DESCRIPTIONS OF LARVAE OF CALIFORNIA YELLOWTAIL, *SERIOLA LALANDI*, AND THREE OTHER CARANGIDS FROM THE EASTERN TROPICAL PACIFIC: *CHLOROSCOMBRUS ORQUETA*, *CARANX CABALLUS*, AND *CARANX SEXFASCIATUS*

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ABSTRACT

Larvae are described for four species of jacks, family Carangidae. Three of these, *Seriola lalandi* (California yellowtail), *Chloroscombrus orqueta*, and *Caranx caballus*, occur in the CalCOFI region. A fourth species, *Caranx sexfasciatus*, occurs from Mazatlan, Mexico, to Panama. Species are distinguished by a combination of morphological, pigmentary, and meristic characters. Larval body morphs range from slender *S. lalandi*, with a relatively elongate gut, to deep-bodied *C. sexfasciatus*, with a triangular gut mass. Pigmentation patterns are characteristic for early stages of each species, but all except *C. orqueta* become heavily pigmented in late stages of development.

RESUMEN

Se describen las larvas de 4 especies de carángidos (Carangidae). Tres de ellas, *Seriola lalandi* (jurel), *Chloroscombrus orqueta*, y *Caranx caballus* se encuentran en la región de la CalCOFI. La cuarta especie, *Caranx sexfasciatus*, se encuentra desde Mazatlán, México, hasta Panamá. Las especies se distinguen por una combinación de rasgos morfológicos, pigmentarios, y merísticos. Los Tipos de larva varían desde delgados, como *S. lalandi*, son vísceras relativamente elongadas, hasta altos, como *C. sexfasciatus*, con una masa visceral triangular. Los patrones de pigmentación son característicos para los estadios tempranos de cada especie, pero todos, excepto *C. orqueta*, se vuelven fuertemente pigmentadas en los estadios de desarrollo tardíos.

INTRODUCTION

Numerous species of carangid fishes occur in the eastern Pacific, but with the exception of jack mackerel (*Trachurus symmetricus*), these species spawn in tropical or subtropical waters. Few species spawn far enough north to occur in the CalCOFI sampling region. One species, the California yellowtail, *Seriola lalandi*, supports an important recreational fishery off southern California and Baja California, and it briefly supported a commercial fishery during the 1950s (MacCall et al. 1976). Larvae of *Seriola* species from other regions of the world have been described (see literature review in Laroche et al. 1984), but larvae of eastern Pacific *Seriola lalandi* have not previously been described[1]. This paper also describes larvae of two other carangids, *Chloroscombrus orqueta* and *Caranx caballus*, occurring in the CalCOFI region, and a third carangid, *Caranx sexfasciatus*, which occurs to the south.

MATERIALS AND METHODS

Larvae used in this work were obtained from various plankton collections made in the eastern tropical Pacific, including those of CalCOFI, EASTROPAC, the Inter-American Tropical Tuna Commission, Bureau of Sport Fisheries and Wildlife, and Scripps Tuna Oceanography cruises. In addition, specimens of *Chloroscombrus orqueta*, dipnetted near San Carlos Bay in the Gulf of California, were provided by Robert Behrstock, formerly of Humboldt State University. Several small larval *Seriola lalandi* reared at the Southwest Fisheries Center's La Jolla laboratory were also examined.

Developmental series were assembled for each species, and morphological and pigmentation changes were described using the methods and terminology of Moser and Ahlstrom (1970) and Ahlstrom et al. (1976). Body lengths given in the text and tables represent notochord length in preflexion- and flexion-stage larvae, and standard length in postflexion larvae and juveniles. Descriptions of fin formation were limited by the condition of the specimens, because many had become decalcified in preservative over prolonged storage. A limited number of specimens were successfully stained, allowing observation of meristic characters and head spination.

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[1]Seven of the illustrations in this paper originally were included in a manuscript by E.H. Ahlstrom and B.Y. Sumida entitled "Early life history studies of eastern Pacific carangids." This manuscript was prepared for a symposium held in Ensenada, Mexico, in February 1975, the proceedings of which were not published. The manuscript is a general summary of some ontogenetic and adult taxonomic characters of nine carangid genera that occur in the eastern Pacific. It is now available as Southwest Fisheries Center Administrative Report LJ-85-02.

TABLE 1
Comparative Morphometry of Five Species of Carangid Larvae

	Snout-anus length / Body length	Head length / Body length	Eye diameter / Head length	Snout length / Head length	Body depth / Body length
Seriola lalandi					
A	*59.6 ±1.34(58-61)	28.2 ±1.30(27-30)	31.0 ±1.87(28-33)	30.2 ±2.28(28-33)	19.4 ±0.55(19-20)
B	61.5 ±0.58(61-62)	31.5 ±1.00(30-32)	30.8 ±1.50(29-32)	30.5 ±1.00(29-31)	23.2 ±2.06(21-26)
C	63.8 ±1.68(62-66)	34.6 ±1.40(32-36)	30.7 ±2.14(28-34)	27.1 ±2.61(24-31)	29.7 ±1.50(27-31)
D	60	31	32	26	29
Trachurus symmetricus	calculated from Ahlstrom & Ball (1954) (Size categories were given equal weighting in calculating means; standard deviation not calculable from data as published.)				
A	56.6 (54-58)	25.2 (17-32)	41.6 (36-51)	No snout lengths measured	21.4 (16-26)
B	59.3 (58-61)	33.2 (30-35)	35.8 (34-37)		26.7 (25-28)
C	58.0 (55-60)	36.2 (35-38)	34.0 (32-37)		27.4 (26-28)
D	54.0	29.5 (28-31)	32.0 (31-33)		24.5 (24-25)
Chloroscombrus orqueta					
A	57.3 ±2.31(56-60)	32.7 ±2.52(30-35)	31.7 ±0.58(31-32)	30.7 ±3.21(27-33)	35.0 ±4.36(30-38)
B	57.2 ±0.96(56-58)	38.0 ±0.82(37-39)	36.0 ±1.82(34-38)	28.0 ±0.82(27-29)	41.5 ±3.00(39-45)
C	50.4 ±3.36(44-55)	34.8 ±2.52(30-38)	36.4 ±2.73(32-40)	25.8 ±2.09(23-28)	43.4 ±1.63(41-46)
D	40.5 ±2.12(39-42)	30.5 ±2.12(29-32)	33.0 ±1.41(32-34)	28.0 ±1.41(27-29)	42.0 ±0.00(42)
Caranx caballus					
A	59.7 ±1.53(58-61)	34.3 ±1.53(33-36)	28.3 ±0.58(28-29)	29.3 ±2.31(28-32)	34.3 ±2.31(33-37)
B	57.0 ±2.00(55-59)	35.0 ±1.73(33-36)	33.0 ±1.73(31-34)	27.0 ±2.00(25-29)	42.0 ±1.73(41-44)
C	55.0 ±1.76(52-58)	35.9 ±1.60(33-38)	34.8 ±2.78(30-40)	25.1 ±3.48(21-32)	43.9 ±1.73(42-46)
D	52	36	35	26	39
Caranx sexfasciatus					
A	54.6 ±1.14(53-56)	32.0 ±3.08(29-37)	31.6 ±2.30(28-34)	29.0 ±2.34(27-33)	35.4 ±4.93(29-42)
B	58.3 ±1.53(57-60)	35.3 ±2.52(33-38)	33.3 ±2.08(31-35)	29.0 ±1.73(27-30)	50.3 ±5.51(45-56)
C	57.1 ±3.81(51-62)	37.6 ±1.84(34-40)	34.8 ±1.69(33-38)	25.5 ±2.88(20-28)	53.2 ±2.20(49-57)
D	48.0 ±2.83(46-50)	32.5 ±2.12(31-34)	33.5 ±2.12(32-35)	25.0 ±1.41(24-26)	43.5 ±3.54(41-46)

*Mean, standard deviation, and range expressed as percentage of body length or head length. A, preflexion; B, flexion; C, postflexion; D, juvenile.

DESCRIPTIONS

Seriola lalandi

Literature. Brownell (1979) illustrated an egg and two reared yolk-sac larvae, which he tentatively identified as *S. lalandi*, from waters off South Africa. The egg measured 1.44 mm in diameter with an oil globule diameter of 0.32 mm.

Distinguishing features. Seriola lalandi larvae are slender-bodied and heavily pigmented, lack a supraoccipital crest, and develop the largest number of dorsal fin rays (31-39) among eastern Pacific carangids. The combination of these characters distinguishes *S. lalandi* from all other carangid larvae in the CalCOFI region except for larvae of *Seriola rivoliana*, which co-occur with *S. lalandi* in the southernmost extent of its range, and are presently undescribed.

Morphology and meristics. Early larvae of *S. lalandi* are slender-bodied; body depth at the base of the pectoral fin averages 19% to 23% in preflexion and flexion stages, increasing to about 30% in postflexion and juvenile stages (Table 1). Early stages of *S. lalandi* <10.0 mm are more slender than those of jack mackerel (*Trachurus symmetricus*), in which body depth ranges from 21% to 27% of body length (Table 1, Figure 1).

The gut is comparatively elongate; it increases in length relative to total body length during the larval period, then becomes relatively shorter in juveniles (Tables 1 and 2; Figure 2). The slender gut of early *S. lalandi* differs from the rounded mass found in *Caranx* and *Chloroscombrus*, and from the intermediate robust but somewhat elongate form in *T. symmetricus*. The intestinal coil begins to form at the end of the yolk-sac period at a position about one-fourth of the cleithrum-anus distance. The posterior margin of the

TABLE 2
Measurements (mm) of *Seriola lalandi*

Station	Body length	Snout-anus length	Head length	Eye diameter	Snout length	Body depth at pectoral fin base
6706-S-130.35	4.2 yolk-sac	2.2	0.52	0.26	0.10	0.36
5707-P-107.60	4.4	2.6	1.2	0.38	0.36	0.84
5708-B-113.35	5.2	3.0	1.4	0.46	0.40	1.0
6007-H-133.30	5.9	3.6	1.7	0.47	0.48	1.1
5707-P-107.60	6.1	3.7	1.8	0.56	0.60	1.2
6007-H-133.30	6.4	3.8	1.8	0.56	0.58	1.3
5909-B-133.25	6.6	4.0	2.1	0.64	0.66	1.5
5707-0-110.70	6.9	4.2	2.2	0.64	0.68	1.6
6007-H-133.30	7.2	4.5	2.2	0.70	0.64	1.5
6608-J-123.40	8.6	5.3	2.8	0.90	0.86	2.2
5608-B-130.45	8.9	5.6	3.1	0.92	0.92	2.4
7205-JD-130.80	9.8	6.5	3.5	1.1	0.88	3.0
Baja Calif.	10.9	7.2	3.8	1.3	1.0	3.2
8108-NH-106.7.45	13.7	8.8	4.9	1.6	1.2	4.2
6008-B-137.30	17.9	11.2	6.1	1.8	1.7	5.5
Mazatlan Proj.	20.0	12.9	6.8	1.9	2.1	6.1
Mazatlan Proj.	22.4	14.0	7.2	2.1	1.9	6.5
Cr. 79-DSJ	26.7 juv.	16.0	8.2	2.7	2.2	7.8

Specimens between dashed lines are undergoing notochord flexion.

loop extends posteriad gradually to reach about two-thirds of the cleithrum-anus distance at the beginning of notochord flexion. During this process the gut mass becomes somewhat deeper, tapering posteriad, but retains its elongate shape. By completion of notochord flexion the loop has reached the rectum, about three-fourths of the cleithrum-anus distance, and the entire gut region has become covered by well-developed body-wall musculature.

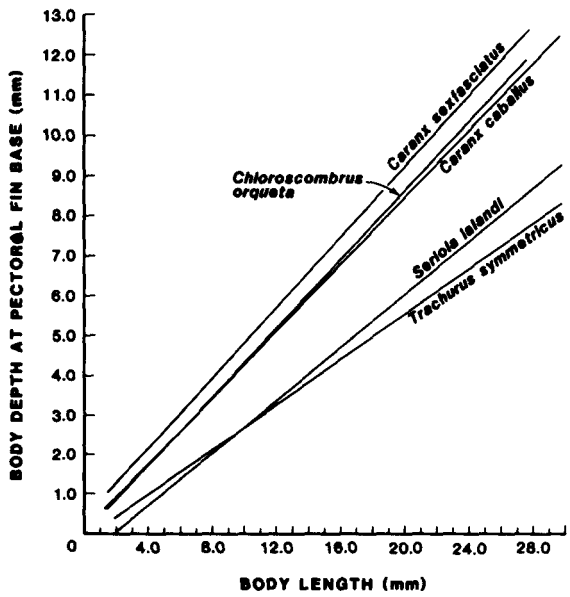

Figure 1. Regression of body depth at pectoral fin base on body length in five species of carangid larvae.

Relative head length increases gradually during larval development ($\bar{x}$ = 28% of body length in preflexion and 35% in postflexion stages) and decreases slightly in early juveniles. Relative eye diameter changes little during development, and relative snout length decreases slightly.

Head spines develop on the following bones: preopercle, frontal, posttemporal, and supracleithrum. Two series of spines develop on the preopercle, one along its posterior margin and one along a ridge just anterior to the margin. The first spine forms at the angle of the posterior margin at about 4.3 mm body length. This becomes the largest preopercular spine, its length reaching 9% of the body length at about 10 mm SL. At about 4.6 mm the first spine in the anterior series forms on the ridge in a position directly anterior to the angle spine of the posterior preopercular series.

Larvae about 5 mm long have developed two additional spines on the posterior margin of the preopercle, one on either side of the angle spine. A second spine forms on the ridge in association with the margin spine below the angle. The spines on either side of the angle spine are about one-half the length of the latter. Also at this stage the frontal bone begins to project above

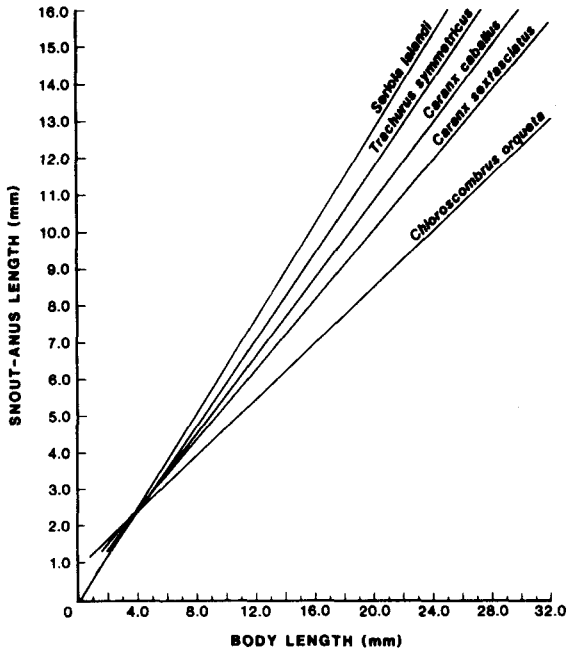

Figure 2. Regression of snout-anus length on body length in five species of carangid larvae.

the eye, forming a supraocular crest, which bears a spine.

Larvae about 6 mm long have added a small spine to each end of the preopercular margin series and begin to develop a single spine on the posttemporal and on the supracleithrum about midway between the posttemporal spine and the pectoral fin base. Also, a prominent longitudinal ridge is present on the pterotic bone.

At the completion of notochord flexion (~8.6 mm), an additional spine is present at each end of the preopercular series, and two more posttemporal spines have developed, one adjacent to the original spine and the other anteroventral to them. At this stage the full head-spine complement is present, and the spines remain prominent until about 13 mm SL, when most of them begin to diminish in size. The two spines on the preopercular ridge are the first to be lost, followed by the outer spines of the preopercular margin series and the supraocular spine. By 26 mm SL only the preopercular spines near the angle are prominent.

Meristic counts of stained specimens are presented in Table 3.

Pigmentation. Seriola lalandi is moderately pigmented in early stages, becoming heavily pigmented during the larval period. Serial melanophores outline the dorsal and ventral body margins of approximately 80% of the length of the body in yolk-sac larvae (Figure 3A-C). These melanophores become expanded and prominent in the preflexion stage (~4.5 mm), extending anteriorly over the snout and posteriorly around the tip of the tail. The melanophores along the tail tip are minute, dispersing outwardly onto the finfold of the developing caudal fin with ensuing growth. Other pigmentation in preflexion larvae includes a lateral midline series on the body and a series on the ventral midline along the isthmus in a continuum with melanophores below the gut (Figure 3D, E). Pigmentation increases rapidly over much of the head and body in early flexion larvae >6.6 mm, and these areas become almost completely covered with melanophores, except for the fin membranes and the posteriormost portion of the body. In larvae ≥7.0 mm, melanophores appear along the edge of the developing dorsal and anal fin pterygiophores. The melanophore pattern undergoes little change in postflexion larvae except for augmented pigmentation on the dorsal, anal, and pelvic fin membranes (Figure 4). By 14.0 mm, melanophores extend over most of the caudal peduncle, which is completely pigmented by 18.0 mm.

The strongly banded pattern exhibited by juveniles apparently forms rapidly, since it is lacking in a 22.4-mm specimen but present in a 24.5-mm specimen (Figure 4C).

Chloroscombrus orqueta

Literature. Larvae of *Chloroscombrus orqueta* have not been described previously.

Distinguishing features. Early *Chloroscombrus orqueta* larvae closely resemble some *Caranx* species in body morph and pigmentation, but have a diagnostic melanophore pattern on the dorsal body margin composed of four melanophores positioned on myomeres 1, 3, 9, and 14. Another feature is a small spine on the pterotic bone in larvae 7.5-11.0 mm. Larvae of *C. orqueta* also develop more dorsal and anal fin rays (25-30 rays for each fin) than any other *Caranx* species in the eastern Pacific.

Morphology and meristics. Chloroscombrus orqueta larvae are deep-bodied, increasing in body depth during all stages of larval development (Table 4; Figure 1). Relative body depth averages 35% in preflexion larvae, and about 42% in later stages (Table 1). Snout-anus distance is about 57% of body length in preflexion and flexion larvae. This is similar to other species described herein; however, in postflexion stages and juveniles the terminal segment of the gut in *C. orqueta* curves more anteriad, resulting in the shortest mean snout-anus length among the species discussed (Table 1; Figure 2). The gut loop is well

TABLE 3
Meristics of Stained *Seriola lalandi*

Station	Body length (mm)	Dorsal fin	Anal fin	Pectoral fin	Caudal fin	Pelvic fin	Branchiostegals
7808-VA-137.35	3.2	—	—	—	—	—	—
5707-B-120.75	3.9	—	—	—	—	—	—
6907-G-117.50	4.1	—	—	—	—	—	—
5609-B-120.45	4.3	—	—	—	—	—	—
5707-0-110.70	4.6	—	—	—	—	—	—
5408-C-130.45	4.9	—	—	—	—	—	4
5807-93.50	5.2	—	—	—	—	—	—
6007-H-133.30	5.6	—	—	—	—	—	4
5707-P-110.55	5.7	—	—	—	0+1+1+0	—	6
5906-0-123.60	6.0	—	—	—	0+1+1+0	—	7
5408-C-117.35	6.3	—	—	—	0+2+2+0	—	7
5707-0-110.70	6.9	10	12	6	0+6+5+0	—	7
6007-H-133.30	7.2	16	7	7	0+6+5+0	—	7
6608-J-123.40	8.6	VII,27	I+I,16	13	1+9+8+1	—	7
7205-J-130.80	9.8	VI,36	II+I,21	14	4+9+8+4	I,4	7
Off Baja Calif.	10.9	VII+I,35	II+I,21	19	5+9+8+5	I,5	7
8108-NH-106.7.45	13.7	VII+I,34	II+I,21	20	9+9+8+9	I,5	7
6008-B-137.30	17.9	VII+I,33	II+I,20	21	12+9+8+12	I,5	7
Mazatlan proj., 6-3-S	20.0	VII+I,36	II+I,22	21	12+9+8+12	I,5	7
RV/DSJ Cr. 79	26.7 juv.	VII+I,31	II+I,21	22	10+9+8+10	I,5	7

Specimens between dashed lines are undergoing notochord flexion.

formed in our smallest larvae (2.7 mm), and the posterior edge of the loop extends to about 60% of the cleithrum-anus distance. During this stage the gut mass lies in a longitudinal plane. By 3 mm, the ascending portion of the loop extends above the gut mass, and the rectal portion descends ventroposteriad at about a 45° angle. The loop portion increases in diameter and in relative mass and occupies most of the perivisceral cavity by about 4.0 mm. At this stage the rectal portion is oriented vertically and curves around the posterior edge of the coil. The gut and the prominent gas bladder above it form a triangular mass with sides of about equal length. The gut mass becomes more rounded with continued development, and by 8.0 mm the body-wall musculature is well developed.

Relative head length increases during preflexion and flexion stages ($\bar{x}$ = 33%-38% of body length), but decreases ($\bar{x}$ = 35%-30%) thereafter. Relative eye diameter increases during larval development and decreases slightly in juveniles. Relative snout length decreases in progressive larval stages but increases slightly in the juvenile stage (Tables 1 and 4).

Head spines develop on the following bones: preopercle, frontal, posttemporal, supracleithrum, and pterotic. Small larvae (2.7 mm) bear a large spine at the angle of the preopercular margin and three smaller spines below the angle. By 3.0 mm, larvae have two more spines above the angle. Larvae >3 mm have a fourth and fifth spine below the angle and a third spine above the angle. By 4 mm, a sixth spine is added below the angle and a fourth above the angle. By 5 mm, larvae have a fifth spine above the angle. Larvae larger than 8.0 mm have 8-10 spines below the angle and 6-7 above the angle. The angle spine reaches a

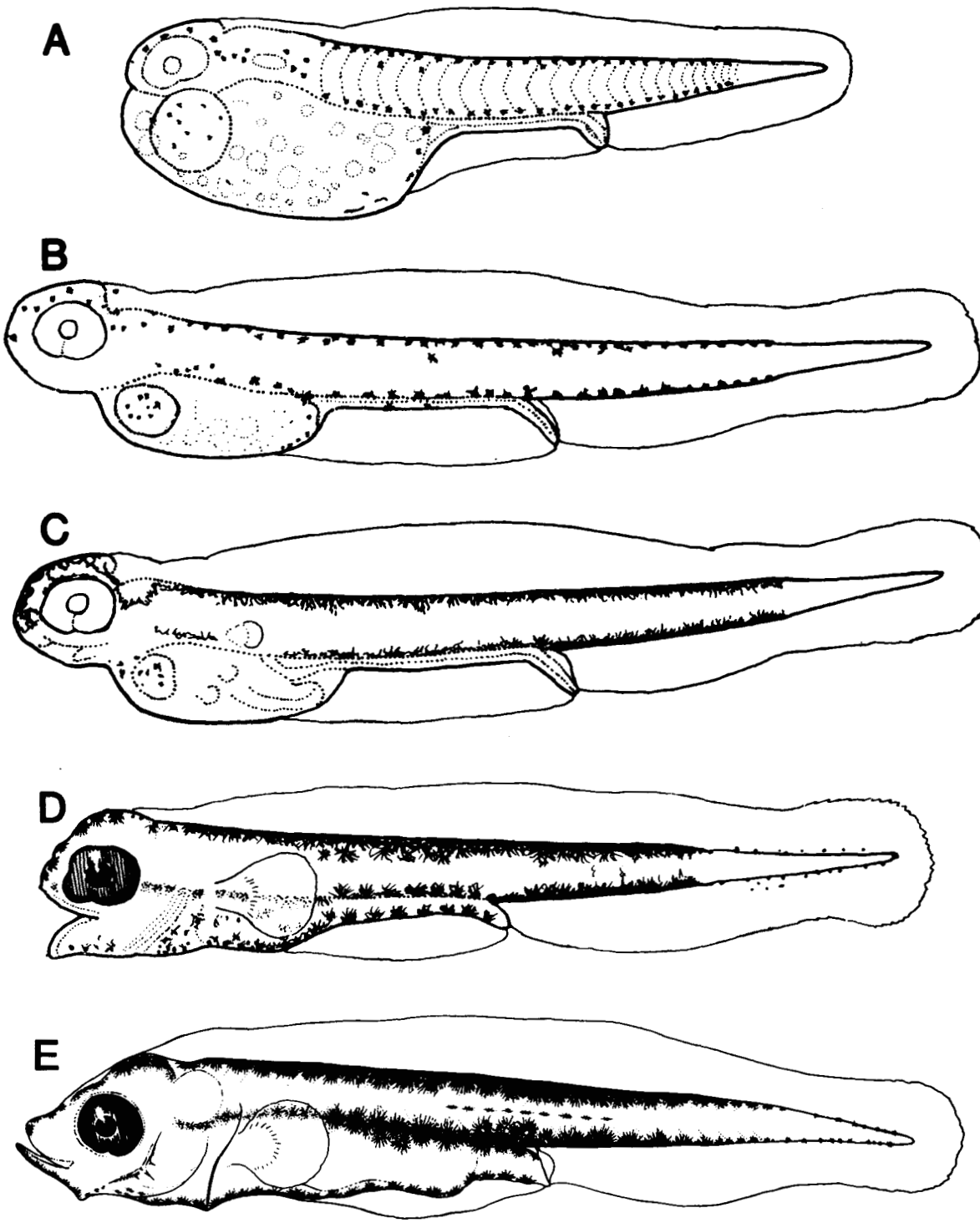

Figure 3. Early larvae of *Seriola lalandi*: *A*, 2.8 mm; *B*, 3.8 mm; *C*, 3.8 mm; *D*, 3.5 mm; *E*, 4.6 mm.

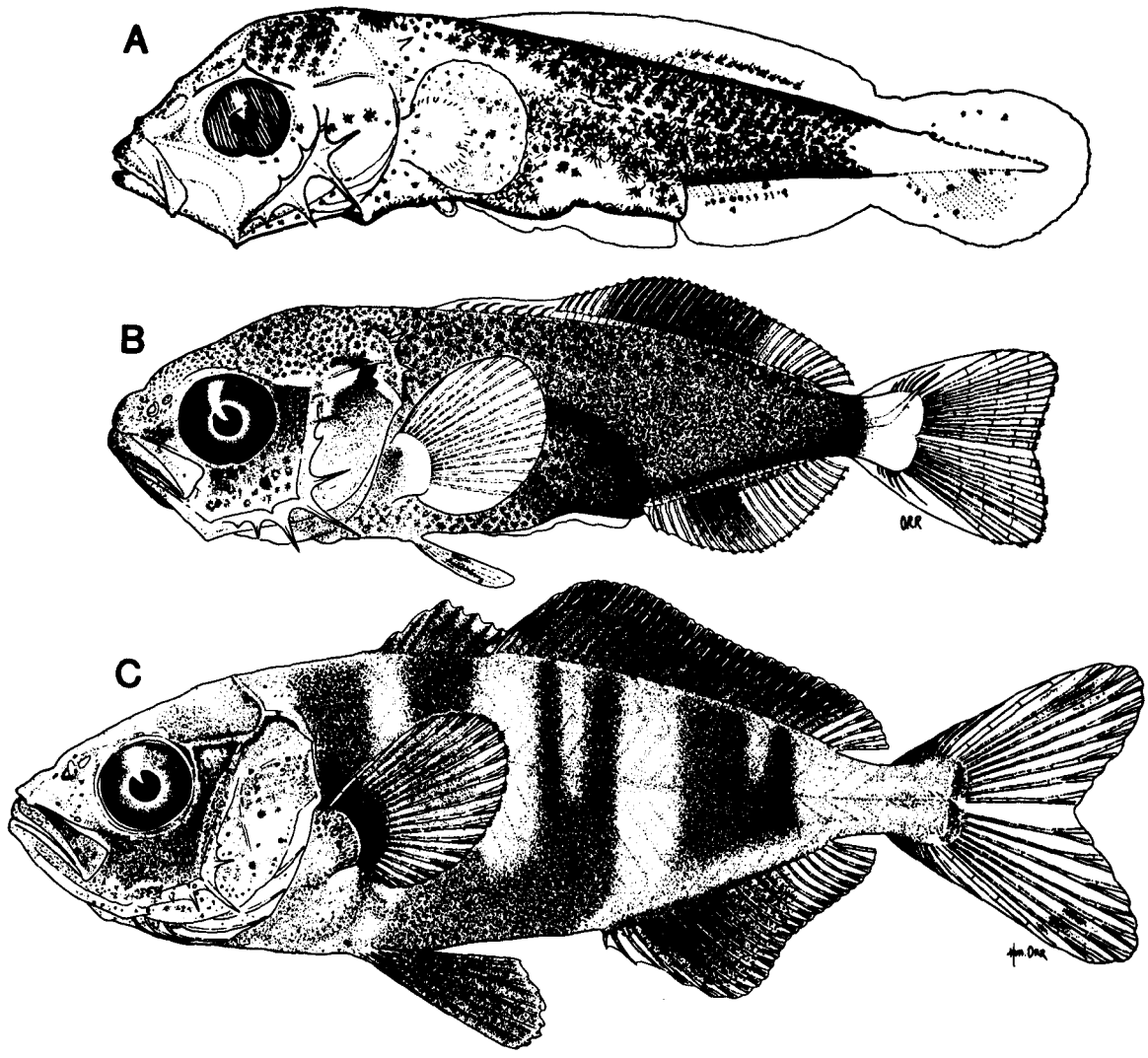

Figure 4. Larvae and early juvenile of *Seriola lalandi*: *A*, 7.0 mm; *B*, 11.7 mm; *C*, 24.5-mm juvenile.

maximum relative length of about 15% of the body length in 3-mm larvae, is reduced to 8%-11% of body length in 4-7-mm larvae, and then decreases abruptly in relative size. The spines above and below the angle spine are about one-half its length, and the others decrease in size gradually toward each end of the series. The uppermost margin spines begin to disappear at about 13 mm; by 16 mm only the spine adjacent to the angle remains in the upper series. Specimens larger than 20 mm retain only the angle spine.

Larvae <3.0 mm have 4 small spines on the lower part of the preopercular ridge. These spines increase in number to a maximum of 9-11 on the lower limb and 3-4 on the upper limb of the ridge in 6-11-mm larvae. Thereafter they decrease in number and are absent by 15 mm.

By about 3.0 mm, larvae have single spines on the posttemporal, supracleithrum, and on the supraocular shelf (frontal bone). Additional posttemporal spines appear by 5 mm, and in larvae >6.6 mm there are 4 spines arranged in an arc on the lower region of the bone. Larvae ≥7.0 mm form additional supracleithral spines, and larvae >8.0 mm have 4 spines arranged in a vertical series on the upper region of the bone. Larvae 8-11 mm in length have a maximum of 9-11

TABLE 4
Measurements (mm) of *Chloroscombrus orqueta*

Station	Body length	Snout-anus length	Head length	Eye diameter	Snout length	Body depth at pectoral fin base
B-5608-137.23	2.7	1.5	0.80	0.26	0.26	0.82
B-5608-137.23	3.0	1.8	0.98	0.30	0.32	1.1
B-5608-137.23	3.4	1.9	1.2	0.38	0.32	1.3
ETP 13.019	3.7	2.1	1.4	0.54	0.38	1.6
ETP 13.019	4.0	2.3	1.5	0.56	0.44	1.8
TO 59-1 #46	4.1	2.4	1.6	0.54	0.44	1.6
TO 59-1 #46	4.6	2.6	1.7	0.60	0.48	1.8
ETP 13.019	5.1	2.7	1.8	0.70	0.48	2.1
ETP 13.019	5.3	2.9	2.0	0.72	0.54	2.2
ETP 13.019	5.9	3.2	2.2	0.76	0.60	2.5
TO 59-1 #46	6.6	3.3	2.3	0.84	0.64	2.8
TO 59-1 #35	7.2	3.6	2.4	0.92	0.60	3.1
TO 59-1 #35	8.0	4.2	2.9	1.0	0.66	3.6
ETP 13.021	8.3	4.3	3.1	1.0	0.72	3.6
ETP 13.019	9.8	5.0	3.5	1.2	1.0	4.2
RAB S-14	11.4	5.5	4.0	1.6	1.0	5.2
ETP 13.019	13.4	6.2	4.0	1.5	1.1	6.0
RAB 71-III (a,b)	15.2	6.7	4.7	1.9	1.1	6.8
Rab S-14	23.5 juv.	9.8	7.5	2.4	2.2	9.8
RAB S-2	29.7 juv.	11.5	8.6	2.9	2.3	12.4

Specimens between dashed lines are undergoing notochord flexion.

spines on the supraocular shelf. Specimens >15 mm lack supraocular spines, and the posttemporal and supracleithral spines become obsolescent at about the same stage.

Small larvae <3.0 mm possess a supraoccipital crest with a scalloped margin. By about 3.0 mm it has developed to its maximum relative size, extends from the midregion of the optic lobes to the second myoseptum, and has formed 10-12 rounded projections. By about 8.0 mm it is much reduced in size and is restricted to the occipital region, and is lost by 13.0 mm.

A small spine-bearing ridge develops on the pterotic bone at about 7.5 mm. A maximum of two spines appear on the ridge. The ridge is absent in specimens larger than 11.0 mm.

Meristic counts of stained material are presented in Table 5.

Pigmentation. Chloroscombrus larvae are lightly pigmented and resemble larvae of some *Caranx* species; however, they may be distinguished by characters discussed below. Pigmentation on preflexion and flexion larvae (~2.6-4.6 mm) is found in the following areas: (1) head—region of the midbrain and jaws; (2) abdomen—over the gas bladder, dorsally over the free portion of the gut terminus, ventrally on the gut wall, and along the margin of the preanal finfold; (3) body—dorsally and ventrally on the body margin, along the lateral midline, internally above the notochord medial to the midline pigment, and a melanophore or two below the developing caudal fin (Figure 5A-C). This is a typical pattern for many early carangid larvae, but a diagnostic melanophore pattern for preflexion and early flexion *C. orqueta* is the dorsal body margin pigment consisting of four melanophores positioned over myomeres 1, 3, 9, and 14 (Figure 5A, B). This character occurs in other *Chloroscombrus* species—*C. cosmopolita* in the eastern Atlantic (Aboussouan 1968) and *C. chrysurus* in the western Atlantic and Gulf of Mexico[2].

Pigmentation gradually increases in postflexion larvae (>5.0 mm), particularly in the head and trunk region (Figures 5D and 6A). Melanophores along the dorsal body margin increase in number to form a continuous dashed line of pigment by 7.2 mm. Myoseptal pigmentation on the ventral surface of the body is first evident at about 5.0 mm (Figure 5D), positioned below the lateral midline streak; internal

[2]Laroche, W.A., D. Ruple, and S.L. Richardson. MS. Young carangid fishes from the Gulf of Mexico: a generic diagnosis of larvae, with additional descriptive notes including early development of three species. Gulf Coast Research Lab., Ocean Springs, MS 39564.

TABLE 5
Meristics of Stained *Chloroscombrus orqueta*

Station	Body length (mm)	Dorsal fin	Anal fin	Pectoral fin	Caudal fin	Pelvic fin	Branchiostegals
5608-B-137.23	2.7	—	—	—	—	—	6
Cabo Blanco, Costa Rica 10 miS	2.9	—	—	—	—	—	6
5608-B-137.23	3.0	—	—	—	—	—	7
P-42-130.30	3.2	anlagen	anlagen	—	—	—	7
5608-B-137.23	3.4	anlagen	anlagen	—	0+2+2+0	—	7
P-42-130.30	3.7	anlagen	anlagen	—	0+4+4+0	—	7
ETP 13.019	4.0	VII+I,11	II+I,16	5	0+8+7+0	—	7
ETP 13.019	4.3	VII+I,18	II+I,18	7	0+8+7+0	—	7
ETP 13.019	4.5	VIII+I,22	II+I,23	10	2+9+8+2	—	7
ETP 13.019	5.1	VIII+I,23	II+I,20	12	2+9+8+2	—	7
ETP 13.019	5.6	VIII+I,22	II+I,22	12	2+9+8+2	—	7
TO 59-1 #46	5.9	VIII+I,26	II+I,25	15	3+9+8+3	I,2	7
TO 59-1 #46	6.6	VIII+I,26	II+I,25	14	4+9+8+4	I,2	7
ETP 60.295	7.5	VIII+I,28	II+I,28	20	6+9+8+6	I,3	7
TO 59-1 #35	7.7	VIII+I,26	II+I,25	19	7+9+8+7	I,4	7
TO 59-1 #35	8.0	VIII+I,26	II+I,25	20	6+9+8+6	I,4	7
ETP 13.021	8.3	VIII+I,27	II+I,26	20	8+9+8+8	I,5	7
Cabo Blanco, Costa Rica 10 miS	8.7	VIII+I,27	II+I,28	20	9+9+8+9	I,5	7
RABMEX S-13	9.5	VIII+I,28	II+I,28	21	9+9+8+9	I,5	7
RABMEX 71 III (a,b)	10.2	VIII+I,28	II+I,27	20	9+9+8+9	I,5	7
RABMEX S-14	11.0	VIII+I,27	II+I,26	20	9+9+8+9	I,5	7
RABMEX S-14	12.2	VIII+I,28	II+I,26	21	10+9+8+10	I,5	7
RABMEX S-13	13.2	VIII+I,28	II+I,26	21	9+9+8+9	I,5	7
RABMEX 71 III (a,b)	15.2	VIII+I,28	II+I,29	20	10+9+8+9	I,5	7
RABMEX S-10	15.7	VIII+I,28	II+I,27	21	9+9+8+9	I,5	7
RABMEX S-14	23.5	VIII+I,28	II+I,26	20	9+9+8+9	I,5	7
RABMEX S-2	29.7	VIII+I,28	II+I,28	20	9+9+8+9	I,5	7

Specimens between dashed lines are undergoing notochord flexion.

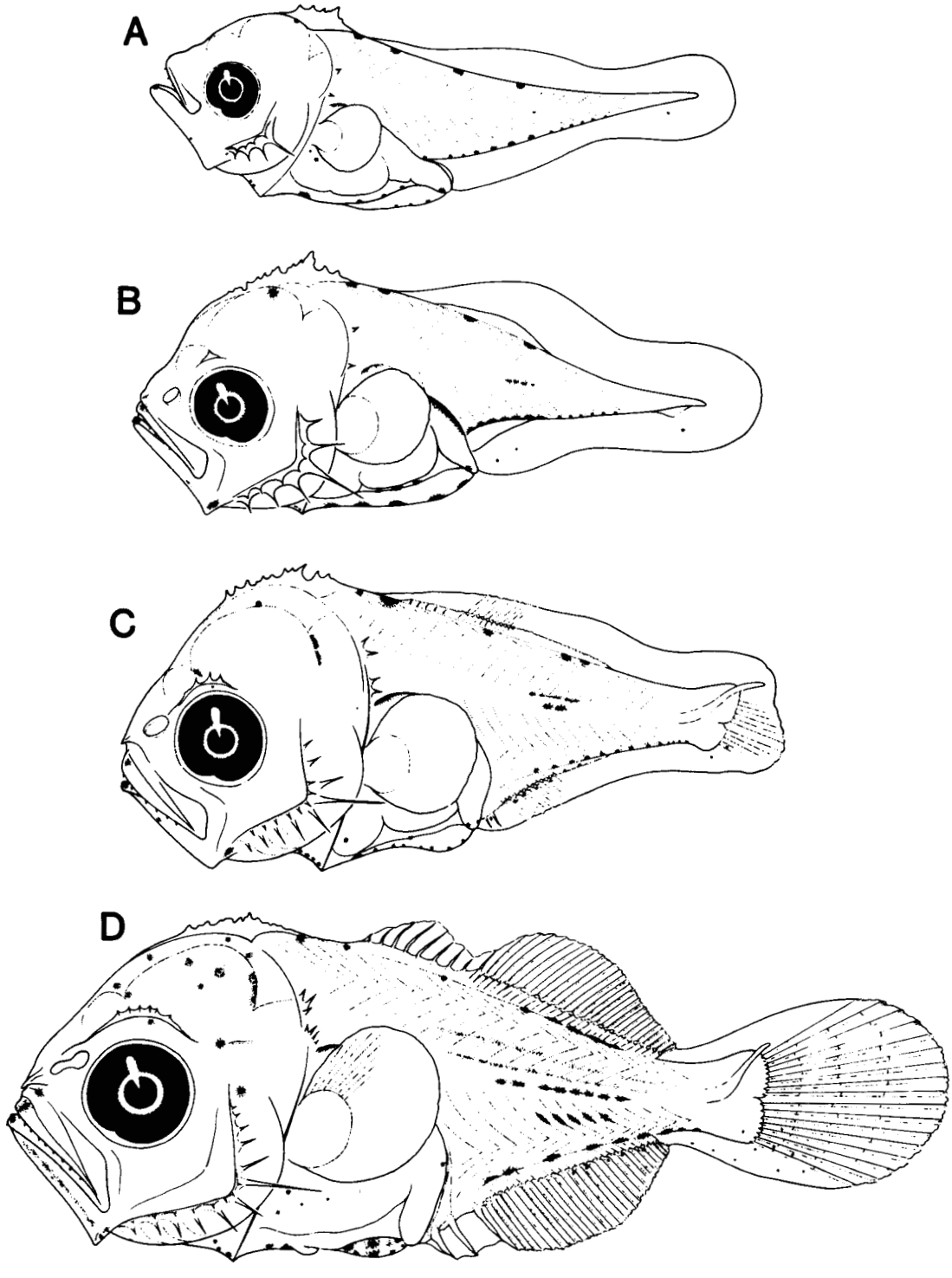

Figure 5. Larvae of *Chloroscombrus orqueta*: *A*, 2.7 mm; *B*, 2.9 mm; *C*, 3.7 mm; *D*, 5.1 mm.

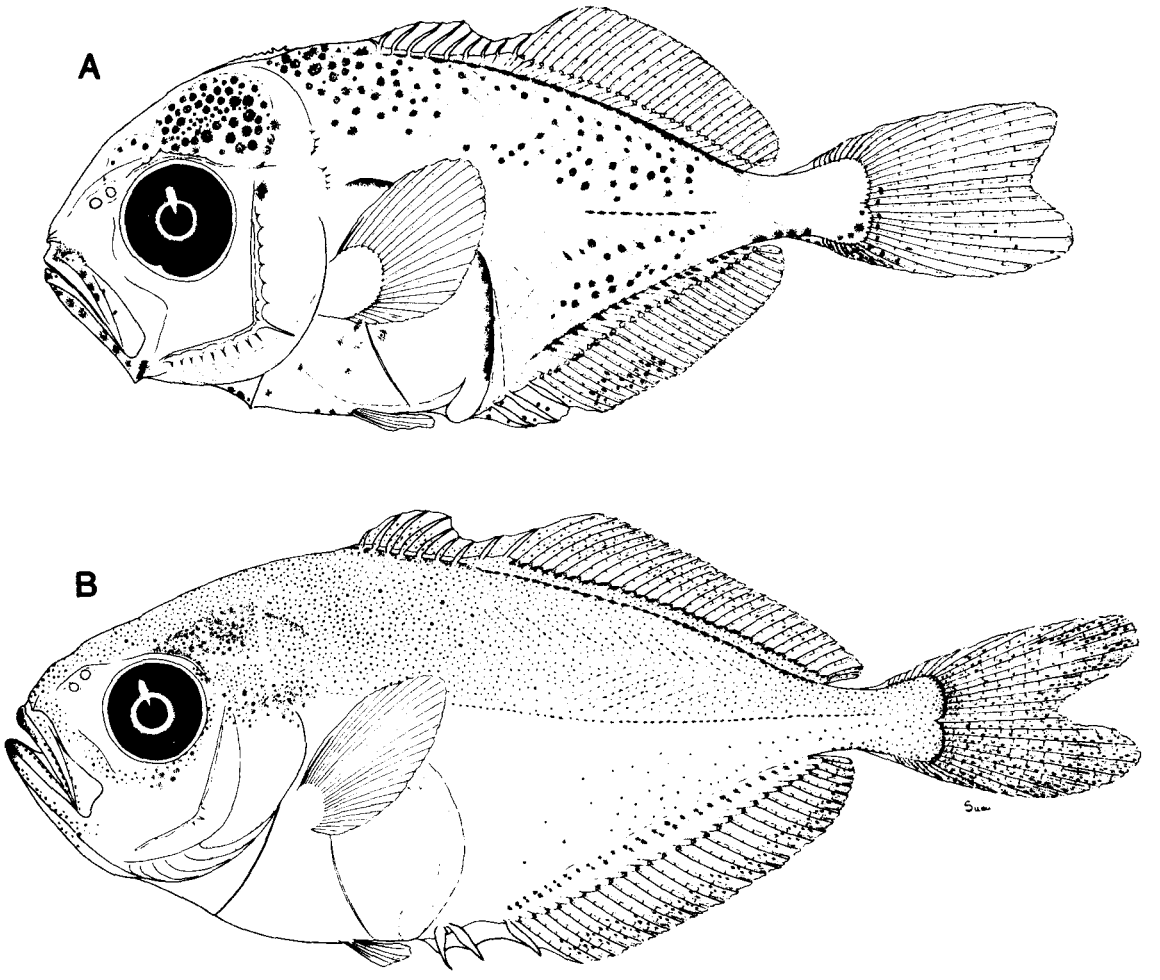

Figure 6. Postflexion larva and early juvenile of *Chloroscombrus orqueta*: A, 10.2 mm; B, 23.5-mm juvenile.

pigmentation above the spinal column also develops at this time, but is obscured by overlying body musculature. Myoseptal pigmentation on the dorsal surface of the body as well as melanophores in the shoulder region appear later, at about 7.2 mm.

By the early juvenile stage (~23.5 mm; Figure 6B), pigmentation is confined to the dorsolateral half of the head and body region, and remains sparse or lacking on the ventrolateral half. Fin pigmentation initially develops on the anal and caudal fins by about 10.0 mm, and concentrates on the musculature overlying the pterygiophores of the dorsal and anal fins and on the distal margins of the dorsal, anal, and caudal fins in early juvenile stages (Figure 6A, B). The pectoral fins lack pigment throughout the larval and juvenile period.

Caranx caballus

Literature. Larvae of *Caranx caballus* have not been previously described.

Distinguishing features. Caranx caballus larvae are distinguishable by their pigmentation pattern and meristic count of 25 vertebrae. The body morph of early larvae resembles that of *Chloroscombrus orqueta*; however, differences in pigmentation, particularly on the dorsal body margin, differentiate the species. Small *Caranx caballus* (to ~4.0 mm) possess opposing dorsal, lateral, and ventral pigmentation streaks on the body and lack the four characteristic melanophores on the dorsal body margin of early *Chloroscombrus orqueta* larvae.

Morphology and meristics. Relative body proportions of *Caranx caballus* larvae are similar to those of

TABLE 6
Measurements (mm) of *Caranx caballus*

Station	Body length	Snout-anus length	Head length	Eye diameter	Snout length	Body depth at pectoral fin base
ETP 46.135	3.0	1.8	1.0	0.28	0.32	1.0
ETP 46.135	3.6	2.2	1.3	0.36	0.36	1.2
Cabo Blanco, Costa Rica	3.8	2.2	1.3	0.38	0.36	1.4
Cabo Blanco, Costa Rica	3.9	2.3	1.4	0.44	0.38	1.7
" "	4.4	2.5	1.6	0.54	0.40	1.8
TO 59-1 #38 surf.	4.9	2.7	1.6	0.54	0.46	2.0
Cabo Blanco, Costa Rica	5.0	2.7	1.7	0.56	0.46	2.1
" "	5.4	3.0	2.0	0.60	0.64	2.3
Mazatlan 8, Sta. 6	6.3	3.5	2.2	0.76	0.64	2.8
ETP 47.040	7.8	4.4	2.9	1.0	0.68	3.6
67-2, N19	9.3	5.2	3.4	1.2	0.72	4.2
67-2, N19	10.9	6.0	4.2	1.5	1.0	5.0
ETP 47.019	11.7	6.8	4.3	1.4	1.1	5.4
67-2, N19	13.2	7.2	4.8	1.7	1.2	5.7
67-2, N50	16.7	8.9	5.5	2.2	1.2	7.0
67-2, N50	18.4	9.5	6.4	2.4	1.4	7.7
RABMEX S-13	21.7 juv.	11.4	7.7	2.7	2.0	8.5

Specimens between dashed lines are undergoing notochord flexion.

Chloroscombrus orqueta at equivalent stages of development (Tables 1 and 6). Larvae are deep-bodied (Figure 1); relative body depth increases throughout the larval period and decreases slightly in juveniles. Relative snout-anus distance decreases throughout the larval period. Gut development is similar to that described for *C. orqueta*. Relative head length and eye diameter increase during the larval period, while relative snout length decreases.

Spines develop on the preopercle, posttemporal, and supracleithrum. By 3.0 mm, larvae have a large spine at the angle, three below the angle, and one above the angle on the preopercular margin. Larvae 5-6 mm have up to 5 spines below the angle, 7-17-mm larvae have 6-7 spines, and 18-24-mm larvae have 8-9 spines below the angle. The number of spines above the angle increases to about 2 in 4-mm larvae, 4 in 5-8-mm larvae, and 5-6 in larger larvae. The angle spine is relatively largest in 3-mm larvae (10% of body length) and becomes relatively smaller gradually in later larval stages. Larvae $\leq$3.0 mm develop 3 spines below the angle of the preopercular ridge, and 4-8-mm larvae have 5 spines. Larvae 3-8 mm have only a single spine above the angle. Larvae larger than 8 mm resorb all preopercular ridge spines.

By 3 mm, larvae form a single posttemporal and a supracleithral spine, and develop no additional posttemporal spines; however, by 5.0 mm, a second supracleithral spine appears. Larvae lose both types of spines at about 10 mm.

By 3 mm a supraoccipital crest is present. It extends from the midregion of the optic lobes to the second myoseptum and has wide irregular serrations. After notochord flexion it is restricted to the occipital region and is absent in larvae larger than 8.0 mm. Postflexion larvae develop a supraocular shelf and pterotic ridge, but they do not develop spines.

Table 7 provides meristic counts of stained specimens.

Pigmentation. Pigmentation on *C. caballus* larvae is sparse in early stages, with a generalized pattern of opposing dorsal, lateral, and ventral streaks on the body, and melanophores on the top of the head and over the abdominal region (Figure 7). Preflexion and flexion larvae are characterized by a few melanophores in the ventral region of the gut. These mela-

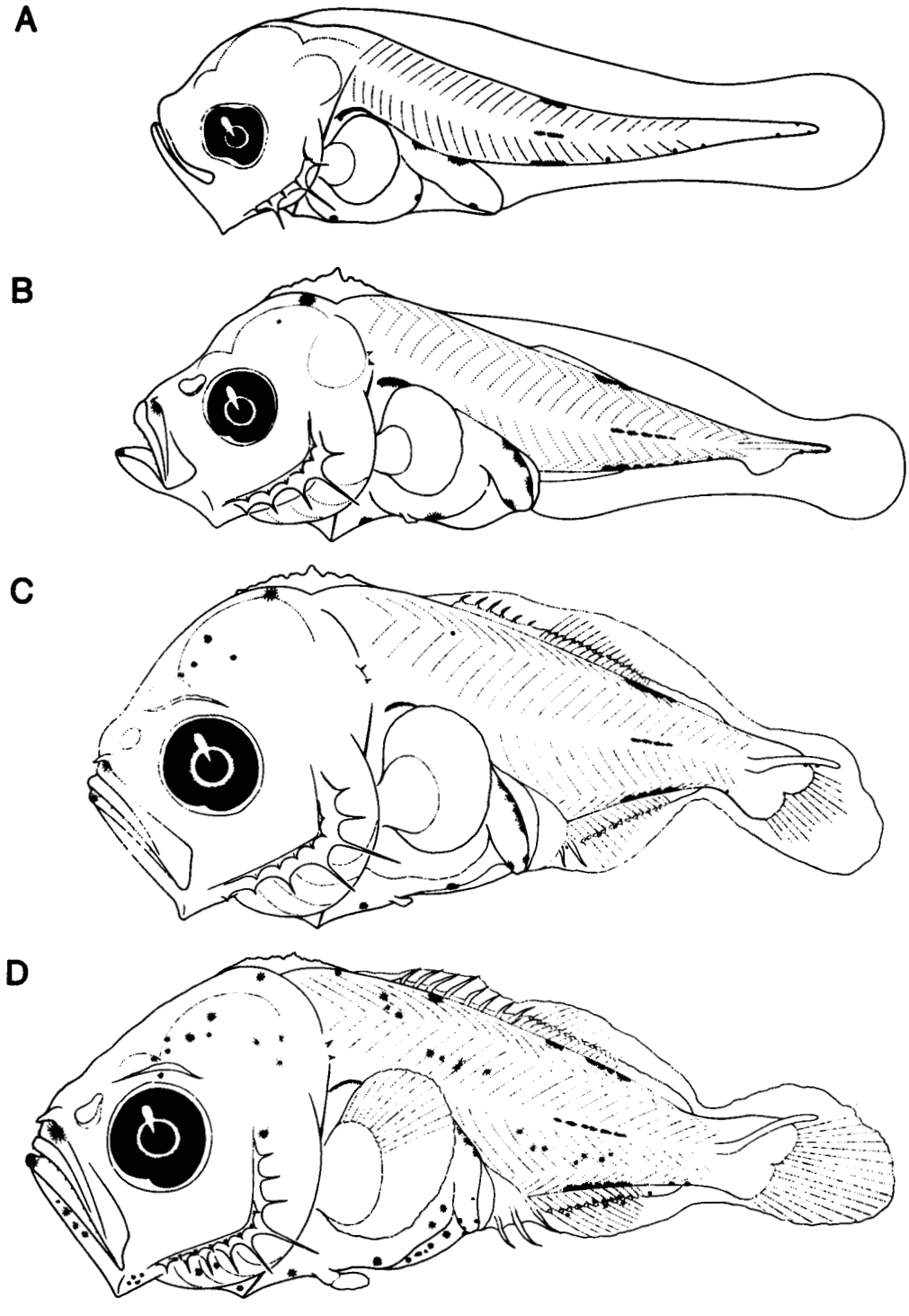

Figure 7. Larvae of *Caranx caballus*: *A*, 2.3 mm; *B*, 3.6 mm; *C*, 3.9 mm; *D*, 4.4 mm.

TABLE 7
Meristics of Stained *Caranx caballus*

Station	Body length (mm)	Dorsal fin	Anal fin	Pectoral fin	Caudal fin	Pelvic fin	Branchiostegals
ETP 46.135	3.0	—	—	—	—	—	5
TO 58-1 #59	4.0	V,13	II+I,10	—	0+4+4+0	—	7
#59	4.2	anlagen	anlagen	—	0+5+5+0	—	7
Cabo Blanco, Costa Rica	4.4	VIII+I,20	II+I,14	9	2+9+8+2	I,2	7
Cabo Blanco, Costa Rica	5.0	VIII+I,21	II+I,19	13	3+9+8+2	I,4	7
67-2 #19	6.2	VIII+I,21	II+I,18	16	4+9+8+5	I,5	7
Cabo Blanco, Costa Rica	6.7	VIII+I,23	II+I,19	17	5+9+8+5	I,5	7
Cabo Blanco, Costa Rica	7.7	VIII+I,22	II+I,20	20	6+9+8+6	I,5	7
67-1, N-22	8.6	VIII+I,22	II+I,19	20	8+9+8+8	I,5	7
67-2, #19	9.3	VIII+I,22	II+I,19	22	9+9+8+9	I,5	7
67-2, #19	10.9	VIII+I,22	II+I,19	22	9+9+8+9	I,5	7
ETP 47.019	11.7	VIII+I,23	II+I,20	22	9+9+8+9	I,5	7
67-1, N-2	13.0	VIII+I,23	II+I,19	22	9+9+8+9	I,5	7
67-2, #27A	13.9	VIII+I,23	II+I,20	22	9+9+8+9	I,5	7
ETP 14.014	16.9	VIII+I,23	II+I,19	22	9+9+8+9	I,5	7
67-2, N-50	18.4	VIII+I,23	II+I,19	22	9+9+8+9	I,5	7
ETP 14.014	23.5 juv.	VIII+I,24	II+I,20	22	9+9+8+9	I,5	7

Specimens between dashed lines are undergoing notochord flexion.

nophores are usually in an anterior, median, and posterior (next to the anus) position along the ventral margin of the gut area, with additional pigmentation along the upper section of the terminal segment of the gut.

During notochord flexion (~3.9-4.9 mm), melanophores become lightly scattered over the head and body (Figures 7C, D and 8A) in contrast to the dense pigmentation that covers all but the posterior sections of the tail in postflexion specimens. Postflexion larvae (6.3-8.5 mm) develop a cluster of pigment around the lateral midline streak (Figure 8B), which is obscured in later stages by heavy pigmentation over the trunk. Beginning at about 13.0 mm, melanophores begin forming in the middle of the caudal peduncle, and subsequently spread to the margins of the peduncle.

Bars of pigmentation are first evident on the body in specimens about 17.0 mm long (Figure 8C), persisting into the juvenile stage. Because of the heavy background pigment over the entire surface of the body, these bars are not as prominent as those in *C. sexfasciatus*.

Fin pigmentation is heavy and conspicuous on the fin membranes of the spinous dorsal, spinous portion of the anal, and the pelvic fins in postflexion larvae from about 10.5 mm through the juvenile stage. Pigment first appears on the anal and pelvic fins by about 5.5 mm and on the spinous dorsal fin by about 6.2 mm.

Caranx sexfasciatus

Literature. Larvae of *Caranx sexfasciatus* have not been previously described.

Distinguishing features. A unique feature of

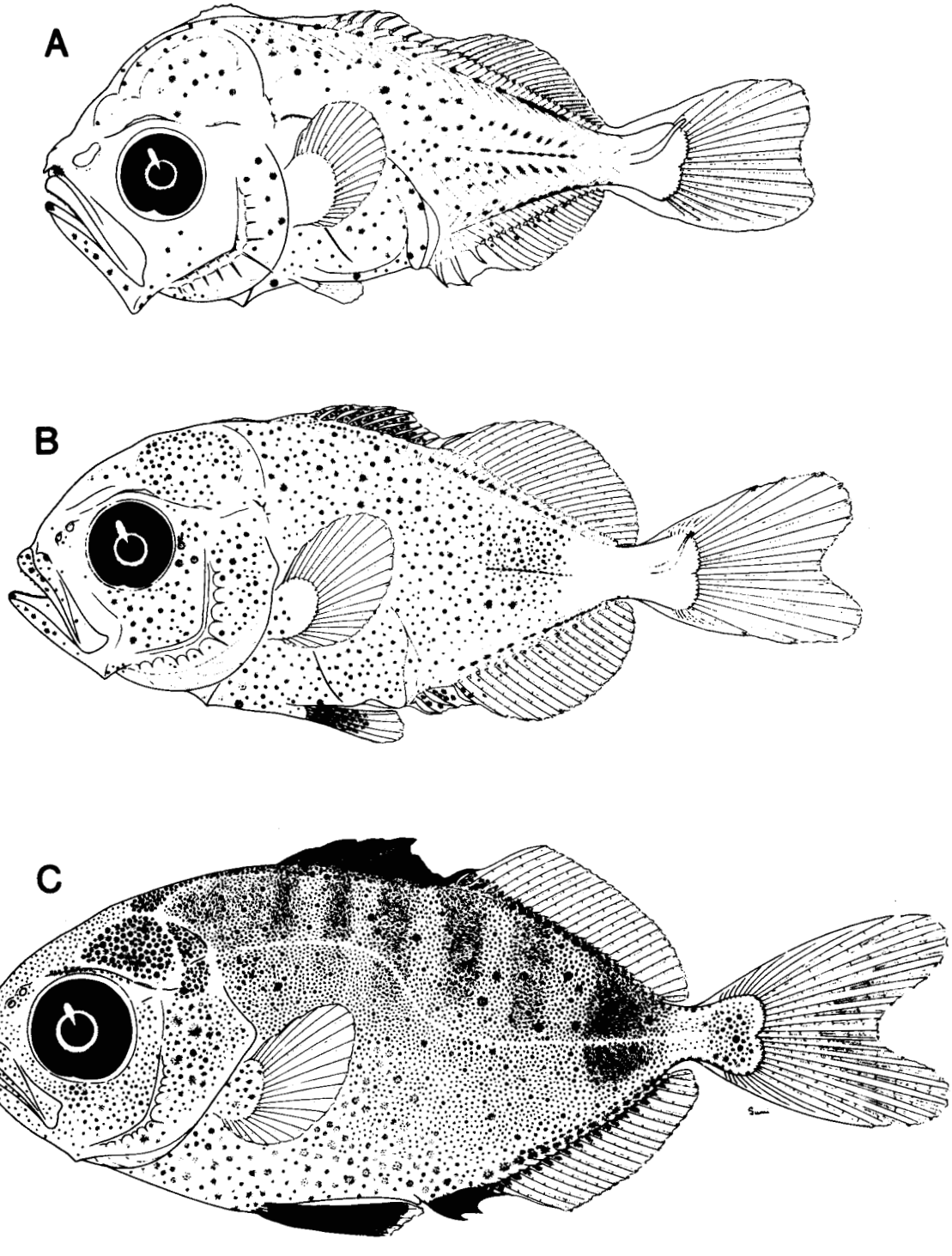

Figure 8. Postflexion larvae of *Caranx caballus*: *A*, 4.9 mm; *B*, 8.4 mm; *C*, 17.0 mm.

TABLE 8
Measurements (mm) of *Caranx sexfasciatus*

Station	Body length	Snout-anus length	Head length	Eye diameter	Snout length	Body depth at pectoral fin base
7205-JD						
157G.150	2.6	1.4	0.76	0.24	0.22	0.76
ETP 13.019	3.0	1.6	0.90	0.30	0.24	1.0
7205-157G.150	3.1	1.7	1.0	0.34	0.28	1.1
7205-157G.150	3.4	1.9	1.1	0.34	0.36	1.3
TO 58-1 #69	3.8	2.1	1.4	0.40	0.40	1.6
ETP 13.019	4.0	2.3	1.4	0.44	0.42	2.0
Cabo Blanco, Costa Rica	4.2	2.4	1.4	0.48	0.42	1.9
TO 59-1 #35	4.5	2.7	1.7	0.60	0.46	2.5
TO 58-1 #69	4.6	2.8	1.8	0.60	0.50	2.5
Mazatlan 5-14-0	4.8	2.8	1.7	0.60	0.46	2.5
Cabo Blanco, Costa Rica	5.3	3.3	2.1	0.70	0.50	2.8
ETP 12.033	5.9	3.3	2.0	0.72	0.56	2.9
ETP 46.134	6.6	4.0	2.6	0.88	0.68	3.6
ETP 30.114	7.7	4.2	2.9	1.0	0.80	4.4
7205-G-157G.150	8.5	5.1	3.2	1.2	0.76	4.6
ETP 47.019	9.4	5.1	3.6	1.3	0.80	5.2
ETP 14.232	12.5	6.4	4.6	1.5	0.91	6.6
TO 5801 #141	15.4	8.4	5.8	2.1	1.6	7.8
SIO 64-140	22.8 juv.	11.4	7.7	2.5	2.0	10.5
67-2, N51	30.4 juv.	14.0	9.5	3.3	2.3	12.4

Specimens between dashed lines are undergoing notochord flexion.

Caranx sexfasciatus larvae is a conspicuously pigmented supraoccipital crest. All other described carangid larvae with a supraoccipital crest lack pigment on this structure. Another distinctive character in larvae larger than about 3.4 mm is a preanal finfold that is covered with pigment until resorption of the finfold at about 10.0 mm. Larvae are considerably deep-bodied following notochord flexion, and possess the smallest number of anal fin rays (15-17) among *Caranx* species in the eastern Pacific.

Morphology and meristics. Preflexion larvae of *C. sexfasciatus* are of moderate body depth, but become markedly deep-bodied in later stages (Tables 1 and 8; Figure 1). Body depth averages 35% of body length in preflexion larvae, but increases to over 50% of body length in flexion and postflexion larvae, diminishing to about 44% in early juveniles.

Relative gut length, head length, and eye diameter increase slightly in the larval period, but diminish in juveniles. Relative snout length remains constant at about 29% in preflexion- and flexion-stage larvae, decreasing to about 25% in postflexion larvae and juveniles. Gut development is similar to that described for *C. orqueta*.

As in *C. caballus*, spines develop on the preopercle, posttemporal, and supracleithrum. Small larvae <3 mm have a large spine at the angle of the preopercular margin, 2 below the angle, and 1 above the angle. Postflexion larvae up to about 8.5 mm develop 4 spines below the angle; 9-12-mm larvae have 5 spines; and specimens larger than 13 mm have 6 spines. The number above the angle increases to 3-4 in postflexion larvae up to about 9.0 mm and is reduced to 1 or none in specimens larger than 12 mm. The angle spine is relatively largest in 3-mm larvae (maximum of 15% of body length) and subsequently decreases gradually in relative size. Larvae ≤3 mm develop 4 spines below the angle of the preopercular ridge; by 6.0 mm, 4-5 spines are present. These spines are lost in larvae >6.0 mm. A single spine is present above the angle of the ridge until the completion of notochord flexion (~4.5 mm), after which there is none.

By 4.0 mm, larvae have a single spine on the su-

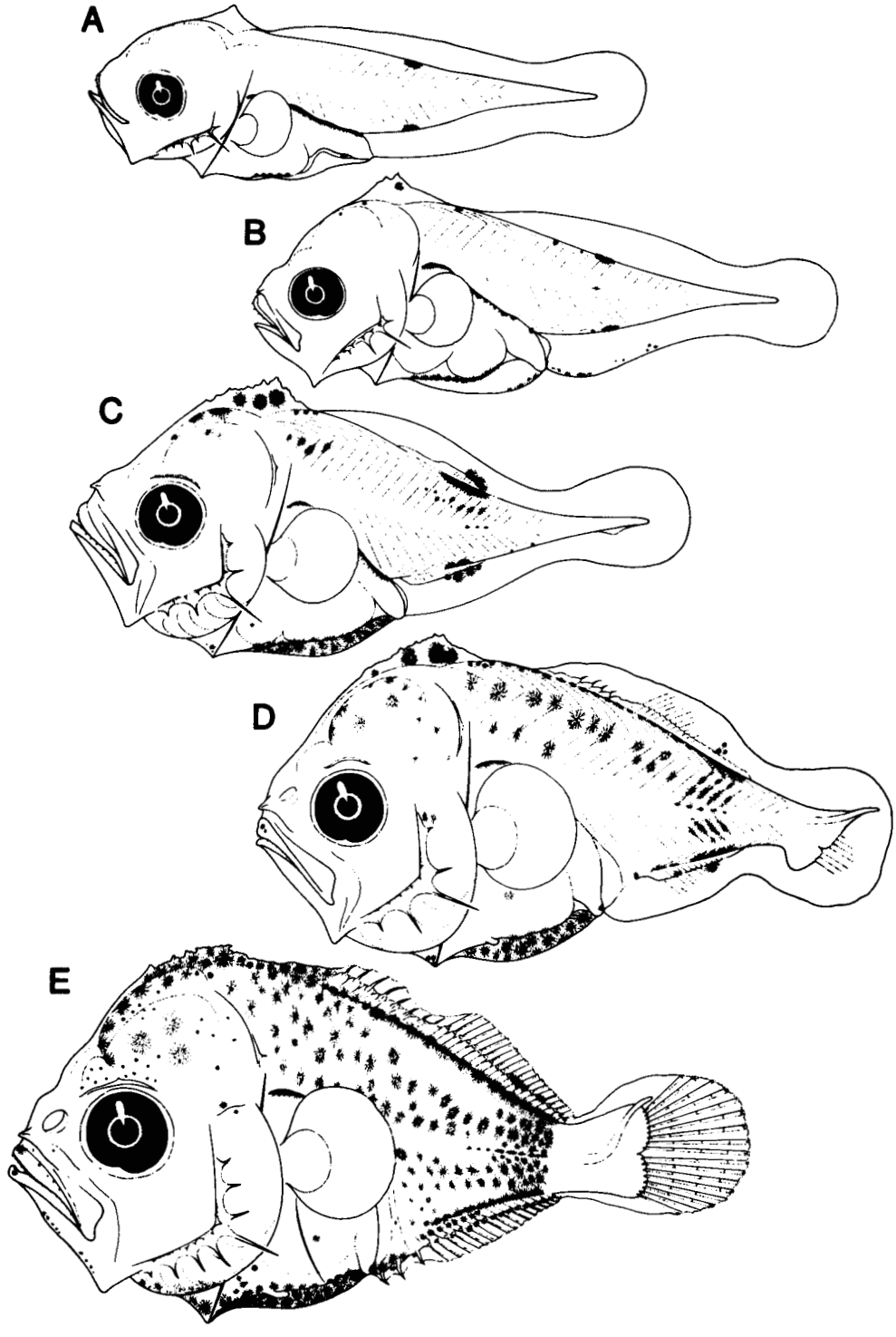

Figure 9. Larvae of *Caranx sexfasciatus*: *A*, 2.6 mm; *B*, 3.0 mm; *C*, 3.4 mm; *D*, 4.0 mm; *E*, 4.2 mm.

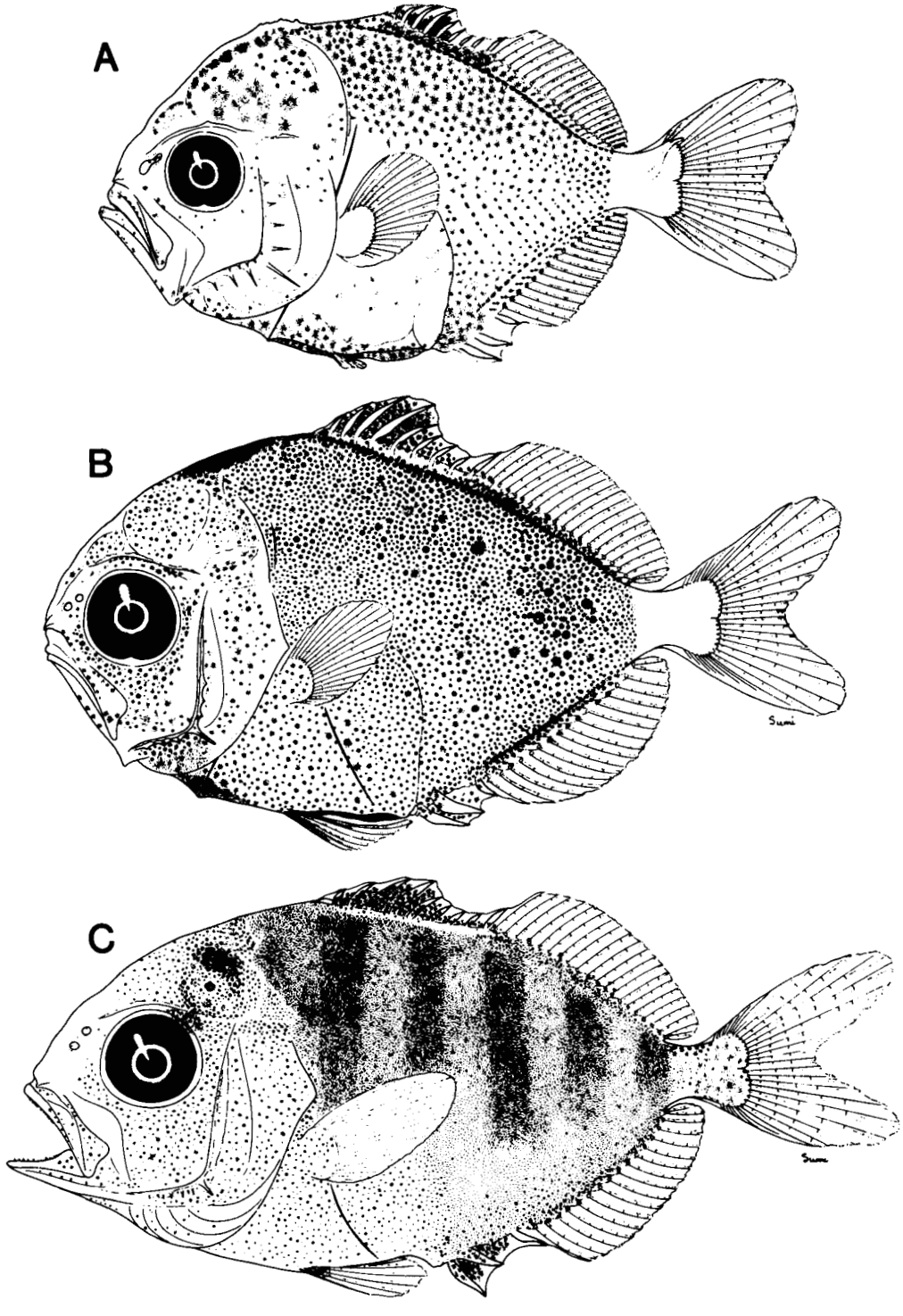

Figure 10. Postflexion larvae of *Caranx sexfasciatus*: *A*, 5.5 mm; *B*, 9.4 mm; *C*, 15.4 mm.

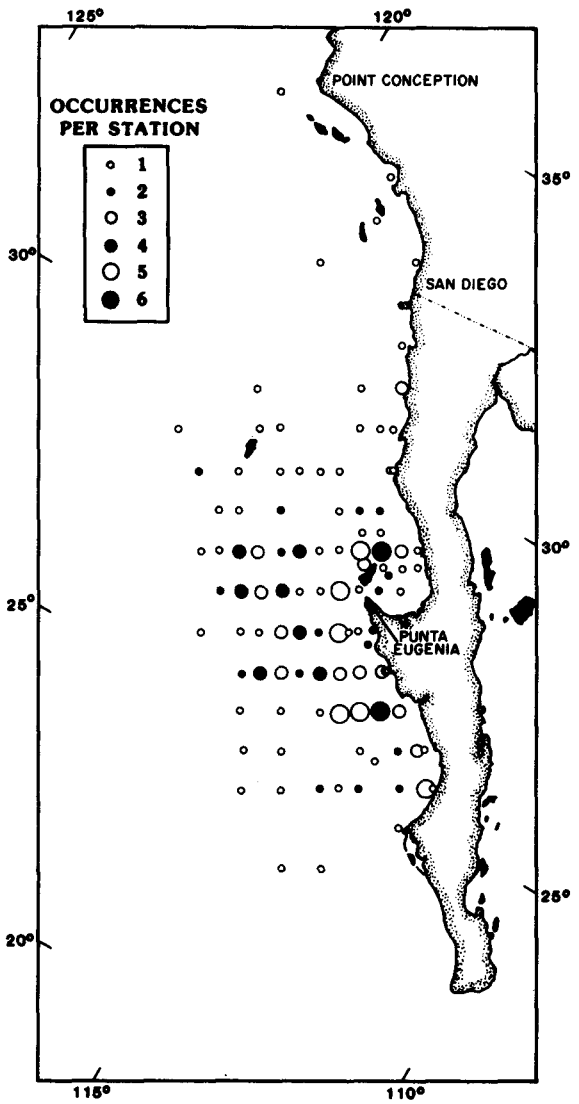

Figure 11. Pooled numbers of occurrences of larvae of *Seriola lalandi* in standard CalCOFI tows taken from 1954 to 1969.

pracleithrum; it remains until about 12.0 mm. At about 4.5 mm, a single posttemporal spine forms directly above the supracleithral spine and is variously present or absent in larvae up to about 8.5 mm, after which it is absent.

Our smallest larvae, <3.0 mm long, have developed a small supraoccipital crest. It enlarges rapidly to its maximum development at about 3.0 mm. It is triangular, with a peak above the occipital region and a convex forward margin, sometimes with minute serrations. It becomes flat and inconspicuous during notochord flexion and is absent in larvae larger than 8.0 mm. An inconspicuous supraocular crest and pterotic ridge develop in postflexion larvae, but these do not develop spines.

Meristic counts of stained specimens are presented in Table 9.

Pigmentation. Caranx sexfasciatus larvae possess striking melanistic pigment on the supraoccipital crest, a character unique among larval carangids that have been described. Our smallest specimens, 2.4-2.6 mm in length, have no pigmentation on the supraoccipital crest, but a single melanophore appears there by 3.0 mm (Figure 9A, B). Melanophores on the crest increase in number and intensity during the larval period until the crest is completely resorbed by 8.0 mm (Figures 9 and 10).

Another distinctive character in larvae larger than about 3.4 mm is a preanal finfold that is completely pigmented until resorption of the finfold at about 10.0 mm. Other pigmentation on early *C. sexfasciatus* consists of a pattern typical for many carangid larvae, with opposing dorsal, lateral, and ventral streaks on the body, as well as pigment on the head and abdominal region. Pigmentation spreads rapidly on the head and body in postflexion larvae (Figures 9E and 10), resulting in a very heavily pigmented body, with the exception of the caudal peduncle. By 15.4 mm, the caudal peduncle is pigmented, and the body exhibits the dark vertical stripes characteristic of the juvenile stage (Figure 10C).

Fin pigmentation remains sparse except for the spinous dorsal fin, which is pigmented early in the larval period, at about 5.5 mm. Pigmentation on this fin persists and intensifies to the late juvenile stage. The anterior portion of the anal fin is also pigmented in the early stages, but the pigment is transitory.

DISTRIBUTION

Seriola lalandi is reported to range from southern Washington to Chile, including the Gulf of California (Miller and Lea 1976); however, the larval distribution is limited to warmer waters. Within all CalCOFI plankton tows taken from 1954-69, *S. lalandi* larvae occurred in 206 samples. The northernmost occurrence was off Point Conception in July 1965; incidence was highest off central Baja California, where larvae were found in a broad band from nearshore to about 200 miles offshore (Figure 11). Incidence of yellowtail larvae was low off southern California (4% of occurrences) compared to Baja California, which had 96% of the occurrences.

Yellowtail larvae were collected from April to October, with 83% of the occurrences in July and

TABLE 9
Meristics of Stained *Caranx sexfasciatus* Larvae

Station	Body length (mm)	Dorsal fin	Anal fin	Pectoral fin	Caudal fin	Pelvic fin	Branchiostegals
7205-157G.150	2.5	—	—	—	—	—	—
7205-157G.150	2.7	—	—	—	—	—	4
7205-157G.150	3.0	—	—	—	—	—	6
75.04 Sta. 8	3.5	—	—	—	—	—	7
TO 59-1 #35	4.7	IX,15	II+I,11	8	1+9+8+1	—	7
Cabo Blanco, Costa Rica	5.3	VIII+I,19	II+I,15	14	4+9+8+4	bud	7
ETP 12.033	5.9	VIII+I,19	II+I,16	15	3+9+8+3	bud	7
75.04 Sta. 2	6.1	VII+I,19	II+I,15	15	5+9+8+5	bud	7
ETP 30.114	7.7	VIII+I,19	II+I,16	18	7+9+8+7	I,3	7
Costa Rica 37-2	9.0	VIII+I,20	II+I,15	20	8+9+8+8	I,5	7
ETP 14.232	12.5	VIII+I,19	II+I,16	21	9+9+8+9	I,5	7
TO 58-1 #69	13.7	VIII+I,20	II+I,17	21	9+9+8+9	I,5	7

Dashed line separates preflexion from postflexion larvae.

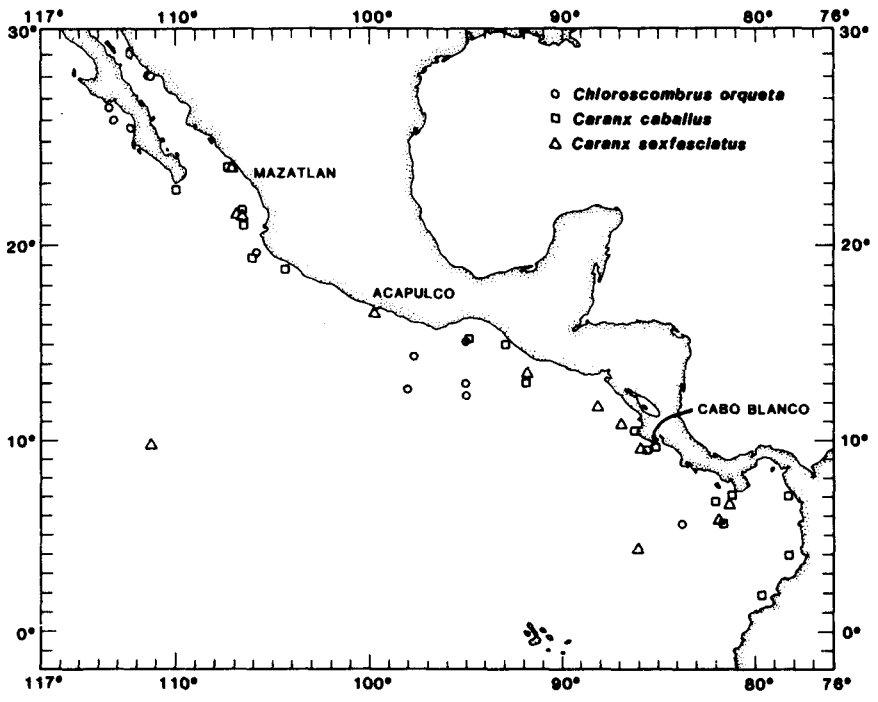

Figure 12. Occurrences of larvae of *Chloroscombrus orqueta*, *Caranx caballus*, and *Caranx sexfasciatus*. Omitted in this figure are a cluster of *Chloroscombrus orqueta occurrences* near San Carlos Bay, Gulf of California, and clusters of occurrences of the above three species off Cabo Blanco, Costa Rica.

August. This seasonal pattern correlates with the spawning period, reported to be in the spring and summer (Walford 1974). In their observations of maturing ova, Smith and Paul (1960) concluded that spawning generally begins in July and continues until October.

The size-frequency distribution of yellowtail larvae collected in CalCOFI samples in 1954-69 was narrow, with a mean length of 4.1 mm ± 1.16 SD and a range of 2.8-17.9 mm for the 429 larvae measured.

Figure 12 shows localities where larvae of *Chloroscombrus orqueta*, *Caranx caballus*, and *Caranx sexfasciatus* were taken. Of these three species, *Chloroscombrus orqueta* and *Caranx caballus* range as far north as southern California (Hubbs et al. 1979; Miller and Lea 1976), but none of our larvae was taken north of Baja California.

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