3 and 4+5 of *E. microstomus* and *E. rimosus* were similar to those of *Citharichthys* spp. except for an apparent tendency to split slightly at the distal margins.

In *C. cornutus* larvae all precaudal neural spines stain with alizarin by about 4.8 mm NL. Some caudal neural spines and hemal spines stain with alizarin at 4.8 mm NL and all do by 6.1 mm NL. The urostyle stains with alizarin at 6.3 mm NL. All precaudal and caudal centra stain with alizarin by 7.2 mm NL. The smallest speci-

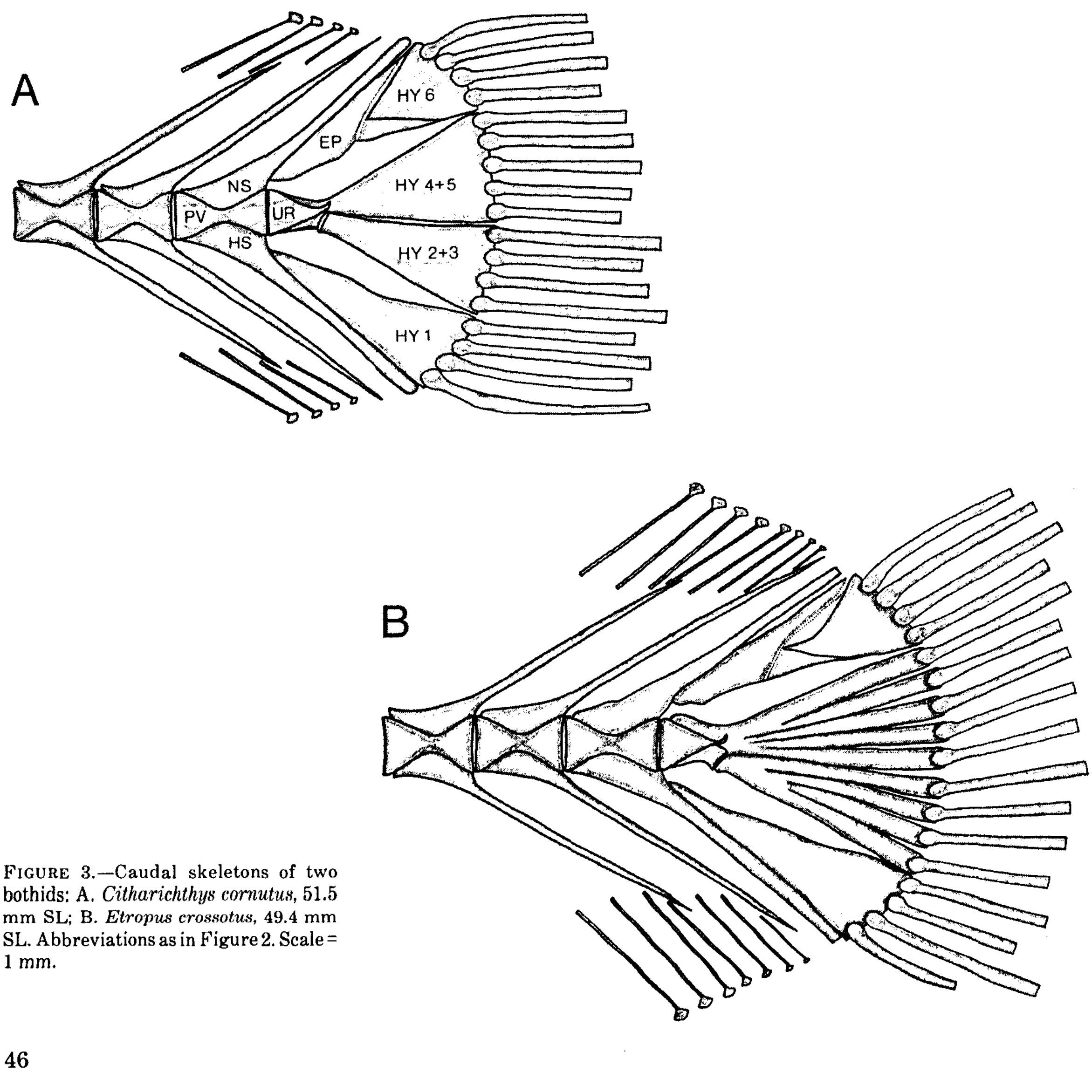


FIGURE 3.—Caudal skeletons of two bothids: A. *Citharichthys cornutus*, 51.5 mm SL; B. *Etropus crossotus*, 49.4 mm SL. Abbreviations as in Figure 2. Scale = 1 mm.

men in which caudal centra could be counted was 5.8 mm NL (midflexion).

The second, third, and fourth dorsal rays are elongate and widely separated at the bases from preflexion (about 4 mm NL) through transformation (17.4 mm SL). During early caudal formation (5.0 mm NL), rays near the middle of the dorsal fin begin to calcify. Calcification proceeds anteriorly and posteriorly. Adult counts are present from late flexion (6.4 mm NL) onward. The first ray and the most posterior rays are calcified just prior to transformation (17.4 mm SL).

During early caudal formation (5.0 mm NL), anal rays near the middle of the fin begin to calcify. Calcification proceeds anteriorly and posteriorly. Adult counts are present from late flexion (about 8 mm NL) onward. The most posterior rays are calcified just prior to transformation (17.4 mm SL).

Development of the left pelvic fin precedes that of the right fin. The left pelvic fin bud appears during preflexion (3.7 mm NL). Rays develop between preflexion (4.0 mm NL) and late flexion (about 8.9 mm NL). The most anterior two rays are the first to appear; the second is elongate and the first slightly elongate. The right pelvic fin bud appears during early caudal formation (4.9 mm NL). Rays develop between midflexion (6.0 mm NL) and late or postflexion (9-10 mm BL). Each complete fin has six rays.

Rayless, fanlike, larval pectoral fins were present on the smallest available specimen (preflexion, 2.2 mm NL). Calcification of rays in the left fin occurs between about 13 mm and 17.4 mm SL. Calcification of rays in the right fin had not begun in the largest specimen (17.4 mm SL).

Cephalic Spination

Preopercular spines (Table 4) were present in the smallest preflexion specimen (2.2 mm NL, Fig. 4A). With development (Fig. 4B, C), additional spines appear until maximum numbers of about 33 on the left (range 26-52) and 39 on the right (range 23-50) are reached during late flexion (6.4-8.9 mm NL). Thereafter, spines are lost until none or only a few remain at transformation (17.4 mm SL, Fig. 5B).

Frontal-sphenotic spines were evident in the second smallest preflexion specimen (3.2 mm NL) and throughout the larval series, though less conspicuous near transformation (13-17 mm SL). The lowermost spine on the left side is usually just above the center of the eye and on the right side slightly anterior to the center of the eye. (During transformation those on the right side are at the anterior margin of the skull.) The spines are arranged in a slightly posteriorly concave arch following the curve of the skull. There are usually six (up to eight) spines per side, including three stronger spines arising from a small bulge of the skull.

Larval Teeth (Table 5)

No teeth are present at 2.2 mm NL (Fig. 4A). At 3.2-4.1 mm NL, larvae usually have two upper and two lower teeth on each side. A 5.3 mm NL preflexion specimen had three upper and four lower teeth on each side. The same numbers were present in the largest early caudal formation specimen (5.7 mm NL). During flexion, numbers of teeth increase from about four upper and five lower (about 6 mm NL) to about eight upper and seven lower (8.9 mm NL) on each side. Postflexion larvae (10.4-13.8 mm SL) have about nine upper and nine lower teeth on each side. The nearly transformed specimen (17.4 mm SL, Fig. 5B) had fewer upper teeth on the left side (about 11) than on the right side (19) but the same number (about 15) in both lower jaws.

Transformation

Migration of the right eye may begin as early as midflexion (6.4 mm NL) or as late as postflexion (10.6 mm SL). The right eye moves from the right side of the head through a space between the dorsal fin and supraorbital bars (Fig. 5A) as in *Cyclopsetta fimbriata* (Gutherz 1971). The right eye reaches its final position on the left side of the head by about 18 mm SL. No early juvenile specimen was available, but eye migration in one of the 17.4 mm specimens was nearly complete (Fig. 5B).

Occurrence

Larvae were collected in the Atlantic during February, March, April, May, October, and November (Powles[4]). There was no apparent size progression by month, indicating an extended spawning season. Water depth was 46-640 m.

[4]H. W. Powles, Assistant Marine Scientist, South Carolina Marine Resources Research Institute, P.O. Box 12559, Charleston, SC 29412, pers. commun. July 1976.

TABLE 4.—Number of left and right preopercular spines by stage of larval development. Pref = preflexion, ECF = early caudal formation (preflexion), Early = early flexion, Mid = midflexion, Late = late flexion, Post = postflexion, Trans = right eye on or past dorsal ridge.

Species	Stage	BL range (mm)	Left $\bar{X}$	Left N	Left Range	Right $\bar{X}$	Right N	Right Range
Citharichthys cornutus	Pref	2.2- 5.0	12.1	7	4-18	12.7	7	4-19
	ECF	4.7- 5.7	18.2	4	13-20	19.8	4	18-23
	Early	6.0	23	1		22	1	
	Mid	5.6- 6.4	26.4	7	21-30	31.1	7	26-34
	Late	6.4- 8.9	32.9	19	26-52	38.7	19	23-50
	Post	10.4-13.8	22.0	8	11-33	33.8	8	24-44
	Trans	17.4	~0	1		~4	1	
Citharichthys spilopterus	ECF	3.7	31	1		27	1	
	Late	5.7- 6.7	31	2	26-36	35.5	2	33-38
	Post	8.3-10.2	16.0	7	2-29	20.0	6	11-32
	Trans	8.7-10.2	17.4	5	0-41	21.5	4	1-44

Species	Stage	BL range (mm)	Left $\bar{X}$	Left N	Left Range	Right $\bar{X}$	Right N	Right Range
Citharichthys gymnorhinus	Pref	4.5- 5.4	15.3	3	13-17	17.0	3	16-19
	ECF	4.6- 5.3	20.0	2	19-21	14.0	2	11-17
	Early	5.3- 6.0	21.7	3	17-27	24.3	3	21-28
	Mid	6.6	21.0	2	19-23	27.0	2	26-28
	Late	6.7- 7.5	23.0	6	17-29	26.8	6	20-35
	Post	8.3-10.2	31.4	5	25-38	38.6	5	34-43
Etropus crossotus	ECF	4.6	17	1		19	1	
	Early	4.9- 5.4	19.0	2	17-21	21.5	2	21-22
	Mid	5.4- 6.0	24.5	10	18-29	22.0	10	16-27
	Late	6.1- 9.5	15.9	12	7-20	15.2	12	10-20
	Post	9.3-10.8	10.6	5	4-18	8.6	5	3-13
	Trans	10.3	0	1		2	1	

TABLE 5.—Number of larval teeth by developmental stage. Pref = preflexion, ECF = early caudal formation (preflexion), Early = early flexion, Mid = midflexion, Late = late flexion, Post = postflexion, Trans = right eye on or past dorsal ridge, UJ = upper jaw, LJ = lower jaw.

Species	Stage and BL range (mm)	Jaw	Left $\bar{X}$	Left N	Left Range	Right $\bar{X}$	Right N	Right Range
Citharichthys cornutus	Pref	UJ	1.9	8	0- 3	1.9	8	0- 3
	2.2- 5.3	LJ	2.4	8	0- 4	2.4	7	0- 4
	ECF	UJ	3	3	3	3	5	3
	4.7- 5.7	LJ	3.5	4	3- 4	3.5	4	3- 4
	Early	UJ	4	1		4	1	
	6.0	LJ						
	Mid	UJ	5.8	4	5- 6	5.5	6	5- 6
	6.1- 6.4	LJ	6.5	4	6- 7	6.0	5	5- 7
	Late	UJ	6.6	20	5- 8	6.8	17	5- 8
	6.4- 8.9	LJ	6.8	13	6- 8	6.9	13	6- 8
	Post	UJ	8.6	10	8-10	8.9	8	8-10
	10.4-13.8	LJ	8.7	7	8-11	8.7	7	8-10
	Trans	UJ	~11	1		19	1	
	17.4	LJ	~15	1		~15	1	
Citharichthys spilopterus	ECF		2	1		2	1	
	3.7		3	1		3	1	
	Late	UJ	4	3	3- 5	4.3	3	4- 5
	5.7- 6.8	LJ	5	1		4.5	2	4- 5
	Post	UJ	4.0	6	3- 5	3.8	5	3- 4
	9.0-10.6	LJ	4.8	4	4- 5	5	1	
	Trans	UJ	4.8	5	4- 6	4	1	
	9.1-10.7	LJ	5.3	3	5- 6			

Species	Stage and BL range (mm)	Jaw	Left $\bar{X}$	Left N	Left Range	Right $\bar{X}$	Right N	Right Range
Citharichthys gymnorhinus	Pref	UJ	2.3	3	2- 3	2.3	3	2-3
	4.5- 5.4	LJ	2.7	3	2- 4	2.7	3	2-4
	ECF	UJ	2.5	2	2- 3	2.5	2	2-3
	4.6- 5.3	LJ	3.5	2	3- 4	3.5	2	3-4
	Early	UJ	3.3	3	2- 4	3.3	3	2-4
	5.3- 6.0	LJ	4.5	2	4- 5	4.5	2	4-5
	Mid	UJ	4.7	3	4- 5	4.5	2	4-5
	6.4- 6.6	LJ	5.5	2	5- 6	6	1	
	Late	UJ	5.7	6	4- 7	5.3	6	4-7
	6.7- 7.7	LJ	6.5	4	6- 8	6.5	4	6-8
	Post	UJ	7.1	11	6- 8	6.9	9	6-8
	7.9-12.9	LJ	8.0	7	6- 9	8.0	5	8
Etropus crossotus	ECF	UJ	3	1		3	1	
	4.6	LJ	5	1		5	1	
	Early	UJ	3	2	3	3	2	3
	4.9- 5.4	LJ	5.5	2	5- 6	5.5	2	5-6
	Mid	UJ	3.4	10	3- 5	3.4	10	3-5
	5.4- 6.0	LJ	6.4	8	5- 7	6.7	9	5-7
	Late	UJ	4.1	11	3- 5	3.8	9	3-4
	6.1- 9.5	LJ	7.0	10	6- 8	7	7	7
	Post	UJ	4.5	4	4- 5	5.2	5	4-7
	9.3-10.8	LJ	7.2	4	5-10	7.4	5	6-9
	Trans	UJ	7	1		7	1	
	10.3	LJ	>9	1		>9	1	

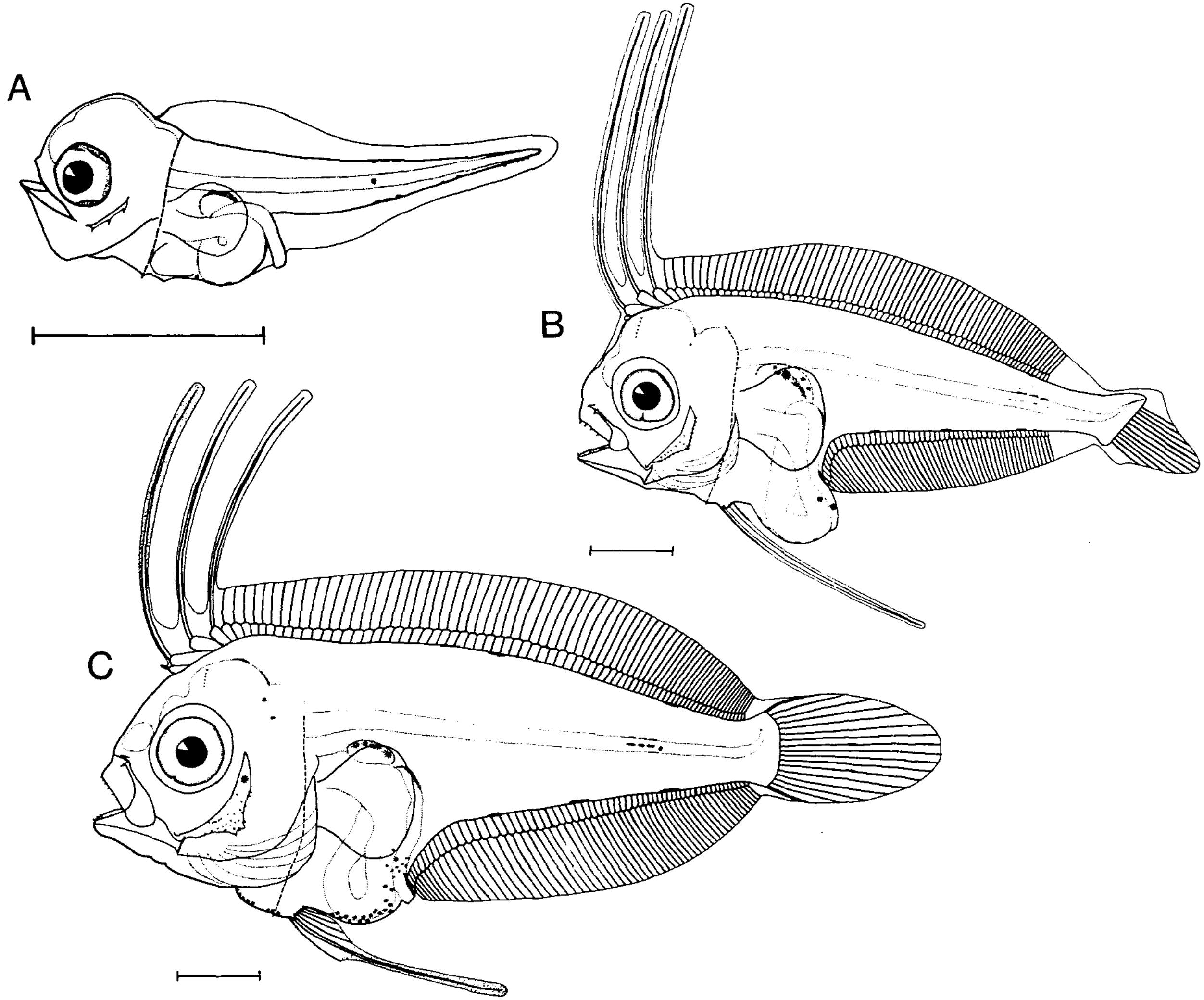


FIGURE 4.—Larval stages of *Citharichthys cornutus*: A. Preflexion, 2.2 mm; B. Midflexion, 6.9 mm; C. Late flexion, 8.2 mm. Scale = 1 mm.

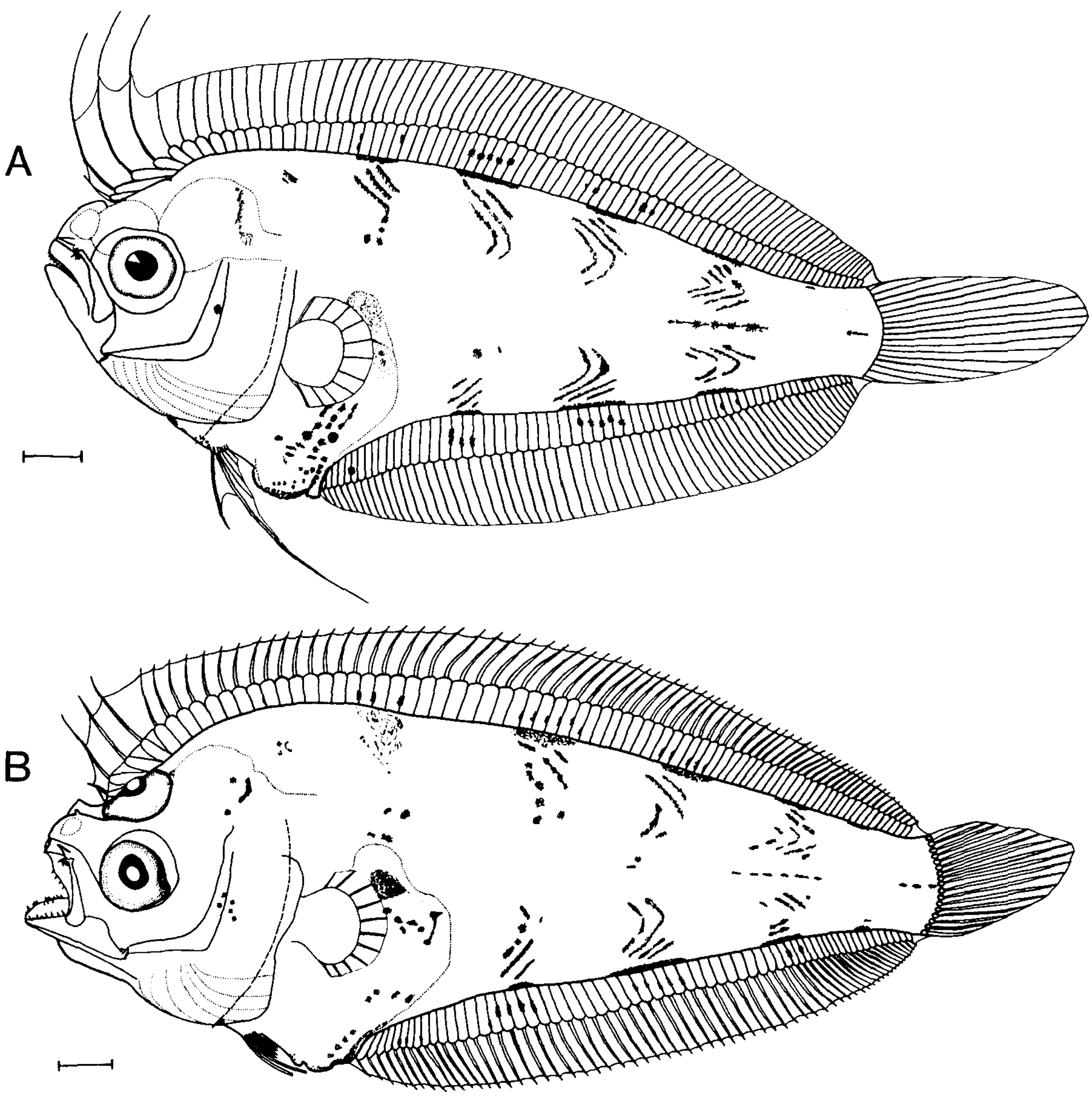


FIGURE 5.—*Citharichthys cornutus*: A. Transforming larva, 14.2 mm; B. Nearly transformed larva, 17.4 mm; C. Adult, 37.2 mm. Scale = 1 mm.

Surface temperature and salinity were 20.4°-27.3°C and 35.5-36.8 ‰. Almost no larvae were caught east of the average Gulf Stream axis (Fig. 1). The reported northern limit for adults is Florida (with one exception— an adult male taken off Cape Hatteras (Stewart[5])). Larval occurrences shown in Figure 1 are evidence of the effectiveness of Gulf Stream transport. The eastward shift of positive tows just north of lat. 32°N corresponds to the location of a semipermanent meander of the Gulf Stream induced by the Charleston Rise (at about lat. 32°N, long. 79°W (Pietrafesa et al. 1978)).

In the eastern Gulf of Mexico, larvae smaller than 4 mm NL were common in January, February, May, June, July, August, and November, indicating year-round spawning in that area (Dowd 1978).

[5]D. J. Stewart, Graduate Student, Laboratory of Limnology, University of Wisconsin, Madison, WI 53706, pers. commun. June 1978.

Citharichthys gymnorhinus (Figs. 1, 6, 7)

Identification

Larvae approaching transformation had complete complements of countable characters. Those specimens were identified by comparing the following larval counts with known adult counts. Number of specimens is given in parentheses.

Caudal fin formula = 4-5-4-4 (15)
Caudal vertebrae = 23(3)-24(18)
Gill rakers (lower limb, first left) = ~12 (1)
Left pelvic rays = 5 (12)
Anal rays = 55-59 (11)
Dorsal rays = 70-75 (11)

Of the potential species listed in Table 1, only *C. gymnorhinus* has counts that agree with these (it is unique in having only five left pelvic rays). In addition, larvae were captured over the outer shelf, but not as far offshore as *C. cornutus* (Fig. 1). This is consistent with bathymetric distribution of adults.

Distinguishing Characters

Citharichthys gymnorhinus larvae have no pectoral melanophore, and notochordal pigment is restricted to the caudal region. Three elongate dorsal rays are present from preflexion (4.6 mm) through postflexion (probably through transformation). Caudal vertebrae (23-24) can be counted by early flexion (6 mm). Lateral pigment is relatively sparse except for the caudal band. Flexion is complete at 7-8 mm SL. Morphology is similar to that of *C. cornutus*. However, the left pelvic fin of *C. gymnorhinus* has a full complement of only five rays, and in larvae the first ray is much reduced in size compared with that of *C. cornutus*. Length of *C. gymnorhinus* at transformation is probably about 18 mm. Larvae may appear in collections year-round.

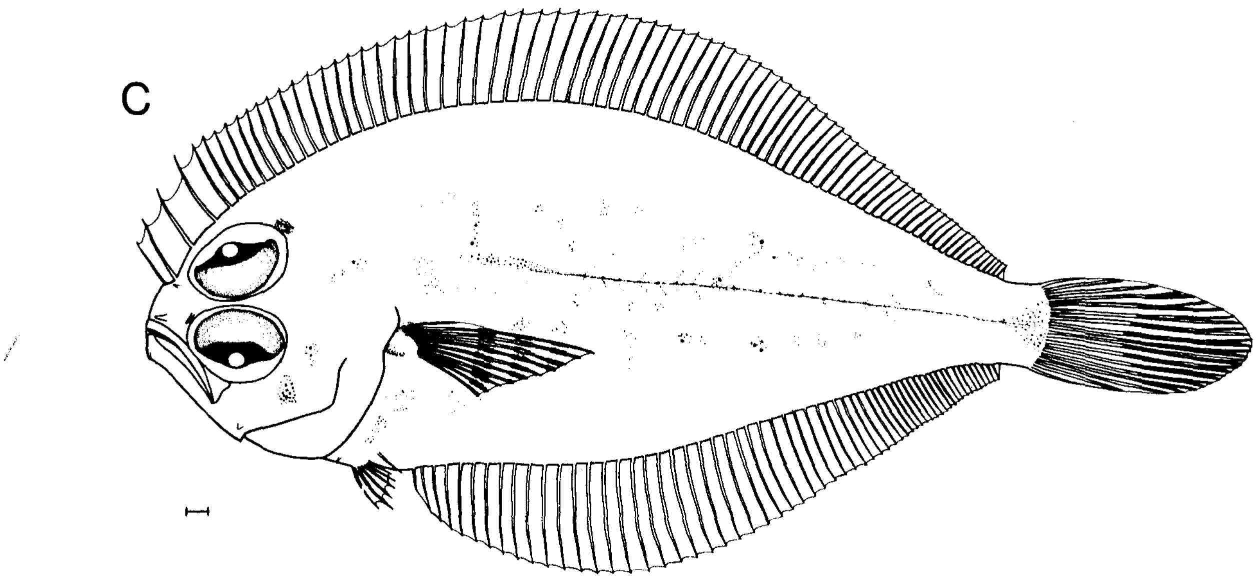
Pigmentation

Pigmentation of *C. gymnorhinus* larvae is moderate. Gas bladder and caudal band pigment are the most striking.

By 4.6 mm and throughout larval development, the dorsal one-third of the left side of the gas bladder is fairly heavily pigmented, usually with distinct melanophores. With growth, the number of melanophores increases. There are usually more of them than in *C. cornutus* larvae. The maximum number in a preflexion specimen was about 15 (4.6 mm, Fig. 6A). The right side of the gas bladder is either unpigmented or has only one or two melanophores.

By 4.6 mm (Fig. 6A) a caudal band of melanophores is present on the dorsal and ventral finfolds and sides and margins of the body about halfway from the anus to the notochord tip. This band is more distinct and regular than in other

C



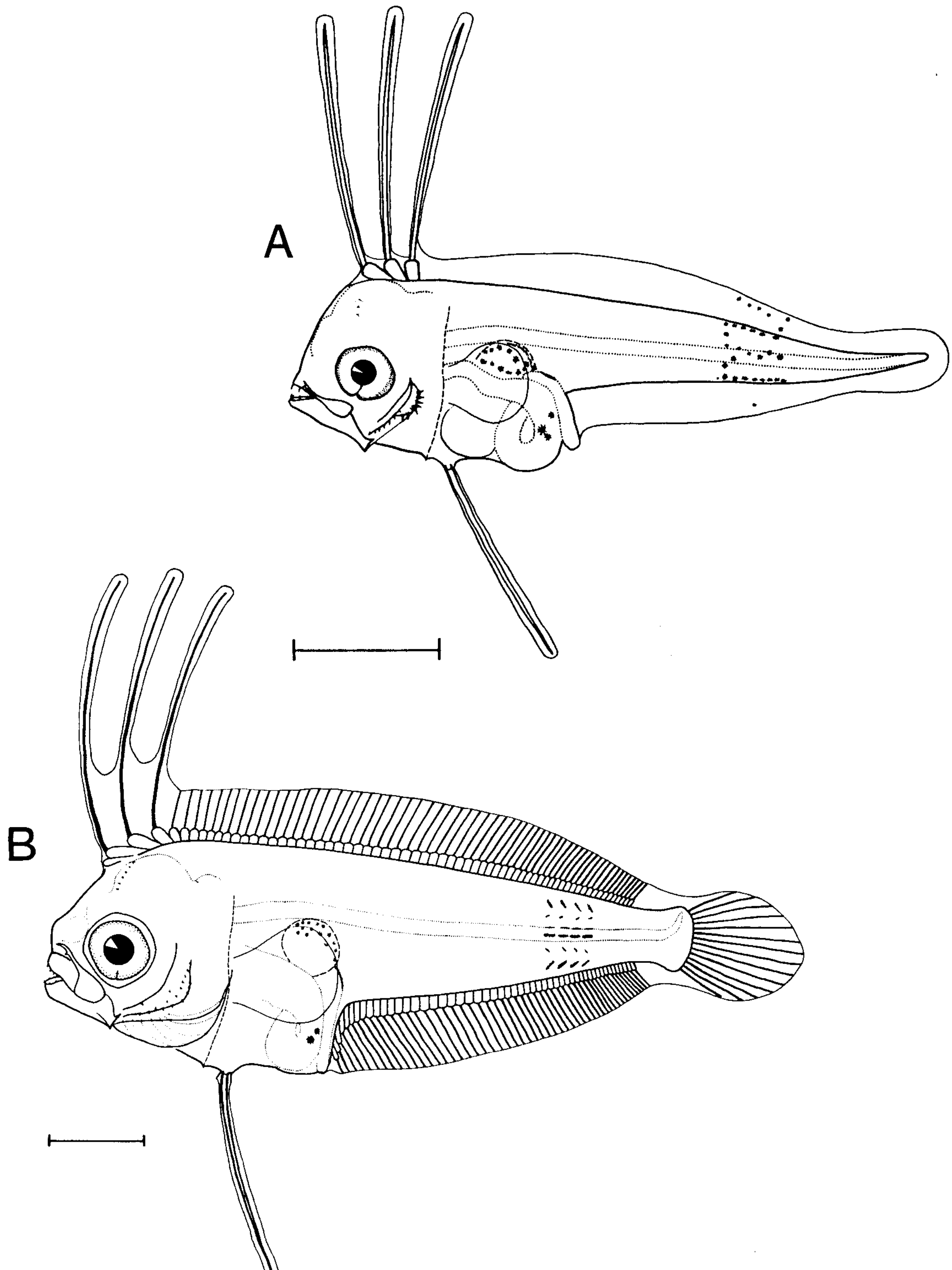


FIGURE 6.—Larval stages of *Citharichthys gymnorhinus*: A. Preflexion, 4.6 mm; B. Late flexion, 6.7 mm. Scale = 1 mm.

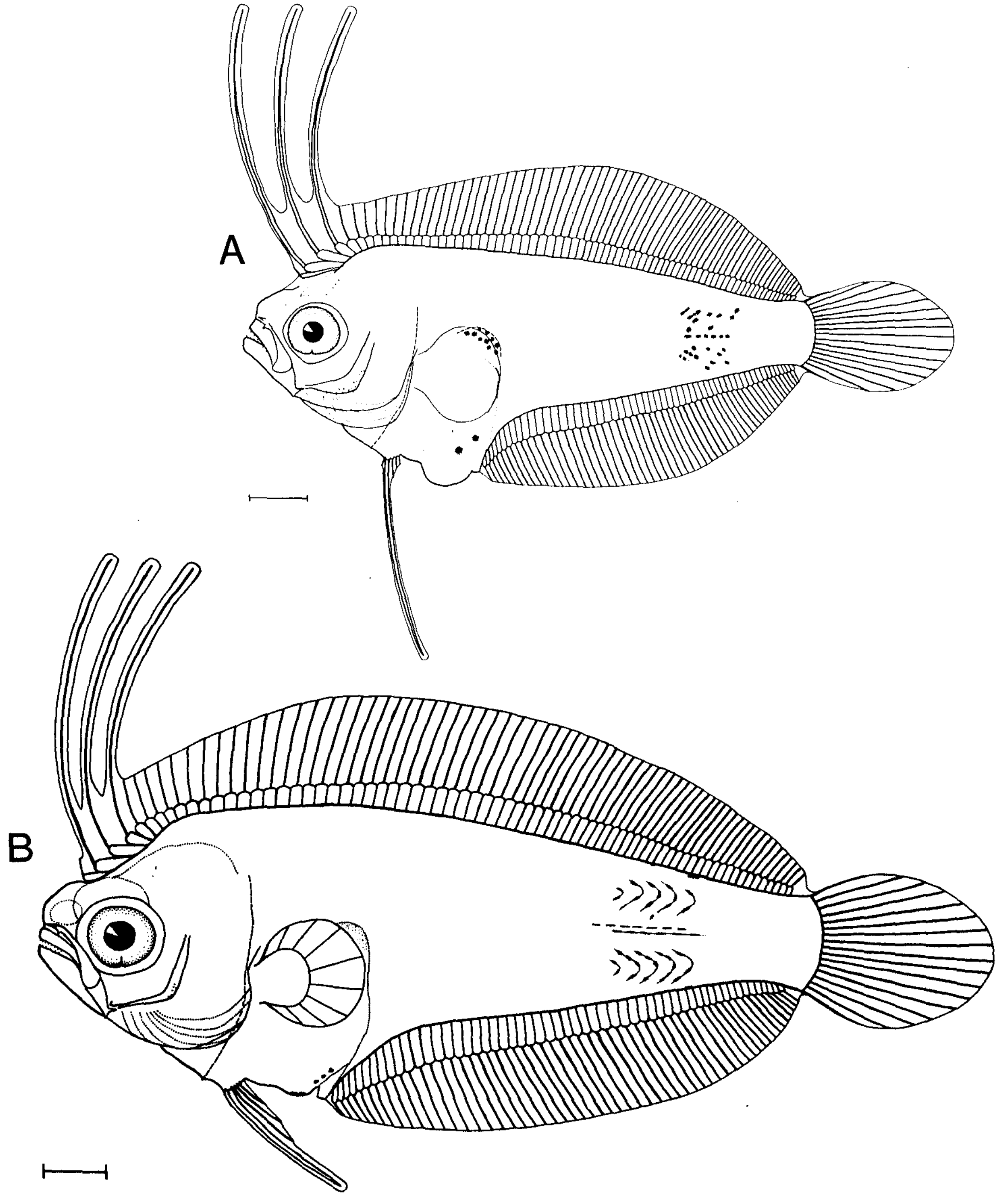


FIGURE 7.—Larval stages of *Citharichthys gymnorhinus*: A. Transforming, 9.6 mm; B. Transforming, 12.6 mm. Scale = 1 mm.

known larvae of western North Atlantic *Citharichthys* and *Etropus* species. In preflexion larvae, before pelvic rays form, one or two melanophores are present on the ventral body margin at the future site of the pelvic fin. By 4.6 mm and throughout development (at least to 13 mm), a few external melanophores are present along the posterior surface of the gut loop. A small melanophore is found over the posterodorsal surface of the midgut of preflexion larvae.

Flexion larvae (Fig. 6B) usually have 15-20 melanophores on the dorsal one-third of the left side of the gas bladder. The caudal band is mostly confined to the body and contains myoseptal pigment. Visible internal notochordal pigment is restricted to the vicinity of the external caudal band. The dorsal surfaces of one or two forming centra are darkened at about 5 mm. By about 6 mm and throughout development (at least to 13 mm), there may be a few melanophores along the ventral surface of the gut loop. By late flexion, notochordal pigment appears as fine dashes along four to six centra of caudal vertebrae 13-19. By late flexion, pigment along the posterodorsal surface of the midgut extends to the gas bladder and appears as a black lining over the gut.

By postflexion (about 8 mm, Fig. 7A), both sides of the gas bladder usually are obscured by body musculature, and pigment in this area appears diffuse. Small melanophores appear on the left pelvic fin membrane along both sides of the elongate second ray. Body musculature tends to obscure notochordal pigment in larvae longer than 12 mm.

Morphology (Figs. 6, 7; Tables 3, 6)

General morphological features are similar to those of *C. cornutus*, with the qualification that the smallest *C. gymnorhinus* specimen examined was 4.6 mm NL. Adult morphometrics given in the following discussion were derived from Gutherz and Blackman (1970) and Topp and Hoff (1972).

The mouth is relatively large in larvae and adults. Larval upper jaw length/BL is fairly constant at 9.3-9.5%. Adult upper jaw length/BL is 11.2%, range 9.9-13.0%. Larval upper jaw length/HL decreases greatly from 38% (preflexion) to 33% (flexion and postflexion). Adult upper jaw length/HL is 41%, range 39-45%. Larval lower jaw length/BL increases from 11.5% to 12.7%. Adult lower jaw length/BL is 13.2%, range 11.6-14.8%. Larval lower jaw length/HL decreases slightly from 46% to 44% and is only slightly less than that of *C. cornutus*. Adult lower jaw length/HL is 48%, range 43-53%.

The larval snout is pointed but relatively short. Larval snout length/BL increases slightly from 5.2% to 6.1%. Adult snout length/BL is 5.4%, range 4.6-6.6%. Larval snout length/HL is constant at 21%. Adult snout length/HL is 20%, range about 18-20%.

The eye is relatively large in larvae and adults (only slightly smaller than that of *C. cornutus*). Larval eye diameter/BL is constant at about 8.8%. Adult orbit length/BL is 9.6%, range 8.0-11.4% (Topp and Hoff 1972); eye diameter/BL is 10.1%, range 9.1-11.0% (Gutherz and Blackman 1970). Larval eye diameter/HL decreases from 35% to 31% and is similar to that of *C. cornutus*. Adult orbit length/HL is 35% (Topp and Hoff 1972); eye diameter/HL is 36.5%, range 33-38% (Gutherz and Blackman 1970).

The head is fairly long but shallow in larvae and of moderate length in adults. Larval head length/BL increases greatly from 25% to 29%. Postflexion head length/BL is similar to those of *C. arctifrons* and *C. cornutus*. Adult head length/BL is 27%, range 25-29%. Larval head depth/BL increases from 29% to 33% and is similar to that of *E. crossotus*.

Larval snout to anus length is fairly great until postflexion. Snout to anus length/BL increases slightly from 43% (preflexion) to 44% (flexion) and then decreases to 40% (postflexion). This length is similar to that of *E. crossotus* during flexion and postflexion.

With the exception of a relatively deep caudal peduncle, the body is of moderate depth in larvae and adults. Larval body depth at pelvic fin/BL increases from 30% to 39%. Larval body depth at loop of gut/BL increases from 29% to 44%. Larval body depth at anus/BL increases greatly from 25% to 42% and during flexion and postflexion is similar to that of *E. crossotus*. Larval body depth at third hemal spine/BL increases greatly from 14% to 35%. Adult body depth/BL is 47%, range 39-50%. Larval caudal peduncle depth/BL increases from 11.6% (flexion) to 13.2% (postflexion). Adult caudal peduncle depth/BL is 11.5%, range 10.5-12.6%.

Fin and Axial Skeleton Formation

Caudal skeleton development is similar to that of *C. cornutus*. Size ranges of available speci-

TABLE 6.—Measurements (mm) of larvae of *Citharichthys gymnorhinus.* Pref = preflexion, ECF = early caudal formation, Early = early flexion, Mid = midflexion, Late = late flexion, Post = postflexion. S = symmetrical, 1 = 0 to one-third of the way to the dorsal ridge, 2 = one-third to two-thirds of the way to the dorsal ridge, 3 = two-thirds to all the way to the dorsal ridge.

Body length	Upper jaw length	Lower jaw length	Snout length	Eye diameter	Head length	Snout to anus length	Total length	Head depth	Body depth at pelvic fin	Body depth at loop of gut	Body depth at anus	Body depth at third hemal spine	Caudal peduncle depth	Flexion stage	Right eye position
4.4	0.45	0.53	0.24	0.42	1.2	1.9	4.6	1.2	[1]1.4	[1]1.4	[1]1.2	[1]0.69		ECF	S
4.5	0.41	0.49			1.1	2.0				[1]1.3	[1]1.0	[1]0.53		Pref	S
4.6	0.38	0.50	0.21	0.40	1.1	2.1	4.6	1.4	[1]1.3	[1]1.3	[1]1.1	[1]0.60		ECF	S
4.6	0.44	0.56	0.25	0.39	1.1	2.0		1.2	[1]1.3	[1]1.3	[1]1.1	[1]0.64		Pref	S
4.6	0.43	0.47	0.17	0.42	1.1	2.0	4.7	1.4	[1]1.2	[1]1.2	[1]1.1	[1]0.59		Pref	S
5.0	0.52	0.65	0.34	0.41	1.3	2.1	5.1	1.5	1.7	1.7	1.5	0.92		ECF	S
5.3	0.50	0.66	0.26	0.52	1.3	2.4		1.7	1.8	1.9	1.6	1.1		Early	S
5.9	0.55	0.73	0.31	0.51	1.5	2.4		1.7	1.9	1.9	1.8	1.2		Early	S
6.0	0.50	0.70	0.30	0.42	1.5	2.5	6.2	1.7	2.0	2.0	2.0	1.2		Early	S
6.4	0.59	0.86	0.43	0.54	1.8	2.9		2.2	2.4	2.7	2.3	1.6	0.67	Mid	S
6.6	0.61	0.85	0.36	0.63	1.9	3.0		2.3	2.5	2.8	2.5	1.9		Mid	S
6.6	0.60	0.79	0.37	0.58	1.8	2.9		2.1	2.3	2.3	2.2	1.6	0.64	Mid	2
6.7	0.63	0.84	0.40	0.59	1.9	2.8		2.3	2.5	2.4	2.4	1.8	0.70	Late	S
6.8	0.63	0.83	0.41	0.60	1.8	2.9		2.3	2.6	2.8	2.6	1.8	0.76	Late	2
6.7	0.65	0.90	0.38	0.60	1.9	3.2			2.7	3.0	2.7	2.0	0.82	Late	1
6.9	0.63	0.83	0.38	0.59	1.9	3.2		2.2	2.5	2.5	2.3	1.6	0.64	Late	2
7.2	0.67	0.98	0.44	0.72	2.2	3.1	8.6	2.5	2.9		3.0	2.3	0.94	Late	1
7.2	0.69	0.94	0.40	0.63	2.1	3.3		2.6	2.9	3.0	2.9	2.1	0.90	Late	1
7.2	0.72	0.96	0.51	0.62	2.1	3.2		2.4	2.7	2.8	2.7	2.0	0.84	Late	1
7.5	0.68	0.99	0.49	0.67	2.3	3.5		2.7	3.1	3.4	3.3	2.5	1.0	Late	2
7.7	0.72	0.99	0.48	0.77	2.3	3.5	9.7	2.8	3.3	3.4	3.2	2.5	1.1	Late	2
7.9	0.79	1.1	0.50	0.73	2.7	3.4		2.8	3.3	3.6	3.4	2.6	1.0	Post	1
8.2	0.93	1.2	0.63	0.81	2.6	3.8	9.9	3.0	3.6	4.1	3.9	2.9	1.2	Post	3
8.3	0.75	1.0	0.47	0.74	2.3	3.4		2.9	3.2	3.4	3.3	2.4		Post	2
8.6	0.80	1.1	0.47	0.78	2.4	3.6	10.4	3.0	3.4	3.6	3.5	2.7	1.1	Post	2
9.0	0.83	1.2	0.52	0.77	2.6	3.7		3.2	3.6		3.9	3.2	1.3	Post	3
9.6	0.94	1.3	0.64	0.87	2.8	3.9	11.6	3.2	3.8	4.3	4.1	3.4	1.3	Post	2
9.8	0.91	1.3	0.63	0.84	2.8	4.1		3.2	3.8	4.3	4.2	3.4		Post	2
9.8	0.92	1.2	0.60	0.87	2.8			3.1	3.8			3.3	1.2	Post	3
9.9	0.85	1.2	0.60	0.84	2.8	4.0	12.0	3.3	3.7	4.2	4.0	3.1	1.3	Post	2
10.2	0.94	1.2	0.63	0.92	2.8	4.2	12.5	3.5	4.0	4.5	4.4	3.5	1.3	Post	3
10.4	0.93	1.3	0.50	0.95	2.8	4.2		3.6	3.9	4.4	4.3	3.5	1.4	Post	3
10.6	0.98	1.4	0.71	0.87	3.1	4.0			4.2	4.6	4.5	3.9	1.5	Post	2
11.2	1.0	1.4	0.54		3.1	4.2		3.6	4.4	4.9	4.8	4.0	1.5	Post	2
11.7	1.2	1.4	0.74	0.99	3.2	4.5		3.7	4.5	5.0	4.9	4.0	1.5	Post	3
11.7	0.95	1.5	0.70	0.92	3.2	4.0		3.7	4.4	5.2	4.9	4.4	1.4	Post	3
12.6	1.1	1.6	0.73	1.1	3.5	4.6	15.3	4.0	4.9		5.2	5.3	1.7	Post	3
12.9	1.2	1.7	0.84	1.2	3.6	4.8		4.2	5.0	5.7	5.5	4.8	1.6	Post	3
12.9	1.2	1.6	0.78	1.1	3.7	4.5		4.0	4.8	5.4	5.2	4.7	1.7	Post	3
12.9	1.1	1.5	0.82	1.0	3.6	5.0	15.8	4.1	4.7	5.8	5.5	4.4	1.7	Post	2

[1]Measurement does not include dorsal or anal pterygiophores.

mens in each stage are as follows: Preflexion, 4.5-5.4 mm NL; early caudal formation, 4.4-5.3 mm NL; early flexion, 5.3-6.0 mm NL; midflexion, 6.0-6.6 mm NL; late flexion, 6.7-7.7 mm NL; postflexion, 7.9-12.9 mm SL. Caudal rays become calcified between early flexion (5.9 mm NL) and late flexion (7.2 mm NL).

All precaudal neural spines stain with alizarin by about 6.0 mm NL. Some caudal neural spines and hemal spines stain with alizarin at 4.6 mm NL, and all do by 6.0 mm NL. All precaudal centra stain with alizarin by about 6.7 mm NL. All caudal centra, including the urostyle, stain with alizarin by about 7.2 mm NL. The smallest specimen in which caudal centra could be counted was 6.1 mm NL (early flexion). The second, third, and fourth dorsal rays are elongate and widely separated at the bases from preflexion (4.4 mm NL) through postflexion (12.9 mm SL). During early caudal formation (5.0 mm NL) rays near the middle of the fin begin to calcify.

Calcification proceeds anteriorly and posteriorly. Adult counts are present from late flexion (about 7.0 mm NL) onward. The first ray and the most posterior rays are probably calcified prior to transformation.

During early caudal formation (5.0 mm NL), anal rays near the middle of the fin begin to calcify. Calcification proceeds anteriorly and posteriorly. Adult counts are present from midflexion (about 6.6 mm NL) onward. The most posterior rays are probably calcified by the time transformation is complete.

Development of the left pelvic fin precedes that of the right fin. The left pelvic fin bud appears during preflexion (before 4.5 mm NL, probably at about 4.0 mm NL). Rays develop between preflexion (about 4.5 mm NL) and postflexion (7.9 mm SL). The second ray is the first to appear (4.5 mm NL); it is elongate. (This ray may actually be the result of fusion of the second and third rays.) The first ray does not appear until early flexion (5.9 mm NL). It is weak, never elongate, and usually the shortest ray in the fin. The right pelvic fin bud appears during early flexion (5.3 mm NL). Rays develop between late flexion (6.7 mm NL) and postflexion (about 9.0 mm SL). There are five rays in the complete left fin and six in the right.

Rayless, fanlike, larval pectoral fins were present on the smallest available specimen (preflexion, 4.4 mm NL). Calcification of rays in the left fin begins during postflexion (about 11 mm SL).

Cephalic Spination

Preopercular spines (Table 4) were present in the smallest preflexion specimen (4.4 mm NL). With development (Figs. 6A, B, 7A), additional spines appear until maximum numbers of about 31 on the left side (range 25-38) and 39 on the right side (range 34-43) are reached during postflexion (8.3-10.2 mm SL). The largest specimen (12.9 mm SL) has only about three left (uncertain count) and seven right spines. Most are probably lost by transformation.

Frontal-sphenotic spines were evident in the smallest preflexion specimen (4.4 mm NL) and throughout the larval series, though less conspicuous in larger specimens (10-13 mm SL). The lowermost spine on the left side is usually just above the center of the eye and on the right side slightly anterior to the center of the eye. (During transformation those on the right side are at the anterior margin of the skull.) The spines are arranged in a slightly posteriorly concave arch following the curve of the skull. There are usually six (maximum of six) per side, including three stronger spines arising from a small bulge of the skull.

Larval Teeth (Table 5)

Numbers of teeth of preflexion (4.5-5.4 mm NL) larvae range from two upper and two lower to three upper and four lower on each side. During early caudal formation (4.6-5.3 mm NL), numbers range from two upper and three lower to three upper and four lower on each side. During early flexion (5.3-6.0 mm NL), teeth increase from two upper and four lower to four upper and five lower on each side. During midflexion (6.4-6.6 mm NL), there are four or five upper and five or six lower teeth on each side. During late flexion (6.7-7.7 mm NL), teeth increase from four upper and six lower to seven upper and eight lower on each side. During postflexion (7.9-12.9 mm SL), teeth increase from about six upper and six lower on each side to about eight upper on both sides, more than nine in the lower left jaw, and more than eight in the lower right jaw.

Transformation

Migration of the right eye may begin as early as midflexion (6.6 mm NL) or as late as postflexion (7.9 mm SL). The right eye moves from the right side of the head through a space between the dorsal fin and supraorbital bars (Fig. 7B) as in *Cyclopsetta fimbriata* (Gutherz 1971). The right eye probably reaches its final position on the left side of the head by about 18 mm SL. No early juvenile specimen was available. This size is based on a transformation rate similar to that of *Citharichthys cornutus* and a 16.0 mm SL specimen of *C. gymnorhinus* in which the right eye was about halfway to the dorsal ridge.

Occurrence

Larvae were collected in the Atlantic during February, March, April, May, and October (Powles footnote 4). There was no apparent size progression by month, indicating an extended spawning season. Water depth was 14.6-446 m. Surface temperature and salinity were 19.0°-26.5°C and 33.8-37.0‰. *Citharichthys gymnorhinus* larvae occurred slightly closer to shore and not quite as far north as those of *C. cornutus.* The reported northern limit for adult *C. gymnorhinus* is Georgia. (See *C. cornutus*, section on Occurrence.)

In the eastern Gulf of Mexico, larvae smaller than 4 mm NL were common in January, February, May, June, July, August, and November, indicating year-round spawning in that area (Dowd 1978).

Citharichthys spilopterus (Figs. 8, 9)

Identification

Most specimens had complete complements of countable characters. They were identified by comparing the following larval and juvenile counts with known adult counts. Number of specimens is given in parentheses.

Caudal fin formula = 4-5-4-4 (40)
Caudal vertebrae = 23(16), 24(38), 25(6)
Gill rakers (lower limb, first left) = 11-14 (9)
Left pelvic rays = 6 (24)
Anal rays = 55-62 (53)
Dorsal rays = 74-82 (53)

Of the potential species listed in Table 1, only 3 have 23-24 caudal vertebrae (Append. Table 1). *Citharichthys gymnorhinus* has only five left pelvic rays, and lower anal and dorsal fin ray counts. *Etropus rimosus* has 3-7 gill rakers and usually only 24-25 caudal vertebrae. In addition, most larvae were caught in an estuary, which is consistent with *C. spilopterus* adult distribution.

Distinguishing Characters

Citharichthys spilopterus larvae have no pectoral melanophore, and notochordal pigment is restricted to the caudal region. Two elongate dorsal rays are present from preflexion (3.7 mm) through transformation. Caudal vertebrae (23-24, rarely 25) can be counted by late flexion (5.7 mm). Lateral larval pigmentation is relatively light, but juvenile pigmentation is heavy. Flexion is complete at 7-8 mm SL. The larval snout is very blunt and the body is deep. Relative snout to anus length is small. The left pelvic fin has a full complement of six rays. Length at transformation is 9-11 mm. Larvae usually appear in collections from September through April.

Pigmentation

Pigmentation of *C. spilopterus* larvae is relatively light, but it becomes heavy in juveniles. Gas bladder, lower gut, and lateral tail pigment are the most striking.

By about 3.7 mm (early caudal formation, Fig. 8A) and throughout larval development, the left side of the gas bladder is fairly heavily pigmented, usually with one or two distinct melanophores. No pigment is evident on the right side of the gas bladder. Additional melanophores sometimes appear later in development, but are usually larger and fewer in number than in the preceding two species. The only other pigment apparent in the 3.7 mm specimen is a small amount along the ventral surface of the gut loop.

During late flexion (6.7 mm, Fig. 8B), two dashlike melanophores are present on the ventral body margin between the anus and the caudal fin base. A few melanophores appear on each side of the symphysis of the lower jaw. A melanophore is on the posterior margin of the articular. Pigment along the ventral surface of the gut loop increases. Some pigment may occur on the ventral body margin anterior to the cleithrum. A stellate melanophore is present at the junction of left and right branchiostegal membranes, just forward of the isthmus. A series of small melanophores usually is present along the distal tips of anal pterygiophores.

During postflexion, one to five (usually one or two) melanophores are present on the left side of the gas bladder. Additional dashlike clusters of pigment (up to four total) appear on the ventral body margin along the anal fin base, but the first two remain the most distinct (8.7 mm). Similar clusters of pigment appear on the dorsal body margin along the dorsal fin base (up to six from above the hindbrain to the caudal fin base). Heavy pigment is present along the ventral body margin anterior to the cleithrum. The area immediately around the anus is usually densely pigmented internally. Several external melanophores are present on the body below the pectoral fin base and along the ventral and lateral surfaces of the abdomen. Internal melanophores are present along the hindgut. Visible internal notochordal pigment is restricted to a small area just forward of the caudal peduncle. This appears as fine dashes along the dorsal surfaces of one to a few centra in the area of caudal vertebrae 15-16. Some internal pigment is present near the pectoral fin base and just forward of the cleithrum beneath the angle of the last gill arch (visible through the opercle). The left pelvic fin becomes pigmented, mostly around the first to third rays. Clusters of melanophores appear on the dorsal and anal fins. Often, melanophores occur along the sides of the middle caudal rays. By about 9 mm, lateral melanophores appear on the snout, jaws, and posterior part of the head. One or two internal melanophores appear above the brain.

Gas bladder pigment becomes diffuse after

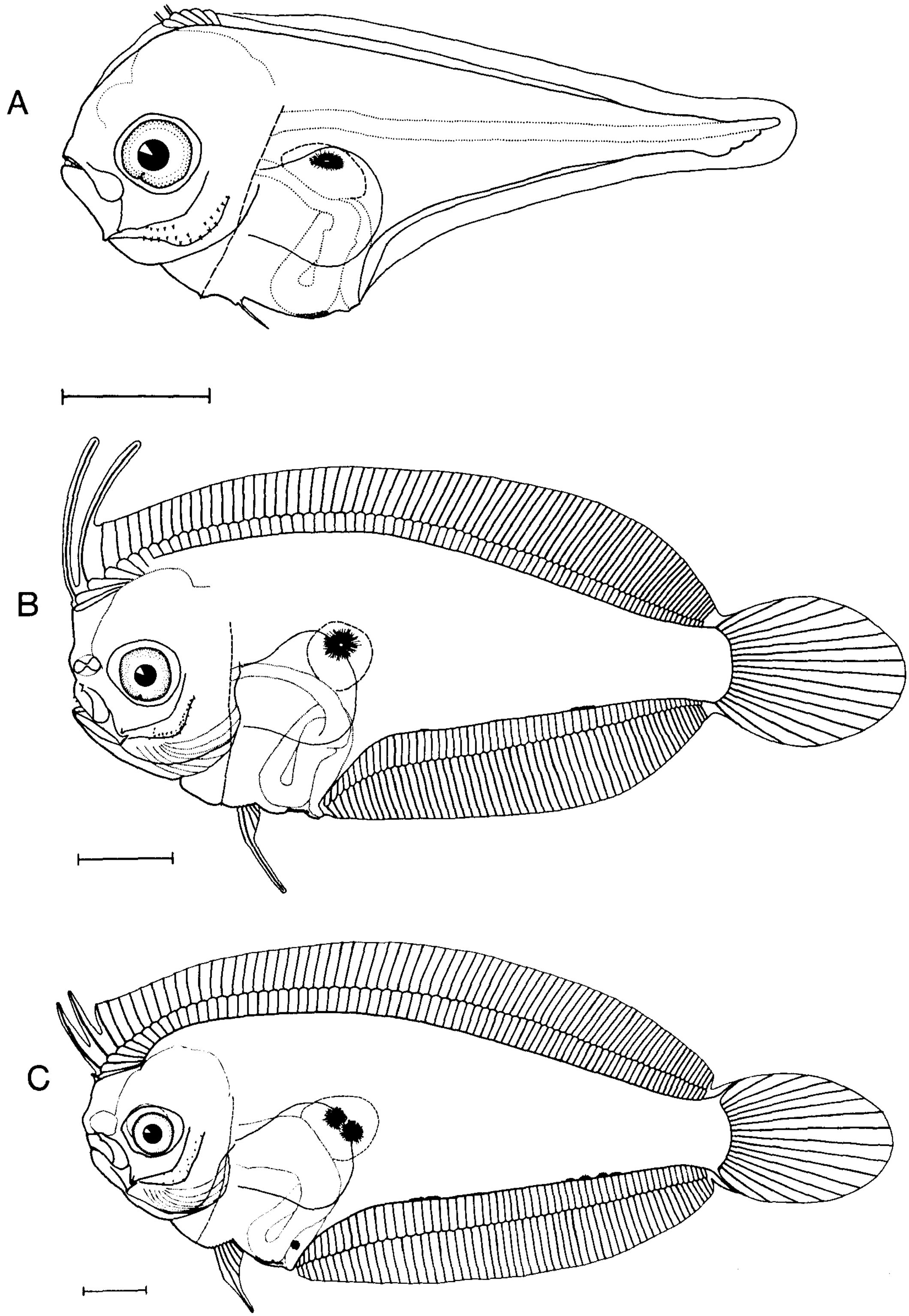


FIGURE 8.—Larval stages of *Citharichthys spilopterus*: A. Preflexion (early caudal formation), 3.7 mm; B. Late flexion, 6.7 mm; C. Transforming, 9.9 mm. Scale = 1 mm.

transformation and is obscured by body musculature in most specimens longer than 10 mm. A caudal band does not appear until the myoseptal pigment pattern of early juveniles is established (9-10 mm, Fig. 9B). By the end of transformation, myoseptal pigment is well developed, mostly adjacent to dorsal and anal pigment clusters; it often forms additional vertical bands across the body. In older juveniles (16 mm, Fig. 9C), the dorsal and anal clusters and myoseptal pigment become less distinct and partially blend in with the increasing brownish ground color.

Morphology (Figs. 8, 9; Tables 3, 7)

General morphological features are similar to those of *C. cornutus*, with the qualification that the smallest *C. spilopterus* specimen examined was 3.7 mm NL. Adult morphometrics given in the following discussion were derived from Gutherz (1967) and Dawson (1969).

During flexion and postflexion, the mouth is relatively small and is similar in size to that of *E. crossotus*. The adult mouth is also small for the genus. Upper jaw length/BL decreases greatly from 9.9% (preflexion) to 6.7% (postflexion) and then increases greatly to 9.0% (midjuvenile). Adult upper jaw length/BL is 10.5%. Upper jaw length/HL decreases greatly from 36% (preflexion) to 27-29% (flexion to early juvenile) and then increases greatly to 36% (midjuvenile). Adult upper jaw length/HL is about 37%, range 31-40%. Lower jaw length/BL decreases greatly from 12.1% (preflexion) to 9.1% (postflexion) and then increases greatly to 13.1% (midjuvenile). Adult lower jaw length/BL is 12.4%. Lower jaw length/HL decreases greatly from 43% (preflexion) to 38% (flexion and postflexion) and then increases greatly to 53% (midjuvenile). Adult lower jaw length/HL is 44%, range 41-47%.

The larval snout is relatively long but blunt. The adult snout is relatively pointed. Snout length/BL decreases from 7.5-7.6% (preflexion and flexion) to 6.4% (postflexion) and 5.0% (midjuvenile). Adult snout length/BL is 5.6%. Snout length/HL is fairly constant at 27-29% from preflexion through postflexion and then decreases to 20% (midjuvenile). Adult snout length/HL is 20%, range 18-22%.

The eye is moderate in larvae and small in adults. Eye diameter/BL decreases greatly from 9.7% (preflexion) to 6.5% (postflexion) and then increases slightly to 7.0% (midjuvenile). Postflexion eye diameter/BL is similar to those of *E. crossotus* and *E. microstomus*. Adult orbit diameter/BL is 5.6%. The large decrease in larval eye diameter/BL is exceptional among known western North Atlantic *Citharichthys* and *Etropus* larvae. Eye diameter/HL decreases greatly from 35% (preflexion) to 27-28% (postflexion to midjuvenile). Adult orbit diameter/HL is 20%, range 13-25%.

The head is very blunt, with a nearly vertical anterior profile, prior to transformation. It is relatively long during preflexion, moderate during flexion, short during postflexion, and moderate in adults. Head length/BL decreases greatly from 28% (preflexion) to 24% (postflexion) and then increases to 25% (early and midjuvenile). Adult head length/BL is 28%, range 26-31%. The decrease in relative larval head length is exceptional among known western North Atlantic *Citharichthys* and *Etropus* larvae. The head is relatively deep during preflexion and flexion, and shallow during postflexion. Head depth/BL increases from 37% (preflexion) to 39% (flexion), then decreases greatly to 33% (postflexion) and 31% (midjuvenile). Postflexion head depth/BL is similar to those of *C. gymnorhinus* and *E. crossotus.*

Snout to anus length is relatively short. Snout to anus length/BL decreases greatly from 39-40% (preflexion and flexion) to 31-32% (postflexion to midjuvenile).

The body is deep throughout the larval stages, except that the abdomen becomes only moderately deep by postflexion. During postflexion, the dorsal and ventral profiles are not as convex as in other known western North Atlantic *Citharichthys* and *Etropus* larvae. Adult body depth is moderate. Body depth at pelvic fin/BL increases from 40% (preflexion) to 47% (flexion) and then decreases to 39% (postflexion) and 35% (midjuvenile). Body depth at anus/BL increases from 39% (preflexion) to 51% (flexion) and then decreases to 43% (postflexion) and 39% (midjuvenile). Body depth at third hemal spine/BL increases from 23% (preflexion) to 41% (flexion), decreases to 37% (early juvenile), and then increases to 40% (midjuvenile). Adult body depth/BL is 46%, range 40-51%. Caudal peduncle depth/BL decreases from 14.4% (preflexion) to 13.5% (postflexion) and 11.4% (midjuvenile). Adult caudal peduncle depth/BL is 12.8%, range 11.0-13.9%. The decrease in relative larval caudal peduncle depth is exceptional among known western North Atlantic *Citharichthys* and *Etropus* larvae.

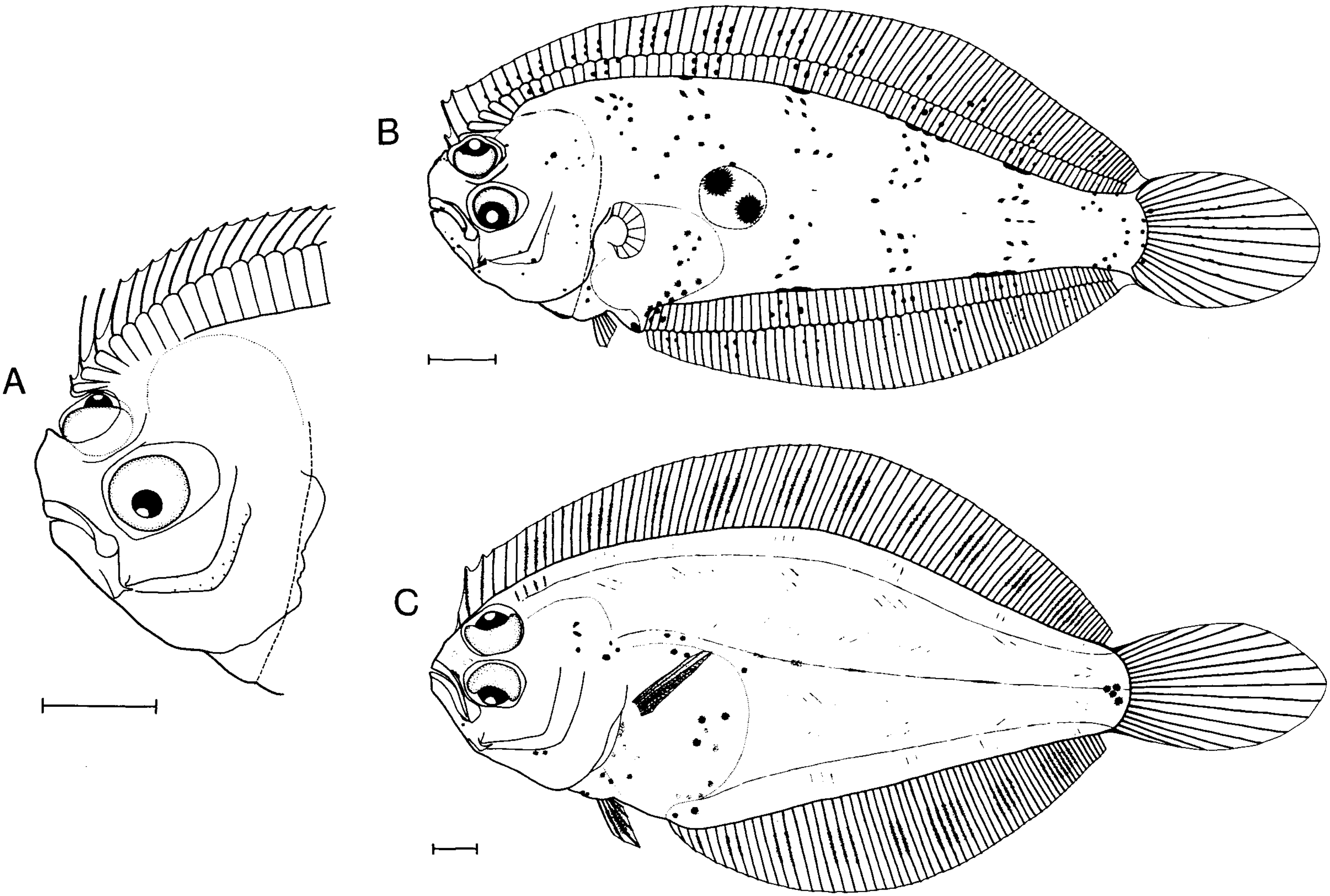


FIGURE 9.—*Citharichthys spilopterus*: A. Head of 9.9 mm larva showing migration of right eye around origin of dorsal fin (pigment omitted); B. Early juvenile, 10.7 mm; C. Juvenile, 16.6 mm. Scale = 1 mm.

TABLE 7.—Measurements (mm) of larvae and juveniles of *Citharichthys spilopterus*. ECF = early caudal formation, Late = late flexion, Post = postflexion. S = symmetrical, 1 = 0 to one-third of the way to the dorsal ridge, 2 = one-third to two-thirds of the way to the dorsal ridge, 3 = two-thirds to all the way to the dorsal ridge, R = on the dorsal ridge, T = transformed.

Body length	Upper jaw length	Lower jaw length	Snout length	Eye diameter	Head length	Snout to anus length	Total length	Head depth	Body depth at pelvic fin	Body depth at anus	Body depth at third hemal spine	Caudal peduncle depth	Flexion stage	Right eye position
3.7	0.37	0.45	0.28	0.36	1.0	1.5	3.8	1.4	[1]1.5	[1]1.4	[1]0.84		ECF	S
5.7	0.42	0.58	0.46	0.46	1.5	2.2		2.4	2.7	2.9	2.2	0.74	Late	S
6.7	0.42	0.61	0.53	0.51	1.7	2.5	8.5	2.5	3.1	3.3	2.6	0.93	Late	S
6.8	0.54	0.71	0.46	0.54	1.8	2.7		2.6	3.2	3.5	3.0	1.1	Late	1
8.3	0.66	0.80	0.55	0.53	2.0	2.7	10.4	2.8	3.4	3.7	3.2	1.2	Post	3
8.7	0.66	0.88	0.53	0.54	2.3	2.8	11.3	3.0	3.5	3.8	3.4	1.3	Post	T
8.9	0.54	0.83	0.50	0.52	2.0	3.0	11.1	3.0	3.6	4.0	3.5	1.2	Post	1
8.9	0.61	0.82	0.61	0.56	2.1	2.9	11.0	3.0	3.6	4.0	3.4	1.2	Post	2
8.9	0.65	0.85	0.50	0.63	2.2	2.9	11.1	3.1	3.5	3.8	3.4	1.3	Post	R
9.0	0.73	1.0	0.58	0.58	2.4	2.9	11.7	3.1	3.5	3.6	3.4	1.2	Post	T
9.0	0.62	0.81	0.60	0.58	2.2	2.8	11.0	3.0	3.6	4.0	3.6	1.2	Post	S
9.1	0.58	0.80	0.56	0.60	2.1	2.9	11.3	3.0	3.4	3.6	3.3	1.2	Post	3
9.1	0.70	0.90	0.65	0.60	2.4	3.1	11.2	2.9	3.3	3.4	3.1	1.2	Post	T
9.1	0.67	0.93	0.56	0.60	2.3	3.0	11.2	2.9	3.3	3.5	3.3	1.3	Post	T
9.2	0.70	0.93	0.58	0.70	2.4	2.8	11.4	3.2	3.7	3.9	3.6	1.3	Post	R
9.2	0.64	0.97	0.46	0.64	2.3	2.7	11.4	2.9	3.6	3.8	3.4	1.3	Post	T
9.2	0.67	0.87	0.60	0.62	2.4	2.8	11.4	3.0	3.6	3.8	3.5	1.3	Post	T
9.2	0.68	0.89	0.62	0.60	2.3	2.8	11.2	2.9	3.4	3.9	3.2	1.3	Post	R
9.3	0.57	0.80	0.56	0.60	2.2	2.9	11.4	3.0	3.6	3.9	3.4	1.2	Post	1
9.3	0.67	0.90	0.65	0.63	2.4	2.9	11.7	3.0	3.4	3.8	3.7	1.3	Post	T
9.4	0.68	0.93	0.53	0.68	2.4	2.7	11.7	3.0	3.5	3.7	3.4	1.3	Post	T
9.4	0.69	1.0	0.56	0.68	2.3	3.0	11.6	3.1	3.5	3.7	3.8	1.4	Post	T
9.4	0.67	0.94	0.59	0.67	2.4	2.9	11.7	2.9	3.4	3.7	3.3	1.3	Post	T
9.5	0.71	1.0	0.60	0.68	2.4	3.1	11.8	3.0	3.6	3.8	3.4	1.3	Post	T
9.6	0.66	0.91	0.71	0.53	2.3	3.1	12.0	3.3	3.8	4.1	3.8	1.4	Post	R
9.7	0.69	0.93	0.64	0.68	2.5	2.9	11.8	3.2	3.6	3.9	3.6	1.3	Post	R
9.7	0.61	0.80	0.70	0.56	2.2	3.3	11.9	3.2	3.9	4.3	3.7	1.2	Post	S
9.8	0.65	0.89	0.58	0.74	2.4	3.2	11.9	3.1	3.8	4.1	3.6	1.2	Post	1
9.8	0.67	0.87	0.70	0.64	2.4	3.2	11.9	3.1	3.8	4.4	3.8	1.2	Post	1
10.0	0.72	1.0	0.54	0.72	2.5	3.0	12.2	3.2	3.6	3.8	3.6	1.3	Post	T
10.0	0.76	1.0	0.67	0.73	2.6	3.2	12.5	3.2	3.8	3.9	3.7	1.4	Post	T
10.0		1.1		0.73	2.5	3.0	12.2	3.2	3.7	4.0	3.6	1.3	Post	T
10.2	0.68	0.90	0.70	0.67	2.4	3.2	12.4	3.2	3.9	4.2	3.8	1.3	Post	3
10.2	0.71	1.0	0.56	0.64	2.6	3.1	12.5	3.1	3.5	3.7	3.6	1.4	Post	T
10.2	0.78	1.1	0.58	0.75	2.5	3.2	12.7	3.4	3.9	4.2	3.9	1.4	Post	T
10.2	0.73	1.1	0.53	0.76	2.6	3.2	12.5	3.3	3.8	4.0	3.8	1.4	Post	T
10.2		1.0	0.60	0.70	2.4	3.2	12.2	3.3	3.9	4.1	3.9	1.4	Post	T
10.3	0.83	1.1	0.64	0.64	2.6	3.2	12.7	3.4	3.8	4.1	3.8	1.4	Post	T
10.3	0.79	1.1	0.60	0.74	2.7	3.3	13.0	3.4	3.9	4.2	3.9	1.4	Post	T
10.5	0.76	1.1	0.60	0.71	2.6	3.4	13.0	3.4	3.8	4.2	4.0	1.4	Post	T
10.5	0.59	0.92	0.60	0.66	2.4	3.2	12.9	3.5	3.9	4.4	4.2	1.4	Post	R
10.6	0.73	1.1	0.63	0.68	2.7	3.2	13.1	3.4	4.0	4.2	4.0	1.4	Post	T
10.6	0.65	1.1	0.50	0.67	2.6	3.2	13.1	3.5	4.0	4.3	4.1	1.4	Post	T
10.6	0.60	0.90	0.64	0.60	2.5	3.2	13.0	3.4	4.1	4.5	4.1	1.4	Post	1
10.7	0.74	0.95	0.47	0.77	2.6	3.2	13.0	3.2	3.8	4.1	3.9	1.4	Post	T
10.8	0.82	1.1	0.65	0.72	2.7	3.3	13.3	3.2	3.9	4.2	3.8	1.4	Post	T
10.9	0.76	1.1	0.55	0.66	2.7	3.1	13.4	3.4	4.0	4.3	4.0	1.4	Post	T
10.9	0.75	1.1	0.62	0.67	2.8	3.2	13.3	3.3	4.0	4.3	4.0	1.4	Post	T
11.0	0.81	1.1	0.61	0.65	2.7	3.2		3.4	3.8	4.0	3.9	1.3	Post	T
11.6	0.84	1.3	0.61	0.89	3.1	3.8	14.3	3.7	4.2	4.5	4.4	1.5	Post	T
14.3	1.3	1.9	0.77	1.2	3.8	4.9	18.3	4.6	5.2	5.6	5.6	1.6	Post	T
16.6	1.6	2.3	0.91	1.3	4.4	5.3	21.0	5.5	5.9	6.6	7.0	1.7	Post	T
16.7	1.5	2.2	0.75	1.1	4.0	5.0		5.2	6.0	6.4	6.6	1.9	Post	T
19.4	1.7	2.5	0.84	1.3	4.8	6.0	24.1	5.8	6.7	7.5	7.8	2.2	Post	T
22.0	2.1	3.0	1.2	1.4	5.4	6.8	27.9	6.9	7.6	8.6	9.0	2.7	Post	T
23.1	1.9	2.9	1.1	1.6	5.6	7.1	28.5	7.0	7.7	8.6	9.0	2.7	Post	T
23.3	2.1	3.1	1.2	1.6	5.8	7.2	28.9	7.2	8.4	9.2	9.4	2.8	Post	T
24.0	2.2	3.1	1.1	1.6	6.0	7.8	30.0	7.4	8.3	9.2	9.7	2.6	Post	T
25.4	2.3	3.2	1.3	1.6	6.2	8.1	31.9	7.5	8.9	9.7		3.0	Post	T

[1]Measurement does not include dorsal or anal pterygiophores.

Fin and Axial Skeleton Formation

Caudal skeleton development apparently is similar to that of *C. cornutus*. Size ranges of available larval specimens in each stage are as follows: Early caudal formation, 3.7 mm NL; late flexion, 5.7-6.8 mm NL; postflexion, 9.0-10.6 mm SL. All caudal rays are calcified by 5.7 mm.

All precaudal neural spines, the first 13 caudal neural spines, the first 13 hemal spines, and no precaudal or caudal centra stain with alizarin at 3.7 mm NL. All neural spines and hemal spines, some precaudal centra, and the urostyle stain with alizarin at 5.7 mm NL. All precaudal and caudal centra stain with alizarin at 6.7 mm NL. The smallest specimen in which caudal centra could be counted was 5.7 mm NL (late flexion).

The second and third dorsal rays are moderately elongate and moderately separated at the bases from preflexion (3.7 mm NL) through transformation (about 10 mm SL). No other dorsal rays were formed at 3.7 mm, but adult counts were present from 5.7 mm NL onward. All dorsal rays had calcified by postflexion (8.3 mm SL).

No anal rays were formed at 3.7 mm, but adult counts were present from 5.7 mm onward. All anal rays had calcified by 8.3 mm.

The second left pelvic ray is formed by 3.7 mm; in larger specimens it is elongate. By 5.7 mm, four left and four right pelvic rays are calcified. All six rays in each fin are calcified by 6.8 mm NL.

Rayless, fanlike, larval pectoral fins were present in the smallest specimen (3.7 mm). Calcification of rays in the left fin begins during postflexion (9-10 mm SL), and is complete by the end of transformation (9-11 mm SL).

Cephalic Spination

Preopercular spines (Table 4) were present from early caudal formation (3.7 mm NL, Fig. 8A) through transformation (10.2 mm SL). Maximum numbers may be reached during or before late flexion (31 left, about 36 right); however, counts from early and midflexion larvae are lacking and those from older ones are highly variable. No preopercular spines are evident in juveniles.

The 3.7 mm NL specimen had one frontal-sphenotic spine on each side. Several postflexion (8-10 mm SL) specimens had one or two relatively inconspicuous frontal-sphenotic spines on each side. These spines may be more numerous in larvae smaller than 5.7 mm NL. None are evident in juveniles.

Larval Teeth (Table 5)

The early caudal formation (3.7 mm NL, Fig. 8A) specimen had two upper and three lower teeth on each side. During late flexion and postflexion (5.7-10.6 mm BL), larvae usually have four upper and five lower teeth on each side. Transforming larvae and early juveniles (9.1-10.7 mm SL) usually have about five upper left (probably about five upper right) and five or six lower left (probably five to eight lower right) teeth.

Transformation

Migration of the right eye may begin as early as late flexion (6.8 mm NL) or as late as postflexion (10.6 mm SL). The right eye moves from the right side of the head around the dorsal fin origin (Fig. 9A) as in *Citharichthys arctifrons* and *Etropus microstomus* (Richardson and Joseph 1973). The right eye reaches its final position on the left side of the head at about 9-11 mm SL.

Occurrence

Larvae were collected from September through December in the Gulf of Mexico off Texas (Daher[6]) and from October through April in the Cape Fear River estuary, North Carolina (pers. obs.). Temperature and salinity ranges at capture locations in the Cape Fear River were 4.1°-26.6°C and 0.0-31.7‰.

Etropus crossotus (Figs. 10, 11)

Identification

Larvae approaching transformation had complete complements of countable characters. Those specimens were identified by comparing the following larval counts with known adult counts. Number of specimens is given in parentheses.

Caudal fin formula = 4-5-4-4 (15)
Caudal vertebrae = 24(1), 25(19), 26(3)
Gill rakers (lower limb, first left) = ~7 (1)
Left pelvic rays = 6 (11)
Anal rays = 60-66 (13)
Dorsal rays = 76-84 (13)

Of the potential species listed in Table 1, only *E. crossotus* has counts that agree with these. In addition, most specimens were captured west of the Mississippi River in the Gulf of Mexico, an

[6]M. A. Daher, Graduate Student, Department of Wildlife Science, Texas A&M University, College Station, TX 77843, pers. commun. June 1978.

area from which other *Etropus* spp. have not been reported.

Distinguishing Characters

Etropus crossotus larvae have a dashlike melanophore at the base of each pectoral fin. Internal pigment along the dorsal surface of the notochord is extensive. Two elongate dorsal rays are present from preflexion (4.6 mm) through transformation. Caudal vertebrae (25-26, very rarely 24) can be counted by midflexion (5.4 mm). Lateral pigment is relatively heavy. Flexion is complete at 9-10 mm SL. The larval mouth and eye are small. The left pelvic fin has a full complement of six rays. Length at transformation is 10-12 mm. Larvae usually appear in collections from March through August.

Pigmentation

Pigmentation of *E. crossotus* larvae is relatively heavy. Pigment on the gas bladder and on the ventral and dorsal surfaces of the body is the most striking. Most useful for identification is internal pigment along the dorsal surface of the notochord and a melanophore at the base of the pectoral fin.

By about 4.6 mm (Fig. 10A) and throughout larval development, the dorsal one-third of the

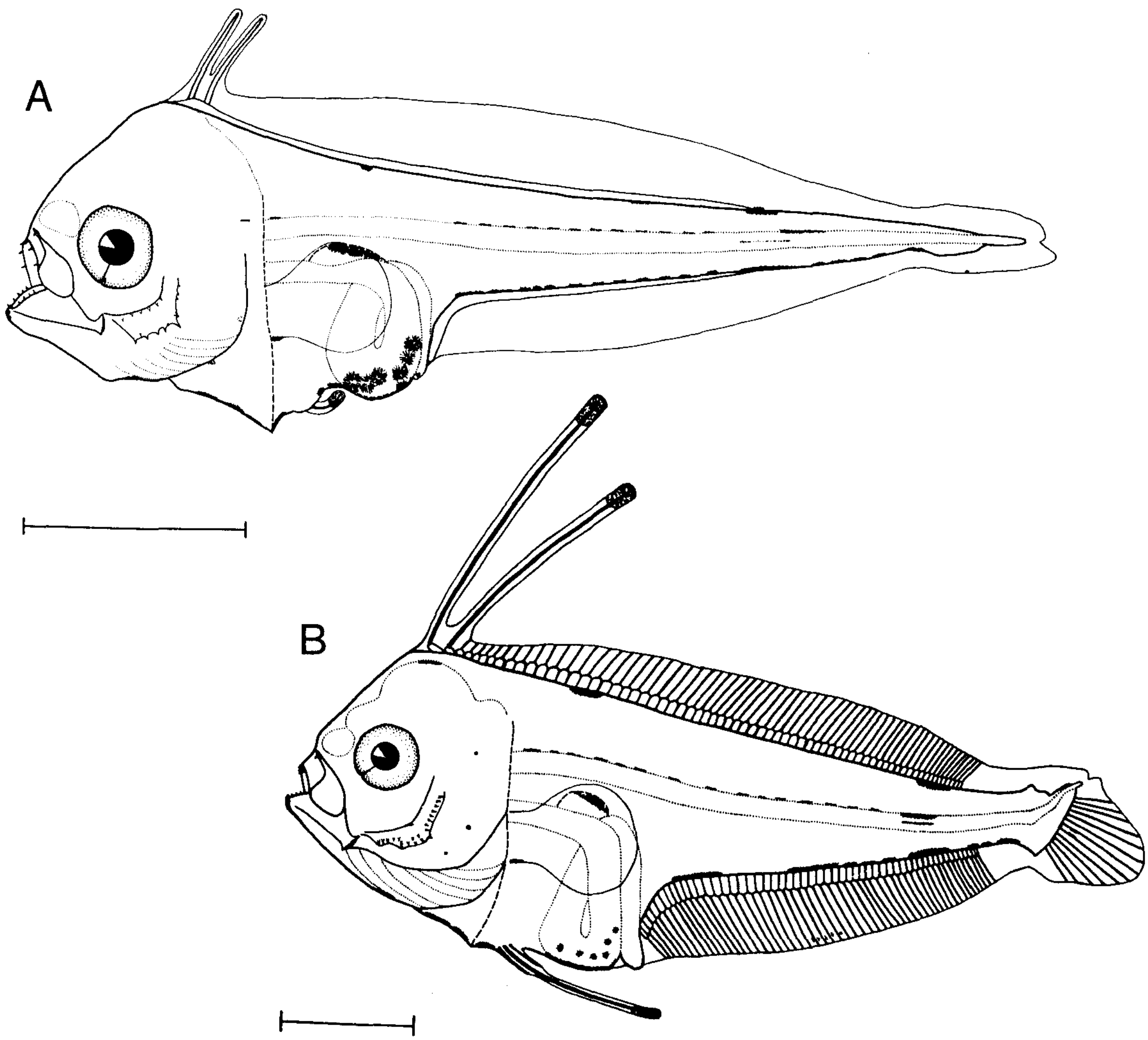


FIGURE 10.—Larval stages of *Etropus crossotus*: A. Preflexion (early caudal formation), 4.6 mm; B. Midflexion, 6.0 mm. Scale = 1 mm.

left side of the gas bladder is fairly heavily pigmented, usually with three or four distinct melanophores. The right side of the gas bladder is similarly pigmented until late flexion. Internal notochordal pigment consists of a series of fine dashes along the dorsal surface and is more extensive then in known *Citharichthys* larvae. Preflexion and early flexion larvae have up to about 12 pigment dashes between the gas bladder and caudal centrum 15. From about caudal centra 15 to 18 (range 14-20) there is a distinct series of heavy dashes which usually form a nearly solid line throughout development. An internal melanophore that appears to be associated with the notochord is located below the hindbrain near the otic capsule, where the notochord joins the brain. Dashlike clusters of pigment develop along the dorsal and ventral body margins between the pectoral fin and the caudal fin base. These clusters have not completely formed in the preflexion specimen, but three dorsal clusters and ventral pigment are present. During preflexion, a melanophore may be present on the ventral edge of the caudal finfold, opposite the midpoint of incipient hypural bones.

Throughout larval development, a continuous or broken line of pigment (the length of three to five centra) is on the lateral midline about two-thirds of the way from the anus to the notochord tip. One or two melanophores are on each side of the symphysis of the lower jaw. The posterior margin of the articular is covered with a stellate melanophore. A stellate melanophore is present at the junction of left and right branchiostegal membranes, just forward of the isthmus. About one to three internal melanophores are present near the pectoral fin base and just forward of the cleithrum beneath the angle of the last gill arch (visible through the opercle). Usually, a melanophore is on the anterodorsal edge of the urohyal. The ventral body margin between the isthmus and pelvic fin is fairly heavily pigmented with a few distinct melanophores or a continuous band of pigment. Several melanophores are present along the ventral and lateral surfaces of the abdomen and sometimes along the hindgut near the anus. The lower edge of both pectoral fin bases is lined with a dashlike melanophore. The second left pelvic ray has melanophores along its distal end. A series of small melanophores is present along the distal tips of anal pterygiophores.

During early flexion (4.9 mm), one, or rarely two, diffuse internal melanophores appear above the hindbrain.

During midflexion (5-6 mm, Fig. 10B), melanophores appear along the distal ends of the elongate dorsal rays. A group of melanophores may be present at the distal ends of the middle anal rays. Melanophores begin appearing at the bases and along the sides of middle caudal rays.

During flexion, internal notochordal pigment increases. Midflexion and late flexion larvae have up to about 5 pigment dashes between the cleithrum and gas bladder and up to about 18 dashes between the gas bladder and caudal centrum 15. From midflexion through postflexion, a small amount of pigment usually is on the anteroventral edge of the maxillary.

By late flexion (6 mm), the gas bladder has become oriented toward the left side, and greater development of musculature obscures the gas bladder from the right side. By about 8.5 mm, musculature begins to obscure notochordal pigment, except for the heavy dashes in the caudal band area. There is no evidence of a melanophore on the opercle; however, one or two small melanophores occasionally appear on the interopercle during late flexion. By about 8.5 mm, concentrations of pigment have formed around the first through third left pelvic rays. Pigment at the distal margin of the right pelvic fin appears at about the same time.

During postflexion (10.5 mm, Fig. 11A), a small melanophore appears on the upper lip. Groups of melanophores are present along the margins of dorsal and anal fins of some specimens.

In the nearly transformed specimen (10.3 mm, Fig. 11B), heavy posterior notochordal pigment is still obvious. Additional internal melanophores have appeared posterior to the hindbrain. Myoseptal pigment is well developed, mostly adjacent to dorsal and anal pigment clusters. As in *Citharichthys* larvae, this forms a caudal band. A midlateral cluster of melanophores is present near the caudal fin. Melanophores have formed along the anterior surface of the head from the snout to the dorsal fin. External and internal melanophores are present along the hindgut. Melanophores have formed along the proximal ends of groups of some dorsal and anal rays.

Morphology (Figs. 10, 11; Tables 3, 8)

General morphological features are similar to those of *Citharichthys cornutus*, with the qualification that the smallest *E. crossotus* specimen examined was 4.6 mm NL. Adult morphomet-

A

B

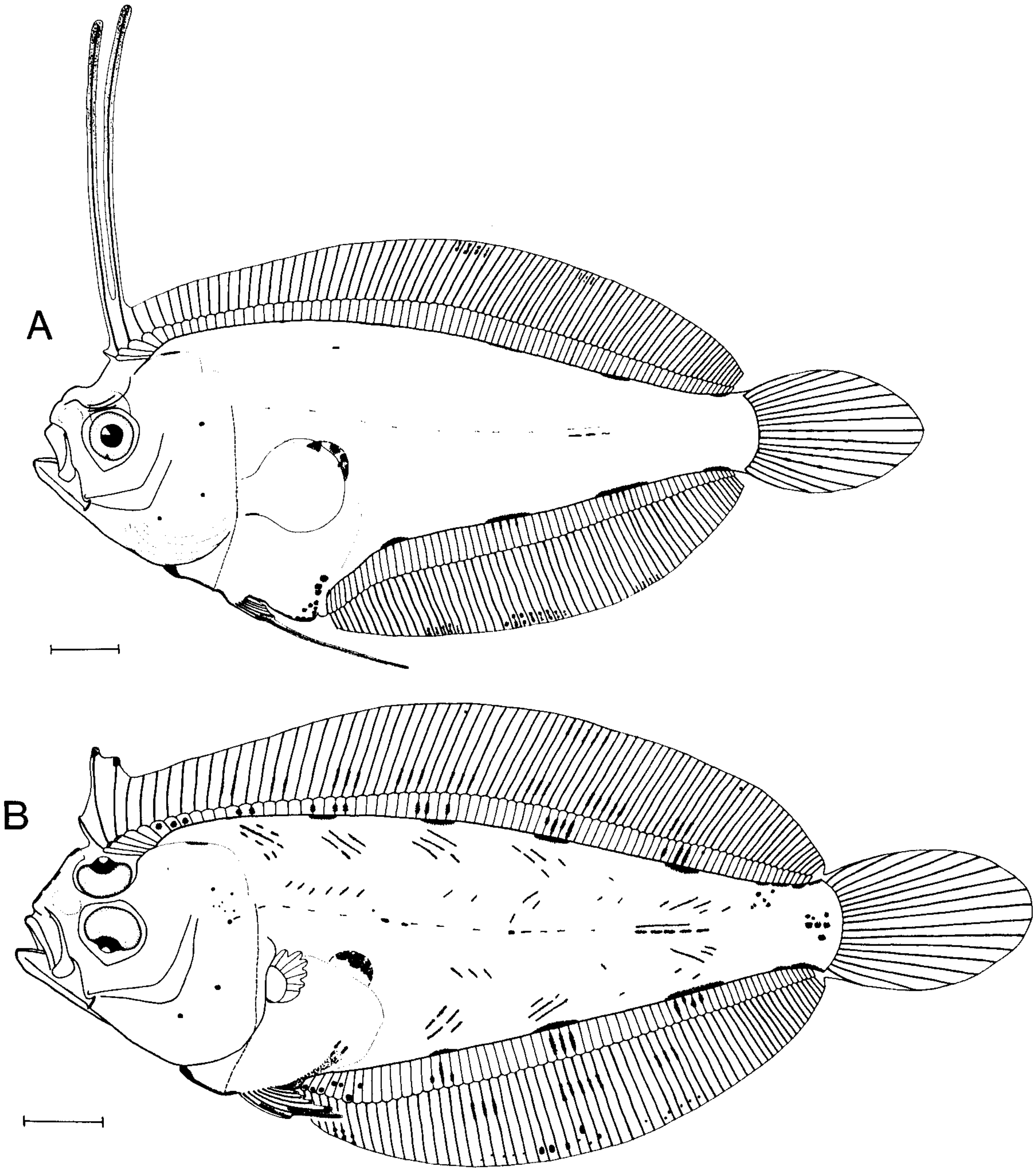


FIGURE 11.—Larval stages of *Etropus crossotus*: A. Transforming, 10.5 mm; B. Nearly transformed, 10.3 mm. Scale = 1 mm.

rics given in the following discussion are from Gutherz (1967).

The larval mouth is relatively small. During flexion and postflexion relative mouth size is similar to that of *C. spilopterus*. The adult mouth is the smallest of known western North Atlantic *Etropus* and *Citharichthys* species. Larval upper jaw length/BL is fairly constant at 7.0-7.2%. Larval upper jaw length/HL decreases from 30% to 27% (preflexion to postflexion). Adult upper jaw length/HL is 21-27%. Larval lower jaw length/BL is fairly constant at 9.6-9.8%. Larval lower

TABLE 8.—Measurements (mm) of larvae and a juvenile of *Etropus crossotus*. Pref = preflexion, ECF = early caudal formation, Early = early flexion, Mid = midflexion, Late = late flexion, Post = postflexion. S = symmetrical, 1 = 0 to one-third of the way to the dorsal ridge, 2 = one-third to two-thirds of the way to the dorsal ridge, 3 = two-thirds to all the way to the dorsal ridge, T = nearly transformed.

Body length	Upper jaw length	Lower jaw length	Snout length	Eye diameter	Head length	Snout to anus length	Total length	Head depth	Body depth at pelvic fin	Body depth at anus	Body depth at third hemal spine	Caudal peduncle depth	Flexion stage	Right eye position
4.6	0.32	0.44	0.24	0.34	1.1	1.8	4.6	1.3	[1]1.2	[1]0.98	[1]0.53		ECF	S
4.9	0.35	0.43	0.27	0.37	1.2	2.1		1.6	1.6	1.4	0.89	0.23	Early	S
5.4	0.38	0.50	0.32	0.39	1.4	2.4	5.6	1.7	1.9	1.7	0.99	0.27	Early	S
5.4	0.43	0.66	0.32	0.41	1.4	2.4	6.0	1.9	2.1	1.9	1.3	0.48	Mid	S
5.5	0.40	0.53	0.40	0.36	1.4	2.5	5.8	1.9	2.0	1.8	1.3	0.43	Mid	S
5.5	0.37	0.52	0.35	0.40	1.5	2.6	6.0	1.9	2.0	1.8	1.2	0.43	Mid	S
5.6	0.43	0.57	0.33	0.40	1.4	2.4	5.9	1.8	2.1	1.9	1.3	0.37	Mid	S
5.7	0.40	0.51	0.33	0.37	1.4	2.4	5.7	1.7	1.9	1.7	1.1	0.31	Mid	S
5.7	0.35	0.49	0.29	0.35	1.4	2.4	6.0	1.8	1.9	1.8	1.2	0.35	Mid	S
5.8	0.34	0.49	0.35	0.38	1.4			1.8	1.9		1.2	0.34	Mid	S
6.0	0.43	0.56	0.40	0.42	1.6	2.7	6.5	2.0	2.2	2.1	1.4	0.43	Mid	S
6.0	0.37	0.51	0.32	0.41	1.5	2.8	6.6	2.0	3.0	1.8	1.3	0.52	Mid	S
6.0	0.50	0.62	0.42	0.43	1.6	2.8	6.8	2.1	2.4	2.2	1.6	0.53	Mid	S
6.1	0.51	0.72	0.37	0.47	1.7	2.6		2.1	2.3	2.3	1.6	0.68	Late	S
6.2	0.41	0.57	0.38	0.41	1.6	3.0	7.2	2.2	2.5	2.4	1.8	0.63	Late	S
6.9	0.50	0.67	0.47	0.46	1.9	3.2	8.2	2.3	2.8	2.6	2.0	0.73	Late	S
7.4	0.54	0.74	0.53	0.49	2.0	3.3	8.8	2.5	3.1	3.0	2.5	0.83	Late	1
8.2	0.49	0.70	0.56	0.50	2.3	3.8	10.1	2.8	3.5	3.7	3.0	1.1	Late	1
8.3	0.53	0.71	0.53	0.54	2.2	3.6	10.1	2.8	3.3	3.5	2.8	1.0	Late	S
8.3	0.63	0.78	0.53	0.54	2.2	3.6	10.1	2.9	3.5	3.8	3.2	1.1	Late	1
8.5	0.69	0.84	0.63	0.58	2.4	3.6	10.8	3.0	3.6	3.7	3.1	1.1	Late	1
9.1	0.70	0.92	0.57	0.61	2.4	3.6	11.4	3.0	3.7	3.9	3.4	1.2	Late	1
9.3	0.73	0.96	0.70	0.67	2.7	3.9		3.4	4.0	4.1	3.5	1.2	Late	1
9.3	0.64	0.84	0.63	0.65	2.6	4.0	11.9	3.4	3.8	4.1	3.6	1.2	Late	1
9.3	0.60	0.86	0.67	0.57	2.4	3.9	11.2	3.0	3.8	4.0	3.4	1.1	Post	1
9.5	0.71	0.90	0.70	0.63	2.6	4.0	11.9	3.3	4.0	4.3	3.7	1.3	Late	2
9.6	0.72	0.96	0.73	0.61	2.6	4.1	11.9	3.4	4.2	4.4	3.9	1.3	Post	1
10.3	0.80	1.1	0.75	0.71	3.0	3.4	12.7	3.3	3.7	3.7	3.7	1.2	Post	T
10.5	0.75	0.99	0.63	0.66	2.7	4.0	12.9	3.5	4.3	4.8	4.0	1.3	Post	2
10.5	0.76	1.1	0.80	0.64	2.8	4.1	12.9	3.5	4.2	4.6	4.0	1.3	Post	3
10.8	0.71	1.0	0.59		2.6	4.1	13.2	3.4	4.3	4.7	4.1	1.4	Post	1

[1]Measurement does not include dorsal or anal pterygiophores.

jaw length/HL decreases greatly from 41% to 36-37%.

The larval snout is moderate but exhibits a relatively fast growth rate. Snout length/BL increases from 5.2% to 6.8%. Snout length/HL increases from 22% to 26%.

The eye is relatively small in larvae and moderate in adults. Larval eye diameter/BL decreases from 7.4% to 6.3%. Larval eye diameter/HL decreases greatly from 32% to 24%. Adult eye diameter/HL is about 22-28%.

The larval head is of moderate length but relatively shallow depth. In adults, the head is the shortest of known western North Atlantic *Etropus* and *Citharichthys* species. Larval head length/BL increases from 23% to 26%. Adult head length/BL is 20-25%. Larval head depth/BL increases from 29% to 33-34% and is similar to that of *C. gymnorhinus*.

Larval snout to anus length is moderate. Snout to anus length/BL increases from 39% (preflexion) to 44% (flexion) and then decreases to 39% (postflexion). This length is similar to that of *C. gymnorhinus* during flexion and postflexion.

Early larvae are relatively shallow, but abdominal and tail depths increase quickly, and as adults, this species and *E. rimosus* are the deepest bodied of known western North Atlantic *Etropus* and *Citharichthys* species. During postflexion, the dorsal and ventral profiles of *E. crossotus* are relatively convex. Larval body depth at pelvic fin/BL increases greatly from 26% to 40%. Larval body depth at anus/BL increases greatly from 21% to 43% and is similar to that of *C. gymnorhinus* during flexion and postflexion. Larval body depth at third hemal spine/BL increases greatly from 12% to 38%. Adult body depth/BL is 50-58%. Larval caudal peduncle depth/BL increases from 9.6% (flexion) to 12.6% postflexion).

Fin and Axial Skeleton Formation

Caudal skeleton development is similar to that of *C. cornutus*. Size ranges of available specimens in each stage are as follows: Early caudal formation, 4.6 mm NL; early flexion, 4.9-5.4 mm NL; midflexion, 5.4-6.0 mm NL; late flexion, 6.1-9.5 mm NL; postflexion, 9.3-10.8 mm SL. Caudal rays become calcified between early flexion (4.9 mm NL) and late flexion (about 6.5 mm NL).

All precaudal neural spines stain with alizarin at 4.6 mm NL. Some caudal neural spines and hemal spines stain with alizarin at 4.6 mm NL, and all do by 5.6 mm NL. All precaudal and caudal centra stain with alizarin at about 6.0 mm NL. The urostyle stains with alizarin at 6.2 mm NL. The smallest specimen in which caudal centra could be counted was 5.4 mm NL (midflexion).

The second and third dorsal rays are elongate and moderately separated at the bases from preflexion (4.6 mm NL) through transformation (about 11 mm SL). During early flexion (4.9 mm NL), rays near the middle of the fin begin to calcify. Calcification proceeds anteriorly and posteriorly. Adult counts are present from late flexion (about 8.0 mm NL) onward. The first ray and most posterior rays are calcified prior to transformation (by about 9.6 mm SL).

During early flexion (4.9 mm NL), anal rays near the middle of the fin begin to calcify. Calcification proceeds anteriorly and posteriorly. Adult counts are present from late flexion (about 8.0 mm NL) onward. The most posterior rays are calcified during late flexion (about 9.3 mm NL).

Development of the left pelvic fin precedes that of the right. The left pelvic fin bud appears during preflexion (before 4.6 mm NL). Rays develop between early caudal formation (4.6 mm NL) and late flexion (8.5 mm NL). The second ray is the first to appear; it is elongate. The first ray appears soon after the second; it may be slightly elongate. The right pelvic fin bud appears during midflexion (5.5 mm NL). Rays develop between midflexion (5.8 mm NL) and late flexion (8.5 mm NL). Each complete fin has six rays.

Rayless, fanlike, larval pectoral fins are present on the smallest available specimen (4.6 mm NL). Calcification of rays in the left fin occurs during late transformation (10-11 mm SL).

Cephalic Spination

Preopercular spines (Table 4) were present in the smallest preflexion specimen (4.6 mm NL, Fig. 10A). With development (Fig. 10B), additional spines appear until maximum numbers of about 24 on the left (range 18-29) and 22 on the right (range 16-27) are reached during midflexion (5.4-6.0 mm NL). Thereafter, spines are lost until none or only a few remain at transformation (Fig. 11B).

Most specimens had three or four relatively inconspicuous frontal-sphenotic spines on each side, including one or two that were noticeably stronger.

Larval Teeth (Table 5)

The early caudal formation specimen (4.6 mm NL, Fig. 10A) had three upper and five lower teeth on each side. Early flexion larvae (4.9-5.4 mm NL) have three upper and five or six lower teeth on each side. During midflexion (5.4-6.0 mm NL), there are three to five upper and five to seven lower teeth on each side. During late flexion (6.1-9.5 mm NL), larvae usually have four upper and seven lower teeth on each side. During postflexion (9.3-10.8 mm SL), there are usually four or five upper and seven lower teeth on each side. The nearly transformed specimen (10.3 mm SL, Fig. 11B) had seven upper and more than nine lower teeth on each side.

Transformation

Migration of the right eye may begin as early as late flexion (7.4 mm NL) or as late as postflexion (10.8 mm SL). The right eye moves from the right side of the head around the dorsal fin origin (Fig. 11A) as in *C. arctifrons* and *E. microstomus* (Richardson and Joseph 1973). The right eye reaches its final position on the left side of the head at about 10-12 mm SL.

Occurrence

Larvae were collected in the Cape Fear River Estuary during May (pers. obs.) and in the Gulf of Mexico off Louisiana west of the Mississippi River Delta during July and August (Walker[7]). Moe and Martin (1965) suggested a spawning season from March to at least June for the eastern Gulf of Mexico off Florida (based on ripe

[7]H. J. Walker, Research Technician, North Carolina State University, Cape Fear Estuarine Laboratory, P.O. Box 486, Southport, NC 28461, pers. commun. July 1977.

females). Capture of a ripe female from the same area in June was reported by Topp and Hoff (1972). Christmas and Waller (1973) suggested that spawning may be nearly continuous throughout the year. However, that observation was partly based on the occurrence of one juvenile specimen during January and another during February that could have been spawned in the late summer or early fall. Therefore, the season may extend beyond August, but the evidence is not yet complete.

Comparisons

Larval Characters

Morphology seems to be influenced by the environment and duration of larval existence. *Citharichthys cornutus* and *C. gymnorhinus* are found in deeper water and may have longer pelagic larval stages than *C. spilopterus* or *E. crossotus*. In some respects, the latter two species are similar to each other and dissimilar to the first two. *Citharichthys spilopterus* and *E. crossotus* have only two elongate dorsal rays, as opposed to three in the other two species. They have smaller, less conspicuous frontal-sphenotic spines, and fewer larval teeth. (However, the jaws of *C. spilopterus* later grow at a relatively fast rate and acquire correspondingly more adult teeth.) During transformation, the origin of the dorsal fin is slightly farther forward relative to the right eye in *C. cornutus* and *C. gymnorhinus* than in the other two species. (However, after transformation the dorsal origin is more anterior relative to the right eye in all three *Citharichthys* species than in *E. crossotus*.) *Citharichthys spilopterus* and *E. crossotus* larvae have smaller eyes and mouths than the other two. They also complete transformation at a smaller size.

Known similarities among *Citharichthys* larvae that are not shared with *Etropus* larvae include the absence of a pectoral melanophore (except possibly in *C. macrops*), less extensive internal notochordal pigmentation, and, later, more gill rakers. Except for a shallower body and smaller eyes, *C. arctifrons* larvae are morphologically similar to those of *C. cornutus* and *C. gymnorhinus*. *Etropus microstomus* larvae are similar to those of *E. crossotus*.

Larval Occurrence

Differences among distributions of larvae (Append. Table 5) can be helpful in identifying them to species. Months of occurrence of larvae reported here are those in which larvae have been collected throughout the ranges of the respective species (except that data for *C. macrops* are from the southern part of its range, and data for *C. arctifrons* and *C. arenaceus* are from the northern parts of their ranges). Because most sampling was not continuous throughout the year, presence in other months is not precluded; however, enough is known to delineate approximate spawning seasons for most of the species. Larval occurrence of *C. cornutus*, *C. gymnorhinus*, *C. spilopterus*, and *E. crossotus* was discussed in the earlier species' accounts.

Throughout their ranges, *E. microstomus* spawns from March through August and *E. rimosus* spawns from September to April (Leslie 1977). Leslie suggested that spawning of the two species may be temporally distinct. This conflicts with spawning of *E. microstomus* reported from May to December (Richardson and Joseph 1973), and my information is not sufficient to resolve this conflict. However, Scherer and Bourne (1980) collected *E. microstomus* eggs in September and larvae in October in Block Island Sound, which is north of the reported adult range (Table 1). In the eastern Gulf of Mexico, larvae of *E. rimosus* smaller than 4 mm NL were common in November, January, February, and May (Dowd 1978).

Small juveniles (≥13 mm SL) of *C. abbotti* were caught in the Gulf of Mexico from Veracruz to Campeche, Mexico, in June and September (Dawson 1969), indicating a spawning season approximately from May through August, or longer.

Citharichthys macrops larvae smaller than 4 mm NL were caught in the eastern gulf in May and November (Dowd 1978). Topp and Hoff (1972) reported juveniles from the same part of the gulf during the fall and winter. The season probably extends from May through November, and possibly longer.

Richardson and Joseph (1973) reported a spawning season approximately from May to December for *C. arctifrons* in the Chesapeake Bight, with peak spawning from July through October.

Dawson (1969) reported a 27 mm SL specimen of *C. arenaceus* caught in the British West Indies in November. This may indicate summer spawning, probably during August or September at least.

Citharichthys amblybregmatus and *C. dinoceros* are deepwater forms. Because of the constancy of their environment, they may have extended spawning seasons, but little is known of their habits.

Considering the geographic and bathymetric distributions of adults (Table 1) and probable spawning periods (Append. Table 5), it is unlikely that large numbers of larvae of different species of western North Atlantic *Citharichthys* and *Etropus* cooccur in the ichthyoplankton at any given time. Among the six deepwater species, *C. amblybregmatus* and *C. dinoceros* larvae probably occur relatively far from shore. Apparently, there is little difference between larval occurrence of *C. gymnorhinus* and *C. cornutus*, but spawning centers or peak periods could be distinct. Topp and Hoff (1972) suggested that adults of the two species were bathymetrically separated, *C. gymnorhinus* being found in shallower water. *Etropus rimosus* adults occur in shallow water and do not spawn during the summer. *Citharichthys arctifrons* has a more northern distribution than the preceding three species and its spawning peak is in the summer, probably earlier than that of *E. rimosus*. Among the three coastal species, the geographic range of *C. arenaceus* is distinct from those of the other two, and *C. macrops* and *E. microstomus* cooccur only off the Carolinas. In this area of overlap, *C. macrops* probably spawns in the fall and *E. microstomus* in the spring. Among the three estuarine and coastal species, *C. abbotti* spawns in the warmer months and may be restricted to very shallow water. *Citharichthys spilopterus* spawns in the colder months, beginning in late summer in the Gulf of Mexico and in mid to late fall off the Carolinas. *Etropus crossotus* may spawn from March through the summer, or later, in the gulf, but probably does not begin off the Carolinas until after most spawning activity of *C. spilopterus* is finished.

SUMMARY

The caudal fin formula (4-5-4-4) is the most reliable character for linking larval specimens to the group of paralichthyine genera *Citharichthys*, *Cyclopsetta*, *Etropus*, and *Syacium*.

The most useful characters for identification to genus are number of elongate dorsal rays, degree of cephalic spination, and pigmentation. Known western North Atlantic *Syacium* and *Cyclopsetta* larvae have 5-10 elongate dorsal rays and well-developed preopercular and frontal-sphenotic spines. Known western North Atlantic *Citharichthys* larvae have two or three elongate dorsal rays, small (or no) preopercular spines, small frontal-sphenotic spines, no pectoral melanophore (except possibly *C. macrops*), little notochordal pigmentation, usually large eyes and mouths, and (except for *C. arctifrons*) high gill raker counts. Known western North Atlantic *Etropus* larvae have no or two elongate dorsal rays, small preopercular and frontal-sphenotic spines, a melanophore at the base of the pectoral fin, extensive notochordal pigmentation, small eyes, and low gill raker counts.

Table 9 summarizes the most useful characters for distinguishing larvae of the six species of western North Atlantic *Citharichthys* and *Etropus* that have been described in detail. The best characters for determining species are number of elongate dorsal rays, number of caudal vertebrae, pectoral and notochordal pigmentation, number of left pelvic rays (*C. gymnorhinus*), head shape and snout to anus length (*C. spilopterus*), number of gill rakers, and length at transformation.

Citharichthys arctifrons larvae have three elongate dorsal rays, no preopercular spines, many caudal vertebrae, a small eye, large mouth, and few gill rakers. *Citharichthys cornutus* larvae have three elongate dorsal rays, a strong first left pelvic ray, heavy pigmentation, a large eye and mouth, and relatively many gill rakers. *Citharichthys gymnorhinus* larvae have three elongate dorsal rays, few caudal vertebrae, five left pelvic rays (with the first weak), a distinct caudal pigment band, large eye and mouth, and relatively many gill rakers. *Citharichthys spilopterus* larvae have two elongate dorsal rays, few caudal vertebrae, little pigmentation, a small eye and mouth, very blunt anterior profile, short snout to anus length, and relatively many gill rakers.

Etropus crossotus larvae have two elongate dorsal rays, heavy pigmentation, a small eye and mouth, and many (for the genus) gill rakers. *Etropus microstomus* larvae have no elongate dorsal rays, a small eye, and few gill rakers.

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TABLE 9.—The most useful characters, in order of ontogenetic appearance, for distinguishing larvae of four species of *Citharichthys* and two species of *Etropus*.

Character	*C. arctifrons*[1]	*C. cornutus*	*C. gymnorhinus*	*C. spilopterus*	*E. crossotus*	*E. microstomus*[1]
Pectoral melanophore (before transformation)	Absent	Absent	Absent	Absent	Present	Present
Notochordal pigment (before transformation)	Caudal only	Caudal only	Caudal only	Caudal only	From brain to caudal area	From brain to caudal area
Elongate dorsal rays (before transformation)	3	3	3	2	2	0
Caudal vertebrae	26-28	25-26	23-24	[2]23-24(25)	[2](24)25-26	[2]24-25(26)
Lateral pigment (before transformation)	Moderate	Heavy	Moderate	Light	Heavy	Moderate
Length at flexion (mm)	9	9-10	7-8	7-8	9-10	7
Left pelvic rays (full complement)	6	6	5	6	6	6
Left preopercular spines (during preflexion-flexion-postflexion)	0	14-31-22	17-22-31	31-31-16	17-20-11	Several
Eye diameter/BL in % (during preflexion-flexion-postflexion)	7	10-10- 8	9- 9- 9	10- 8- 7	7- 7- 6	7
Upper jaw length/BL in % (during preflexion-flexion-postflexion)	10	10-11-10	10- 9- 9	10- 7- 7	7- 7- 7	9
Lower jaw length/BL in % (during preflexion-flexion-postflexion)		13-14-13	12-13-13	12-10- 9	10-10-10	
Snout to anus length/BL in % (during preflexion-flexion-postflexion)	42	46-46-39	43-44-40	40-39-32	39-44-39	40
Gill rakers on the lower limb of the first arch (at transformation)	6- 8	10-15	9-14	9-15	6- 9	4- 7
Length at transformation (mm)	13-15	~18	~18	9-11	10-12	10-12
Snout spine (at about transformation)	May be present	Present (in males?)	Present (in males?)	Absent	Absent	Absent
Symphyseal spine (after transformation)	Absent	Present (in males?)	Present (in males?)	Absent	Absent	Absent

[1]Data for *C. arctifrons* and *E. microstomus* are mostly from Richardson and Joseph (1973).
[2]Uncommon counts given in parentheses.

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APPENDIX TABLE 1.—Frequency distributions of caudal vertebral counts for western North Atlantic species of *Citharichthys* and *Etropus*.[1]

Species	21	22	23	24	25	26	27	28	29	*N*	$\bar{X}$
C. abbotti	19	96	9							124	21.92
C. arenaceus	3	38	8							49	22.10
C. gymnorhinus			9	27						36	23.75
C. spilopterus			23	109	8					140	23.89
E. rimosus			3	50	53	5				111	24.54
E. microstomus				51	61	2				114	24.57
C. macrops				27	46					73	24.63
E. crossotus				1	69	15				85	25.16
C. cornutus					15	29				44	25.66
C. amblybregmatus					5	16				21	25.76
C. arctifrons						5	34	3		42	26.95
C. dinoceros						([2])			([2])		

[1]Compiled from Gutherz 1967; Dawson 1969; Gutherz and Blackman 1970; Leslie 1977; S. L. Richardson, Research Assistant Professor, School of Oceanography, Oregon State University, Corvallis, OR 97331, pers. commun. December 1976 (unpubl. data for *E. microstomus* and *C. arctifrons*); and original data for larvae, juveniles, and adults of *C. gymnorhinus*, *C. spilopterus*, *C. macrops*, *E. crossotus*, and *C. cornutus*.
[2]Extremes of counts.

APPENDIX TABLE 2.—Frequency distributions of anal fin ray counts for western North Atlantic species of *Citharichthys* and *Etropus*.[1]

Species	48	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	76	*N*	$\bar{X}$
C. arenaceus	([2])		1	11	8	14	9	3																	46	53.6
E. microstomus		([2])	1	1	2	8	14	22	32	31	23	15	6	5	([2])										160	57.5
C. gymnorhinus			2		4	3	3	9	13	6	10	3	2												55	56.8
C. abbotti				1	5	13	37	35	22	14	4	1													132	55.9
E. rimosus					1	5	5	17	25	42	57	57	38	41	16	6	1								311	59.5
C. spilopterus							([2])	15	24	30	41	26	11	4	([2])										151	58.6
C. macrops								1	1	6	2	5	17	16	13	12									73	61.6
E. crossotus										1	1	1	6	10	12	13	13	3		([2])					60	63.2
C. arctifrons										([2])		1	1	7	6	10	23	16	8	6	2	2	1		83	65.3
C. cornutus											([2])	3	2	7	4	6	3	1	1						27	63.0
C. amblybregmatus															1	3	2	3	1	9		1	2		22	67.0
C. dinoceros																						([2])		([2])		

[1]Compiled from Gutherz 1967; Dawson 1969; Gutherz and Blackman 1970; Topp and Hoff 1972; Leslie 1977; S. L. Richardson, Research Assistant Professor, School of Oceanography, Oregon State University, Corvallis, OR 97331, pers. commun. December 1976 (unpubl. data for *C. arctifrons*); and original data for juveniles and adults of *C. gymnorhinus*, *C. spilopterus*, *C. macrops*, *E. crossotus*, and *C. cornutus*.
[2]Extremes of counts, not included in totals.

APPENDIX TABLE 3.—Frequency distributions of dorsal fin ray counts for western North Atlantic species of *Citharichthys* and *Etropus*.[1]

Species	67	68	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	90	95	*N*	$\bar{X}$
E. microstomus	([2])	2	1	2	7	8	22	21	26	24	23	12	6	4	1	1	([2])						160	76.1
C. arenaceus		([2])	1	2	11	10	9	7	3	2													45	73.5
C. gymnorhinus			7	8	12	9	8	5	3	1													53	72.7
E. rimosus			2		8	16	18	43	57	52	48	40	17	4	4	1							310	76.7
C. abbotti					1	5	13	23	30	23	23	11	2	1									132	76.4
C. spilopterus						1	4	4	14	35	32	24	26	11	5	1		1					158	78.3
C. cornutus							1	1	1	3	5	8	6	5	1	1	1						33	79.2
C. macrops							1	1	1	1		3	9	10	12	12	11	8	3				72	82.1
C. arctifrons								1	1	3	8	8	14	14	17	7	2	3	3	2			83	81.0
E. crossotus								([2])	3	2	8	12	10	11	8	6			1	([2])			61	80.1
C. amblybregmatus											2	3	1	2	6	3	2	1	2				22	81.9
C. dinoceros																					([2])	([2])		

[1]Compiled from Gutherz 1967; Dawson 1969; Gutherz and Blackman 1970; Topp and Hoff 1972; Leslie 1977; Sopher, T. R., a meristic and morphometric study of geographic populations of *Etropus microstomus*. Unpubl. manuscr., 5 p., Virginia Institute of Marine Science, Gloucester Point, VA 23062; S. L. Richardson, Research Assistant Professor, School of Oceanography, Oregon State University, Corvallis, OR 97331, pers. commun. December 1976 (unpubl. data for *C. arctifrons*); and original data for juveniles and adults of *C. gymnorhinus*, *C. spilopterus*, *C. cornutus*, *C. macrops*, and *E. crossotus*.
[2]Extremes of counts, not included in totals.

APPENDIX TABLE 4.—Ranges of number of gill rakers on the lower limb of the first arch for western North Atlantic species of *Citharichthys* and *Etropus*.[1]

Species	Range	Species	Range
E. rimosus	3-7	*C. spilopterus*	9-15
E. microstomus	4-7	*C. cornutus*	10-15
C. arctifrons	6-8	*C. arenaceus*	12-15
E. crossotus	6-9	*C. macrops*	12-16
C. dinoceros	7-10	*C. abbotti*	13-16
C. gymnorhinus	9-14	*C. amblybregmatus*	18-24

[1]Compiled from Gutherz 1967; Dawson 1969; Gutherz and Blackman 1970; and Topp and Hoff 1972.

APPENDIX TABLE 5.—Probable spawning seasons of seven species of *Citharichthys* and three species of *Etropus*.[1] Estuarine = usually found in estuaries and shallow coastal waters<40 m; Shallow = usually found in shallow coastal waters<40 m, rarely in estuaries; Intermediate = usually found at 30-140 m depths, rarely shallower; Deep = usually found deeper than 140 m, seldom shallower.

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Adults occur	Larvae occur
C. gymnorhinus	×	×	×	×	×	×	×	×		×	×		Intermediate	Offshore
C. cornutus	×	×	×	×	×	×	×	×		×	×		Deep	Offshore
E. crossotus			×	×	×	×	×	×					Estuarine	Offshore and in estuaries
E. microstomus			×	×	×	×	×	×	×				Shallow	Offshore
C. abbotti					+	+	+	+					Estuarine	?
C. macrops					×	+	+	+	+		×		Shallow	Offshore
C. arctifrons					×	×	×	×	×	×	×	×	Intermediate (and Deep)	Offshore
C. arenaceus									+				Shallow	?
C. spilopterus	×	×	×	×					×	×	×	×	Estuarine	Offshore and in estuaries
E. rimosus	×	×	×	×	×				×	×	×	×	Intermediate	Offshore
C. amblybregmatus						?							Deep	Offshore?
C. dinoceros						?							Deep	Offshore?

[1]Compiled from Dawson 1969; Topp and Hoff 1972; Richardson and Joseph 1973; Leslie 1977; Dowd 1978; Scherer and Bourne 1980; and unpublished data from collections of South Carolina Marine Resources Research Institute, Louisiana State University, North Carolina State University, and Texas A&M University. × = times based on collections of larvae and ripe females, + = times based on collections of juveniles.