EGG AND LARVAL DEVELOPMENT OF THE SPOT, *LEIOSTOMUS XANTHURUS* (SCIAENIDAE)[1]

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ABSTRACT

The egg and larval development of the spot, *Leiostomus xanthurus*, was described mainly from laboratory-reared specimens. Egg diameters averaged 0.80 mm and ranged from 0.72 to 0.87 mm. The number of oil globules varied, but coalesced during development. Oil globule diameters of eggs with one globule averaged 0.21 mm and ranged from 0.18 to 0.28 mm. Newly hatched larvae measured 1.6-1.7 mm standard length, had a single oil globule located at the posterior margin of the yolk sac, and were inconspicuously pigmented. Late yolk-sac larvae developed a characteristic pigment pattern of a single row of melanophores along the ventral midline that persisted throughout the larval period. An important pigment pattern—embedded pigment at the anterior of the gut—was first observed in clear and stained late flexion larvae (2.9 mm standard length). Vertebrae and anal fin pterygiophore counts were considered useful in separating spot from other sciaenids. Vertebral counts (25) were established by 4.6 mm standard length, and precaudal (10) and caudal (15) vertebrae were recognized at 5.1 mm standard length. Anal fin pterygiophores which numbered two fewer than the number of anal fin elements were established at 6.3 mm standard length.

The spot, *Leiostomus xanthurus* (Lacépède), is a commercially important sciaenid found along the Northwest Atlantic and Gulf of Mexico coasts from Massachusetts Bay to the Bay of Campeche (Johnson 1978). Spot spawns in offshore waters during late fall and early winter, throughout its range (Hildebrand and Cable 1930; Nelson 1969). The larvae are transported towards shore and into estuaries which serve as nursery areas (Fahay 1975; Chao and Musick 1977).

The eggs and yolk-sac larvae of spot have not been described. Pearson (1929) briefly described larvae ranging from 7 to 15 mm. Hildebrand and Cable (1930) described larvae in greater detail and attempted to distinguish spot larvae from morphologically similar larvae of Atlantic croaker, *Micropogonias undulatus* (the generic name change from *Micropogon* follows Chao 1978). Hildebrand and Cable (1934) summarized early life history data for 13 species of sciaenids, including spot, but the keys they prepared were limited since the early developmental stages for many species were unknown. Lippson and Moran (1974) and Johnson (1978) summarized early life history studies on sciaenids and included previously unpublished illustrations useful in separating spot and croaker larvae. Fruge and Truesdale (1978) and Powles and Stender (1978) described developmental stages of spot larvae from the Gulf of Mexico and the South Atlantic Bight. Fruge and Truesdale provided comparative data useful for separating larvae of spot from larvae of Atlantic croaker, while Powles and Stender emphasized characters useful in separating early sciaenid larvae.

In this paper we describe the life history of spot from egg to juvenile, using the dynamic approach of Ahlstrom and Ball (1954). Our objective is to provide descriptive information useful in identification and classification, as patterns of larval development and larval anatomical features may provide keys to possible relations among groups (Aprieto 1974). Furthermore, studies of variations of these patterns and features could provide keys to how environmental factors may affect larval development.

METHODS

Spot used for spawning were collected from a commercial long-haul seine in Back Sound off Harkers Island, N.C., during their spawning migration to the ocean. Eggs were obtained from fish using an induced spawning technique developed

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by Hettler et al.[3] This technique allows for a voluntary release of ova by females injected with human chorionic gonadotropin (HCG) and sperm by uninjected males. The quality of eggs produced by this technique is far superior to injecting HCG and manually removing and mixing gametes. The rotifer *Brachionus plicatilis*, cultured in the laboratory, was used as food for spot larvae till they were approximately 30 d old. Zooplankton captured from the field and predominated by copepod nauplii and copepodites were sporadically included in their diets during this period. Newly hatched *Artemia* nauplii were used as food for larvae older than about 30 d. Eggs and larvae were maintained at temperatures and salinities of ca. 20° C and ca. 30-35‰. Some advanced larvae and juveniles were collected with a modified neuston net (Hettler 1979) near Beaufort, N.C.

Two developmental series of larvae were used. Specimens in the first series were used for compiling morphometric data, describing pigment patterns and illustrating larval stages. Those in the second series were cleared with trypsin, stained with a combination of alcian blue and alizarin red according to Dingerkus and Uhler (1977), and Taylor and Van Dyke[4] and used for meristic studies. Egg stages follow those described by Ahlstrom and Ball (1954). The embryonic period was divided into three stages: early (fertilization to blastopore closure), middle (from blastopore closure until the tail twists out of the plane of the embryonic axis), and late (from tail twisting to hatching). Larval stages followed those described by Ahlstrom et al. (1976). The larval period was separated into the preflexion, flexion, and postflexion stages associated with the development of the caudal fin; the stages occurring before, during, and after the upward flexion of the notochord tip. We also included a yolk-sac stage, which we believed should be treated separately.

Pterygiophore nomenclature followed Houde and Potthoff (1976). Nominal, full complement counts were taken from Johnson (1978), although we obtained pectoral ray counts directly from 15 specimens (University of North Carolina; UNC 563). Measurements from eggs and larvae preserved in 5% buffered Formalin[5] are identified as follows:

Standard length (SL) — in preflexion and flexion larvae, the horizontal distance from the tip of the snout to the tip of the notochord. In postflexion larvae, from the tip of the snout to the base of the hypural plate.

Preanus length — horizontal distance from the tip of the snout to the posterior part of the anus.

Head length — horizontal distance from the tip of the snout to the posterior margin of the otic capsules in yolk-sac larvae and the horizontal distance from the tip of the snout to the opercular margin in other larvae and juveniles.

Snout length — horizontal distance from the tip of the snout to the anterior margin of the pigmented region of the eye.

Eye diameter — maximum horizontal width of the pigmented eye.

Body depth — the vertical depth of the body measured at the pectoral fin base exclusive of the finfold.

RESULTS

Embryonic Development

General

Spot eggs are pelagic. The chorion was transparent and unsculptured. The yolk was unsegmented, unpigmented, and the perivitelline space narrow in live eggs. Oil globules were yellow. We have obtained batches of eggs with almost all single oil globules, almost all multiple oil globules, or a gradient between these conditions. Batches of eggs with single oil globules occurred most commonly. When oil globules were multiple, they were grouped together and not scattered throughout the yolk. The maximum number of oil globules observed was 12. Oil globules coalesced during egg development and it appeared that only one oil globule was present on newly hatched larvae. Egg diameter averaged 0.80 mm and ranged from 0.72 to 0.87 mm ($N = 265$). Oil globules, from eggs with one oil globule, averaged 0.21 mm in diameter and ranged from 0.18 to 0.28 mm ($N = 86$). The eggs hatched in about 48 h at 20° C.

[3]Hettler, W. F., A. B. Powell, and L. C. Clements. 1978. Laboratory induced spawning of spot, *Leiostomus xanthurus* (Lacepede). Annual Report of the Beaufort Laboratory to the U.S. Department of Energy, p. 351-356.

[4]Taylor, W. R., and G. C. Van Dyke. 1978. Staining and clearing small vertebraes for bone and cartilage study. Unpubl. manuscr., 19 p. National Museum of Natural History, Washington, DC 20560.

[5]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Early Stage Eggs

Pigment was never observed on the embryo or oil globule of early stage eggs. By the end of the early stage, when the blastopore was reduced to a small opening, optical vesicles were discernible, there were no visible myomeres, and the oil globule was situated adjacent to the blastopore, slightly posterior to the tail.

Middle Stage Eggs

Pigment first appeared on the embryo and oil globule during the middle stage (Figure 1A). Melanophores, which were mainly punctate, were scattered on the dorsal and lateral surface. Pigment was sparse or missing from the snout and on the posterior one-fourth of the body and was never present near the notochord tip. Melanophores appeared to be most dense in an area about one-third the body length from the snout. At the end of the middle stage, dendritic melanophores were more common and the pigment pattern was transitional from that illustrated for middle and late stage embryos (Figure 1). Also at this stage melanophores were relatively more dense on the dorsal surface of the head just posterior to the eyes and appeared to migrate laterally to form, eventually, a longitudinal row of dorsolateral melanophores. Initially, melanophores occurred on the posterior surface of the oil globule, but by the end of the middle stage they were located on the anterodorsal surface.

Late Stage Eggs

The embryos of late stage eggs developed a characteristic pigment pattern (Figure 1B) similar

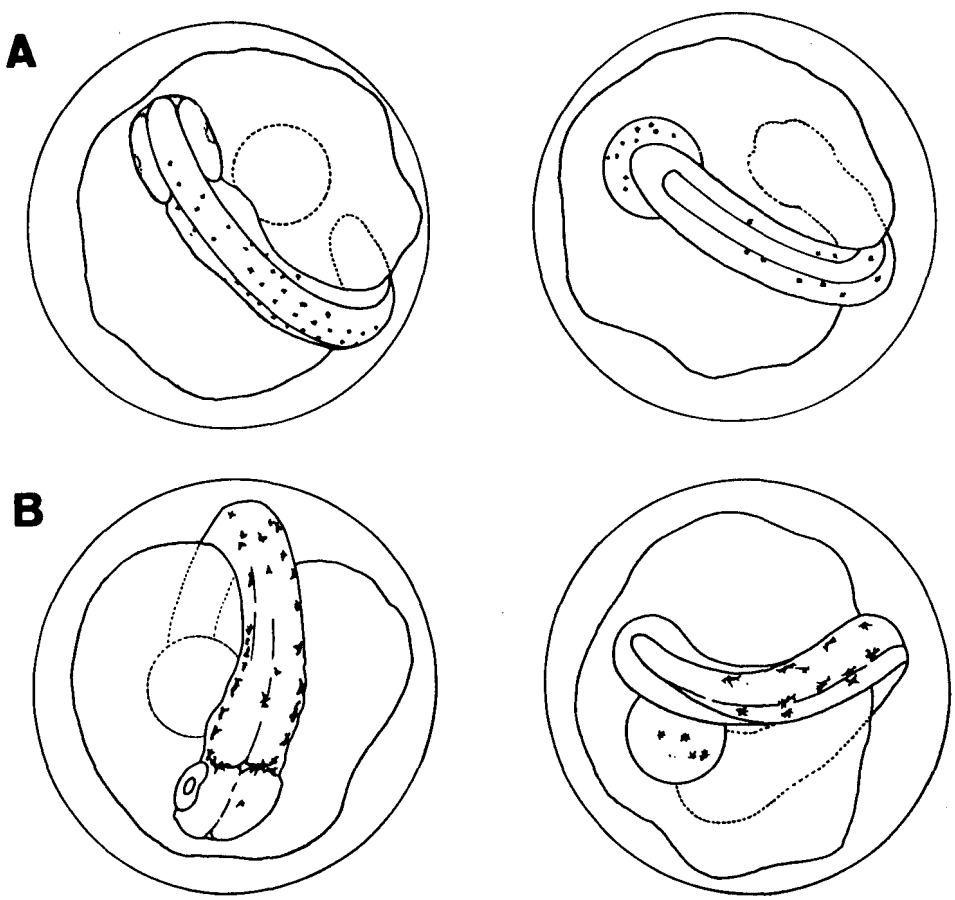

FIGURE 1.—Eggs of *Leiostomus xanthurus*: A, middle stage; left, the anterior part of embryo, right, the posterior part of embryo; B, late stage: left, the anterior part of embryo, right, the posterior part of embryo.

to that of Atlantic mackerel, *Scomber scombrus* (Berrien 1975). Melanophores on late stage eggs were relatively more dendritic than on earlier stage eggs. A row of dorsolateral melanophores on each side of the body extended from the posterior edge of the eyes posteriad. At about midbody, melanophores scattered over the dorsal surface disrupted this row of dorsolateral melanophores. Additional melanophores, which formed a transverse row across the head just posterior to the eyes were commonly observed. In the head region, anterior to the eyes and on the posterior portion of the body, melanophores were sparse. They were never observed on the posterior portion of the body near the notochord tip. Melanophores on the surface of the oil globule were located anteriorly.

Larval Development

Body Proportions

Newly hatched larvae measured 1.6-1.7 mm SL. A single oil globule was situated near the posterior margin of the yolk sac. The anterior portion of the body was arched over the yolk sac, but straightened out at ca. 2.0 mm SL (Figure 2). The yolk sac and oil globule were absorbed within 5 d at 20° C.

Most body proportions changed gradually during ontogeny except during very early development, when abrupt changes were observed. At this time, the head length, preanus length, body depth, and snout length became proportionately greater (Figures 3-5). On the other hand, the eye diameter, relative to the head length, became proportionately smaller with increasing body length (Figure 5A).

The most striking change in body shape was the development of the robust head which characterizes sciaenid larvae (Lippson and Moran 1974). This change, as revealed by an increase in the head length to body length ratio, occurred during the transition from the yolk sac to the preflexion stage, a time when little increase in body length occurred (Figure 3B).

Body proportions of larvae collected from the South Atlantic Bight (Powles and Stender 1978) and our laboratory-reared larvae are in good agreement, except that laboratory-reared larvae may be slightly more robust, especially those >7.0 mm SL. Fourteen percent of our laboratory-reared larvae (>7.0 mm SL) and 60% of our laboratory-reared juveniles (>14.4 mm SL) had body depths greater than the maximum (29.3%) reported by Powles and Stender (1978).

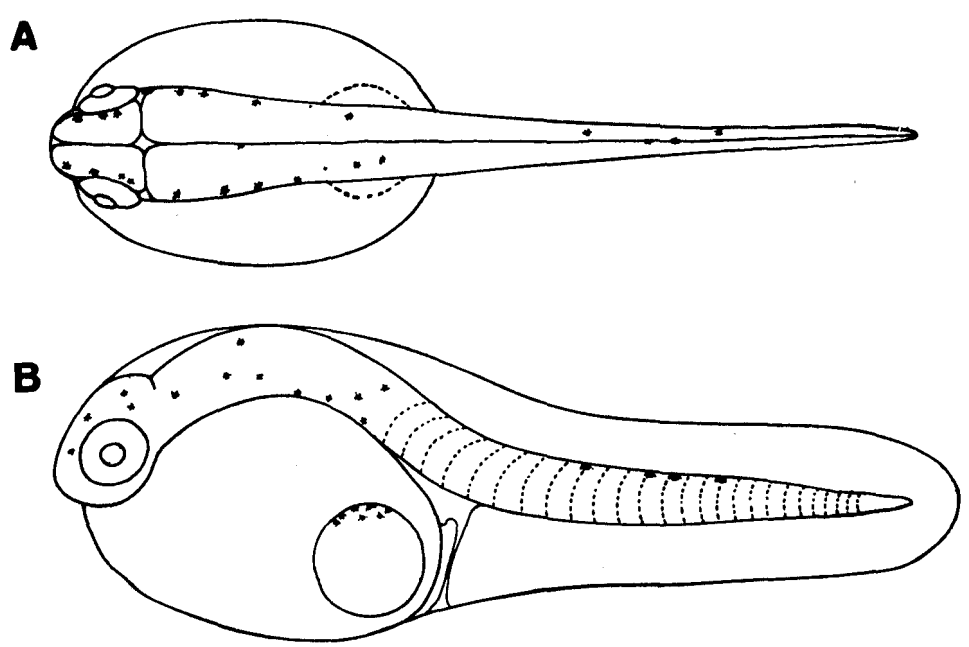

FIGURE 2.—Newly hatched *Leiostomus xanthurus*: A, dorsal view; B, lateral view.

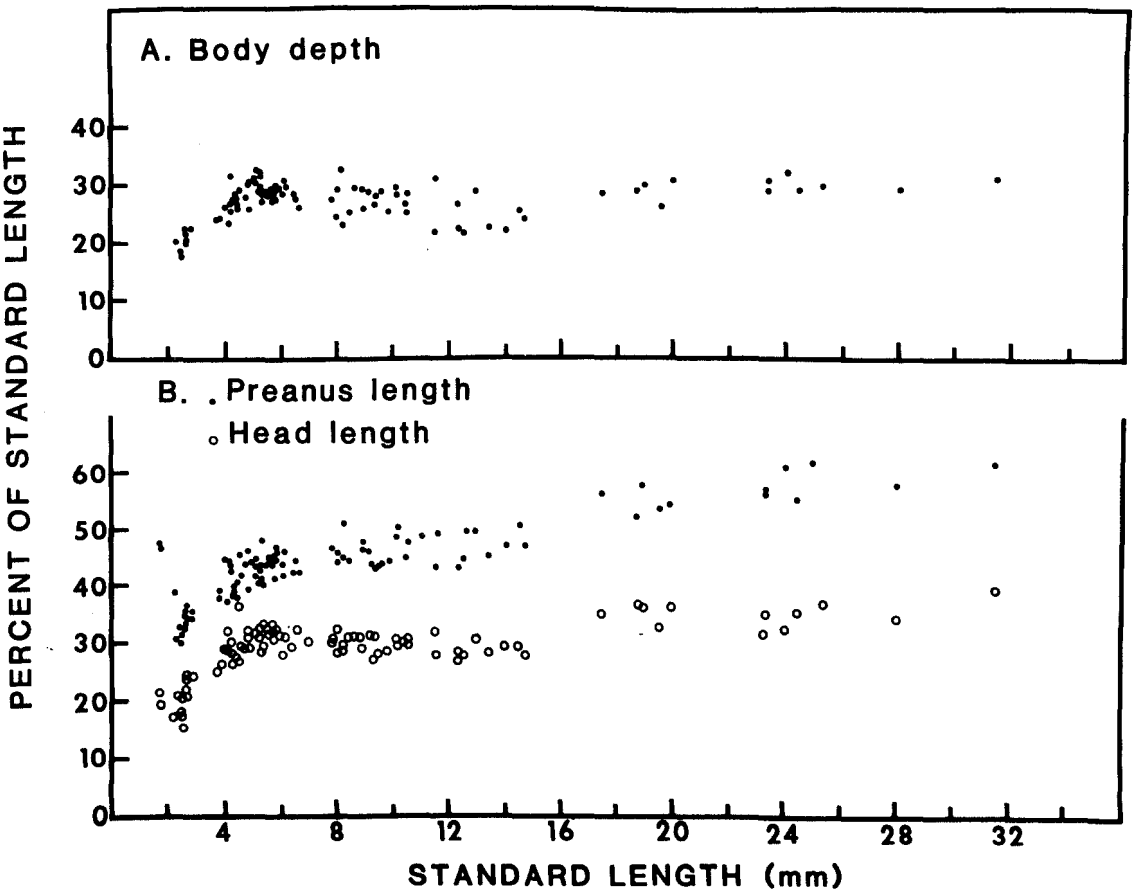

FIGURE 3.—Body proportions of *Leiostomus xanthurus* relative to the standard length: A, body depth; B, preanus length and head length.

Fin Development (Table 1)

Rayed fins initiated development in the following sequence: caudal, anal, second dorsal, first dorsal and pectoral, and pelvic. The adult complement of spines and rays was attained in the following sequence: principal caudal rays (9 upper + 8 lower), anal (II, 12-13), second dorsal (I, 29-35), first dorsal (IX-XI) and pelvic (I,5), secondary caudal rays (6-8 upper and lower), and pectoral (20-22).

A thickened area of tissue on the ventral side of the notochord was the first indication of caudal fin development (Figure 6). The rays began to form at the middle of the fin and developed dorsally and ventrally simultaneously. Principal caudal rays developed rapidly. They were first visible at 4.6 mm SL and by 65.3 mm SL the adult complement (9 upper + 8 lower), which is shared by all sciaenids, was reached. On the other hand, secondary caudal rays were slow to form. All specimens ≥14.4 mm SL had a complete caudal fin.

Dorsal fin rays started to form near the middle of the fin, between the 8th and 17th vertebrae, then developed anteriorly and posteriorly simultaneously. Soft rays were first observed at 6.7 mm SL. A full complement of second dorsal fin spines and soft rays was attained at 8.8 mm SL. A full complement of first dorsal fin spines was attained at 9.0 mm SL, and although the second dorsal on that particular larvae had a ray count within the adult range, the last soft ray was not formed. All specimens ≥10.8 mm SL had a complete dorsal fin. All our specimens had a first dorsal fin of 10 spines.

Anal fin rays started to form near the middle of the fin, between the 11th and 15th vertebrae, and then developed rapidly anteriorly and posteriorly. Soft rays were first observed at 6.3 mm SL and

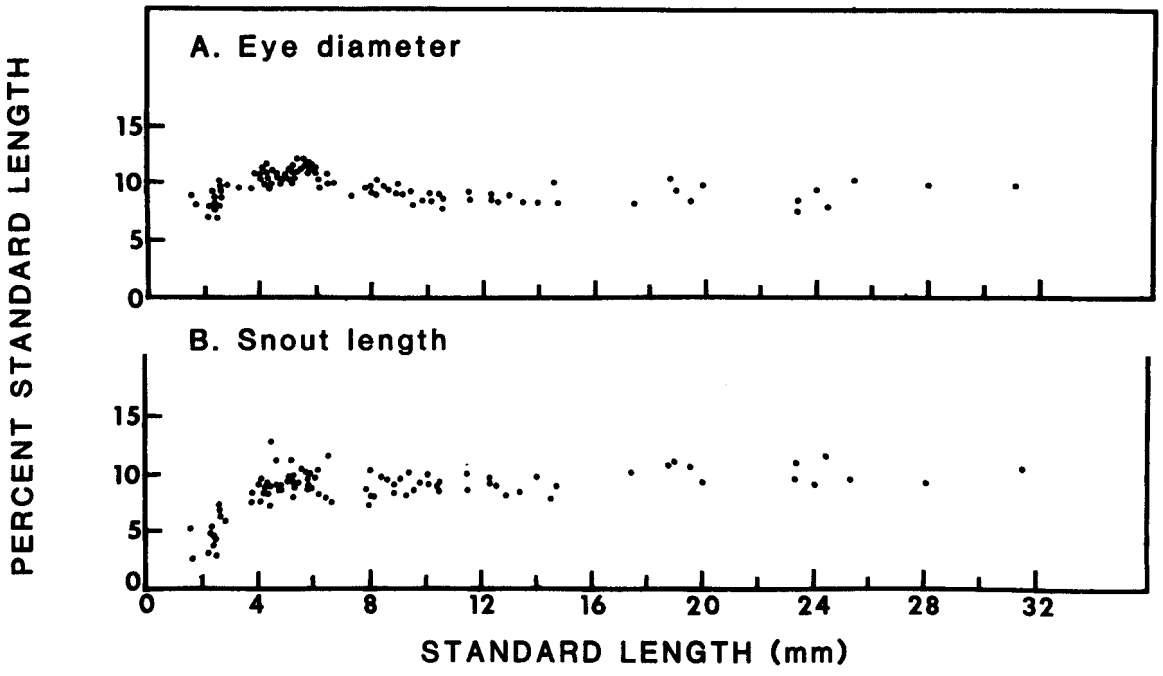

FIGURE 4.—Body proportions of *Leiostomus xanthurus* relative to the standard length: A, eye diameter; B, snout length.

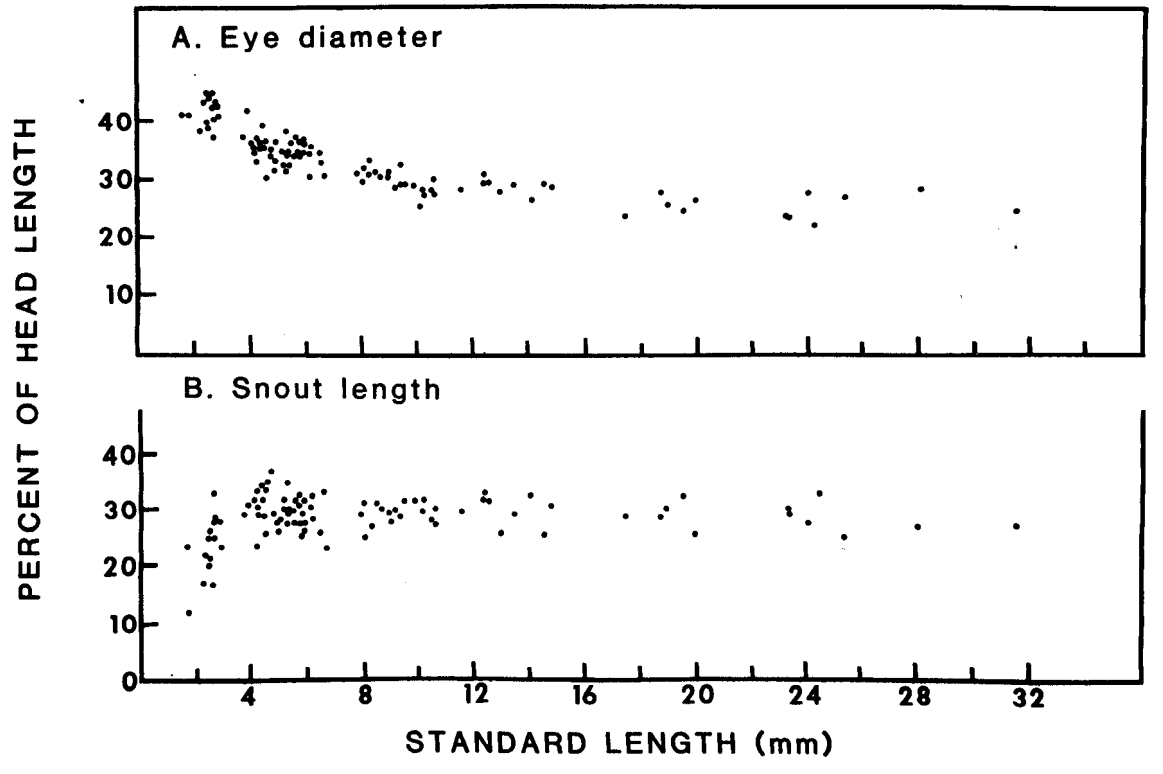

FIGURE 5.—Body proportions of *Leiostomus xanthurus* relative to the head length: A, eye diameter; B, snout length.

TABLE 1.—Meristic data from cleared and stained larval and juvenile *Leiostomus xanthurus*. Standard lengths suffixed with W indicate wild-caught specimens. All others are laboratory reared.

Standard length (mm)	Dorsal fin	Anal fin	Pelvic fin	Left pectoral fin[1]	Principal caudal rays[2]	Secondary caudal rays[2]	Branchiostegal rays	Gill rakers (left first arch)		
								Epibranchial	Ceratobranchial	Hypobranchial
2.3	—	—	—	LF	—	—	—	—	—	—
2.7	—	—	—	LF	—	—	—	—	—	—
3.0	—	—	—	LF	—	—	—	—	—	—
3.7	—	—	—	LF	—	—	3	—	—	—
4.4	—	—	—	LF	—	—	5	—	—	—
4.6	—	—	—	LF	3+3	—	6	—	—	—
4.7	—	—	—	LF	—	—	6	—	—	—
5.1	—	—	Bud	LF	7+7	—	6	—	4	—
5.5	—	—	Bud	LF	7+7	—	6	—	4	—
5.5	—	—	Bud	LF	6+6	—	7	—	6	—
5.7	—	—	Bud	LF	8+7	—	6	—	6	—
6.3	—	6	Bud	LF	9+8	0+1	7	2	8	—
6.7	18	10	Bud	LF	9+8	1+1	7	1	8	—
6.8	14	7	Bud	LF	9+8	1+1	7	—	7	—
6.9	20	I,10	Bud	LF	9+8	1+2	7	2	8	—
7.9	23	I,11	Bud	LF	9+8	2+1	7	1	8	—
8.0	VIII,I,23	I,13	Bud	4	9+8	2+2	7	1	9	—
8.2	IX,I,26	II,12	I,3	7	9+8	2+2	7	3	11	—
8.4	IX,I,27	II,12	I,3	7	9+8	3+3	7	2	10	—
8.8	VIII,I,29	II,12	I,1	5	9+8	2+2	7	2	9	—
8.9	VIII,I,28	II,12	I,2	5	9+8	3+2	7	2	9	—
9.0	X,I,29	II,13	I,5	10	9+8	3+3	7	([3])	([3])	([3])
9.5	IX,I,30	II,12	Bud	5	9+8	2+2	7	2	9	—
9.7	IX,I,31	II,13	I,3	9	9+8	3+3	7	3	10	—
10.0	IX,I,31	II,12	I,4	10	9+8	3+2	7	3	10	—
10.8W	X,I,31	II,12	I,5	14	9+8	4+4	7	5	12	—
12.9	X,I,31	II,13	I,5	15	9+8	5+5	7	5	13	—
14.4	X,I,30	II,12	I,5	18	9+8	6+6	7	6	13	1
14.4	X,I,30	II,13	I,5	20	9+8	7+7	7	7	13	3
15.0	X,I,30	II,13	I,5	19	9+8	6+6	7	6	13	1
16.0	X,I,30	II,12	I,5	22	9+8	8+8	7	8	13	4
16.6W	X,I,31	II,12	I,5	20	9+8	7+7	7	8	13	2
17.7W	X,I,29	II,12	I,5	21	9+8	7+6	7	9	13	3
18.5W	X,I,31	II,12	I,5	21	9+8	7+7	7	7	13	4
19.1W	X,I,31	II,12	I,5	21	9+8	8+7	7	9	13	4
19.6W	X,I,29	II,12	I,5	21	9+8	7+7	7	9	13	4
20.1W	X,I,30	II,13	I,5	20	9+8	7+7	7	9	13	4
21.5W	X,I,31	II,12	I,5	22	9+8	7+7	7	8	13	5
48.0W	X,I,32	II,12	I,5	22	9+8	8+7	7	12	13	8

[1]LF designates larval fin.
[2]Upper + lower.
[3]Damaged.

spines at 6.9 mm SL. All specimens ≥8.2 mm SL had a completely developed anal fin.

The pelvic fin appeared as a bud at 5.1 mm SL. All specimens ≥10.8 mm SL had a completely developed pelvic fin. The fin formula I,5 is typical among sciaenids.

The pectoral, the last fin to develop a full complement of rays, persisted as a rayless blade for a relatively long period. Rays began to appear at 8.0 mm SL at the dorsal position of the blade and then developed ventrally. All specimens ≥16.0 mm SL had a complete pectoral fin.

Fin development, relative to body length of larvae, collected from the South Atlantic Bight (Powles and Stender 1978) was similar to fin development of laboratory-reared larvae, but spot larvae collected from the Gulf of Mexico (Fruge and Truesdale 1978) began and completed fin development at a much smaller size (Table 2). Rate of fin development could be influenced by temperature. Size at hatching, at least, has been shown to be influenced by incubation temperature (Laurence and Rogers 1976).

TABLE 2.—The size (mm SL) when fins and associated structures begin and complete development for laboratory-reared spot (this study), spot collected from the South Atlantic Bight (Powles and Stender 1978) and spot collected from the Gulf of Mexico (Fruge and Truesdale 1978).

Fin or associated structure	Begins formation			Completes formation		
	Powles and Stender (1978)	Fruge and Truesdale (1978)	This study	Powles and Stender (1978)	Fruge and Truesdale (1978)	This study
Notochord flexion	4.4	4-5	3.8	4.7	4-5	5.3
Caudal fin:						
Principal rays	4.5	3	4.6	7.2	5	6.3
Secondary rays	6.2	5	6.3	15.5	>10.7	14.4
Anal fin pterygiophores	4.4	—	5.5	6.2	—	6.3
Anal fin	7.2	5	6.3	9.3	7	8.2
Dorsal fin:						
Pterygiophores	4.4	—	5.1	—	—	7.3
Second	7.2	5	6.7	9.3	8	8.8
First	7.2	7	8.0	14.1	9	10.8
Pelvic fin bud	5.2	5-6	5.1	—	—	—
Pelvic fin	8.0	6	8.2	10.7	7-9	10.8
Pectoral fin	10.7	7	8.0	16.8	>10.7	16.0

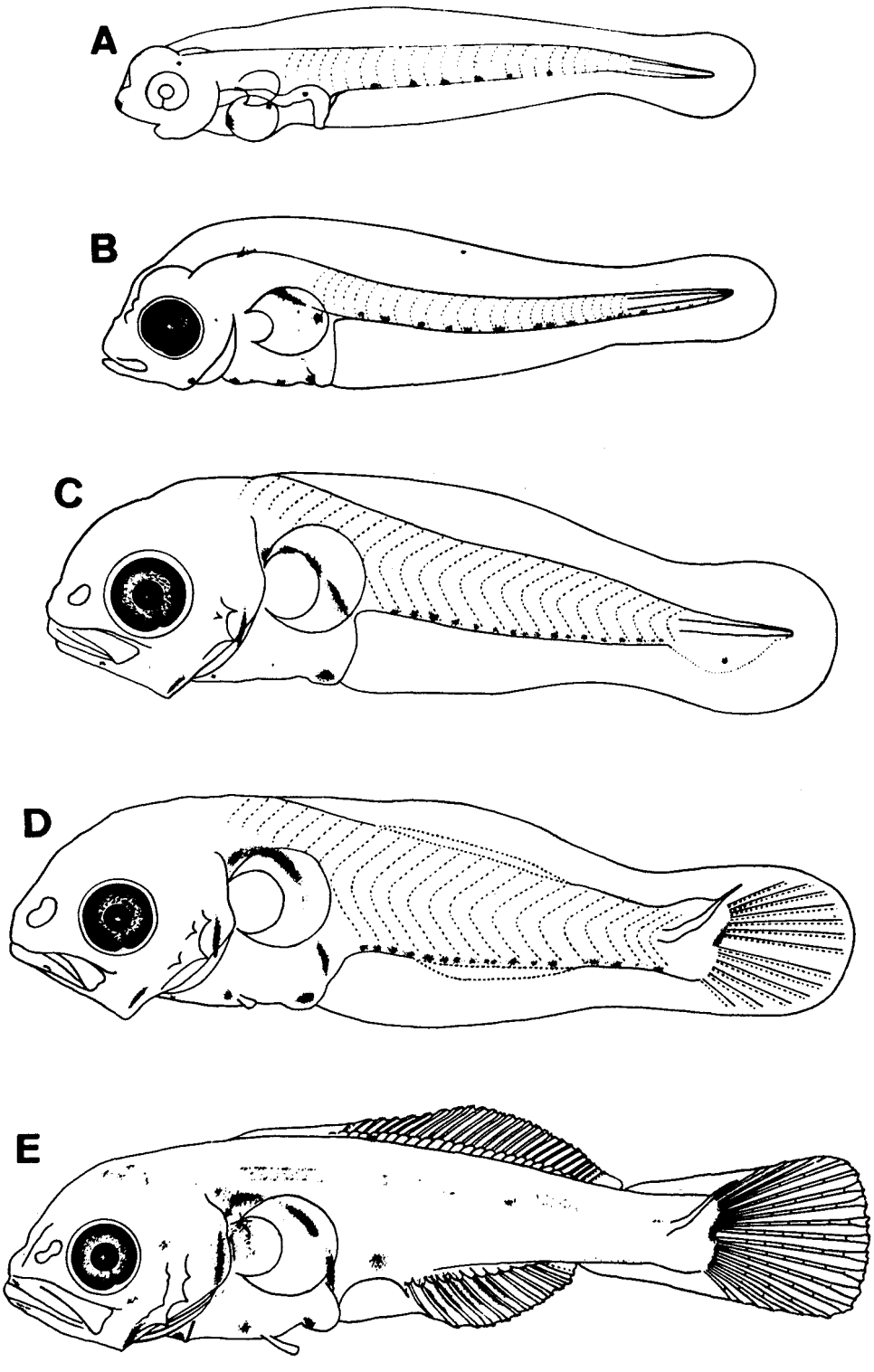

FIGURE 6.—Developmental stages of *Leiostomus xanthurus*: A, 2.4 mm SL late yolk-sac larva; B, 2.6 mm SL preflexion larva; C, 4.1 mm SL early-flexion larva; D, 5.2 mm SL postflexion larva; E, 8.0 mm SL postflexion larva.

Pterygiophore Development and Arrangements

Fully developed spot had three predorsal bones which did not support spines (Figure 7): One such bone was located between the skull and first neural spine, one between the first and second neural spines, and one between the second and third neural spines. They began to develop at 5.7 mm SL, anteroposteriorly, and the full complement was recognizable at 8.2 mm SL (Figure 8).

There were two fewer pterygiophores than dorsal fin elements (spines and soft rays) on fully developed spot. The anteriormost pterygiophore was associated with three spines (Figure 7). It was secondarily associated with the first two spines and serially associated with the third spine. All other pterygiophores were serially associated with one dorsal fin element and secondarily associated with a preceding element.

Dorsal fin pterygiophores were first apparent at 5.1 mm SL between neural spines 9 through 14 and development proceeded anteriorly and posteriorly simultaneously (Figure 8). The adult complement was achieved at 8.2 mm SL.

Although there was a variable number of dorsal pterygiophores between neural spines (Table 3), a nearly consistent pattern was observed (Figure 7). The formula[6]

P / P / P+1 / 2 / 1 / 2 / 1 / 2 / 2 /

[6]Each P represents a predorsal bone, each slant a neural spine and the numerals indicate the number of pterygiophores between neural spines.

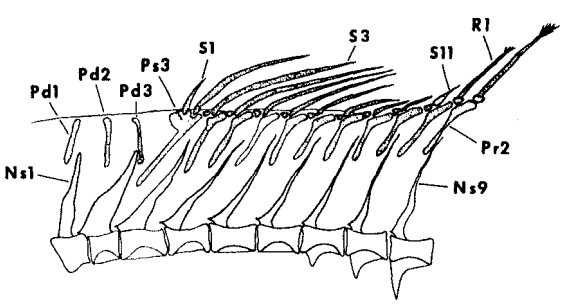

FIGURE 7.—Arrangement of predorsal bones, and the first 11 dorsal fin pterygiophores in relation to neural spines for *Leiostomus xanthurus* (19.6 mm SL). Spine S11 is the first spine of the second dorsal fin. Ps3, represents the pterygiophore in serial association with the third dorsal spine; Pr2, the pterygiophore in serial association with the second ray of the second dorsal fin; S1, the first spine on the first dorsal fin; R1, the first ray on the second dorsal fin; Ns1, the neural spine on the first centrum; and Pd, the predorsal bones.

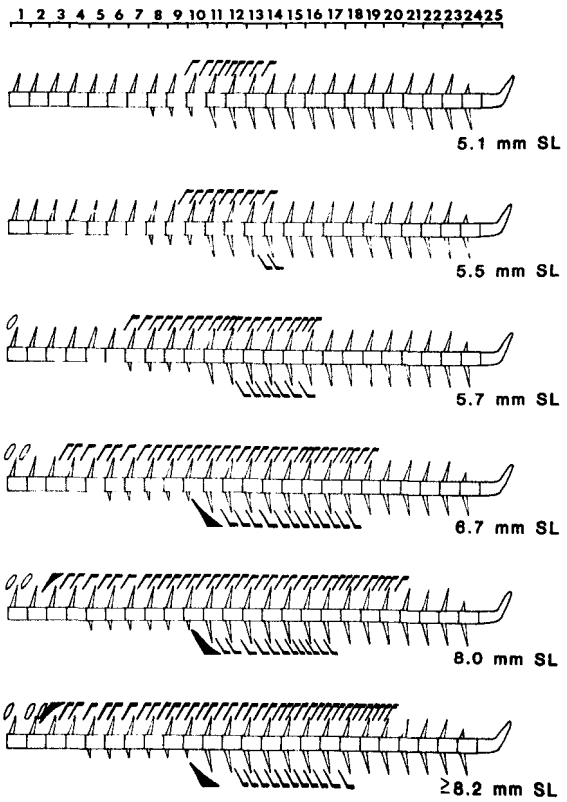

FIGURE 8.—Schematic representation of the development of predorsal bones (unshaded), and dorsal and anal fin pterygiophores (darkened) in *Leiostomus xanthurus*.

TABLE 3.—Frequencies of dorsal fin pterygiophores between neural spines in 23 *Leiostomus xanthurus* (8.2-48.0 mm SL).

Neural spine number	No. of pterygiophores between neural spines					Neural spine number	No. of pterygiophores between neural spines				
	0	1	2	3	4		0	1	2	3	4
2-3	—	23	—	—	—	12-13	—	—	19	4	—
3-4	—	1	22	—	—	13-14	—	—	17	6	—
4-5	—	22	1	—	—	14-15	—	—	10	13	—
5-6	—	1	22	—	—	15-16	—	—	15	8	—
6-7	—	21	2	—	—	16-17	—	—	11	12	—
7-8	—	—	23	—	—	17-18	—	—	9	14	—
8-9	—	—	23	—	—	18-19	—	—	2	21	—
9-10	—	1	20	2	—	19-20	—	1	—	16	6
10-11	—	—	21	2	—	20-21	11	9	2	—	1
11-12	—	—	13	10	—						

occurred in 87% of our 23 specimens. We also observed that in 96% of those specimens the anteriormost pterygiophore between neural spines 7 and 8 was serially associated with the last spine of the first dorsal fin (Figure 7).

Fully developed spot had two fewer pterygiophores than anal fin elements. Like the dorsal fin, the anteriormost anal fin pterygiophore was as-

sociated with three elements (Figure 9). It was secondarily associated with the first two spines and serially associated with the first ray. All other pterygiophores were serially associated with one anal fin ray and secondarily associated with a preceding ray. In the largest specimen (48.0 mm SL) a stay was associated with the last anal fin pterygiophore.

The number of anal fin pterygiophores between haemal spines was highly variable. The first pterygiophore, however, always occurred, singly, between the last precaudal vertebra (number 10) and the first caudal vertebra (number 11) (Table 4).

Anal fin pterygiophores were first observed at 5.5 mm SL (Figure 8). Development began between haemal spines 3 and 4 and proceeded anteriorly and posteriorly simultaneously. Development was rapid. The adult complement was reached at 6.3 mm SL.

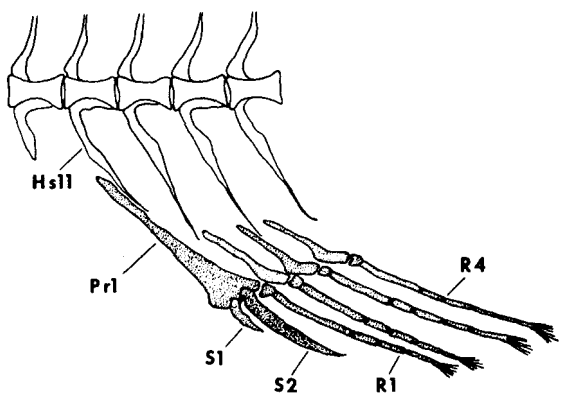

FIGURE 9.—Arrangement of the first four anal fin pterygiophores in relation to haemal spines for *Leiostomus xanthurus* (19.6 mm SL). Pr1, pterygiophore in serial association with the first anal fin ray; Hs11, the first haemal spine on the 11th centrum; S, anal spine; R, anal ray.

Other Structures

Centra were not fully differentiated until ca. 9 mm SL, but the adult complement of vertebrae (25, including urostyle) was determined from larvae as small as 4.6 mm SL by counting combinations of neural spines and myosepta (Figure 10A). Precaudal vertebrae (10) were differentiated from caudal vertebrae (15) in larvae as small as 5.1 mm SL (Figure 10B). The first caudal vertebra was easily identified as its haemal spine was approximately three times longer than the preceding parapophysis.

TABLE 4.—Frequencies of anal fin pterygiophores between haemal spines in 30 *Leiostomus xanthurus* (5.7-40.8 mm SL).

Haemal spine number	No. of pterygiophores between haemal spines				Haemal spine number	No. of pterygiophores between haemal spines			
	0	1	2	3		0	1	2	3
10-11	—	30	—	—	14-15	—	1	28	1
11-12	19	10	1	—	15-16	—	—	28	2
12-13	—	9	21	—	16-17	—	—	22	8
13-14	—	1	29	—	17-18	9	14	7	—

One important adult characteristic of the genus *Leiostomus* is an entire preopercular margin. Spot larvae and early juveniles, however, exhibited preopercular, subopercular, and interopercular spines (Figure 11). Preopercular spines formed first (4.4 mm SL). They occurred in two rows, one of weak lateral spines and one of stouter marginal spines. Preopercular spines increased during ontogeny, but juveniles eventually lost these spines. Interopercular and subopercular spines are less important characters for larval identification because they formed during the late larval period (Figure 11). They also were lost during the early juvenile stage.

Branchiostegal rays appeared early in development and attained the adult complement (7), shared by all sciaenids, at 6.3 mm SL (Table 1).

Spot have a high number of gill rakers among sciaenids (29-36, Chao and Musick 1977), but since the adult complement was not attained until a large size was reached (Table 1), total gill raker counts were not considered to be a good diagnostic character. The full complement of gill rakers on the ceratobranchial, however, was obtained at ca. 13 mm SL.

Pigmentation

Newly hatched larvae were inconspicuously pigmented (Figure 2). An ill-defined row of faint melanophores on the anterior portion of the body extended from the anterodorsal surface of the head to the ventrolateral surface of the trunk. Posterior to the anus on the dorsal midline, there were about two to five faint punctate melanophores. Faint melanophores occurred on the anterodorsal surface of the oil globule.

Shortly after hatching (ca. 1 d), a characteristic pattern began to form on the body. Initially, on almost all larvae, there was a faint dorsal and ventral melanophore opposite each other, located about midbody. In addition, there were other faint melanophores which, initially, occurred mainly on the dorsal midline. With larval growth, there were

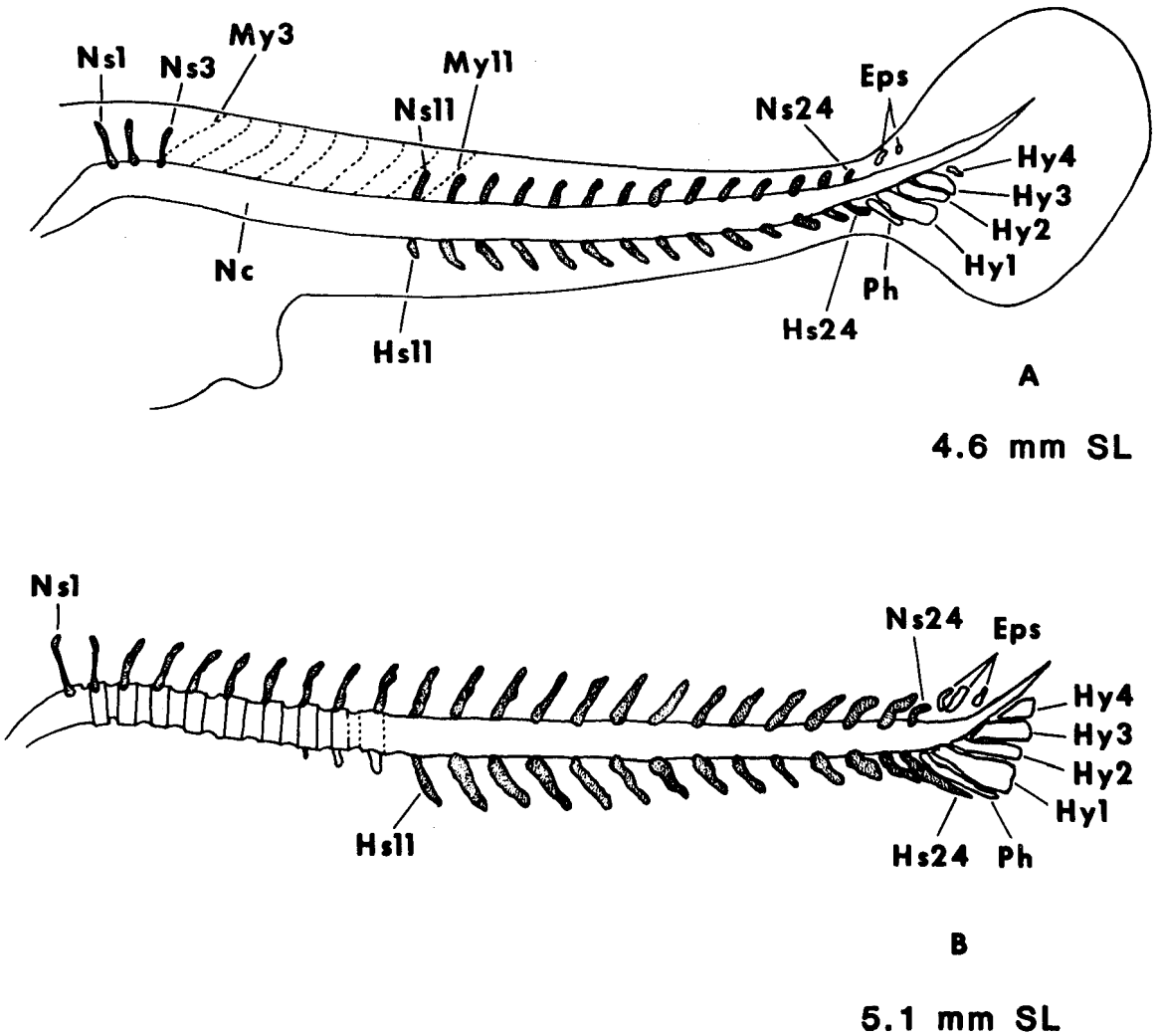

FIGURE 10.—Parts of axial skeleton used in counting: (A) total vertebrae (only myosepta useful in counting vertebrae are shown) and (B) precaudal and caudal vertebrae in *Leiostomus xanthurus* early larvae. Ns, neural spine; Hs, haemal spine; My3, myosepta associated with the third neural spine; Ph, parhypural; Hy, hypural bone; Eps, epurals; Nc, notochord.

fewer dorsal melanophores and more ventral melanophores. Finally, at the late yolk-sac stage (Figure 6A) a characteristic body pigment pattern was established (i.e., a single row of melanophores along the ventral midline) that persisted throughout the larval period.

Distinguishing characteristics of postyolk-sac spot larvae have been reported (Fruge and Truesdale 1978; Powles and Stender 1978), but the size or stage when spot larvae acquire these characteristics has generally been unknown. After yolk-sac absorption, there were five characteristic pigmented areas that developed in the region of the head and abdomen (Figure 6B-E)

1. Embedded melanophores over the air bladder and hindgut. They were observed on the youngest preflexion larvae (2.3 mm SL).
2. A triangle on the ventral side of the abdomen composed of a well-defined melanophore just anterior to the anus and a faint melanophore at each future pelvic fin base, although one was lacking at times (see Lippson and Moran 1974 for illustration), This pattern was occasionally

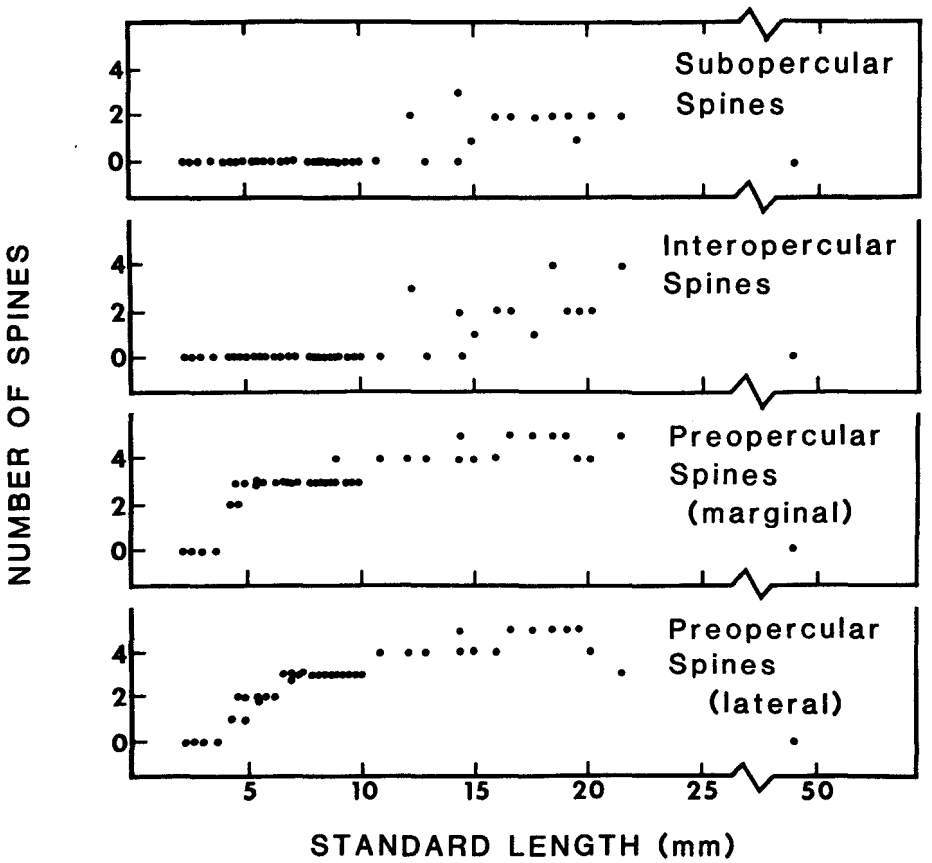

FIGURE 11.—Frequency of preopercular, interopercular, and subopercular spines in *Leiostomus xanthurus*.

observed on preflexion larvae and on almost all older larvae.

3. A well-defined melanophore at the cleithral symphysis on the ventral side of the abdomen. This melanophore first appeared on flexion larvae (3.8 mm SL).
4. A melanophore at the lower jaw angle first appeared on preflexion larvae (2.6 mm SL).
5. Embedded pigment at the anterior of the gut between the left and right cleithrum first became apparent on flexion larvae (4.0 mm SL), but were seen on cleared and stained late preflexion larvae (2.9 mm SL).

Two other characteristic pigment patterns were observed on the body: 1) a faint melanophore at the base of the caudal fin first appeared on most early flexion larvae (Figure 6C); then additional melanophores were added (Figure 6D) which eventually outlined the base of the caudal fin (Figure 6E), and 2) imbedded melanophores on the perineural sheath appeared at ca. 6-7 mm SL (Figure 6E).

Distinguishing Spot from Other Sciaenids

The eggs and larvae of most sciaenids are not likely to occur with spot eggs and larvae since the spawning seasons and localities of these sciaenids and spot do not overlap (Guest and Gunter 1958; Johnson 1978; Powles and Stender 1978). Spot, which spawns in continental shelf waters during the winter, share this spawning locality with *Cynoscion nothus, Equetus* spp., *Larimus fasciatus*, and *Micropogonias undulatus*. Of these sciaenids, only the Atlantic croaker appears to share the same spawning season with spot (the spawning season of *Equetus* spp. is unknown). The eggs and early preflexion larvae of Atlantic croaker have not been described and, therefore,

cannot presently be separated from spot, but distinguishing characteristics useful in separating older larvae are well documented (Fruge and Truesdale 1978; Powles and Stender 1978). During late fall and early spring, eggs and early larvae of *L. fasciatus* and *C. nothus* could occur with those of spot (Berrien et al. 1978; Powles and Stender 1978). The eggs of both these species are undescribed, whereas their larvae bear no resemblance to spot larvae (Powles and Stender 1978).

Meristic characters are useful in separating spot larvae from those of other sciaenids (Table 5). Flexion and older stage spot can be separated from *C. nothus*, which may be the only species of *Cynoscion* whose eggs and early larvae occur with spot, by total vertebrae counts. *Cynoscion nothus* has 27, rarely 26 vertebrae (high for sciaenids); spot has 25. Beginning at ca. 5 mm SL, spot can be separated from all members of the genus *Cynoscion* inhabiting the western North Atlantic by the number of precaudal vertebrae. *Cynoscion* spp. have more precaudal vertebrae (13-15) than spot (10).

The arrangement of predorsal bones and pterygiophores can be important in determining phylogenetic relationships (Kendall 1976) and in distinguishing between closely related species (Potthoff 1974; Berrien 1978; Butler 1979).

TABLE 5.—Meristic characters useful for separating spot larvae from other sciaenids. Check (√) indicates nonoverlapping counts, dash (—) indicates overlapping counts. Meristics were obtained from cleared and stained specimens.

Species	Meristic character and (in parenthesis) the size (mm SL) at which spot attained the full complement in this study			
	Total vertebrae (4.6)	Precaudal + caudal vertebrae (5.1)	Anal fin[1] pterygiophores (6.3)	Dorsal fin[2] pterygiophores (7.3)
Bairdiella chrysoura	—	—	√	√
Cynoscion arenarius	—	√	—	√
C. nebulosus	—	√	—	—
C. nothus	√	√	√	—
C. regalis	—	√	—	—
Larimus fasciatus	—	—	√	—
Menticirrhus americanus	—	—	√	√
M. littoralis	—	—	√	√
M. saxatilis	—	—	√	√
Micropogonias undulatus	—	—	√	—
Pogonias cromis	√	√	√	√
Sciaenops ocellata	—	—	√	√
Stellifer lanceolatus	—	—	√	√

[1]The full complement of anal fin spines and rays was attained at 8.2 mm SL.
[2]The full complement of dorsal fin spines and rays was attained at 10.8 mm SL.

Pterygiophores are important larval meristic characters, since their full complement is attained before accompanying spines and rays are formed. Since spot have high anal fin ray counts among sciaenids, then anal fin pterygiophore counts would be of utmost importance in separating spot larvae from other sciaenid larvae (Table 5).

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LITERATURE CITED

AHLSTROM, E. H., AND O. P. BALL.
1954. Description of eggs and larvae of jack mackerel (*Trachurus symmetricus*) and description and abundance of larvae in 1950 and 1951. U.S. Fish Wildl. Serv., Fish. Bull. 56:209-245.

AHLSTROM, E. H., J. L. BUTLER, AND B. Y. SUMIDA.
1976. Pelagic stromateoid fishes (Pisces, Perciformes) of the Eastern Pacific: kinds, distributions, and early life histories and observations on five of these from the Northwest Atlantic. Bull. Mar. Sci. 26:285-402.

APRIETO, V. L.
1974. Early development of five carangid fishes of the Gulf of Mexico and the south Atlantic coast of the United States. Fish. Bull., U.S. 72:415-443.

BERRIEN, P. L.
1975. A description of Atlantic mackerel, *Scomber scombrus*, eggs and early larvae. Fish. Bull., U.S. 73:186-192.
1978. Eggs and larvae of *Scomber scombrus* and *Scomber japonicus* in continental shelf waters between Massachusetts and Florida. Fish. Bull., U.S. 76:95-115.

BERRIEN, P. L., M. P. FAHAY, A. W. KENDALL, JR., AND W. G. SMITH.
1978. Ichthyoplankton from the RV *Dolphin* survey of Continental Shelf waters between Martha's Vineyard, Massachusetts and Cape Lookout, North Carolina, 1965-1966. U.S. Natl. Mar. Fish. Serv., Northeast Fish. Cent., Sandy Hook Lab., Tech. Ser. Rep. 15, 152 p.

BUTLER, J. L.
1979. The nomeid genus *Cubiceps* (Pisces) with a description of a new species. Bull. Mar. Sci. 29:226-241.

CHAO, L. N.
1978. A basis for classifying western Atlantic Sciaenidae

(Teleostei: Perciformes). U.S. Dep. Commer., NOAA Tech. Rep. NMFS Circ. 415, 64 p.

CHAO, L. N., AND J. A. MUSICK.
1977. Life history, feeding habits, and functional morphology of juvenile sciaenid fishes in the York River estuary, Virginia. Fish. Bull., U.S. 75:657-702.

DINGERKUS, G., AND L. D. UHLER.
1977. Enzyme clearing of alcian blue stained whole small vertebrates for demonstration of cartilage. Stain Technol. 52:229-232.

FAHAY, M. P.
1975. An annotated list of larval and juvenile fishes captured with surface-towed meter net in the South Atlantic Bight during four RV *Dolphin* cruises between May 1967 and February 1968. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-685, 39 p.

FRUGE, D. J., AND F. M. TRUESDALE.
1978. Comparative larval development of *Micropogon undulatus* and *Leiostomus xanthurus* (Pisces: Sciaenidae) from the northern Gulf of Mexico. Copeia 1978:643-648.

GUEST, W. C., AND G. GUNTER.
1958. The seatrout or weakfishes (genus *Cynoscion*) of the Gulf of Mexico. Gulf States Mar. Fish. Comm., Tech. Summ. 1, 40 p.

HETTLER, W. F.
1979. Modified neuston net for collecting live larval and juvenile fish. Prog. Fish-Cult. 41:32-33.

HILDEBRAND, S. F., AND L. E. CABLE.
1930. Development and life history of fourteen teleostean fishes at Beaufort, N.C. Bull. U.S. Bur. Fish. 46:383-488.
1934. Reproduction and development of whitings or kingfishes, drums, spot, croaker, and weakfishes or sea trouts, family Sciaenidae, of the Atlantic coast of the United States. Bull. U.S. Bur. Fish. 48:40-117.

HOUDE, E. D., AND T. POTTHOFF.
1976. Egg and larval development of the sea bream *Archosargus rhomboidalis* (Linnaeus): Pisces, Sparidae. Bull. Mar. Sci. 26:506-529.

JOHNSON, G. D.
1978. Development of fishes of the Mid-Atlantic Bight, vol. 4. U.S. Fish. Wildl. Serv., Biol. Serv. Program, Wash., D.C., 314 p.

KENDALL, A. W., JR.
1976. Predorsal and associated bones in serranid and grammistid fishes. Bull. Mar. Sci. 26:585-592.

LAURENCE, G. C., AND C. A. ROGERS.
1976. Effects of temperature and salinity on comparative embryo development and mortality of Atlantic cod (*Gadus morhua* L.) and haddock (*Melanogrammus aeglefinus* (L.)). J. Cons. 36:220-228.

LIPPSON, A. J., AND R. L. MORAN.
1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Md. Dep. Nat. Resour., Baltimore, 282 p.

NELSON, W. R.
1969. Studies on the croaker, *Micropogon undulatus* Linnaeus, and the spot, *Leiostomus xanthurus* Lacepede, in Mobile Bay, Alabama. J. Mar. Sci. (Ala.) 1:4-92.

PEARSON, J. C.
1929. Natural history and conservation of redfish and other commercial sciaenids on the Texas coast. Bull. U.S. Bur. Fish. 44:129-214.

POTTHOFF, T.
1974. Osteological development and variation in young tunas, genus *Thunnus* (Pisces, Scombridae), from the Atlantic Ocean. Fish. Bull., U.S. 72:563-588.

POWLES, H., AND B. W. STENDER.
1978. Taxonomic data on the early life history stages of Sciaenidae of the South Atlantic Bight of the United States. S.C. Mar. Resour. Cent. Tech. Rep. 31, 64 p.