EARLY DEVELOPMENT OF FIVE CARANGID FISHES OF THE GULF OF MEXICO AND THE SOUTH ATLANTIC COAST OF THE UNITED STATES

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ABSTRACT

Larvae of round scad, *Decapterus punctatus;* rainbow runner, *Elagatis bipinnulata;* banded rudderfish, *Seriola zonata;* lookdown, *Selene vomer;* and leatherjacket, *Oligoplites saurus*, collected in the Gulf of Mexico and off the south Atlantic coast of the United States are described and illustrated. Larvae 2 to 3 mm long show general family characteristics but generic and specific characters are differentiated in later stages. Morphological features including supraoccipital crest, thickness of the first interhemal spine, and body indices; meristic characters; mode of development and modification of the dorsal and pelvic fins; and patterns of pigmentation are useful in distinguishing the family, genera, and species. Information on distribution and spawning is included.

The family Carangidae consists of about 200 species of fishes which vary widely in form and are distributed in tropical and subtropical waters. Various attempts by authors to divide the family into subfamilies proved unsatisfactory in view of the numerous, weak characters used for this purpose and the presence of many transition genera which did not permit delineation of groups which may have been proposed as subfamilies (Ginsburg, 1952).

Twenty-eight species of carangids have been found along the Atlantic and Gulf coasts of the United States (Table 1). The larvae of some of these species occurred frequently in plankton and nekton collected in the Gulf of Mexico and off the south Atlantic coast of the United States during the multiship cruises in October to November 1970 and May to October 1971 during continuing surveys of marine biological communities conducted by the National Marine Fisheries Service (Southeast Fisheries Center) and cooperating agencies. The larval development of five species is described and illustrated in the present work.

Only a few studies dealing with early life history stages of North Atlantic carangids have been carried out by American workers. Hildebrand and Cable (1930) described larvae and early juveniles of *Decapterus punctatus* and *Seriola dumerili*. Fields (1962) described postlarvae of these species of *Trachinotus: T. carolinus, T. falcatus,* and *T. glaucus;* McKenney, Alexander, and Voss (1958) described a rather complete larval series of *Caranx crysos;* Berry (1959) described late-stage larvae and juveniles of five species of *Caranx*, including: *C. crysos, C. bartholomaei, C. ruber, C. hippos,* and *C. latus*. None of the above series included eggs or yolk-sac larvae and the majority lacked early-stage larvae as well.

Over a third of the carangids that occur off the eastern United States are wide-ranging species, and early life history series had been described from other areas for the following: *Selar crumenophthalmus* by Delsman (1926) and Devanesan and Chidambaram (1941), *Naucrates ductor* by Sanzo (1931), *Caranx dentex* by Schnakenbeck (1931), *Seriola dumerili* by Sanzo (1933), *Trachinotus glaucus* by de Gaetani (1940), *Caranx hippos* by Chacko (1950) and Subrahmanyam (1964), *Chloroscombrus chrysurus* and *Alectis crinitus* by Aboussouan (1968), and *Elagatis bipinnulata* by Okiyama (1970). Hence, early life history series—some complete, some fragmentary—were known for 16 of 28 species of carangids that occur along the Atlantic and Gulf coasts of the United States.

A proper understanding of the early life history of fishes, particularly those of species important to man, can never be overemphasized. The presence of larvae is indicative of recent spawning, and

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TABLE 1.—Meristic characters of adult carangids of the Gulf and Atlantic coasts of the United States.

Species	Dorsal fin	Anal fin	Pectoral fin	Gill rakers	Vertebrae	Source
Alectis crinitus	(VII)0; I,18-19	(II)0; I, 15-16	18-20	5- 6+14-16	–	Ginsburg, 1952
Alectis crinitus	–	–	–	–	24	Starks, 1911
Caranx bartholomaei	VIII; I, 25-28	II; I, 21-24	I, 19-21	6- 9+18-21	–	Berry, 1959
Caranx bartholomaei	–	–	–	–	24	Miller and Jorgensen, 1973
Caranx crysos	VIII; I, 22-25	II; I, 19-21	I, 19-23	10-14+23-28	–	Berry, 1959
Caranx crysos	–	–	–	–	25	Miller and Jorgensen, 1973
Caranx crysos	VIII; I, 23-25	–	–		–	McKenney et al., 1958
Caranx crysos	–	–	–	–	25	Starks, 1911
Caranx hippos	VIII; I, 19-21	II; I, 16-17	I, 19-20	6- 9+22-27	–	Berry, 1959
Caranx hippos	–	–	–	–	24	Lane, 1965
Caranx latus	VIII; I, 19-22	II; I, 16-18	I, 18-20	6- 7+16-18	–	Berry, 1959
Caranx latus	20-21	16-18	18-20	16+17	24	Lane, 1965
Caranx lugubris	VIII; I, 22	II; I, 19	I, 19	6+20	–	Berry, 1959
Caranx lugubris	–	–	–	–	24	Lane, 1965
Caranx lugubris	VIII; I, 22	II; I, 18	–	–	–	Fowler, 1936
Caranx ruber	VIII; I, 26-30	II; I, 23-26	I, 18-21	10-14+31-35	–	Berry, 1959
Caranx ruber	–	–	–	–	24	Miller and Jorgensen, 1973
Caranx dentex	VIII; I, 25-26	II; I, 21-23	I, 19-20	11-13+26-28	–	Berry, 1959
Chloroscombrus chrysurus	VIII; I, 26-28	II; I, 25-27	19-20	9-11+31-35	–	Ginsburg, 1952
Chloroscombrus chrysurus	–	–	–	–	24	Miller and Jorgensen, 1973
Chloroscombrus chrysurus	VII-VIII; I, 24-26	II; I, 25-26	–	9-10+32-35	–	Fowler, 1936
Chloroscombrus chrysurus	–	–	–	–	24	Starks, 1911
Decapterus macarellus	VIII; I, 31-37	II; I, 27-31	I, 21-23	9-13+32-39	24	Berry, 1968
Decapterus punctatus	VIII; I, 29-34	II; I, 25-30	I, 18-20	11-16+32-44	25	Berry, 1968
Decapterus punctatus	VIII; I, 28-32	II; I, 25-27	19-21	12-15+34-40	–	Ginsburg, 1952
Decapterus punctatus	VIII; I, 27-31	II; I, 24-27	–	12-15+35-40	–	Fowler, 1936
Decapterus tabl	VIII; I, 29-34	II; I, 24-27	I, 20-22	10-12+30-33	24	Berry, 1968
Elagatis bipinnulata	VI-I, 25-26	0-II; I, 16-17	20-21	10-11+25-26	–	Ginsburg, 1952
Elagatis bipinnulata	V-VI; I, 25-30	II, 18-22	I, 18-21	9-12+25-29	24	Berry, 1969
Hemicaranx amblyrhynchus	VII-VIII; I, 27-29	II; I, 23-25	19-22	8-10+19-23	–	Ginsburg, 1952
Hemicaranx amblyrhynchus	–	–	–	–	26	Miller and Jorgensen, 1973
Naucrates ductor	III-IV; I-II, 26-28	O-II; II, 15-16	–	6+18-19	–	Fowler, 1936
Naucrates ductor	–	–	–	–	25	Starks, 1911
Oligoplites saurus	V-VI; I, 19-21	II; I, 18-21	15-17	6- 9+13-15	–	Ginsburg, 1952
Oligoplites saurus	–	–	–	–	26	Miller and Jorgensen, 1973
Selar crumenophthalmus	VIII; I, 24-26	II; I, 21-23	20-22	9-11+27-30	–	Ginsburg, 1952
Selar crumenophthalmus	–	–	–	–	24	Miller and Jorgensen, 1973
Selar crumenophthalmus	VIII; I, 26	II; I, 22	–	10-12+28-31	–	Fowler, 1936
Selar crumenophthalmus	–	–	–	–	24	Starks, 1911
Selene vomer	VIII; I, 21-23	O-II; I, 18-20	20-21	6- 8+23-27	–	Ginsburg, 1952
Selene vomer	–	–	–	–	24	Miller and Jorgensen, 1973
Selene vomer	VII-VIII; I, 21-23	II; I, 18-19	–	7- 8+24-28	–	Fowler, 1936
Seriola dumerili	VII; I, 30-35	II; I, 19-22	19-22	2- 3+11-13	–	Ginsburg, 1952
Seriola dumerili	–	–	–	–	24	Miller and Jorgensen, 1973
Seriola dumerili	VII; I, 29-35	–	–	11-24	–	Mather, 1958
Seriola fasciata	VIII; I, 30-32	II; I, 19-20	19-20	7- 8+18-20	–	Ginsburg, 1952
Seriola fasciata	VII-VIII; I, 29-32	II; I, 18-21	–	6+15	–	Fowler, 1936
Seriola fasciata	VIII; I, 28-32	–	–	22-26	–	Mather, 1958
Seriola rivoliana	VII-VIII; I, 28-32	I-II; I, 19-22	19-20	7- 8+16-18	–	Ginsburg, 1952
Seriola rivoliana	–	–	–	–	24	Miller and Jorgensen, 1973
Seriola rivoliana	VII; I, 29	II; I, 21	–	–	–	Fowler, 1936
Seriola rivoliana	VII; I, 27-33	–	–	18-28	–	Mather, 1958
Seriola zonata	VII-VIII; I, 33-40	I-II; I, 19-21	16-21	2- 3+11-13	–	Ginsburg, 1952
Seriola zonata	VIII; I, 38-40	–	–	12-13	–	Mather, 1958
Seriola zonata	–	–	–	–	24	Starks, 1911
Trachinotus carolinus	V-VI; I, 23-27	II; I, 20-23	17-19	- + 7-11	–	Ginsburg, 1952
Trachinotus carolinus	V-VI; I, 22-27	II; I, 20-23	I, 16-18	4- 7+ 6-13	–	Fields, 1962
Trachinotus carolinus	–	–	–	–	24	Starks, 1911
Trachinotus falcatus	VI; I, 18-20	II; I, 17-18	18-20	- + 9-13	–	Ginsburg, 1952
Trachinotus falcatus	–	–	–	–	24	Miller and Jorgensen, 1973
Trachinotus falcatus	VI; I, 17-21	II; I, 16-19	I, 17-19	3- 8+12-14	–	Fields, 1962
Trachinotus glaucus	VI; I, 19-20	II; I, 16-18	16-19	- +8-12	–	Ginsburg, 1952
Trachinotus glaucus	VI; I, 19-20	II; I, 16-18	I, 15-19	3- 8+9-14	–	Fields, 1962
Trachurus lathami	VIII; I, 28-33	II; I, 26-30	21-22	12-14+34-39	–	Ginsburg, 1952
Trachurus lathami	VIII; I, 30	II; I, 28	–	15+36	24	Merriman, 1943
Uraspis heidi	VIII; I, 29	0-I, 21	23	6+14	–	Ginsburg, 1952
Vomer setapinnis	VIII; I, 20-23	0-II; I, 17-19	17-19	5- 8+25-29	–	Ginsburg, 1952
Vomer setapinnis	VIII; I, 21-22	II; I, 18-20	–	6- 8+26-30	–	Fowler, 1936
Vomer setapinnis	–	–	–	–	24	Starks, 1911

data derived from the study of larvae provide useful tools in gaining insight into the abundance and fluctuation of the size of spawning populations (Farris, 1961). Patterns of larval development and larval structures, when sufficient groups are studied, are potential keys to possible relations which often are not adequately illustrated in adult morphology and osteology. The present paper aims to contribute to the understanding of the early life stages of members of the family Carangidae.

MATERIALS, METHODS, AND TERMINOLOGY

Larvae, juveniles, and adults were largely in the collections of the Miami Laboratory, Southeast Fisheries Center. The larvae and juveniles were collected with 1-m bongo plankton (Posgay, Marak, and Hennemuth, 1968) and nekton nets on board research vessels during oceanographic and biological surveys and during the routine sampling for larval fish in the Gulf Stream off Miami. Descriptions of vessels, cruise tracks, and sampling methods are available at the Miami Laboratory, Southeast Fisheries Center. Some specimens were contributed from a private collection and from the fish museum of the Center. One species was raised in the marine fish larvae rearing system of the Rosenstiel School of Marine and Atmospheric Science, University of Miami.

The larval development of the carangids in this work is based on 551 larval and early juvenile specimens of *Decapterus punctatus*, 94 of *Elagatis bipinnulata*, 86 of *Selene vomer*, 64 of *Seriola zonata*, and 31 of *Oligoplites saurus*. Meristic characters and sequence of ossification data were taken from stained and cleared specimens. The complete sequence of ossification was not observed, however, in *Selene vomer* and *Oligoplites saurus* on account of the lack of transforming specimens and poorly preserved materials, respectively.

The embryological and anatomical terms and measurements used in this study follow largely those of Lagler, Bardach, and Miller (1962), Mansueti and Hardy (1967), and Moser and Ahlstrom (1970). Terms for ossification are those of Starks (1911), Suzuki (1962), and Weitzman (1962). Chromatophore terminology is from Fujii (1969). However, for clarity, certain terms are defined as they relate to larvae of carangids.

Growth stages beyond the yolk-sac stage are defined according to Moser and Ahlstrom (1970), and the terms prolarva and postlarva of Hubbs (1943) are not used. The larval period lasts from hatching to the attainment of juvenile characters. The transformation or metamorphosis of the larvae into juveniles is called the transitional period and the individuals undergoing this process are called transforming, metamorphic, or transitional specimens. The fish is a juvenile when it has the essential features of the adult, particularly the complete fin ray counts. The juvenile period terminates with the attainment of sexual maturity when the fish is considered an adult.

The dynamic approach of Moser and Ahlstrom (1970) is adapted in the description of larval fish. Here, a complete or fairly complete series of growth stages from the smallest differentiated larvae to the juvenile is assembled, and the development of each character is traced sequentially. The method used for determining apparent relative abundance is based on Ahlstrom (1948).

The youngest specimens collected in the plankton were past the yolk–sac stage. While eggs were present in the collections, identification is uncertain in view of the conspicuous absence of the intervening yolk–sac stages. Perhaps, the yolk sac ruptured or collapsed at capture due to mechanical stress.

All specimens used in this study are deposited in the larval fish laboratory of the Miami Laboratory, Southeast Fisheries Center of the National Marine Fisheries Service.

DESCRIPTIONS

Rainbow runner, *Elagatis bipinnulata* (Quoy and Gaimard)

Figure 1

Literature

Larval stages of this species from the Indo-Pacific oceans were illustrated and described by Okiyama (1970) who also traced their development. Berry (1969) illustrated an 18.5-mm juvenile from the Straits of Florida. Schnakenbeck (1931) illustrated an 11.5-mm larva from the Lesser Antilles under the name of *Caranx helvolus*.

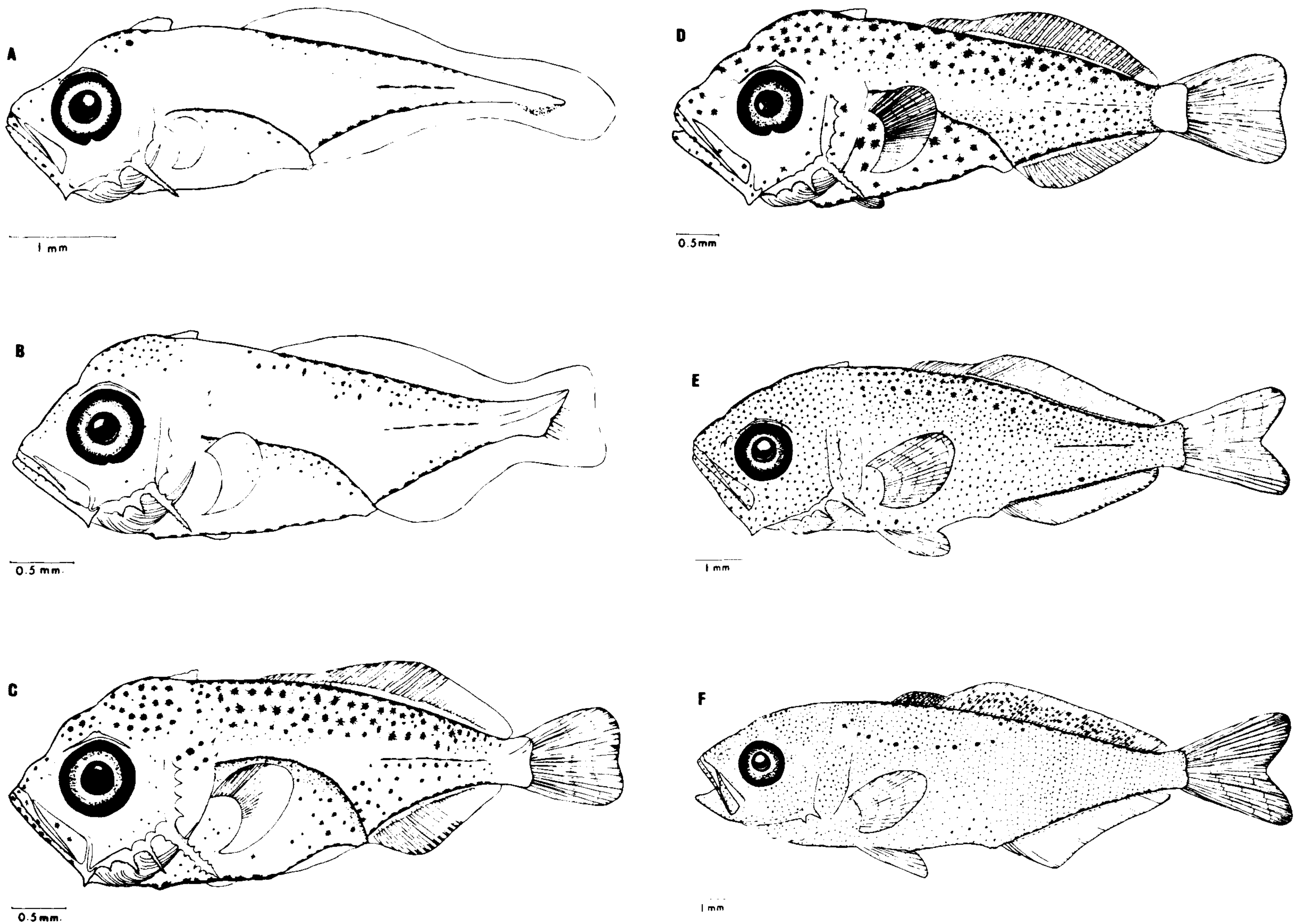


FIGURE 1.—*Elagatis bipinnulata*. **A.** 3.8 mm SL; **B.** 4.6 mm SL; **C.** 5.5 mm SL; **D.** 6.3 mm SL; **E.** 10.0 mm SL; **F.** 15.0 mm SL.

Distinguishing Features

Larvae of *Elagatis bipinnulata* are distinct from those of other carangids in having only two spines in the anal fin. Following transformation, the terminal dorsal and anal soft fin rays become gradually separated from these fins. These larvae are remarkably similar to those of *Seriola* species in size, structure, and pigmentation. Unlike the larvae of *Seriola,* however, they have a supraoccipital crest, serrations on the preopercular spines, and all the dorsal spines are about equal in length. The first interhemal spine is only slightly swollen and is not pressed nor fused with the hemal spine of the first caudal vertebra (Starks, 1911). The larvae transform at 10 to 14 mm.
the other interhemal and hemal spines. In many carangids the first interhemal spine is much enlarged and pressed against or fused with the hemal spine of the first caudal vertebra (Starks, 1911). The larvae transform at 10 to 14 mm.

Morphology

Larvae of *E. bipinnulata* are deep-bodied. Body depth at the base of the pectoral fin is 32% of the standard length at 3.8 mm; it attains a maximum of 40% at initial notochord flexion and is never less than 33% during the entire period of larval development (Table 2).

The head is large and deep. Relative length of the head increases throughout the larval and transition periods. Head length is 31.6% at 3.8 mm, increases to 35 to 49% at notochord flexion,

TABLE 2.—Measurements (mm) of larvae and juveniles of *Elagatis bipinnulata.*

(Specimens between dashed lines are undergoing notochord flexion.)

Standard length	Snout-to-anus distance	Head length	Head depth	Body depth at base of pectoral fin	Orbit Snout length	Orbit diameter	Snout to fin origin		
							Predorsal	Prepelvic	Preanal
3.8	1.9	1.2	1.2	1.2	0.32	0.30	-	-	-
3.9	1.96	1.25	1.25	1.2	.32	.30	-	-	-
4.6	2.9	1.6	1.7	1.5	.48	.55	2.0	2.0	2.0
5.0	3.5	2.0	2.0	2.1	.58	.50	2.7	2.0	4.0
5.2	3.5	2.1	2.2	2.1	.59	.60	2.7	2.2	3.6
5.9	3.5	2.2	2.3	2.2	.50	.65	2.8	2.4	3.6
6.1	3.9	2.1	2.2	2.3	.52	.65	3.0	2.5	4.4
6.2	3.9	2.3	2.4	2.2	.55	.65	3.0	2.5	4.1
7.0	4.4	2.5	2.6	2.4	.60	.70	.35	2.8	4.5
8.5	5.1	2.8	3.0	2.8	.75	.77	4.0	3.2	5.2
8.7	5.3	3.0	3.2	3.1	.75	.77	4.1	3.4	5.5
9.5	6.0	3.2	3.3	3.2	.80	1.0	4.1	3.5	6.1
9.7	6.0	3.2	3.3	3.3	.85	1.0	4.5	3.6	6.2
[1]10.0	6.1	3.8	3.5	3.4	.90	1.2	4.6	3.6	6.2
[1]11.0	7.2	3.8	3.8	3.8	1.0	1.0	5.2	4.0	7.4
[1]11.2	7.2	4.2	4.0	3.5	1.1	1.2	5.5	4.3	7.4
[1]11.5	7.2	4.3	3.8	3.8	1.2	1.2	6.0	4.3	7.5
[1]11.8	7.3	4.0	3.6	3.6	1.1	1.2	6.0	4.3	7.5
[1]12.0	7.4	4.0	3.8	3.8	1.2	1.3	6.0	4.5	7.4
[1]12.5	7.5	4.2	3.8	3.8	1.1	1.4	5.9	4.8	7.8
[1]13.0	7.5	4.0	4.0	3.9	1.2	1.3	6.0	5.0	8.0
[1]13.2	7.8	4.0	4.0	3.9	1.0	1.4	5.8	4.8	8.0
[1]13.3	8.1	4.5	4.1	4.2	1.2	1.3	6.1	5.0	8.6
[1]14.0	8.5	5.3	4.9	4.5	1.5	1.3	6.3	5.5	9.0
[2]14.1	8.5	5.0	4.9	4.5	1.5	1.4	6.1	5.4	9.0
[2]14.5	9.5	5.0	4.8	4.6	1.7	1.3	6.0	5.2	9.8
[2]14.8	9.0	4.8	4.6	4.5	1.7	1.4	6.5	5.4	9.8
[2]15.2	9.5	5.3	4.7	4.3	1.6	1.5	6.5	5.3	9.9
[2]15.5	9.0	5.4	4.7	4.6	1.6	1.3	6.6	5.2	9.7
[2]16.2	10.0	5.6	4.9	4.8	1.7	1.6	7.0	6.0	11.0
[2]16.8	10.2	5.7	5.0	4.7	1.8	1.5	8.0	7.0	10.6
[2]17.0	10.0	5.6	5.0	4.9	1.9	1.3	7.0	6.0	10.5
[2]18.0	10.0	6.0	5.0	5.0	1.9	1.5	7.5	6.0	11.0
[2]18.4	10.5	6.0	5.0	5.6	1.8	1.5	8.1	5.9	11.0

[1]Transforming.
[2]Juveniles.

and averages 35% during the late larval and early juvenile stages. The head is as deep as long at 3.8 mm and is deeper than long for most of the larval period. Head depth reaches a maximum of 110% of the head length at 5 mm and averages 101% in the late larvae. The dorsal profile of the snout is slightly concave at 3.8 mm; at notochord flexion, it becomes indented at the anterior and posterior margins of the slightly swollen forebrain. These indentations disappear in older larvae and at transformation, the dorsal profile becomes convex.

The eyes are round and large. Relative eye diameter ranges from 26.3 to 31.3% of the head length. A low orbital crest is formed above the eyes in early larvae but regresses at metamorphosis.

A supraoccipital crest is present throughout the larval stages. At 15 mm, the crest is much reduced and is no longer visible externally but may be observed in cleared and stained specimens.

There are two series of preopercular spines: one along the margin and another on the lateral surface. Spines on the lower margin are bigger and more serrated than those on the lateral surface. All preopercle spines gradually diminish in size and are completely overgrown by the expanding preopercle bones following metamorphosis.

The gut is long and coiled in a single, rounded loop in larvae up to a length of 12 mm; at 18 mm, a second loop is added. Hypaxial muscles enclose the gut at 5 mm and completely cover the abdominal cavity except at the opening of the gut at 8 mm.

The number of myomeres is constant—10 preanal plus 14 postanal—throughout the larval and early juvenile periods.

The first scales formed are those found along the lateral line near the caudal peduncle. Lateral line scales ossify in a posteroanterior direction at 15 mm. Regular body scales are not ossified until the juveniles are at least 20 mm long.

Pigmentation

Larvae are among the most intensely pigmented of carangids. In the early larvae (3.8-4.6 mm), the most conspicuous pattern of pigmentation includes melanophores along the bases of the dorsal and anal fins and along the lateral midline (Figure 1A, B). Small patches of melanophores are present on the head, jaws, snout, and on the upper sides of the body. Internal pigmentation is concentrated on the dorsal wall of the peritoneum. At 5 to 6 mm, melanophores develop profusely all over the body leaving only a small unpigmented area at the caudal peduncle (Figure 1C,D). A row of closely spaced pigment cells along the midventral line below the gut is notable and distinguishes early larvae from similarly pigmented larvae of *Seriola*. Xanthophores (yellow) develop profusely on the head and back in late larvae. At metamorphosis, iridiophores (reflecting), xanthophores, and melanophores cover the whole length of the body except on the jaws and fins, and an irregular row of large melanophores is formed on the upper side of the body (Figure 1E). The melanophores are capable of expansion and contraction and the larvae are pale or dark depending on the state of the pigment cells. Iridiophores and xanthophores fade upon preservation. The only chromatophores apparent in preserved specimens are the melanophores.

Fin Development

Rudiments of all fins except the ventral fins are present in the smallest larva (3.8 mm) and are situated in about the position they occupy at older stages. The fins ossify in the following sequence: 1) caudal, 2) first dorsal and anal, 3) second dorsal and pectoral, 4) ventral. All fins are essentially complete at metamorphosis (Table 3).

In the pectoral fins the dorsalmost rays are the first to ossify at 5 mm, and the rest of the rays are added ventrally. The full complement of 18 to 21 rays is present at 8 mm.

The pelvic fins ossify at 6 mm, and the full complement of 5 rays is present at 8 mm. The pelvic fin rays grow fast, and at transformation they are about as long as the pectoral fins.

Ossification of the dorsal and anal fin rays proceed in an anteroposterior direction in an orderly manner. The anteriormost rays are the first to ossify at 5 mm, and ossification continues posteriad. The last two fin rays are gradually separated beginning at metamorphosis in a manner described by Berry (1969). The full complement of 7 spines and 25 to 30 soft rays is present at 10 mm. The dorsal spines are of almost uniform height in the larvae. In early juveniles (17 mm), their height is about half that of the soft rays. The first and second dorsal fins are continuous throughout the larval and transition stages. The full complement of 2 spines and 19 to 20 soft rays in the anal fin is completed at 10 mm.

Caudal fin formation has begun in the smallest larva (3.8 mm). This is indicated by the presence of a thickening near the tip of the notochord. When

TABLE 3.—Meristic characters of cleared and stained larvae and juveniles of *Elagatis bipinnulata*.

Standard length	Dorsal fin	Anal fin	Left pectoral fin	Left pelvic fin	Primary caudal fin rays		Secondary caudal fin rays		Gill rakers, left first gill arch	Left pre-opercular margin spines
					Dorsal	Ventral	Dorsal	Ventral		
3.8	-	-	-	-	-	-	-	-	-	7
4.6	-	-	-	-	2	2	-	-	0+5	7
5.4	V; 18	I, 10	5		7	8	-	-	0+11	8
6.0	V; 24	I, 16	13	I, 2	8	8	2	4	2+13	8
7.0	VI; I, 25	I, 18	17	I, 4	9	8	4	5	4+15	7
8.0	VI; I, 24	I, 19	18	I, 5	9	8	8	9	5+18	6
9.0	VI; I, 26	I, 20	19	I, 5	9	8	9	9	5+18	8
10.4	VI; I, 27	II, 20	19	I, 5	9	8	9	9	6+22	7
11.5	VI; I, 26	II, 19	20	I, 5	9	8	10	9	7+21	5
12.0	VI; I, 27	II, 20	19	I, 5	9	8	10	10	7+21	5
13.1	VI; I, 28	II, 19	20	I, 5	9	8	10	9	7+21	4
14.7	VI; I, 28	II, 19	20	I, 5	9	8	10	10	8+21	2
15.2	VI; I, 27	II, 19	20	I, 5	9	8	11	10	8+23	2
16.0	VI; I, 27	II, 19	20	I, 5	9	8	11	10	8+22	2
17.1	VI; I, 27	II, 19	20	I, 5	9	8	10	11	8+23	1
18.0	VI; I, 26	II, 19	20	I, 5	9	8	11	11	8+22	1
19.0	VI; I, 27	II, 19	19	I, 5	9	8	11	10	8+24	1
19.5	VI; I, 27	II, 19	20	I, 5	9	8	11	11	8+24	1
20.0	VI; I, 27	II, 19	19	I, 5	9	8	10	10	9+25	1
23.3	VI; I, 27	II, 19	21	I, 5	9	8	11	10	8+27	1

the larvae are 4 to 5 mm long, the thickening differentiates into hypural elements, the notochord starts flexion, and the median caudal rays ossify. The hypural elements ossify at 6 mm, the full complement of 9 dorsal and 8 ventral principal rays is present at 7 mm, and notochord flexion is completed at 8 mm. The secondary rays ossify at 6 mm beginning with the posteriormost rays. The full complement of 10 to 11 dorsal and of 10 to 11 ventral secondary rays is formed at 12 mm.

The last 3 vertebrae, the hypural elements, and 5 dorsal structures including the neural spine of the antepenultimate vertebra, 3 median epurals, and a specialized neural process support the caudal fin. The supporting structures articulate with the principal and secondary caudal rays. They are generally similar to those occuring in *Trachurus symmetricus* (Ahlstrom and Ball, 1954).

Distribution and Spawning

Elagatis bipinnulata has a circumtropical distribution (Briggs, 1960). It has been previously reported from Texas, Florida, and Long Island (Ginsburg, 1952) and is also known from the West Indies (Jordan and Evermann, 1896), Japan (Okada, 1966), Hawaii (Gosline and Brock, 1960), Africa (Fowler, 1936), Philippines (Herre, 1953), and the Great Barrier Reef (Marshall, 1965). The larvae were reported by Okiyama (1970) to be the most abundant form of epipelagic larval carangid in the tropical as well as in the subtropical Indo-Pacific ocean where spawning occurs throughout the year with a peak in March.

In the present study, larvae and early juveniles less than 20 mm have been taken in every month except in May and December. While the specimens are too few to give conclusive information, it appears that spawning may occur throughout the year. The larvae were taken mainly in offshore waters in the eastern Gulf of Mexico, in the Santaren Channel, the Straits of Florida, and the Carolina Bight off New Brunswick, Ga. (Figure 2). They occurred in 2.6% of the net stations and constituted 2.3% of the young carangids collected.

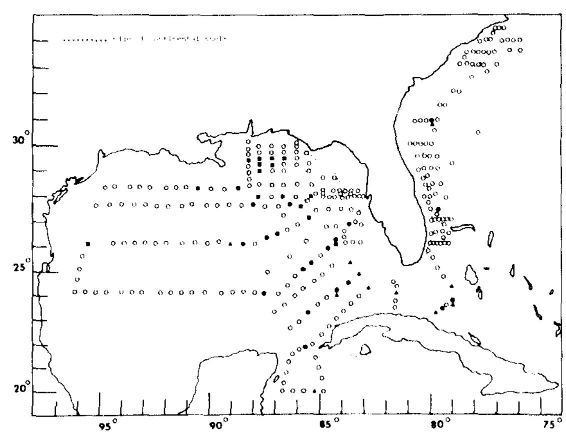


FIGURE 2.—Locations of collections of larval carangids during two cruises of the *Oregon II* from July to August and from October to November 1970 and a cruise of the *Tursiops* in August 1971. Records of occurrences of *Elagatis bipinnulata* are shown as solid circles, those of *Seriola zonata* as solid triangles, and those of *Selene vomer* as solid squares. Open circles represent other stations occupied.

During its larval life, *Elagatis bipinnulata* is planktonic. Some larvae and juveniles become associated with the pelagic sargassum community (Dooley, 1972) and are carried along the Florida Current and Gulf Stream.

Banded rudderfish, *Seriola zonata* (Mitchill)
Figure 3

Literature

Larvae of *Seriola zonata* have not been previously described. Early juveniles of the banded stage were described by Nichols (1946), Ginsburg (1952), and Mather (1958). Lutken (1880) illustrated an unbanded 20-mm juvenile.

As noted earlier, larvae of *Seriola dumerili* were described by Hildebrand and Cable (1930) and Sanzo (1933). Japanese workers have described life history series of three species of *Seriola*. The most detailed study of development from eggs to juveniles was made on *Seriola quinqueradiata* [Uchida, Dotu et al. (1958), Uchida in Uchida, Imai et al. (1958), Mitani (1960), and Mito (1961)]. Larvae and juveniles of two other Japanese species, *S. aureovittata* and *S. purpurascens* were covered by Uchida in Uchida, Imai et al. (1958).

Distinguishing Features

Seriola larvae resemble most those of *Elagatis bipinnulata* in size, body structure, and pigmentation. Unlike *E. bipinnulata*, however, there is no supraoccipital crest; the spines of the dorsal fin are of unequal length, the anterior and posterior ones being shorter; and the preopercular spines have smooth sides until the transition period when the longest spine develops 1 to 2 denticles. The larvae transform at about 13 mm. They are deep-bodied and robust. The head is massive and slightly depressed, and the eyes protrude slightly from the orbit at the dorsal side.

Early larvae of *Seriola zonata* (3-7 mm) are differentiated from those of other species of *Seriola* by the presence of 5 to 6 large melanophores on the middorsal line at the base of the dorsal fin (Figure 3 B). These large melanophores which are apposed to the myomeres stand out among the more numerous and smaller pigment spots on the back and sides. In older larvae these melanophores become embedded in the muscles and covered by superficial melanophores. When the full complement of dorsal fin rays is formed at about 8 mm, larvae of *S. zonata* are distinct in having 35 to 40 soft rays in the second dorsal fin, the highest second dorsal fin ray count of all species of *Seriola*. All dorsal fin rays are sharply visible even in unstained specimens.

The first interhemal spine of the first ventral pterygiophore is only slightly enlarged and does not press against the first hemal spine.

Morphology

Maximum body depth at 3.6 mm is 30% of the standard length. It increases to 37% at initial notochord flexion and does not change significantly during larval and transition periods. In early juveniles, the body depth is never less than 30% of the standard length (Table 4).

Head length is 33% of standard length in the smallest larva (3.6 mm) and attains a maximum of 43% at 7.0 mm. Thereafter, head length decreases gradually, with an average of 35% in early juveniles 18.0 mm in length. Depth of head is 91% of the head length at 3.6 mm and attains a maximum of 122% at 5 mm. Thereafter, head depth decreases slightly and is never less than 89% of the head depth throughout the larval and juvenile periods. The dorsal profile of the snout is slightly concave at 3.6 mm but becomes straight at about 5 mm and then convex in the older larvae and juveniles.

The eyes are round and large, and the orbit diameter increases in relation to head length. Relative orbit diameter ranges from 28 to 36% of the head length in larvae and transforming specimens and gradually increases in early juveniles. A low orbital crest with a weak spine is present in the early larvae and is resorbed at metamorphosis.

Marginal and lateral surface preopercular spines are present. The marginal angle spine which is the longest develops 1 or 2 denticles on its dorsal side in transforming larvae and early juveniles. All preopercular spines gradually diminish in size and become overgrown by the expanding preopercle.

Scales along the posterior end of the lateral line in front of the caudal peduncle are formed at 20 mm. Subsequently, the scales along the anterior portion of the lateral line ossify, followed by those on the head and sides of the body.

The slender gut is coiled in a single loop in larvae up to 10 mm long. The number of loops

TABLE 4.—Measurements (mm) of larvae and juveniles of *Seriola zonata*.

(Specimens between dashed lines are undergoing notochord flexion.)

Standard length	Snout-to-anus distance	Head length	Head depth	Body depth at base of pectoral fin	Snout length	Orbit diameter	Snout to fin origin		
							Predorsal	Prepelvic	Preanal
3.6	2.1	1.2	1.1	1.1	0.35	0.36	–	–	–
3.7	2.3	1.25	1.15	1.2	.36	.36	–	–	–
4.7	3.0	1.6	1.5	1.5	.42	.42	–	–	–
5.5	3.5	1.8	2.1	2.0	.50	.60	2.5	2.1	3.6
5.6	3.5	1.8	2.2	2.0	.52	.62	2.5	2.1	3.7
6.2	4.0	2.0	2.3	2.0	.65	.70	2.9	2.2	4.0
6.4	3.9	2.3	2.3	2.1	.65	.70	2.9	2.5	4.0
6.5	4.0	2.5	2.5	2.3	.65	.72	3.0	2.5	4.2
6.8	4.5	2.8	2.6	2.4	.67	.72	3.4	2.8	4.6
7.0	4.6	3.0	2.8	2.5	.70	.75	3.4	2.9	4.8
7.1	4.7	3.0	3.0	2.6	.72	.75	3.5	2.8	5.0
7.5	4.8	3.0	3.0	2.5	.80	.85	3.8	3.0	5.0
8.0	5.2	3.0	2.8	2.5	.85	.90	3.8	3.0	5.3
8.2	5.2	3.1	3.1	2.8	.90	1.0	3.9	3.2	5.3
8.4	5.4	3.2	3.5	3.2	1.0	1.1	4.0	3.5	5.5
9.1	5.8	3.5	3.5	3.2	1.0	1.2	4.1	3.9	5.9
9.5	6.2	3.5	3.6	3.2	1.0	1.2	4.3	3.9	6.4
9.8	6.2	4.0	3.8	3.5	1.2	1.3	4.3	4.1	6.4
[1]10.0	6.5	4.0	3.8	3.5	1.1	1.3	4.3	4.1	6.6
[1]10.3	6.6	4.0	3.8	3.5	1.1	1.3	4.5	4.1	6.8
[1]10.8	7.4	4.2	4.0	3.6	1.3	1.5	5.2	4.4	7.6
[1]11.9	8.4	4.7	4.8	4.5	1.5	1.6	5.8	5.5	8.6
[1]12.0	8.5	4.9	4.8	4.5	1.6	1.6	6.0	5.6	8.6
[1]12.1	8.5	5.0	4.6	4.5	1.6	1.6	5.9	5.6	8.6
[1]12.5	8.6	5.0	4.8	4.5	1.6	1.6	6.0	5.2	8.7
[1]13.1	8.8	5.0	4.8	4.5	1.4	1.8	6.1	5.3	8.3
[2]13.5	9.2	5.0	4.8	4.6	1.5	1.9	6.1	5.6	9.5
[2]13.6	9.2	5.0	4.6	4.5	1.4	2.0	6.2	5.5	10.0
[2]15.0	9.8	5.5	5.0	5.0	1.4	2.0	6.0	5.5	10.2
[2]15.1	10.0	5.6	5.0	5.0	1.5	2.0	6.3	5.5	10.5
[2]15.2	10.0	5.7	5.1	5.2	1.5	2.0	6.4	5.6	10.6
[2]16.2	10.5	5.8	5.2	5.4	1.6	2.1	7.5	5.8	11.0
[2]17.5	10.5	6.0	5.5	6.0	1.5	2.2	7.5	6.0	11.0
[2]18.1	11.0	6.5	5.8	6.2	1.7	2.3	7.5	7.0	11.0

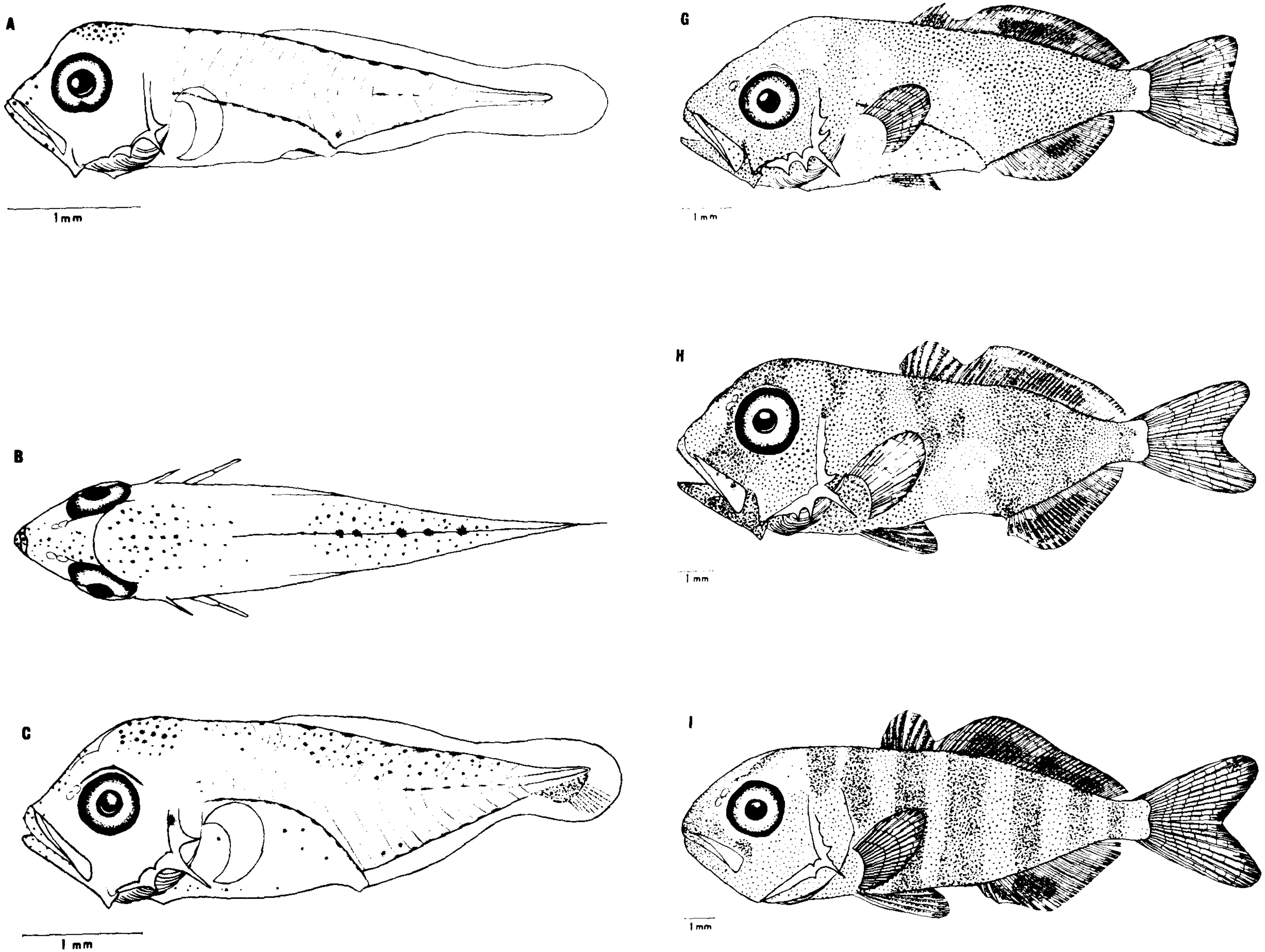
[1]Transforming.
[2]Juveniles.

increases with growth and at 15 mm four loops are present. Snout-to-anus distance increases in relation to standard length. It is 58.3% at 3.6 mm and gradually increases to 70% at transformation. Hypaxial musculature develops at 6 mm and completely surrounds the abdominal cavity except at the gut opening at 10 mm.

There are 24 myomeres—10 preanal plus 14 postanal—throughout the larval and juvenile stages.

Pigmentation

Larval pigmentation consists of conspicuous melanophores along the bases of the dorsal and anal fins, on the lateral midline, and in the peritoneum lining the middorsal wall of the abdominal cavity. In a freshly preserved 9-mm larva there are dense concentrations of xanthophores on the head, preopercle, and on the back and upper sides of the body while iridiophores are profuse on the sides of the body below the lateral midline. In older larvae, the melanophores are apparently actively expanding and contracting as most larvae have either contracted melanophores and are pale looking, or are dark when the melanophores are expanded. Other larvae have alternating patches of expanded and contracted melanophores forming false bands (Figure 3F-H). In early juveniles (17 mm), the body definitely becomes banded. A bold color pattern develops including a distinct nuchal bar and 6 solid bands which extend to the dorsal and anal fins (Figure 3I). In a young juvenile 23 mm long, the lobes of the unpigmented caudal fin have a brown spot developing at the tips. Alcohol-preserved metamorphic larvae and early juveniles have chocolate-brown bands over a silvery background. With the exception of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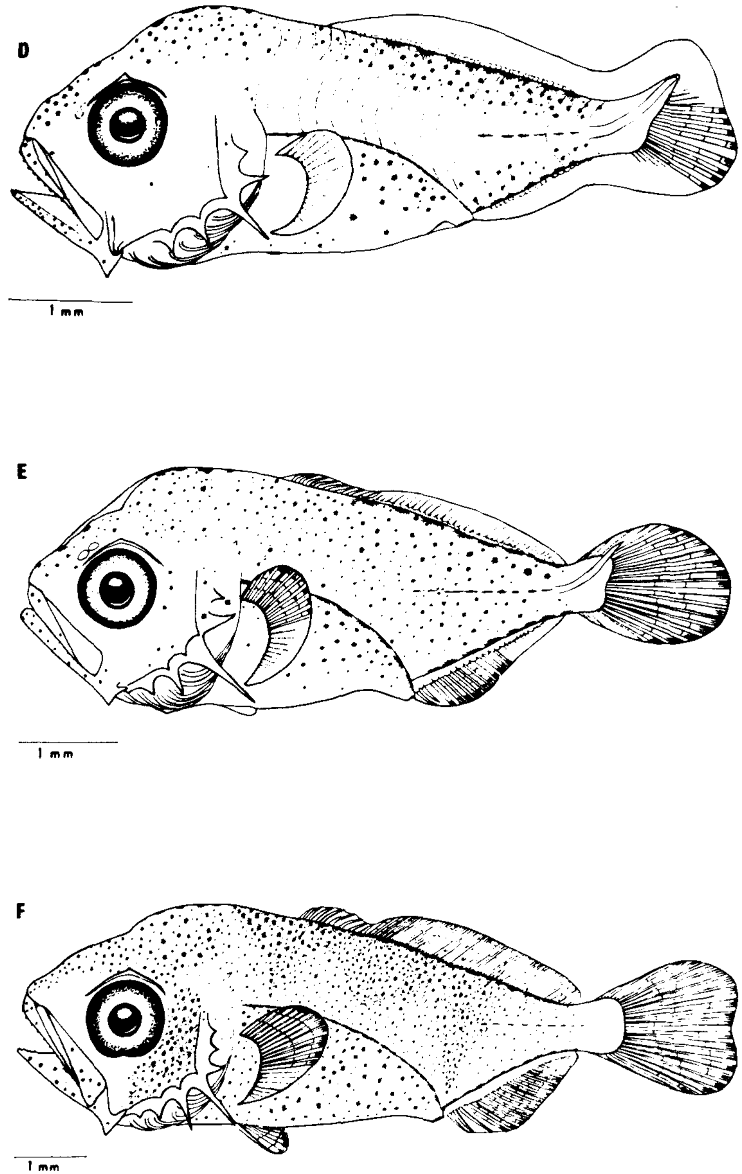


Figure 3.—*Seriola zonata*. **A.** 3.6 mm SL; **B.** 4.8 mm SL (dorsal view); **C.** 4.8 mm SL (lateral view); **D.** 5.5 mm SL; **E.** 6.5 mm SL; **F.** 8.7 mm SL; **G.** 10.6 mm SL; **H.** 13.5 mm SL; **I.** 18.0 mm SL.

melanophores, all other chromatophores fade on preservation in formaldehyde solution.

Fin Development

The dorsal, anal, caudal, and pectoral finfolds are present in the youngest larva (3.6 mm). Differentiation of the fin rays occurs in the following sequence: 1) caudal, 2) first dorsal and anal, 3) second dorsal and pectoral, 4) ventral. All fins are essentially formed at 9 mm (Table 5).

The pectoral fin rays ossify at 6 mm beginning with the most dorsal rays, and the rest ossify ventrally. The full complement of 19 to 20 rays is formed at 10 mm.

The pelvic fin rays differentiate at 7 mm, and the full complement of 5 rays is present at 9 mm.

The dorsal and anal fin rays ossify anteroposteriorly. At 8 to 9 mm the full number of 8 spines in the first dorsal fin and 1 spine and 35 to 40 soft rays in the second dorsal is completed. The first dorsal fin becomes arch-shaped as the spines increase in height and remains continuous with the second dorsal fin until in early juveniles (15-17 mm) a deep notch demarcates the 2 fins. The anal fin rays begin to ossify at 5 mm, and the full complement of 3 spines and 19 to 22 soft rays is completed at 10 mm.

The caudal fin begins to develop at 4 to 5 mm in a manner similar to that occurring in *Elagatis bipinnulata*. The full complement of 9 dorsal and 8 ventral principal rays is present at 7 to 8 mm, while the full complement of 10 to 11 dorsal and of 9 to 10 ventral secondary rays is completed at 9 mm.

Distribution and Spawning

Juveniles of *Seriola zonata* (12-23 mm) have been reported to be regular summer visitors in Cape Cod waters which appear to be their most northernly record (Mather, 1952). Adults have been recorded from various points of the Atlantic coast and in the Gulf of Mexico (Ginsburg, 1952).

Larvae and early juveniles up to 26 mm were taken in all months except in February, April, September, and December. They were caught with a 1-m plankton net in the Gulf Stream off Miami, with dip nets at the pier of the Southeast Fisheries Center in Biscayne Bay, and with neuston nets in the Gulf of Mexico, Yucatan Channel, Straits of Florida, and south Atlantic coast. The larvae occurred in 1.4% of the net stations and constituted 1.8% of the larval carangids in the collection. The occurrence of the larvae is too erratic to indicate whether or not the spawning period is continuous over 12 mo or broken into two parts, winter-spring and fall. Spawning occurred mainly in offshore waters in the eastern Gulf of Mexico, Yucatan Channel, Santaren Channel, along the edge of the continental shelf in the Straits of Florida, and in the Carolina Bight off New Brunswick, Ga. (Figure 2). The planktonic larvae are presumably carried along the Florida Current and Gulf Stream and reach their northern limits as juveniles.

Round scad, *Decapterus punctatus* (Agassiz)

Figure 4

Literature

The early growth of this species were described

TABLE 5.—Meristic characters of cleared and stained larvae and juveniles of *Seriola zonata*.

Standard length	Dorsal fin	Anal fin	Left pectoral fin	Left pelvic fin	Primary caudal fin rays		Secondary caudal fin rays		Gill rakers, left first gill arch	Left preopercular margin spines
					Dorsal	Ventral	Dorsal	Ventral		
3.6	–	–	–	–	–	–	–	–	–	4
4.4	–	–	–	–	4	5	–	–	–	4
5.5	IV	II; 5	–	–	8	7	–	–	0+6	5
6.5	VI; 22	II; 11	8	–	9	8	–	–	0+8	6
7.5	VII; 30	II; 16	10	I, 3	9	8	1	2	0+11	7
8.4	VIII; I, 34	II; 19	13	I, 4	9	8	3	3	3+13	7
9.5	VIII; I, 36	II; 20	17	I, 5	9	8	5	5	4+15	7
10.3	VIII; I, 38	II; I, 20	18	I, 5	9	8	7	8	5+15	7
11.2	VIII; I, 39	II; I, 21	20	I, 5	9	8	8	8	5+15	7
12.0	VIII; I, 36	II; I, 22	20	I, 5	9	8	9	8	5+15	5
13.0	VIII; I, 37	II; I, 20	20	I, 5	9	8	9	9	5+16	3
14.2	VIII; I, 36	II; I, 19	20	I, 5	9	8	10	9	6+16	4
15.2	VIII; I, 38	II; I, 20	19	I, 5	9	8	11	10	6+16	4
16.0	VIII; I, 40	II; I, 21	20	I, 5	9	8	11	10	6+17	4
17.0	VIII; I, 38	II; I, 20	20	I, 5	9	8	11	10	8+18	3

by Hildebrand and Cable (1930) who also studied the abundance and distribution of the young up to 50 mm taken from the coastal and offshore waters of Beaufort, N.C. In addition, life history series were described for two species of *Decapterus* from the Indo-Pacific region: *D. russelli* by Vijayaraghavan (1958) and *D. maruadsi* by Shojima (1962). The latter series is quite similar to that of *D. punctatus*.

Distinguishing Features

Larvae of *D. punctatus* are decidedly deep-bodied although the adults are the most slender of all carangids. The head has a supraoccipital and an orbital crest and preopercular spines. During metamorphosis, the ultimate rays of the dorsal and anal fins become separated and modified into finlets. The first interhemal spine is slightly swollen. Together with the hemal spine of the first caudal vertebra to which it is closely apposed it forms a strong brace at the posterior border of the abdominal cavity. There are 25 vertebrae—10 trunk plus 15 caudal. *D. punctatus* is one of the few carangids with a vertebral count of 25, the usual number being 24; this is a useful character for separating the larvae from other species of *Decapterus*. Berry (1968) used the scales, scutes, and lateral line spots in the identification of the older juveniles from 90 mm long. These characters are not yet formed in the larvae.

Morphology

Body depth decreases relative to standard length and is 30.6 to 35.4% during the entire larval period (Table 6). In transforming larvae and early juveniles, body depth decreased to 28%. The head is long and deep; relative head length increases throughout the larval and juvenile stages. It is 27% in the smallest larvae (3.0 mm) and attains a maximum of 35% in the larval period. In transforming larvae and early juveniles, it is never less than 31% of the standard length. The head is deeper than long in the early larval stages up to notochord flexion and ranges from 108.3 to 113%. Thereafter, head depth decreases gradually with an average of 90% but is never less than 80% of the head length in the early juveniles. A supraoccipital crest is present during the larval period but is resorbed at metamorphosis. The snout is slightly concave in the youngest larvae (3.0 mm), but becomes straight at initial notochord flexion. In older and transforming larvae, the snout develops a convex profile.

The eyes are large and round, and the orbit diameter increases relative to head length. Eye index ranges from 30 to 46.1% during the larval and transition periods and is highest at notochord flexion. A low orbital crest bearing a weak spine is present above the eyes in larvae 3 to 7 mm long. In older larvae, the crest is gradually resorbed and is no longer visible at 10 mm.

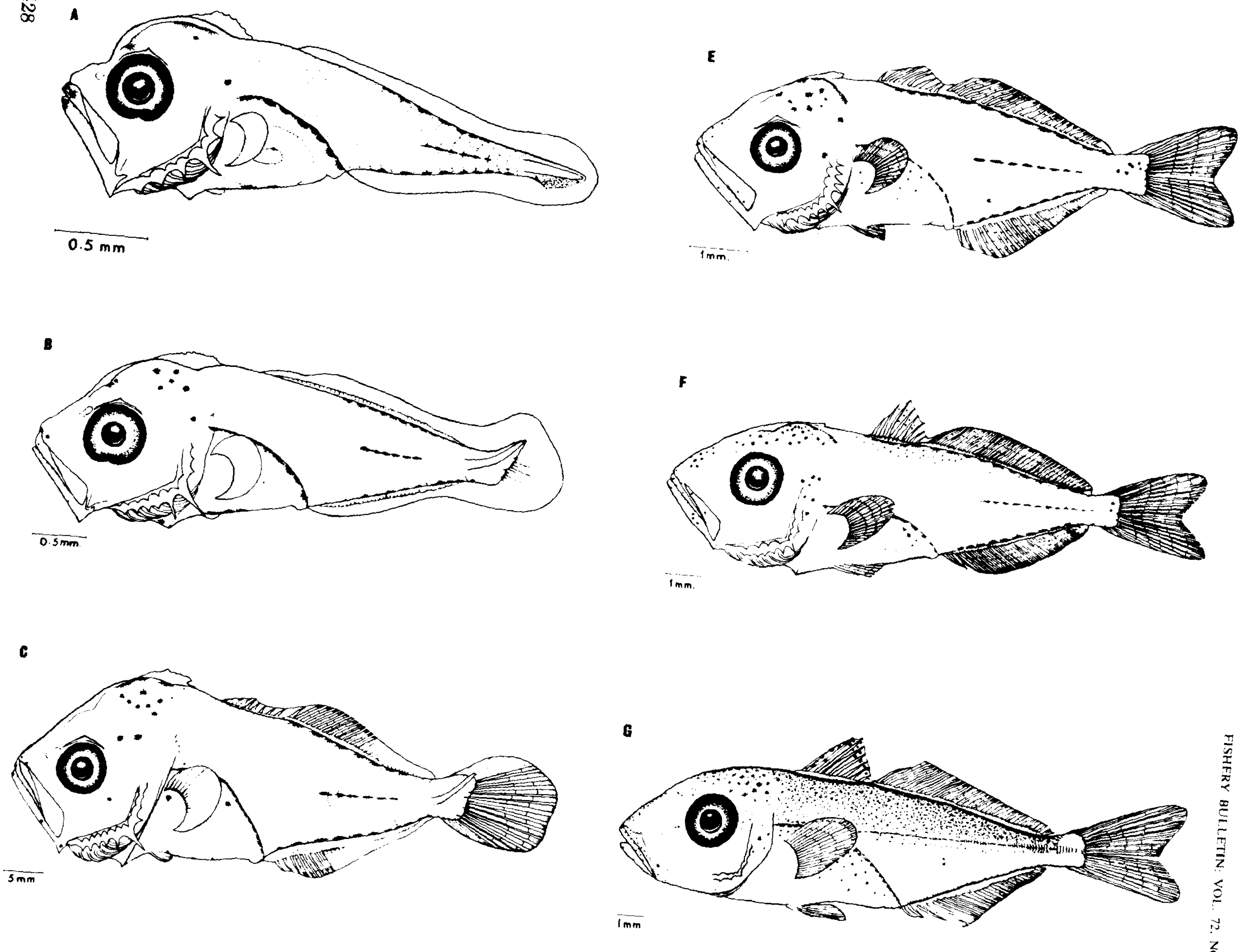
Marginal and lateral surface spines are present on the preopercle. They increase in size and number during the larval period but are gradually resorbed at metamorphosis. At 17 mm, the lateral surface spines are gone and the margin spines are reduced to fine crenulations on the preopercular margin.

The slender gut is coiled in a single loop in the early larvae. A second loop is formed at transformation and a third is added in the early juveniles. Snout-to-anus distance increases relative to standard length; it is 52.3 to 59.5% of the standard length during the entire larval and transition periods and does not change noticeably during the early juvenile stages. Hypaxial muscles begin to develop around the gut in 5-mm larvae, and at 7 mm, the abdominal cavity is completely enclosed except at the anal opening of the gut.

The first scales to ossify are those at the posterior region of the lateral line in juveniles 17 mm long. Ossification of the lateral line scales proceeds anteriad and the full complement of scales and scutes is present at 20 mm when the body scales are formed.

Pigmentation

Chromatophores are slow to develop in the larvae and remain sparse until the early juvenile stages. There are a few melanophores on the back of the head, on the jaws, and infrequently on the snout and cheeks. As in other carangid larvae, there is a row of melanophores on each side of the bases of the dorsal and anal fins, along the lateral line at the caudal region, and on the dorsal wall of the peritoneum. Compared to those of *Seriola zonata* and *Elagatis bipinnulata*, the larvae of *Decapterus punctatus* are pale. Melanophores are not profusely developed until metamorphosis, and they are mostly located above the midline. In the early juveniles, iridiophores spread all over the body but are most dense below the lateral line, giving the fish a metallic sheen.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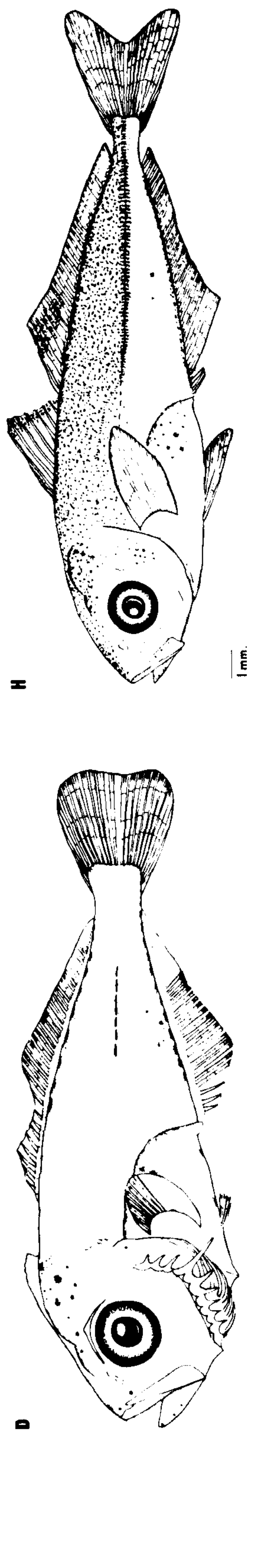


FIGURE 4.—*Decapterus punctatus*. **A.** 3.1 mm SL; **B.** 4.2 mm SL; **C.** 5.5 mm SL; **D.** 6.5 mm SL; **E.** 8.0 mm SL; **F.** 12.0 mm SL; **G.** 17.5 mm SL; **H.** 23.0 mm SL.

Fin Development

The dorsal, anal, caudal, and pectoral finfolds are distinct in the smallest larvae (3.0 mm), but the fin rays begin to ossify at 4 to 5 mm in the following sequence: 1) caudal; 2) dorsal, anal, and pectoral; 3) ventral (Table 7).

The pectoral fin rays are differentiated at 5 mm, and the full complement of 19 to 21 rays is present at 11 mm.

The pelvic fin buds are present at 4 to 5 mm, but the fin rays ossify at 6 mm, and the full complement of 1 spine and 5 soft rays is formed at 7 mm.

As in *E. bipinnulata* and *S. zonata,* ossification of the dorsal and anal fin rays proceed anteroposteriorly. The full complement of 8 spines in the first dorsal fin and of 1 spine and 31 to 34 soft rays in the second dorsal fin is present at 10 mm. At this stage also, the ultimate fin rays gradually separate from the dorsal and anal fins and each modifies into a much branched finlet. The anal fin rays start to ossify at 5 mm, and the full complement of 3 spines and 27 to 31 rays is completed at 9 mm.

The pattern of caudal fin formation is generally similar to that of *E. bipinnulata.* Caudal fin structures initially develop at 4 mm, and all 17 principal rays are present at 6 mm. The full complement of 9 dorsal and 9 ventral secondary rays is formed at 13 mm. Unlike *E. bipinnulata,* only two median epurals are normally developed as the center epural is markedly reduced.

Distribution and Spawning

Adults of *D. punctatus* have been reported from both sides of the Atlantic from Nova Scotia to Brazil (Jordan and Evermann, 1896) and West Africa (Fowler, 1936). The first record of the larvae was reported by Hildebrand and Cable (1930) in Beaufort, N. C. They noted that spawning occurred throughout the summer or from May to November with a peak from July to September. Larvae and juveniles 2 to 50 mm long were present in inshore as well as offshore waters, possibly extending beyond the Gulf Stream, from the surface to the bottom up to a depth of 20 fathoms. In the present study, larvae and juveniles of *D. punctatus* were taken in all the months during the routine fish larvae sampling in the Gulf Stream off Miami and in numerous net stations in the Gulf of Mexico and the south Atlantic coast. Spawning occurs in pelagic inshore as well

TABLE 6.—Measurements (mm) of larvae and juveniles of *Decapterus punctatus*. (Specimens between dashed lines are undergoing notochord flexion.)

Standard length	Snout-to-anus distance	Head length	Head depth	Body depth at base of pectoral fin	Snout length	Orbit diameter	Snout to fin origin		
							Predorsal	Prepelvic	Preanal
3.0	1.7	0.8	0.9	1.0	0.26	0.32	-	-	-
3.1	1.8	.8	1.0	1.1	.30	.37	-	-	-
3.5	2.0	1.0	1.1	1.2	.37	.42	-	-	-
3.7	2.0	1.1	1.2	1.2	.40	.47	-	-	-
4.0	2.2	1.2	1.3	1.2	.45	.52	-	-	-
4.2	2.5	1.3	1.5	1.3	.47	.60	-	-	-
4.8	2.6	1.5	1.6	1.6	.50	.65	-	-	-
5.2	3.0	1.6	1.8	1.8	.55	.70	-	-	-
5.5	3.2	1.8	2.0	1.9	.57	.75	-	-	-
6.4	3.7	2.2	2.1	2.0	.62	.82	2.8	2.2	3.8
6.5	3.8	2.2	2.1	2.0	.62	.82	2.9	2.1	3.8
6.7	3.9	2.2	2.2	2.1	.65	.80	2.8	2.0	3.7
7.1	4.0	2.2	2.4	2.2	.67	.85	3.1	2.4	4.2
7.5	4.1	2.5	2.5	2.4	.72	.90	3.2	2.3	4.2
7.8	4.2	2.5	2.5	2.5	.75	.92	3.2	2.6	4.5
8.0	4.2	2.7	2.6	2.6	.75	.95	3.2	2.6	4.3
8.3	4.5	2.8	2.6	2.6	.75	1.0	3.5	2.7	4.7
8.6	4.5	3.0	2.6	2.7	.80	1.0	3.2	2.6	4.6
9.8	5.5	3.2	3.0	3.0	.85	1.2	3.9	3.0	5.6
10.0	5.8	3.5	3.0	3.0	1.0	1.1	4.5	4.0	6.2
10.2	5.8	3.5	3.2	3.4	1.1	1.2	4.5	4.3	6.6
10.5	6.2	3.5	3.2	3.2	1.1	1.25	4.6	4.0	6.3
11.0	6.1	3.5	3.5	3.4	1.1	1.2	4.5	4.3	6.6
11.2	6.2	3.5	3.5	3.5	1.2	1.2	4.6	4.0	6.4
11.4	6.4	3.7	3.7	3.6	1.2	1.2	4.6	4.5	6.6
[1]12.0	6.9	4.0	3.8	3.7	1.2	1.3	4.8	4.5	6.8
[1]12.3	6.8	4.0	3.8	3.7	1.2	1.3	4.8	4.5	6.8
[1]12.5	7.0	4.2	4.0	3.8	1.2	1.3	5.0	4.8	7.2
[1]13.0	7.2	4.2	4.0	4.1	1.3	1.3	5.2	4.9	7.5
[1]13.2	7.4	4.2	4.0	4.1	1.2	1.4	5.4	4.7	7.6
[1]13.5	7.5	4.3	4.1	4.2	1.3	1.5	5.2	5.0	7.8
[1]14.0	8.0	4.4	4.5	4.3	1.3	1.6	5.8	5.8	8.5
[2]14.4	7.8	4.5	4.1	4.3	1.3	1.6	5.6	5.4	8.3
[2]14.9	8.0	4.8	4.2	4.3	1.4	1.6	5.9	6.0	8.6
[2]15.2	8.2	5.0	4.2	4.4	1.5	1.6	5.8	5.6	8.2
[2]15.5	8.6	5.2	4.1	4.5	1.6	1.6	5.9	5.5	8.3
[2]16.0	8.7	5.3	4.5	4.6	1.5	1.7	6.5	5.8	9.0
[2]16.2	8.8	5.6	4.6	4.6	1.6	1.7	6.4	5.9	9.0
[2]16.5	8.8	5.7	4.7	4.7	1.7	1.8	6.3	5.9	9.0
[2]17.0	9.5	5.7	5.0	4.8	1.8	1.9	7.0	6.0	9.8
[2]17.5	9.2	5.7	4.6	4.9	1.9	1.9	6.4	5.8	9.3
[2]18.0	9.5	6.0	5.0	5.2	1.9	2.0	7.0	6.3	10.0
[2]18.5	9.6	6.0	5.2	5.3	1.8	2.0	7.0	6.5	10.0
[2]19.2	10.0	6.1	5.4	5.5	2.0	2.0	7.0	6.8	11.3
[2]19.5	10.0	6.1	5.4	5.7	1.9	2.0	7.3	6.6	11.5

[1]Transforming.
[2]Juveniles.

as offshore waters and along the edge of the continental shelf (Figures 5, 6). In the Gulf of Mexico, the larvae appear to have their center of abundance in the eastern area. They have the highest frequency of occurrence and are the most abundant among the larval carangids considered

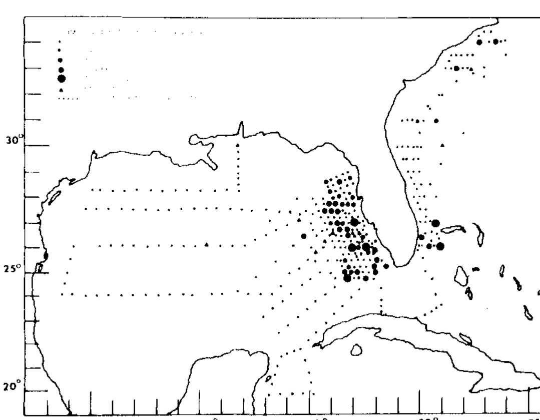


FIGURE 5.—Distribution and apparent relative abundance of the larvae of *Decapterus punctatus* in the Gulf of Mexico and the South Atlantic coast of the United States: a composite record of occurrences at stations occupied in October to November 1970 by the *Joie de Vivre* and in August, October, and November 1971 by the *Dan Braman* and *Oregon II*. Open circles indicate other stations occupied.

TABLE 7.—Meristic characters of cleared and stained larvae and juveniles of *Decapterus punctatus*.

Standard length	Dorsal fin	Anal fin	Left pectoral fin	Left pelvic fin	Primary caudal fin rays		Secondary caudal fin rays		Gill rakers, left first gill arch	Left preopercular margin spines
					Dorsal	Ventral	Dorsal	Ventral		
3.1	—	—	—	—	—	—	—	—	—	5
3.5	—	—	—	—	—	—	—	—	—	6
4.2	—	—	—	—	4	3	—	—	0+ 6	8
5.3	V; 6	II; 6	3	—	6	—	—	—	0+12	10
6.6	VI; I, 19	II; I, 16	10	I, 5	9	8	3	2	0+14	11
7.6	VII; I, 20	II; I, 18	14	I, 3	9	8	4	4	0+16	12
8.2	VIII; I, 25	II; I, 19	17	I, 5	9	8	5	6	0+17	12
9.0	VIII; I, 30	II; I, 21	18	I, 5	9	8	7	8	0+17	11
10.4	VIII; I, 31	II; I, 24	17	I, 5	9	8	8	8	3+17	11
11.5	VIII; I, 23	II; I, 26	19	I, 5	9	8	8	8	3+21	11
12.5	VIII; I, 34	II; I, 31	19	I, 5	9	8	9	9	6+24	10
13.5	VIII; I, 32	II; I, 28	20	I, 5	9	8	9	9	6+25	10
14.4	VIII; I, 32	II; I, 27	20	I, 5	9	8	9	9	6+26	9
15.1	VIII; I, 33	II; I, 29	20	I, 5	9	8	9	9	6+25	10
16.5	VIII; I, 32	II; I, 27	19	I, 5	9	8	9	9	6+25	7
17.0	VIII; I, 31	II; I, 27	20	I, 5	9	8	9	9	6+27	5
19.0	VIII; I, 34	II; I, 27	20	I, 5	9	8	9	9	6+28	3
23.0	VIII; I, 32	II; I, 28	21	I, 5	9	8	9	9	8+28	2
28.2	VIII; I, 31	II; I, 28	20	I, 5	9	8	9	9	9+28	0

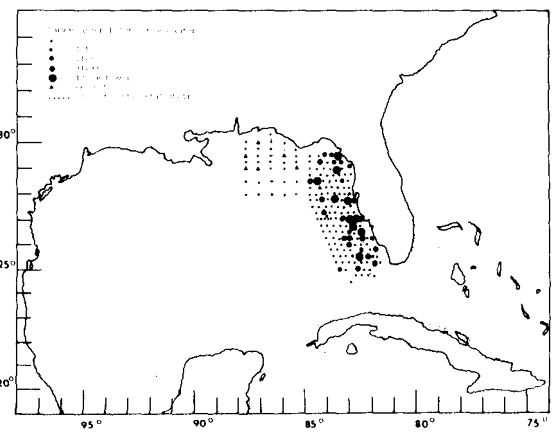


FIGURE 6.—Distribution and apparent relative abundance of the larvae of *Decapterus punctatus* in the Gulf of Mexico: a composite record of occurrences at stations occupied from May to August 1972 by the *Tursiops*, *Dan Braman*, and *Gerda*.

here. They occurred in 18.5% of the net stations and constituted 44.7% of the larval carangids collected.

Lookdown, *Selene vomer* (Linnaeus)
Figure 7

Literature

Larvae of *S. vomer* are previously undescribed. Fowler (1936) illustrated a 15-mm juvenile and Lutken (1880) a 28-mm juvenile.

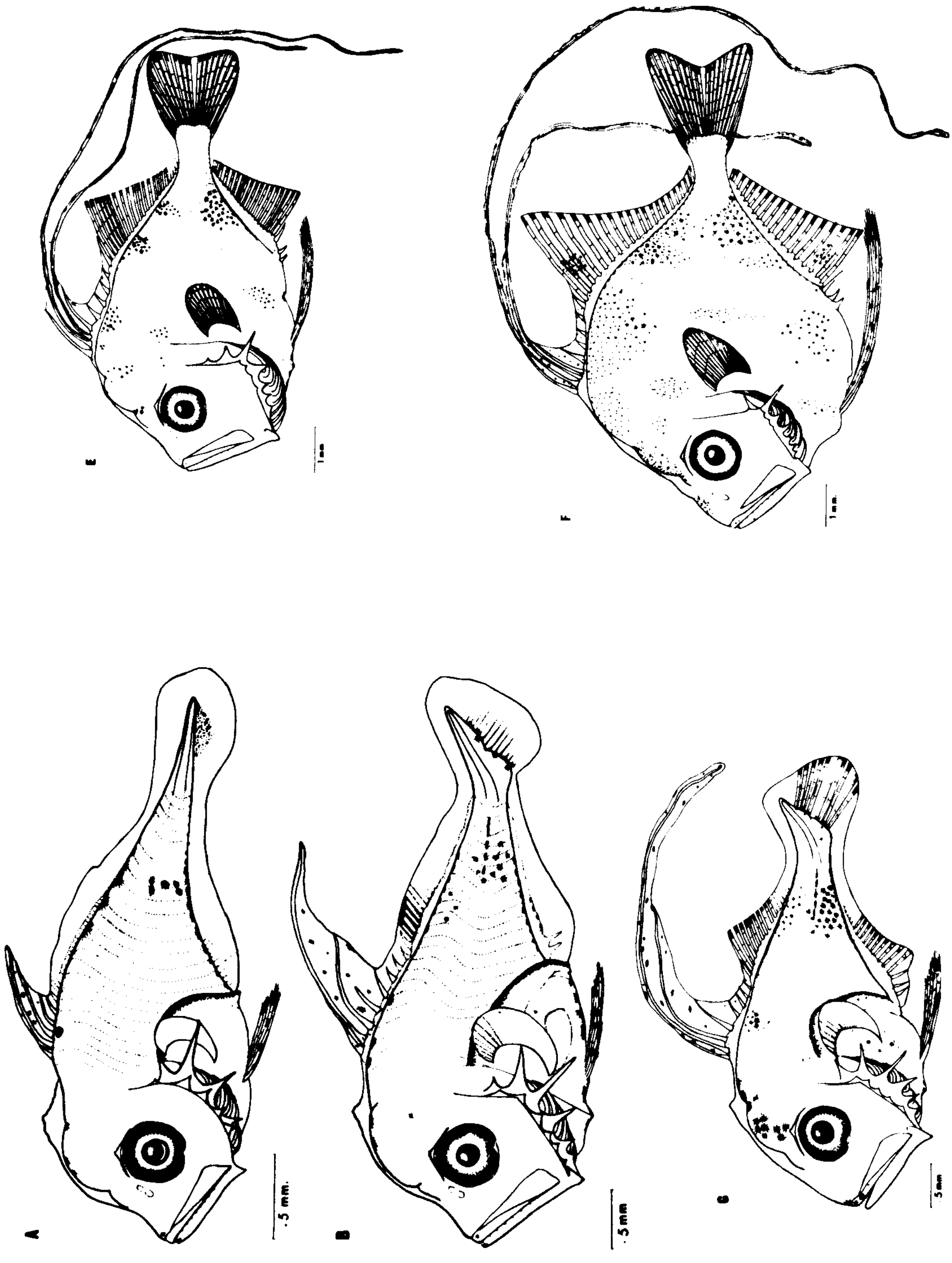
Distinguishing Features

Larvae of *S. vomer* have extremely deep and trenchant bodies. The advanced development of the dorsal and ventral fins is perhaps the most notable feature of their development; it is the earliest observed among carangid larvae. The second and third dorsal spines develop into long filaments often twice the length of the body. The ventral fins are elongated, often extending to the anal fin. The larvae probably attain a maximum length of 12 mm before transformation. The biggest larva in the series in 9 mm long (Figure 7F) and the next size, 13.5 mm, (Figure 7G) is a transforming larva hatched from a planktonic egg and reared in an aquarium. The smallest juvenile is 23.9 mm long and has attained most adult features.

As in most larval carangids, there is a bony crest in the supraoccipital bones, two rows of preopercular spines, and a supraorbital crest. The distance from the snout to the occipitals is long and slopes into an abrupt angle. The first interhemal spine is much enlarged and pressed against an equally enlarged hemal spine.

Morphology

The larvae are among the most deep bodied of all larval carangids. Relative body depth increases during the larval and early juvenile periods (Table 8). It is 32% at 2.5 mm and increases steadily, attaining a maximum of 96% at 23.9 mm. Thereafter, body depth gradually declines but is never less than 74% of the body length in the juveniles. Simultaneous with the deepening of the body is the enlargement of the first interhemal and hemal spine of the first caudal vertebra. The


E
1 mm
F
1 mm.
A
.5 mm.
B
.5 mm
5 mm

two spines fuse at the posterior wall of the abdominal cavity which becomes elongated vertically. Consequently, the long and slender gut forms vertical loops following the shape of the abdominal cavity. The gut opening is pushed anteriorly and lies adjacent to the base of the pelvic fins. Snout-to-anus distance decreases relative to standard length. It is 56% at 2.5 mm and declines to 40% at the end of the larval period. During the early juvenile stages, snout-to-anus distance had an average of 38%.

The length and width of the head increases relative to standard length. Head length is 31.0% in the smallest larva (2.5 mm) and does not increase substantially until the juvenile period when it attains a maximum of 41.9% at 23.9 mm. To obtain the true depth of the head and not the body depth at the head region, the measurement is taken from the posterior margin of the preopercle from the dorsal margin of the head to the articulation of the mandible and maxillary. Head depth is 100% of the head length at 2.5 to 3.2 mm. Thereafter, head depth exceeds head length. During the larval period, the head is deepest at 4.6 mm when it is 140% of the head length. This is, however, exceeded by the progressive deepening of the head during the transition and juvenile stages with a maximum of 182% and an average of 158%. The dorsal profile of the snout is slightly concave in the early larval period (2.5-3.8 mm) but becomes straight in older and transforming larvae. The nasal, frontal, and supraoccipital bones become markedly elongated and slope steeply, giving the head an almost vertical anterior profile.

The eyes are round and large. Relative orbit diameter increases during the larval and juvenile development; it is 32% at 2.5 mm and attains a maximum of 37% at notochord flexion with an average of 31% during the larval and transition periods. In the juveniles, orbit diameter decreases to a range of 20 to 27%.

The orbital and supraoccipital crests are well marked in early larval stages up to 5 mm. The crests are gradually resorbed and are vaguely visible at metamorphosis. Preopercular marginal spines consist of 4 to 7 long and strong spines while the lateral surface spines are smaller and limited to the lower surface. All preopercular spines are resorbed at transformation. Scales are absent.

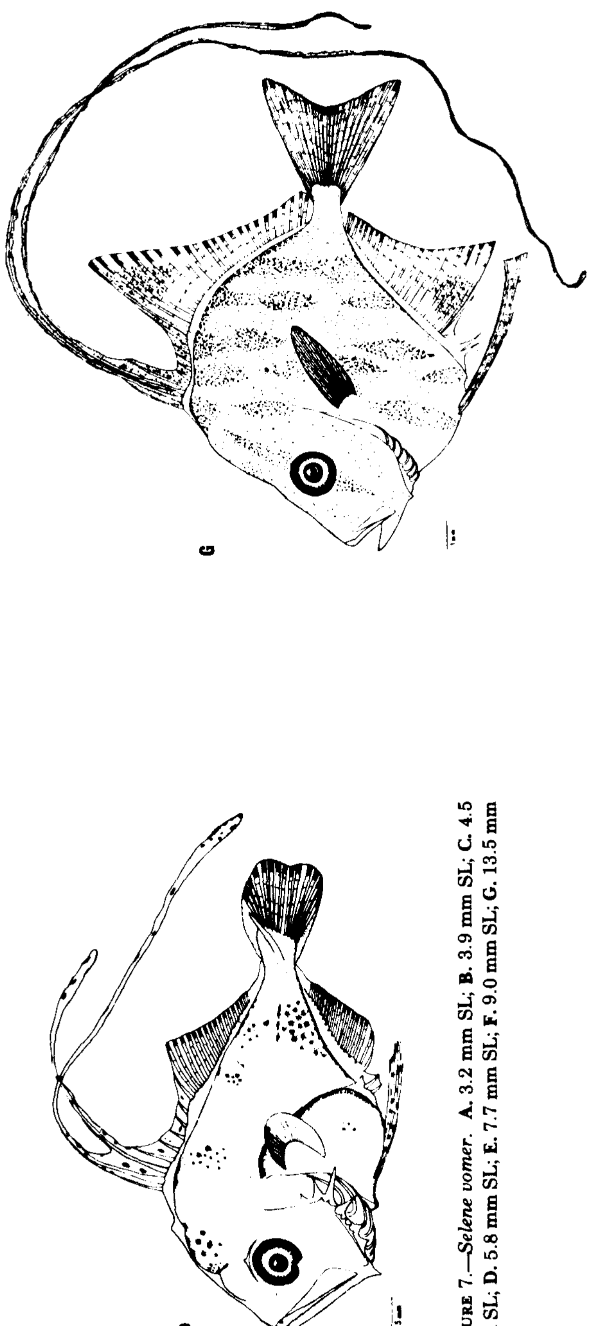


FIGURE 7.—*Selene vomer*. **A.** 3.2 mm SL; **B.** 3.9 mm SL; **C.** 4.5 mm SL; **D.** 5.8 mm SL; **E.** 7.7 mm SL; **F.** 9.0 mm SL; **G.** 13.5 mm SL.

Pigmentation

The common larval pattern of pigmentation in

TABLE 8.—Measurements (mm) of larvae and juveniles of *Selene vomer*.

(Specimens between dashed lines are undergoing notochord flexion.)

Standard length	Snout-to-anus distance	Head length	Head depth	Body depth at base of pectoral fin	Snout length	Orbit diameter	Snout to fin origin: Predorsal	Snout to fin origin: Prepelvic	Snout to fin origin: Preanal
2.5	1.4	0.78	0.78	0.80	0.25	0.25	1.0	0.7	—
3.2	1.7	1.0	1.0	1.0	.37	.32	1.1	1.2	1.7
3.5	1.8	1.1	1.2	1.3	.37	.35	1.2	1.0	1.8
3.8	1.8	1.2	1.4	1.5	.42	.42	1.2	1.35	2.0
4.0	2.0	1.2	1.5	1.5	.47	.37	1.3	1.2	2.0
4.3	2.2	1.5	1.9	1.9	.52	.50	1.5	1.6	1.9
4.4	2.1	1.5	2.0	2.1	.55	.50	1.4	1.6	1.8
4.5	2.2	1.5	2.0	2.0	.52	.45	1.4	1.5	2.0
4.6	1.8	1.5	2.1	2.1	.55	.42	1.6	1.6	2.1
4.8	2.6	1.7	2.0	2.1	.55	.45	1.8	1.7	2.8
5.0	2.7	1.7	2.2	2.2	.52	.47	1.8	1.9	3.0
5.3	3.0	1.7	2.1	2.3	.55	.45	1.7	2.0	3.0
5.5	2.7	2.0	2.5	2.9	.62	.60	1.8	1.8	3.1
6.1	2.8	2.0	3.0	3.2	.87	.62	2.0	2.0	3.0
7.5	3.6	2.6	3.5	3.9	.90	.85	2.4	2.5	4.0
8.2	4.5	3.0	3.8	4.8	1.2	.87	2.9	3.0	4.6
[1]9.0	3.6	3.1	5.2	5.8	1.3	1.0	2.9	2.8	5.0
[1]13.5	6.7	5.2	9.5	6.2	2.2	1.7	5.5	5.5	6.2
[2]23.9	8.7	10.0	14.0	23.0	3.1	2.5	7.0	8.0	11.0
[2]27.5	11.5	10.0	15.0	24.5	3.5	2.6	11.0	8.0	14.0
[2]30.0	12.0	11.0	17.0	27.0	5.0	3.0	14.0	12.0	14.0
[2]34.0	12.0	13.5	22.0	31.0	6.5	3.0	14.0	13.0	14.0
[2]38.0	14.0	14.5	20.0	31.0	5.0	3.2	15.5	11.5	16.0
[2]42.5	14.0	17.0	28.0	35.0	5.5	3.9	17.0	15.0	14.0
[2]47.0	16.0	20.0	30.0	35.0	8.0	4.2	16.0	18.0	17.0

[1]Transforming
[2]Juveniles

carangids, including melanophores along the bases of the dorsal and anal fins and along the lateral-midline, is present in *S. vomer*. In the early larvae (2.5-5.0 mm), a few melanophores develop on the tips of the jaws, head, sides of the body, pelvic fin, dorsal fin, and base of the caudal fin. The earliest patch of melanophores is formed on the lower side of the body anterior to the caudal peduncle. In older larvae, the melanophores gradually proliferate all over the body and form discrete patches which develop into broad spots at transformation and in the juvenile stages. The heaviest concentrations of pigment cells comprise those lining the dorsal wall of the peritoneum. Reglarly spaced melanophores similar to those in *Elagatis bipinnulata* (Figure 1B-D) are present along the midventral line in the trunk region.

Fin Development

The sequence of fin formation and ossification is as follows: 1) pelvic; 2) first dorsal; 3) second dorsal, caudal, and anal; and 4) pectoral (Table 9).

The pectoral finbud is formed at 2.5 mm but the rays are not differentiated until the larvae are 5 to 6 mm. The full complement of 18 to 21 is formed at 9 mm.

The pelvic fins are fully formed in the smallest larva (2.5 mm). They steadily increase in length and at metamorphosis extend beyond the origin of the anal fin.

The first 3 dorsal spines are ossified at 2.5 mm. The second and third spines progressively increase in length throughout the larval period, forming extremely long filaments. At metamorphosis, they are about twice the length of the body. The full complement of 8 spines in the first dorsal fin and of 1 spine and 20 to 22 soft rays in the second dorsal fin is present at 9 mm.

Rudiments of the anal fin are discernible at 3.2 mm and the rays ossify at 4 to 5 mm. The full complement of 3 spines and 16 to 18 soft rays is present at 6 mm.

The development and structure of the caudal fin and supporting structures are similar to those of *E. bipinnulata*. The full complement of 17 principal and 7 to 9 dorsal, and 7-8 ventral secondary caudal rays is present at 9 mm.

TABLE 9.—Meristic characters of cleared and stained larvae and juveniles of *Selene vomer* (Linnaeus).

Standard length	Dorsal fin	Anal fin	Left pectoral fin	Left pelvic fin	Primary caudal fin rays		Secondary caudal fin rays		Gill rakers, left first gill arch	Left preopercular margin spines
					Dorsal	Ventral	Dorsal	Ventral		
2.5	III	—	—	I, 5	—	—	—	—	—	—
3.2	V	—	—	I, 5	—	—	—	—	—	—
3.4	V	—	—	I, 5	—	—	—	—	—	—
3.5	VI	—	—	I, 5	—	—	—	—	—	—
4.0	V; 3	II	—	I, 5	2	3	—	—	0+11	1
4.4	VIII; I, 10	II; 10	—	I, 5	5	6	—	—	0+11	2
4.9	VIII; I, 15	II; I, 14	—	I, 5	7	7	—	—	0+16	2
5.2	VIII, I, 18	II, I, 16	—	I, 5	7	8	—	—	3+16	2
5.5	VIII; I, 18	II; I, 17	6	I, 5	7	8	—	—	3+18	3
6.1	VIII; I, 19	II; I, 17	10	I, 5	8	8	—	—	4+19	2
6.3	VIII; I, 20	II; I, 16	13	I, 5	8	8	3	4	5+20	2
7.6	VIII; I, 21	II; I, 17	17	I, 5	9	8	5	4	6+20	2
8.6	VIII; I, 20	II; I, 17	17	I, 5	9	8	6	6	6+20	2
9.0	VIII; I, 20	II; I, 18	18	I, 5	9	8	7	8	6+22	1
13.5	VIII; I, 21	II; I, 18	18	I, 5	9	8	8	7	6+23	—
23.9	VIII; I, 21	II; I, 18	20	I, 5	9	8	9	8	6+25	—

Distribution and Spawning

Adults of *Selene vomer* have been recorded on both coasts of the United States, from Cape Cod to Brazil and from Lower California to Peru (Jordan and Evermann, 1896). They have also been reported from the Gulf of Mexico (Ginsburg, 1952), the Bahamas (Böhlke and Chaplin, 1968), and West Africa (Fowler, 1936).

Larval and early juveniles of *S. vomer* were taken in all months except in June, October, and December. The monthly occurrence and distribution of the larvae is a composite of the records of specimens which include those taken from the coastal waters of the eastern tropical Pacific from Baja California to Costa Rica, the Gulf of Mexico, and the tropical Atlantic off Brazil and Liberia (Aprieto, 1973). In the Gulf of Mexico, larvae were abundant mainly in the northeastern offshore waters in August which suggests a short spawning period in that area (Figure 2). The larvae occurred in 2.2% of the net stations and constituted 2.6% of the larval carangids collected in the Gulf of Mexico and the south Atlantic coast.

Leatherjacket, *Oligoplites saurus* (Bloch and Schneider)

Figure 8

Literature

Larvae of this species have not been described previously.

Distinguishing Features

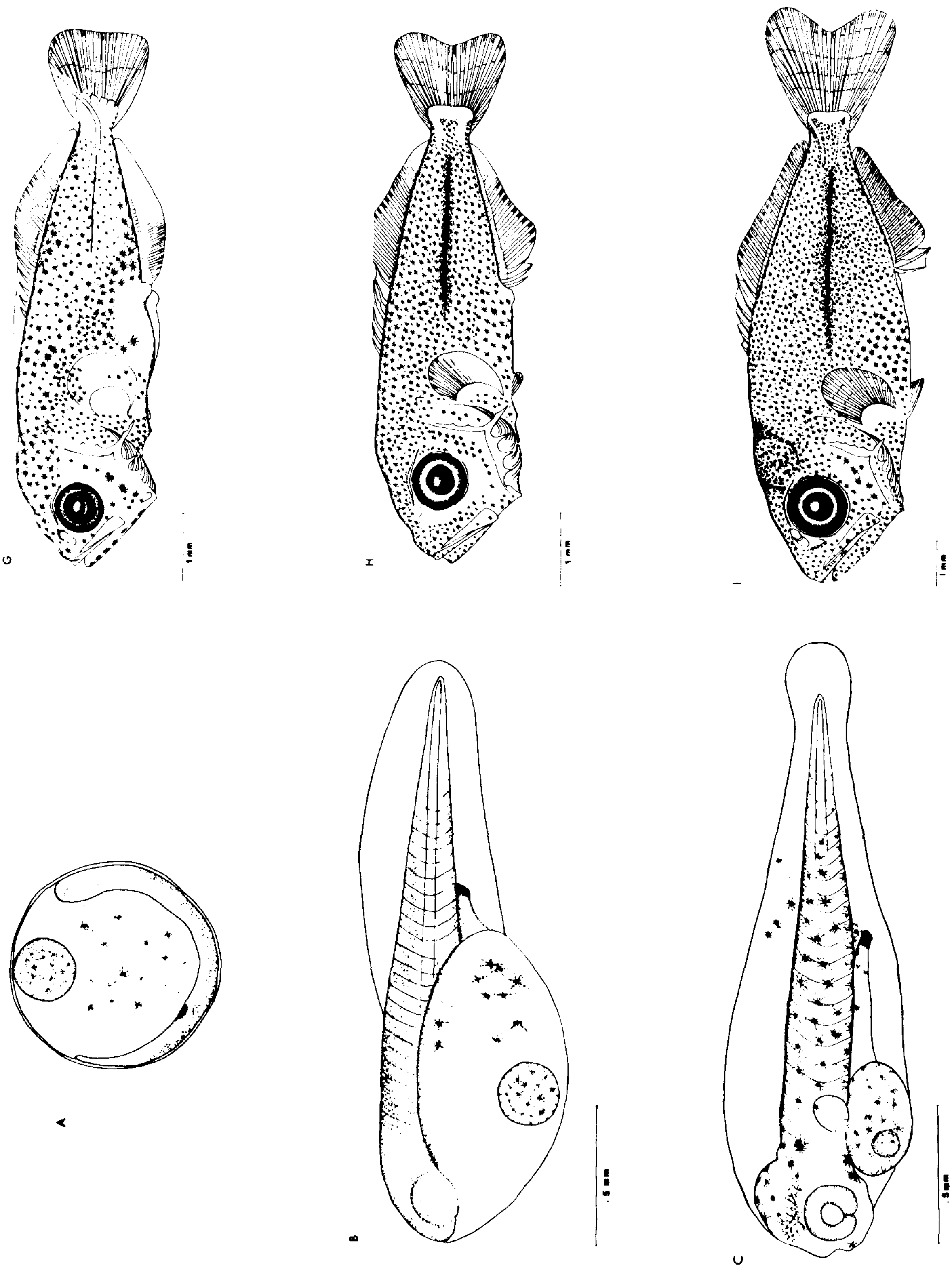
Larvae of *O. saurus* resemble those of *Elagatis bipinnulata* and *Seriola zonata*. Further, as in *E. bipinnulata*, the first interhemal spine is thickened and, as in *S. zonata*, the supraoccipital crest is lacking. Larvae of *O. saurus* are distinct from those of the two species mentioned in having an orbital crest with fine serrations, 1 to 3 denticles which appear early in the larval period on the dorsal side of the longest preopercular spine, and 26 vertebrae—the highest vertebral count among carangids. The number of dorsal spines and pectoral fin rays formed is fewer than in most carangids, 5 to 6 and 15 to 17 respectively. Larval pigmentation is moderately profuse and, as in most carangid larvae, conspicuous melanophores are present along the bases of the dorsal and anal fins, on the lateral midline, and on the dorsal wall of the abdominal cavity. The larvae transform at 7 to 10 mm.

The Embryo

Two preserved eggs of *O. saurus* are 0.87 and 0.88 mm in diameter. They have ventral, single oil globules, 0.33 and 0.34 mm in diameter. The oil globule consists of minute oil droplets and is enclosed in a rather tough, pigmented capsule. The pigmented yolk is bright yellow and unsegmented. The perivitelline space is narrow and the egg case smooth. The embryos are well developed and have stellate melanophores along the back and upper sides of the body. A large melanophore is present at the posteroventral midline (Figure 8A).

Morphology

The larvae are 1.87 and 1.97 mm at hatching.


G
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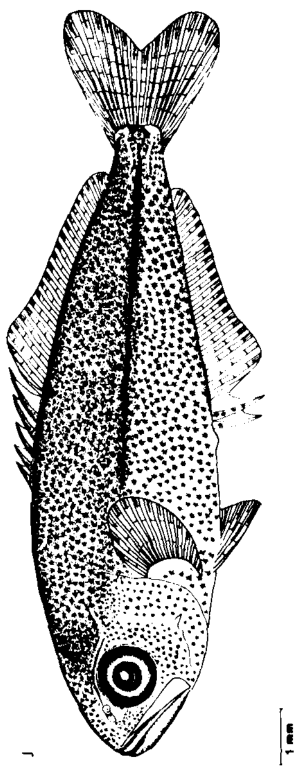
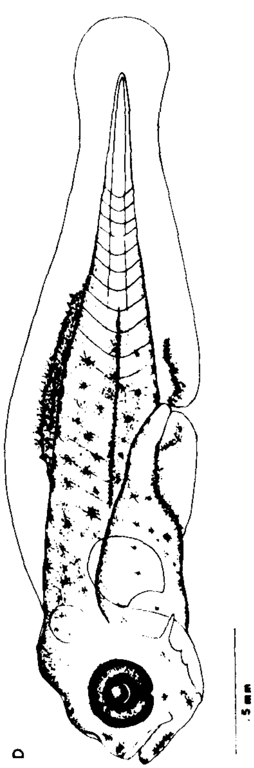


FIGURE 8.—*Oligoplites saurus*. A. Embryo; B. 1.8 mm SL; C. 2.2 mm SL; D. 3.0 mm SL; E. 4.1 mm SL; F. 5.2 mm SL; G. 5.9 mm SL; H. 7.2 mm SL; I. 10.0 mm SL; J. 18.0 mm SL.

The body is slender but appears robust at the anterior end in view of the distended yolk sac (Figure 8B). The head is well marked and the eye buds are discernible. The dorsal finfold originates behind the nape and is continuous with the anal finfold at the tail region. At the first day of hatching, the yolk sac is reduced to a spherule, the eyes are formed but unpigmented, and the dorsal and anal finfolds completely surround the larva except at the mouth. More and bigger melanophores are formed along the sides and back, and a large ventral melanophore is located at the opening of the gut (Figure 8C).

Early larvae of *O. saurus* are slender compared to other larval carangids. Body depth increases relative to standard length and ranges from 20 to 26.9% during the larval period (Table 10). It increases to a maximum of 32% at metamorphosis and thereafter declines to 28 to 29%. The slender gut is straight and forms a single loop at 4 mm. A second loop develops at metamorphosis, and a third is added in the early juvenile period. Snout-to-anus distance ranges from 51 to 61% during the larval period and decreases slightly in subsequent

D



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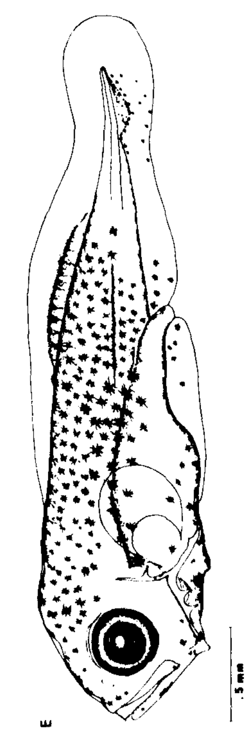

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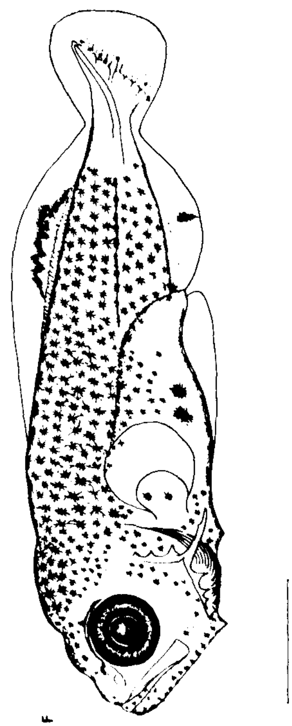

TABLE 10.—Measurements (mm) of larvae and juveniles of *Oligoplites saurus*.

(Specimens between dashed lines are undergoing notochord flexion; W - wild, L - laboratory reared.)

Specimen number	Standard length	Snout-to-anus distance	Head length	Head depth	Snout length	Orbit diameter	Body depth at base of pectoral fin	Snout to fin origin: Predorsal	Snout to fin origin: Prepelvic	Snout to fin origin: Preanal
1(L)	1.87	—	—	—	—	—	—	—	—	—
2(L)	1.95	—	—	—	—	—	—	—	—	—
3(L)	2.17	1.25	0.50	0.45	0.05	0.10	0.45	—	—	—
4(L)	2.25	1.3	.51	.50	.07	.10	.50	—	—	—
5(L)	2.3	1.3	.57	.54	.09	.20	.60	—	—	—
6(L)	2.5	1.4	.60	.59	.09	.25	.60	—	—	—
7(L)	2.5	1.5	.60	.60	.12	.25	.50	—	—	—
8(L)	2.6	1.5	.60	.55	.12	.25	.55	—	—	—
9(L)	2.8	1.6	.67	.65	.12	.30	.60	—	—	—
10(L)	4.1	2.4	1.1	.95	.25	.40	.87	—	—	—
11(W)	4.3	2.2	1.3	1.2	.37	.37	1.0	1.9	—	2.0
12(W)	4.9	2.7	1.4	1.3	.40	.45	1.3	2.1	—	2.8
13(L)	5.2	3.0	1.5	1.4	.40	.52	1.4	2.1	—	3.0
14(L)	5.9	3.5	1.8	1.5	.45	.62	1.4	2.5	—	3.5
15(L)	7.2	4.4	2.6	2.2	.75	.75	2.2	3.6	3.2	4.6
16(W)	8.7	5.1	3.0	2.5	.80	.80	2.4	4.0	3.6	5.4
17(W)	10.4	5.4	3.3	3.0	.75	1.1	3.0	4.7	3.9	5.7
18(L)	10.5	5.8	3.5	2.9	.90	1.0	3.4	4.9	3.7	6.0
19(W)	10.5	5.5	3.5	3.0	1.0	1.0	3.0	4.9	3.7	5.6
20(W)	11.0	5.9	3.6	3.2	1.0	1.0	3.3	5.2	3.8	6.1
21(W)	15.0	6.9	4.4	3.7	1.3	1.3	4.1	6.0	4.8	7.0
22(W)	16.0	8.0	4.5	4.0	1.2	1.3	4.5	6.5	5.0	8.1
23(L)	18.5	9.5	5.3	4.6	1.3	1.9	5.3	8.0	6.0	9.5
24(L)	21.0	10.5	6.0	5.3	1.5	2.1	6.1	8.9	6.0	11.0

stages. Hypaxial muscles enclose the gut at 4 mm, and the abdominal cavity is completely covered at 7.2 mm.

As in most carangid larvae, the head is long and deep. Relative head length ranges from 23 to 36% of standard length during the larval and juvenile periods. Depth of head ranges from 82 to 100% of the head length. The dorsal profile of the snout is convex except for a slight indentation at the anterior margin of the forebrain. The eyes are round and large; eye index ranges from 20 to 44% during the larval and early juvenile periods and is highest in larvae 2 to 3 mm long. Pigmentation develops on the second day of hatching. A finely serrated orbital crest is present in larvae from 4 mm long and is gradually resorbed following metamorphosis. Preopercular spines are present but only the marginal ones are well developed. One to three denticles occur on the dorsal side of the longest marginal spine.

The scales and lateral line are not yet developed in 25-mm juveniles, the oldest of the laboratory-reared specimens.

Pigmentation

Larval pigmentation is well developed and progressively increases during the larval and juvenile stages. Pigment cells are more abundant in laboratory-reared specimens than in the wild ones. A conspicuous U-shaped, unpigmented area at the caudal peduncle persists from 7.2 mm up to the early juveniles 20 mm long (Figure 8H-J). Throughout the larval and juvenile stages xanthophores are present on the sides of the body, but they readily fade on preservation. Melanophores form at the base of the dorsal finfold in the early larvae but disappear when the fin rays are differentiated. The conspicuous anal pigment spot in the embryo and newly hatched larvae disappear at the third day of hatching. In the early juveniles, pigmentation develops on the membrane of the dorsal and anal fin spines.

Fin Development

The dorsal, anal, and caudal finfolds are present at hatching, and the sequence of ossification is as follows: 1) dorsal, anal, and caudal; 2) pectoral and pelvic (Table 11).

The pectoral finfold is formed a day after hatching. As in other larvae described here, the pectoral fin rays begin to ossify dorsally and the rest are added ventrally. The full complement of 15 to 17 rays is completed at 10 mm.

The pelvic fin buds appear 13 days after hatching at 6 mm and the rays soon become differentiated. The full complement of 1 spine and 5 soft rays is present at 10 mm.

TABLE 11.—Meristic characters of cleared and stained larvae and juveniles of *Oligoplites saurus*.

Standard length	Dorsal fin	Anal fin	Left pectoral fin	Left pelvic fin	Primary caudal fin rays: Dorsal	Primary caudal fin rays: Ventral	Secondary caudal fin rays: Dorsal	Secondary caudal fin rays: Ventral	Gill rakers, left first gill arch	Left preopercular margin spines
4.1	—	—	—	—	—	—	—	—	—	4
4.3	—	—	—	—	—	—	—	—	—	4
4.9	—	—	—	—	—	—	—	—	—	4
5.9	III; 8	II; 7	—	—	3	3	—	—	0+4	6
7.2	V; 18	II; I, 16	7	2	9	8	1	2	0+10	8
8.7	V; I, 17	II; I, 17	10	I, 5	9	8	—	—	0+9	9
10.4	IV; I, 20	II; I, 19	13	I, 5	9	8	9	9	3+12	12
11.0	V; I, 20	II; I, 18	14	I, 5	9	8	9	9	3+11	9
12.2	V; I, 21	II; I, 19	14	I, 5	9	8	10	9	3+11	10
13.0	V; I, 19	II; I, 18	14	I, 5	9	8	9	9	3+10	9
15.1	V; I, 20	II; I, 19	14	I, 5	9	8	9	9	5+11	8
15.2	V; I, 21	II; I, 19	15	I, 5	9	8	9	9	5+11	6
16	V; I, 21	II; I, 18	16	I, 5	7	9	9	9	5+11	5
17	V; I, 21	II; I, 20	16	I, 5	9	8	9	10	5+12	6
18.5	V; I, 20	II; I, 20	16	I, 5	9	8	9	8	5+13	4
19	V; I, 20	II; I, 18	15	I, 5	9	8	10	9	5+13	3
21.0	V; I, 21	II; I, 18	16	I, 5	9	8	9	9	5+13	3

The dorsal and anal fin rays differentiate simultaneously in an anteroposterior direction. Unlike previously described species, in which either the middle or anterior spines are longer, the posterior spine of the first dorsal fin is slightly longer than the rest. The full complement of 6 spines and 19 to 21 rays is present at 10 mm. The anal fin rays of 3 spines and 18 to 20 soft rays are also complete at 10 mm.

Caudal fin formation is similar to that of the other species described. The full complement of 9 to 10 dorsal and 8 to 10 ventral principal rays and 18 to 20 secondaries is present at 10 mm.

Distribution and Spawning

Adults of *O. saurus* are known from both coasts of Central America and in the West Indies (Jordan and Evermann, 1896). They also occur along the Atlantic coast of the United States from Massachusetts to Florida and in the Gulf of Mexico (Ginsburg, 1952). The wild larvae and juveniles in the present work were taken from Escambia Bay, Fla., and at Sapelo and St. Simons Islands, Ga., in May and July by means of channel nets and beach seines. The laboratory-reared larvae were hatched from planktonic eggs collected from Biscayne Bay. Larvae and juveniles were not collected in any of the net stations in the Gulf of Mexico and the south Atlantic coast. Distribution of the young in these regions is obscure, and abundance and frequency of occurrence in relation to the other larval carangids could not be established. The wild larvae obtained were too few to derive conclusive information, but apparently spawning occurs in summer. Unlike the other carangids which spawn in offshore pelagic waters, *O. saurus* spawns in inshore and shallow waters. Further investigation is necessary to establish with certainty the spawning period and sites and the distribution of the young.

Laboratory Rearing

Planktonic eggs of *O. saurus* were collected in a 1-m, 505-μ mesh plankton net at the pier of the Rosenstiel School of Marine and Atomospheric Science on 15 July 1972, at 9:00 A.M., EDT. A total of 75 eggs was sorted from the plankton and incubated in a 50-liter glass aquarium. The aquarium water was drawn from Biscayne Bay through the School's seawater system. It was oxygenated and circulated with compressed air added through airstones and lighted continuously by two cool, white, fluorescent bulbs. Temperature ranged from 23.9° to 28°C and salinity from 32 to 36‰ during the experiment. The larvae were fed wild plankton collected from Biscayne Bay as well as nauplii of brine shrimp (*Artemia salina*). A detailed description of the rearing technique employed is given in Houde and Palko (1970).

The eggs began hatching in the afternoon of the day of collection and after 24 h all the eggs were presumed hatched. The larvae averaged 1.92 mm at hatching, were 5.2 mm 8 days after hatching, and about 21 mm at 34 days (Figure 9). Mortality in the first 18 days included 2 eggs and 16 larvae preserved for describing larval development. Six young juveniles averaged 25 mm after 45 days. Thereafter, the juveniles failed to feed and all but one died at 51 days when the rearing experiment was terminated.

Ossification

The sequence of ossification of the skull, axial, and appendicular skeleton is generally similar among the four species in which ossification was observed (Table 12). Without exception, the premaxillaries, preopercular spines, and cleithra ossify in the smallest larvae (2.5-3.8 mm). Next to ossify at 4 to 5 mm are the maxillaries, dentaries, parasphenoid, supraoccipital, articulars, frontals, angulars, and the branchial arches. The entire maxillary arch is ossified before the larvae are 6 mm long. Teeth are formed along the entire margin of the premaxillaries and anterior region of the dentaries in the youngest larvae following the ossification of these elements. It is apparent that the bones related to feeding ossify early, and this is consistent with the need of the larvae for food from external sources following the absorption of the yolk.

Seven branchiostegal rays on each side are present in 3-mm larvae. Ossification begins with the posterior and longer rays and proceeds anteriad. The ceratohyal and epihyal to which the branchiostegal rays are attached ossify simultaneously with the rays. The rest of the hyoid arch including the glassohyal, urohyal, and hypohyal ossify at metamorphosis.

Aside from the quadrate and hyomandibular which ossify during the larval period, the rest of the palatine arch is not calcified until metamorphosis.

The branchial arches initially ossify in larvae 4 to 5 mm long and all arches are calcified at 6 mm. The first branchial arch is the first to ossify starting from the center of the ceratobranchial towards both ends. The epibranchial is the next to ossify beginning from near the angle of the arch outward. Ossification of the other arches follows in a similar sequence.

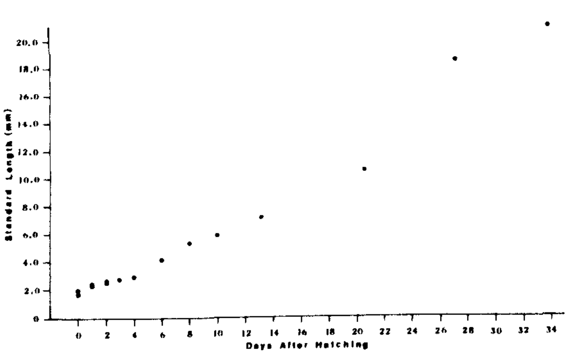

FIGURE 9.—Growth of *Oligoplites saurus* larvae reared in the laboratory at an average temperature of 26.0°C.

The gill rakers calcify following the ossification of the elements to which they are attached. The number of gill rakers increase as growth progresses but gill rakers are slow to ossify, and the full complement usually is not completed until the transition and early juvenile stages. The adult count in *Seriola zonata* is fewer than is formed in the juveniles due to the reduction of the terminal gill rakers into tubercles in the ceratobranchial. Patches of fine teeth are formed on the superior pharyngeals of the third and fourth gill arches while the fifth and shortest gill arch has teeth patches for most of its length. Pharyngeal teeth ossify in larvae 6 to 8 mm long.

In the cranium, the parasphenoid, frontals, and supraoccipitals ossify in the youngest larvae (2.5-3.8 mm). Except for the parietals which ossify in the midlarval period, the rest of the cranium is not ossified until the late larval and transition periods.

The cleithra, postcleithra, and posttemporals are ossified in the early and midlarval stages, but the rest of the pectoral girdle calcifies in late and transforming larvae. From 2 to 4 posttemporal spines protrude from the myotomes during the early larval period. These are small and hardly visible in most species except in stained specimens. These spines are soon overgrown by the developing muscles.

The pelvic girdle calcifies following the ossification of the pelvic fins.

Ossification occurs at 5 to 8 mm in the vertebral column and proceeds in an anteroposterior direction. The neural and hemal spines ossify ahead of the centra of their respective vertebrae. The centra ossify at their anterior margins and ossification proceeds posteriorly. This pattern of ossification in the vertebrae was noted in *Trachurus symmetricus* (Ahlstrom and Ball, 1954).

Ribs similarly ossify in an anteroposterior direction. The pleural ribs are the first to ossify followed by the epipleural ribs. All trunk vertebrae have ossified pleural and epipleural ribs in juveniles 15 to 17 mm long except on the first and second in which pleural ribs are lacking.

Teeth are initially uniserial but become multiserial as tooth formation progresses. Following

TABLE 12.—Sequence of ossification of the skull, branchial arches and girdles in four species of carangids. Numbers indicate length (mm) of smallest specimen in which ossification of each element was observed; dashes indicate undetermined size.

Bone	*Elagatis bipinnulata*	*Seriola zonata*	*Decapterus punctatus*	*Selene vomer*
Cranium:				
Vomer	6.0	6.5	7.6	9.0
Mesethmoid	8.4	8.5	9.0	9.0
Ectethmoid	9.4	8.5	9.0	9.0
Parasphenoid	3.8	3.5	4.2	4.0
Frontal	4.6	4.7	4.2	4.0
Supraoccipital	4.6	4.7	4.2	4.0
Exoccipital	6.0	6.5	7.6	6.3
Basioccipital	6.0	6.5	7.6	9.0
Parietal	7.0	5.5	5.2	6.3
Pterotic	10.4	9.5	9.0	8.6
Prootic	8.4	8.5	9.0	8.6
Epiotic	10.4	9.5	9.0	8.6
Sphenotic	9.5	8.5	9.0	8.6
Opisthotic	11.5	10.3	9.0	9.0
Basisphenoid	11.5	11.2	9.0	9.0
Orbital bones:				
Preorbital	8.4	11.2	10.0	—
1st suborbital	17.1	17.0	15.0	—
2nd suborbital	15.2	16.0	15.0	—
3rd suborbital	12.0	13.0	14.0	—
4th suborbital	13.0	14.0	16.0	—
5th suborbital	13.0	15.0	16.0	—
Opercular apparatus:				
Opercle	5.4	5.5	10.0	9.0
Interopercle	7.0	5.5	12.0	9.0
Preopercle	3.8	3.6	3.5	2.5
Subopercle	7.0	5.5	14.0	9.0
Hyoid apparatus:				
Hypohyal	13.1	11.0	10.0	7.6
Ceratohyal	5.4	5.5	5.3	4.9
Epihyal	6.0	6.5	5.5	5.2
Glossohyal	8.0	7.5	9.0	7.6
Urohyal	8.0	10.0	11.0	7.6
Interhyal	17.0	15.0	22.0	13.5
Maxillary arch:				
Premaxillary	3.8	3.6	3.1	2.5
Maxillary	3.8	3.6	4.2	4.0
Supramaxillary	—	—	—	13.5

Bone	*Elagatis bipinnulata*	*Seriola zonata*	*Decapterus punctatus*	*Selene vomer*
Maxillary arch:				
Dentary	4.6	3.6	4.2	4.0
Articular	4.6	4.7	5.2	4.0
Angular	4.6	4.7	5.2	5.2
Palatine arch:				
Hyomandibular	6.0	7.5	7.6	8.6
Metapterygoid	12.0	10.4	12.5	8.6
Mesopterygoid	12.0	10.4	12.5	9.0
Pterygoid	12.0	11.5	13.5	9.0
Quadrate	4.6	4.7	5.3	4.0
Symplectic	—	—	—	—
Palatine	10.4	9.4	12.5	13.5
Branchial arches:				
1st Branchial arch	4.6	4.8	4.2	4.9
2nd Branchial arch	5.4	5.5	5.3	5.2
3rd Branchial arch	6.0	5.5	5.3	5.5
4th Branchial arch	7.0	5.5	5.3	6.1
5th Branchial arch	7.0	5.5	5.3	6.1
Gill rakers:				
1st Branchial arch	4.6	4.8	4.2	4.9
2nd Branchial arch	5.4	5.5	5.3	5.2
3rd Branchial arch	6.0	5.5	5.3	5.5
4th Branchial arch	7.0	5.5	5.3	6.1
Pharyngeal teeth:				
3rd Branchial arch	8.0	6.5	6.6	8.0
4th Branchial arch	8.0	6.5	6.6	8.0
5th Branchial arch	8.0	6.5	6.6	8.0
Pectoral girdle:				
Cleithrum	3.8	3.6	3.1	2.5
Postcleithrum	5.4	4.8	5.2	6.1
Hypercoracoid	7.2	8.4	11.0	9.0
Hypocoracoid	7.2	8.4	11.0	9.0
Posttemporal	5.4	4.8	4.2	4.9
Supracleithrum	10.4	13.0	—	—
Pelvic girdle:				
Post pelvic process	8.0	10.0	8.0	5.0
Pelvic keels	8.0	10.0	8.0	5.0

metamorphosis 2 to 3 irregular rows of sharp teeth are present.

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