Abstract.—Egg and larval development of California halibut *Paralichthys californicus* and fantail sole *Xystreurys liolepis* are described from specimens collected in the nearshore zone of the Southern California Bight (except early-stage eggs, described from reared material). Eggs of both species have spherical unornamented chorions, homogenous yolk, and a single oil globule. Chorion diameters of *P. californicus* and *X. liolepis* eggs are 0.64–0.83 mm and 0.72–0.90 mm, respectively. Respective oil globule diameters are 0.09–0.16 mm and 0.14–0.24 mm. Initial embryonic pigmentation patterns are similar; however, distinctive pigment patches develop in the dorsal and ventral finfolds and at the tail tip on late-stage *X. liolepis* embryos. Larvae of *P. californicus* can be distinguished from those of *X. liolepis* at all stages of development. Internal notochord pigment is easily observed in *P. californicus* but is not visible in *X. liolepis*; sphenotic spines are present in *P. californicus* but absent in *X. liolepis*. Body shape, robust in *X. liolepis* and laterally compressed in *P. californicus*, and external pigmentation, heavier in *X. liolepis*, separates flexion and postflexion specimens.

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Development of Eggs and Larvae of California Halibut *Paralichthys californicus* and Fantail Sole *Xystreurys liolepis* (Pisces: Paralichthyidae)

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The California halibut *Paralichthys californicus* (Ayres) is an important sport and commercial fish, ranging from the Quillayute River, Washington (Miller and Lea 1972, Eschmeyer et al. 1983), to Almejas Bay, Baja California (LACM 38108-8). In the southern California portion of the range, the eggs and larvae of *P. californicus* are relatively abundant within the nearshore zone (Gruber et al. 1982, Barnett et al. 1984, Lavenberg et al. 1986). However, similarities between the eggs and larvae of *P. californicus* and the fantail sole *Xystreurys liolepis* Jordan and Gilbert may have caused previous identifications of these two species to be confused (Lavenberg et al. 1986), particularly within the geographical overlap of their ranges (*X. liolepis* ranges from Monterey Bay, California to the Gulf of California; Miller and Lea 1972, Eschmeyer et al. 1983). Early-life-history information has been published for both species, but it has not been adequate to separate them at all stages. Ahlstrom and Moser (1975) illustrated a series of four *P. californicus* larvae, but the two smallest specimens (2.5 and 3.8 mm) do not fit pigmentation characters that I will present for *P. californicus*. Ahlstrom et al. (1984) illustrated a postflexion larva of each species and included information on the eggs (chorion and oil globule size, chorion and yolk texture) of *P. californicus* and the larvae of both species (number of elongate dorsal fin rays and sizes at hatching, flexion, and transformation). Eggs of *P. californicus* were erroneously reported as demersal rather than pelagic in Frey (1971).

My purpose is to provide descriptions of the eggs and larvae of *Paralichthys californicus* and *Xystreurys liolepis* and to give characters to separate them from each other and from other commonly occurring fish eggs and larvae in the coastal waters of southern California.

Materials and methods

The main source of material for this study was provided by the Bightwide Ichthyoplankton Program at the Natural History Museum of Los Angeles County (LACM). Beginning in 1978, ichthyoplankton sampling within the Southern California Bight was carried out in nearshore waters (at depths ranging from 8 to 36 m, extended to 75 m in 1981). Samples were collected in discreet depth and oblique tows using manta, bongo, and auriga frames equipped with nets of 333 μ or 1/8-inch stretch mesh (Brewer and Smith 1982, Love et al. 1984, Lavenberg et al. 1986). Plankton samples were fixed in standard 5% buffered formalin on board ship. Most of the samples were maintained

in 5% buffered formalin, but beginning in August 1983 bongo samples (333μ mesh nets) were transferred to 70% ethanol within two weeks of collection.

Collections also were made off King Harbor, Redondo Beach, California, on 12 March and 9 September 1985, using a 1-m plankton net (with 333μ mesh) towed at the surface. Samples of live plankton were brought to the King Harbor Research Laboratory where the fish eggs were removed and separated into types. Each type was reared separately at ambient sea temperature (~16°C), sampled periodically, and fixed and preserved in 5% buffered formalin.

Additional material was generated from spawning brood stock at the King Harbor laboratory. Adults of *Paralichthys californicus* and *Xystreurys liolepis* were maintained and artificially induced to spawn in April (*P. californicus*) and November (*X. liolepis*) 1985. The resulting eggs and larvae were reared in 4-L containers at 16–18°C. Eggs were sampled every two hours, and the larvae were sampled irregularly. These samples were fixed in 5% buffered formalin and preserved in 70% ethanol or 5% buffered formalin.

Table 1
Egg measurements of *Paralichthys californicus* and *Xystreurys liolepis* (diameters in mm).

	N	Chorion	Yolk mass	Oil globule
Paralichthys californicus				
Preserved in 5% formalin				
Field-collected material	1	0.82	0.67	0.14
Reared material	164	0.68–0.83	0.60–0.70	0.12–0.16
Preserved in 70% ethanol				
Field-collected material	70	0.64–0.80	0.40–0.68	0.09–0.12
Reared material	63	0.72–0.77	0.41–0.51	0.10–0.12
Xystreurys liolepis				
Preserved in 5% formalin				
Field-collected material	4	0.83–0.90	0.64–0.72	0.18–0.24
Reared material	278	0.82–0.90	0.65–0.74	0.18–0.24
Preserved in 70% ethanol				
Field-collected material	22	0.72–0.86	0.42–0.56	0.14–0.17
Reared material	70	0.76–0.80	0.50–0.60	0.14–0.17

Descriptions of both species are based primarily on field-collected material as studies of other taxa have noted differences in the appearance of field and reared material (Butler et al. 1982, Watson 1982, Caddell 1988). Field-collected postflexion larvae were identified with the aid of meristic counts. The developmental series was completed by working back towards smaller specimens following the sequential development of pigmentation, morphology, and morphometric patterns. Characters used to identify the earliest yolksac larvae also were used to identify embryos of late-stage eggs. I was unable to identify early-stage eggs from the field collections, so these eggs are described from reared material.

Measurements were made using a Wild M8 Stereomicroscope equipped with a measuring eyepiece. Three measurements were taken on each egg: chorion, yolk, and oil globule diameter. Measurements were made by manipulating the egg so that the oil globule faced up with the embryo at the bottom of the egg and perpendicular to the measurement grid. Larval measurements were made using definitions and methods employed by Moser and Ahlstrom (1970), Ahlstrom et al. (1976) and Leis and Rennis (1983).

The larval period is divided into three stages (preflexion, flexion, and postflexion) based on caudal fin development (Kendall et al. 1984). Prior to notochord flexion, i.e., preflexion, larval length is measured from snout tip to notochord tip and designated NL (notochord length). During flexion, larval length is measured from snout tip to the tip of the notochord or to the posterior margin of the developing hypurals, whichever is longer, and is designated FL (flexion length). The designation SL (standard length) is used for postflexion larvae and is measured from the snout to the posterior margin of the hypurals (now approximately perpendicular to the longitudinal axis of the body). Measurements given in this paper are followed by one of these designations in order to specify the developmental stage of the specimen. All measurements are expressed in millimeters (mm). Separate measurement tables are provided for eggs and larvae preserved in 5% buffered formalin and 70% ethanol because eggs and larvae preserved in ethanol shrink more than those preserved in formalin (Rounds et al. 1984).

Eggs were staged using the method Ahlstrom (1943) proposed for the pilchard. Larvae were cleared and stained following Potthoff (1984), but specimens were left in the acidic alcian blue solution for only two hours to minimize decalcification.

Results

Egg descriptions

Paralichthys californicus Eggs of *Paralichthys californicus* are pelagic and possess a smooth spherical chorion (0.64–0.83 mm), homogenous yolk (0.40–0.70 mm), and a single oil globule (0.09 - 0.16 mm, Table 1).

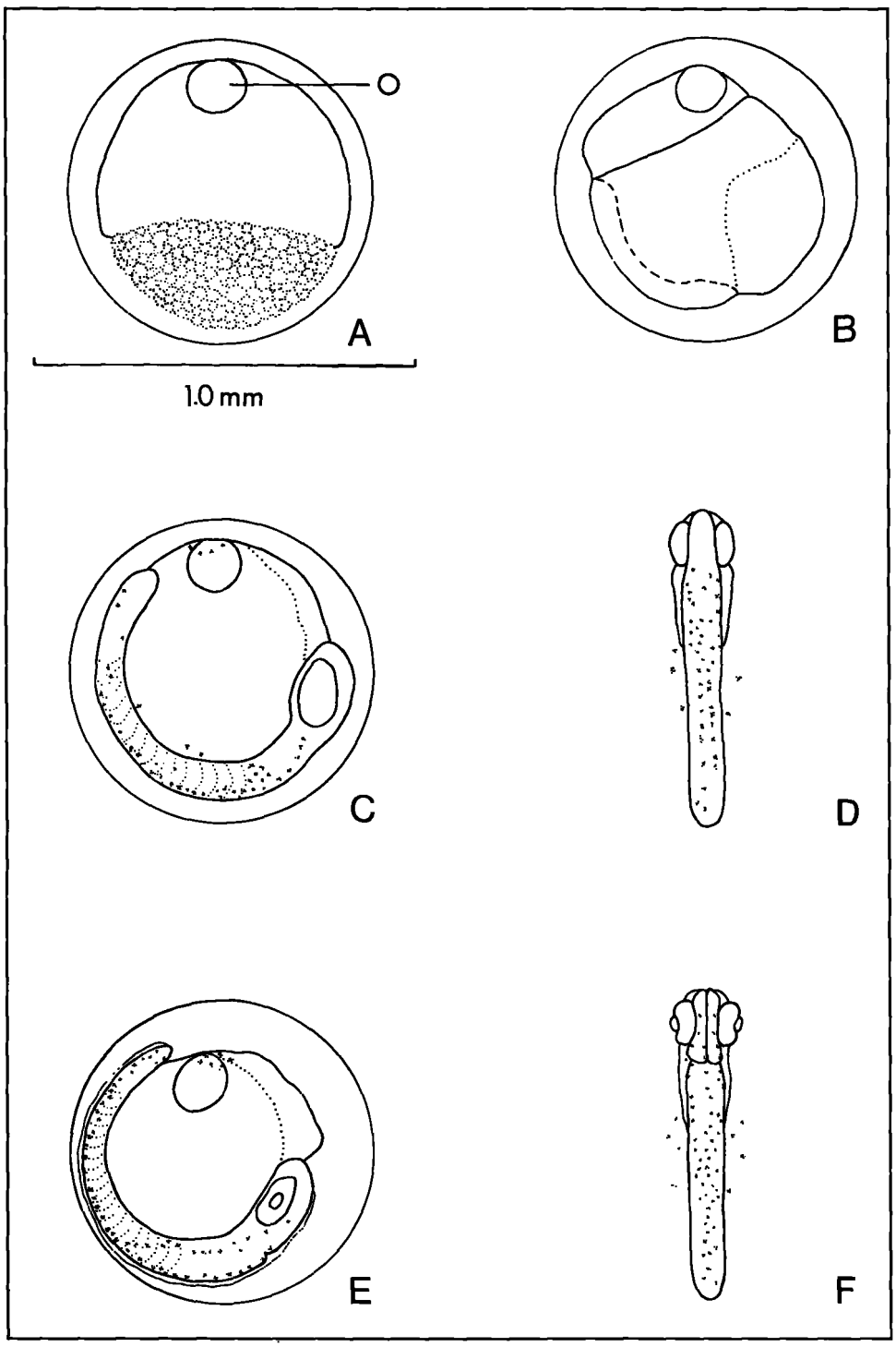

Figure 1
Eggs of *Paralichthys californicus* (o = oil globule): (A) stage II (LACM 44978), (B) stage IV (LACM 44978), (C) stage VI (LACM 44978), (D) dorsal view of embryo, stage VI (LACM 44978), (E) stage VII (LACM 047 88 15 OB 02S), (F) dorsal view of embryo,stage VII (LACM 047 88 15 OB 02S).

The embryonic shield is first visible as a thickening in the blastoderm when the germ ring encloses approximately 70–80% of the yolk (stage IV, Fig. 1B). The eyes and 10–15 somites are visible at about the time the blastopore closes (stage VI). At the end of stage VI, the lateral and posterior margins of the tail are defined, 15–20 somites are present, and pigment develops on the dorsal surface of the embryo posterior to the eyes and on the yolk near the oil globule and off the lateral margins of the body (Figs. 1C,D).

As the tail develops and separates from the yolk (stage VII), a thin finfold becomes visible, the midbrain shows definition, lens primordia form, and 20–25 somites are present. Pigment on the yolk, previously

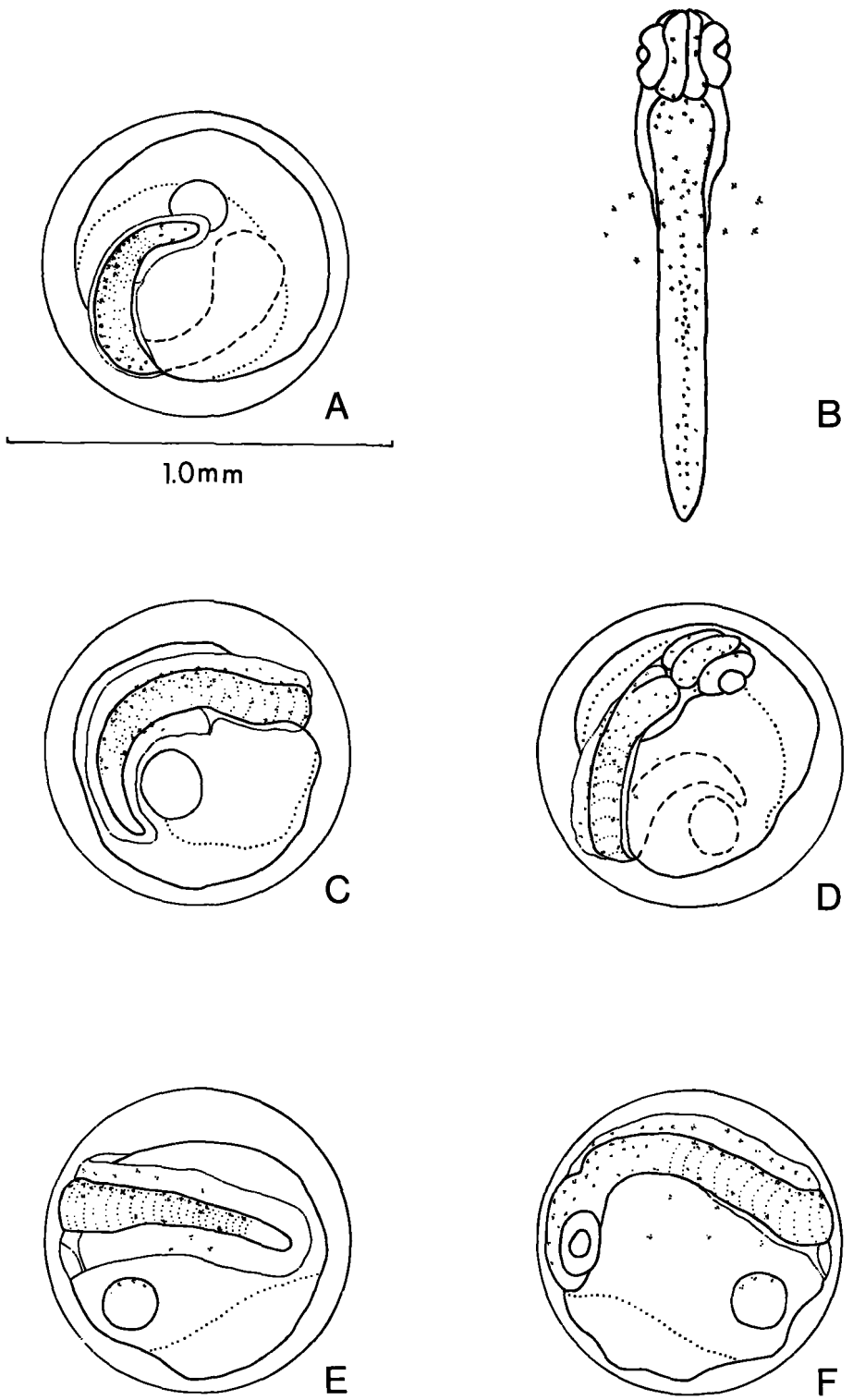

Figure 2
Eggs of *Paralichthys californicus*: (A) stage VIII (LACM 053 SO 08 OB 01P), (B) dorsal view of embryo, stage VIII (LACM 053 SO 08 OB 01P), (C, D) stage IX (LACM 047 OB 15 OB 02P), (E, F) stage X (LACM 060 87 22 OB 01S).

located near the oil globule, encircles and then migrates onto the side of the oil globule nearest the embryo. Pigment on the embryo develops from the eyes to the first somites along the dorsal and dorsolateral surfaces, posteriorly along the dorsum to the tip of the tail, and on the ventral midline of the free portion of the tail (Figs. 1E, F).

When stage IX begins, pigment first migrates into the dorsal finfold between the nape and an area about three-fourths the distance from snout to tail tip and into the ventral finfold opposite the posteriormost dorsal finfold melanophores (Figs. 2C, D). The migration of pigment into the finfolds continues during stage X (Figs. 2E, F), forming a continuous row of melanophores in the dorsal finfold and a patch of pigment in the ventral finfold.

Xystreurys liolepis *Xystreurys liolepis* eggs are pelagic with a smooth chorion (0.72–0.90 mm), homogenous yolk (0.42–0.74 mm), and a single oil globule (0.14–0.24 mm, Table 1). Early- through mid-stage development of *X. liolepis* eggs (stages II–VIII, Figs. 3A–F, 4A, B) is similar to that of *Paralichthys californicus* (Figs. 1A–F, 2A, B) with few differences in the developmental sequence of the embryo, pigment, or oil globule detected. At approximately stage IX, pigment patterns of *X. liolepis* embryos begin to differ diagnostically from those of *P. californicus*.

Melanophore migration into the medial finfolds oc-

curs approximately two-thirds the distance from snout to tail tip in stage IX *Xystreurys liolepis* eggs (Figs. 4C,D). Pigment is present between the eyes, dorsally and dorsolaterally from the eyes to the pectoral region, along the dorsal midline to near the tip of the tail, along the yolk/body interface, on the postanal ventral margin, and at the tail tip (usually on both the dorsal and ventral margins).

At stage X (Figs. 4E,F), melanophores are present in the dorsal finfold at the nape and in both medial finfolds in an area approximately two-thirds of the distance from snout to tail tip. Postanal ventral margin melanophores are generally absent except at the tip of the tail.

Egg comparisons

The larger chorion and oil globule of *Xystreurys liolepis* eggs usually distinguishes them from *Paralichthys californicus* eggs (Table 1), although some overlap exists. Pigmentation patterns of the two species are similar until stage IX, when *X. liolepis* embryos (Fig. 4C) develop heavier pigment at the tail tip and patches of dorsal finfold pigment; pigment is present throughout the dorsal finfold in *P. californicus* (Figs. 2C,D). In addition, stage X *P. californicus* embryos typically have postanal ventral melanophores (Fig. 2E), whereas *X. liolepis* lack pigment along the postanal ventral margin except at the tip of the tail (Fig. 4E).

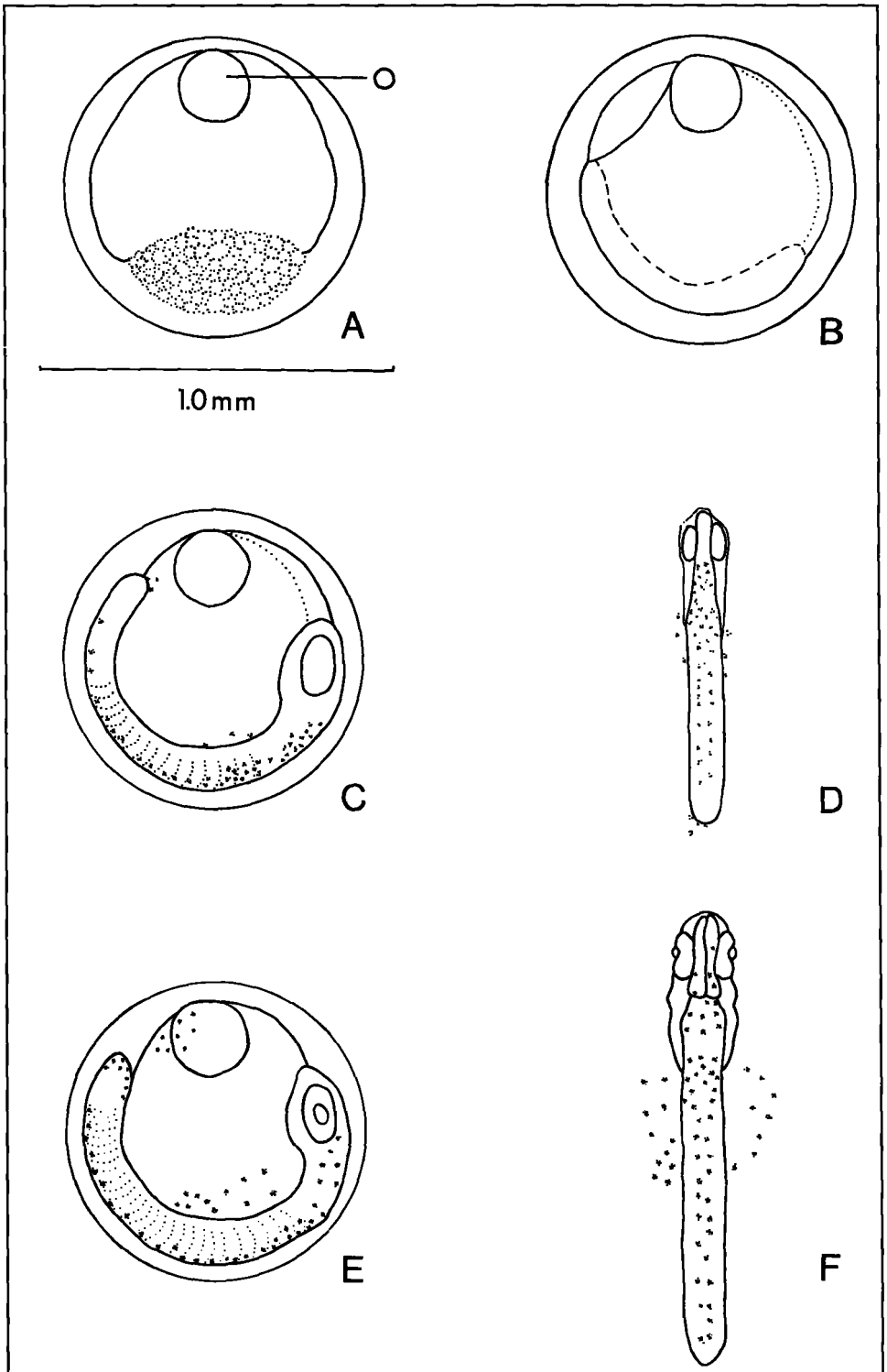

Figure 3
Eggs of *Xystreurys liolepis* (o = oil globule): (A) stage II (LACM 44979), (B) stage IV (LACM 44979), (C) stage VI (LACM 44980), (D) dorsal view of embryo, stage VI (LACM 44980), (E) stage VII (LACM 44980), (F) dorsal view of embryo, stage VII (LACM 44980).

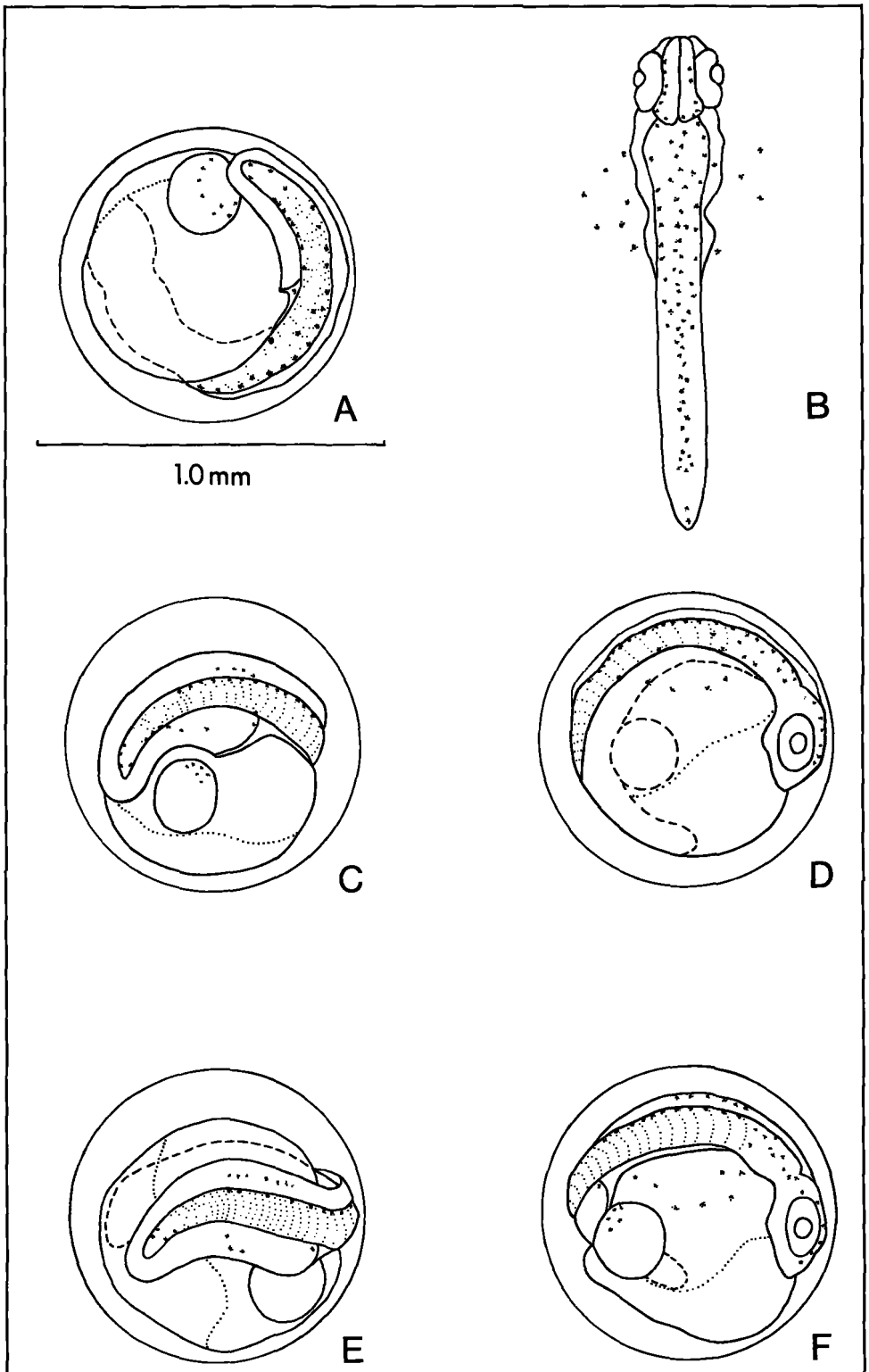

Figure 4
Eggs of *Xystreurys liolepis*: (A) stage VIII (LACM 039 88 22 OB 02S), (B) dorsal view of embryo, stageVIII (LACM 039 88 22 OB 02S), (C, D) stage IX (LACM 050 88 22 OB 01S), (E, F) stage X (LACM 050 88 15 OB 01P).

The eggs of most fishes in the Southern California Bight have not been described; however, the LACM ichthyoplankton group has designated types for the later stages (VII–XI) of eggs commonly collected in the nearshore zone. At these stages, *Paralichthys californicus* and *Xystreurys liolepis* can be separated from the other egg types based on chorion size and texture, yolk homogeneity, oil globule size and position, and pigmentation patterns on the embryo, yolk, and oil globule. Prior to stage VII, identifications are not yet possible.

Descriptions of the two species are based primarily on field-collected material; reared material also was examined. No differences were noted in the sizes of chorion, yolk, or oil globules between the field and reared eggs of either species. Developmental differences of field and reared material for early-stage eggs (less than stage VII) were not determined because of the inability to identify the early-stage eggs from the field material. Pigmentation was similar for field and reared specimens of later stage (VII–X) eggs of both taxa. The field material, however, contained stage X eggs of both species, whereas the reared material hatched at stage IX.

Information is available on the eggs of three other species of *Paralichthys*: *P. dentatus* (Smith and Fahay 1970), *P. olivaceus* (Pertseva-Ostroumova 1961 and Mito 1963) and *P. microps* (Munoz et al. 1988). Eggs

of *P. dentatus* and *P. olivaceus* share similar general morphology and pigmentation with those of *P. californicus*. However, their eggs are slightly larger than *P. californicus* and *P. microps*, and have a larger oil globule than *P. californicus*.

Larval descriptions

Paralichthys californicus

Morphology Preflexion larvae initially are slender (BD ~20% BL) but develop into deep-bodied postflexion larvae (BD 34–39% BL, Table 2). Throughout development larvae are noticeably laterally compressed (HW 12–15% BL). The straight tubular gut of early preflexion larvae develops a coil later in preflexion. The ratio of preanal length to body length remains relatively constant (~45%), but head length increases (from 20 to 30%).

Myomere counts range from 34 to 36. Double-stained specimens (Table 3) have 10 precaudal vertebrae and 24–25 caudal vertebrae.

Table 2

Paralichthys californicus: Morphometric ratio ranges by stage and size (mm). Body length = BL, preanal length = PL, head length = HL, body depth = BD, head width = HW; YS = yolksac, NL = notochord length, FL = flexion length, SL = standard length.

			Range				Mean			
Stage	Preservative	*n*	PL/BL	HL/BL	BD/BL	HW/BL	PL/BL	HL/BL	BD/BL	HW/BL
YS										
2.00–2.99	Formalin	5	42.6–45.8			7.7–10.3	44.3			9.2
	EtOH	11	35.9–45.2			7.6–11.1	40.3			9.2
NL										
2.00–2.99	Formalin	5	41.4–56.7	17.6–25.4	15.9–24.0	10.6–17.4	46.6	20.7	19.4	13.2
	EtOH	9	37.4–47.5	16.5–24.7	17.1–28.8	9.5–16.0	42.4	20.2	20.5	12.6
3.00–3.99	Formalin	10	43.7–53.1	19.6–26.4	17.1–31.0	12.6–19.3	47.8	23.0	22.7	14.7
	EtOH	10	38.0–48.8	19.6–26.4	19.2–31.5	13.3–16.7	42.9	21.7	24.9	14.7
4.00–4.99	Formalin	9	43.4–49.4	21.1–28.4	21.5–32.1	13.6–15.8	45.6	23.3	24.8	14.6
	EtOH	4	41.0–44.8	24.2–25.4	26.3–32.2	14.3–16.0	43.2	24.6	30.5	15.4
FL										
4.00–4.99	Formalin	1	47.9	26.7	32.6	15.1	47.9	26.7	32.6	15.1
	EtOH	4	40.6–46.6	21.2–27.6	27.9–33.2	13.8–14.9	43.6	23.8	31.0	14.3
5.00–5.99	Formalin	7	39.2–51.5	21.2–26.2	26.2–32.1	13.2–15.4	43.0	24.6	29.0	14.0
	EtOH	5	38.3–46.3	23.8–27.9	30.5–34.7	13.0–16.3	42.0	25.5	32.9	13.3
6.00–6.99	Formalin	4	41.9–43.3	21.9–28.0	28.3–38.6	13.0–13.8	42.7	25.5	32.9	13.3
SL										
4.99–6.99	Formalin	4	38.3–47.0	27.4–32.2	34.6–43.3	13.1–15.0	42.9	29.8	38.7	13.9
	EtOH	4	40.2–50.3	27.2–34.1	32.4–45.5	12.5–17.8	43.5	30.5	38.6	15.6
7.00–7.99	Formalin	9	35.4–46.2	25.7–30.0	33.3–40.9	11.0–12.9	41.4	28.8	35.8	11.8
8.00–8.99	Formalin	3	30.8–34.7	27.5–28.7	34.0–34.7	13.4–15.2	33.3	28.6	34.0	13.4

Table 3

Meristics of *Paralichthys californicus* based on double-stained larvae.

		Fins						
Length	Vertebrae	Dorsal	Anal	Caudal	Pelvic	Pectoral	Branchiostegals	Gill raker
3.9 mm NL	–	–	–	–	–	Bud	–	–
4.4 mm NL	–	3	–	–	–	Bud	–	–
4.6 mm NL	–	4	–	–	–	Bud	2	–
6.3 mm FL	10 + 24	11	–	6 + 6	Bud	Bud	7	5
6.5 mm FL	10 + 25	8	23	7 + 8	Bud	Bud	7	7
7.0 mm SL	10 + 25	53	33	9 + 8	3	Bud	7	10
8.1 mm SL	10 + 25	74	57	10 + 8	6	Bud	7	12

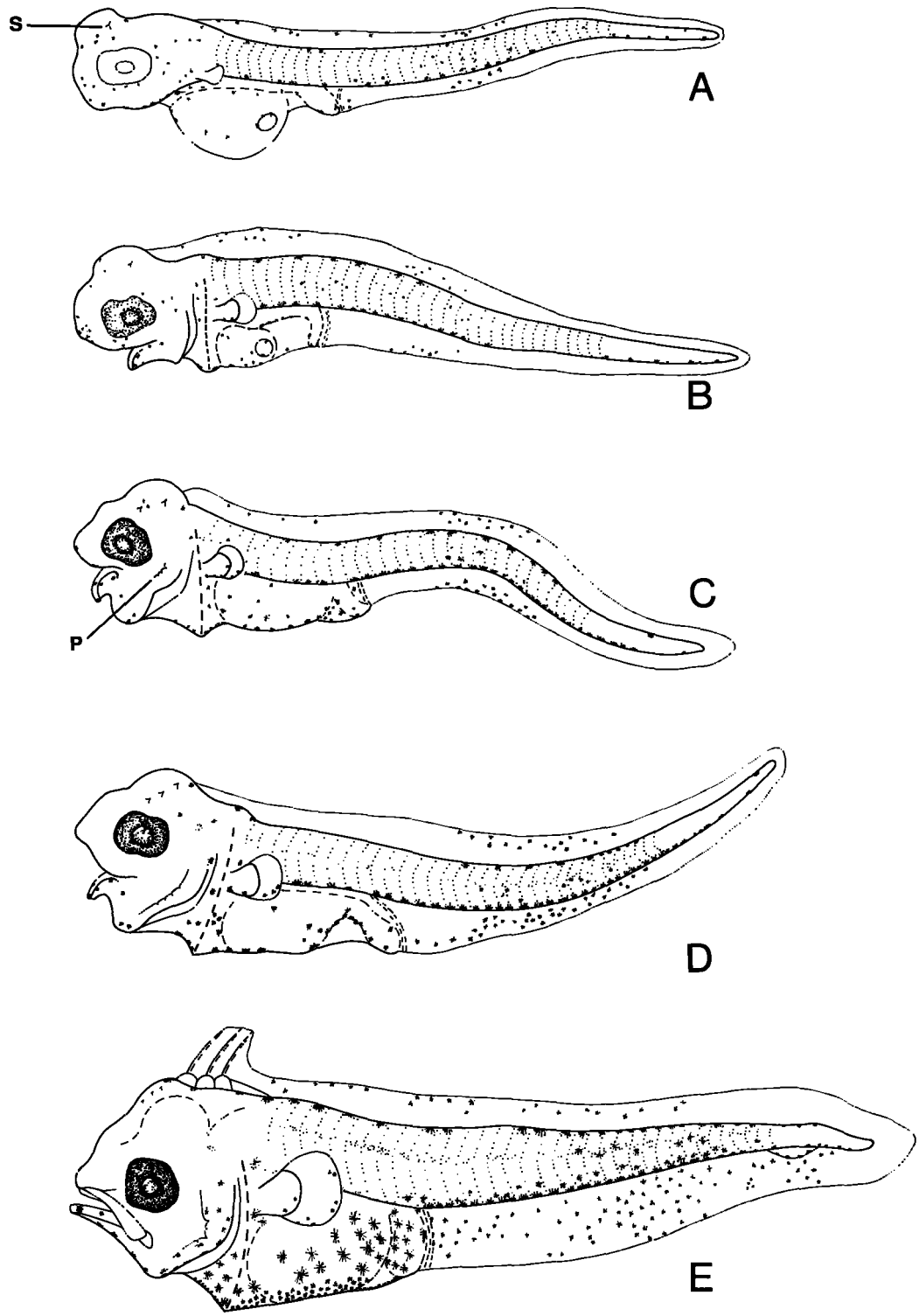

Figure 5

Paralichthys californicus larvae (S = sphenotic spines, P = preopercular spines): (A) 2.0 mm YS (LACM 052 SO 22 OB 02S), (B) 2.0 mm YS (LACM 048 88 75 OB 02S), (C) 2.2 mm NL (LACM 046 87 22 OB 02P), (D) 2.5 mm NL (LACM 048 OB 36 OB 01S), (E) 4.5 mm NL (LACM 048 87 75 OB 01S). (Note: Lightly stippled melanophores represent internal pigment.)

Fin and spine formation Anlagen of the anteriormost dorsal fin rays form at about 3mm NL. The elongate second through sixth dorsal rays develop first, followed by the first ray and anlagen for the remainder of the dorsal fin and for the anal fin. The remaining rays begin to form at approximately 5–6mm FL; development is anterior to posterior. The full complement of dorsal fin rays is complete by ~8mm SL (Table 3).

Larvae develop a series of three sphenotic spines. The dorsal-most spine appears in yolksac larvae just prior to or at the time the lower jaw forms (Fig. 5A). The middle and ventral-most spines develop on first feeding preflexion larvae, and during this stage the spines are relatively easily seen (Figs. 5C,D). The relative size of the spines decreases and they become difficult to locate by about the time the anlagen of the first dorsal fin rays form (Fig. 5E). The spines usually are not visible in late postflexion larvae when eye migration begins (~7–8mm SL); the developing head melanophores obscure the minute spines (Fig. 6C).

Spines on the posterior margin of the preopercle are visible by ~2.5mm NL (Fig. 5C). Five to seven spines are present on the lower margin of the bone, and additional spines form on the upper margin at about 5mm FL (Fig. 6A). Opercular spines, present on postflexion larvae at approximately 6–7mm SL, usually form along the posterior opercle margin. Another cluster of spines develops at the dorsal margin of the opercle. Opercular spines are not easily visible unless the specimen is stained.

The full complement of 10 + 8 principal caudal rays is present by about 8mm SL. A splinter ray, attached to the ventralmost ray, is not included in this count.

Pigmentation Larvae are characterized by a row of internal melanophores on the dorsal surface of the notochord. This pigment first appears in late yolksac larvae (Fig. 5B), forms a complete row in the early preflexion stage (Fig. 5C), and remains visible through the body musculature for the entire larval period.

Pigment in the dorsal finfold of yolksac larvae varies from a continuum of melanophores from the nape to mid-tail, to two distinct patches, one at the nape and the other even with the ventral finfold patch, located about mid-tail (Figs. 5A,B). Finfold pigment increases during preflexion and by the end of the stage is present throughout the medial finfolds (Fig. 5E). During flexion, melanophores form on the elongate dorsal fin rays and anal fin anlage (Fig. 6A).

Some melanophores present on the dorsal midline of newly hatched larvae migrate ventrally to form a double row of postanal ventral pigment extending from the vent to a point about mid-tail. Lateral melanophores are located opposite the posteriormost ventral pigment (Fig. 5B). Early in the preflexion stage, the rows of ventral melanophores increase in length, merging with pigment at the tail tip (Fig. 5C). Rows of dorsal and ventrolateral pigment develop and extend from the nape and anus, respectively, to the last myomere (Fig. 5E). Dorsolateral melanophores form during the postflexion stage (Fig. 6C).

Melanophores are present on the yolk and peritoneum of early yolksac larvae and form on the gut and ventral midline, from isthmus to anus, in preflexion larvae (Fig. 5C). Except for the melanophores that form on the lower jaw of yolksac larvae (Fig. 5B), pigment on the head and snout is sparse.

Xystreurys liolepis

Morphology Preflexion larvae are slender (BD ~20% BL), then transform into robust, deep-bodied flexion and postflexion larvae (BD ~45–48% BL, Table 4). Head width varies from about 15% to 20% BL. Gut shape matures from straight tubular to coiled in preflexion larvae; preanal length remains relatively constant, ~45% BL, and head length increases from ~20 to 32% BL.

Myomere counts range from 37 to 39; double-stained specimens (Table 5) have 11 precaudal vertebrae and 26–27 caudal vertebrae.

Fin and spine formation Anlagen for the first dorsal fin rays are formed by ~4mm NL. The second through the sixth or seventh rays are elongate and develop first, followed by the first dorsal fin ray, and the anlagen for the remainder of the dorsal fin and anal fin. Fin ray formation proceeds posteriorly, and the entire complement of dorsal and anal fin elements are complete by approximately 8mm SL (Table 5).

Primordia for the developing hypural bones are first visible as a thickening in the ventral finfold, and the incipient caudal rays typically form at 5–5.5mm FL. The full complement of 10 + 8 principal caudal rays usually is complete around 7mm SL; a splinter ray on the ventralmost ray is present but not included in this count.

The pectoral bud differentiates into a base and blade between 2 and 2.5mm NL. The largest larva in the LACM ichthyoplankton collection, 8.9mm SL, has no pectoral fin rays.

Spines are visible on the posterior margin of the preopercle in preflexion larvae by 2–2.5mm NL (Fig. 7C). The spines are minute in specimens larger than 7mm SL.

Pigmentation Three patches of finfold pigment, in the dorsal finfold near the nape, and in both the medial finfolds at about mid-tail, are dense in yolksac larvae (Figs. 7A,B) but less concentrated in preflexion individuals (Fig. 7C). Additional melanophores develop in the dorsal finfold during the preflexion period and

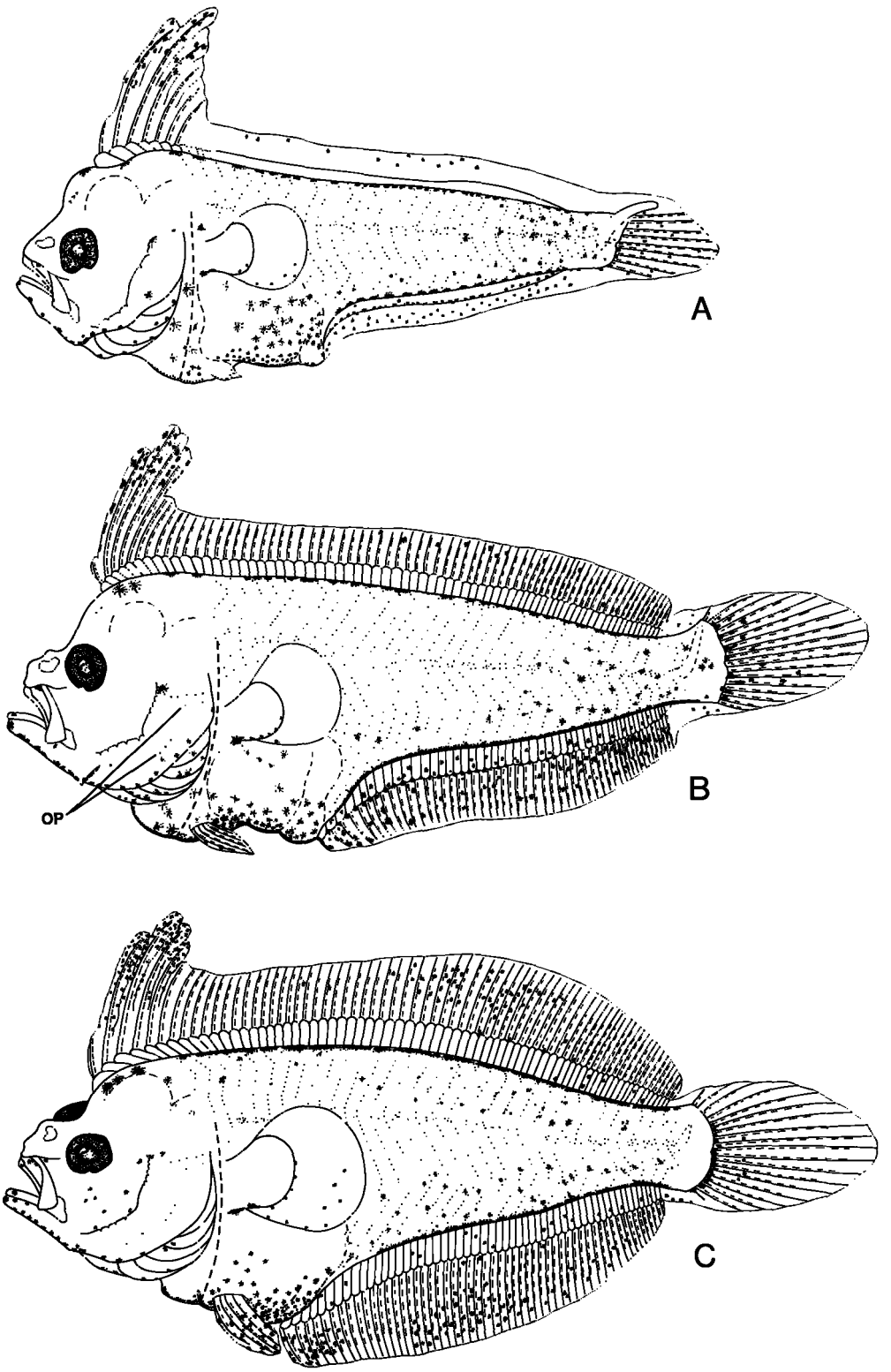

Figure 6

Paralichthys californicus larvae (O = opercular spines): (A) 5.4 mm FL (LACM 048 87 36 OB 02P), (B) 6.6 mm SL (LACM 044 87 22 OB 01P), (C) 8.7 mm SL (LACM 023 RB 15 MA 01). (Note: Lightly stippled melanophores represent internal pigment.)

Table 4

Xystreurys liolepis: Morphometric ratio ranges by stage and size (mm). BL = body length, PL = preanal length, HL = head length, BD = body depth, HW = head width, YS = yolksac, NL = notochord length, FL = flexion length, SL = standard length.

			Range				Mean			
Stages	Preservative	*n*	PL/BL	HL/BL	BD/BL	HW/BL	PL/BL	HL/BL	BD/BL	HW/BL
YS										
1.00–2.99	Formalin	4	37.6–41.9			8.5–12.8	39.9			11.0
	EtOH	2	44.7–52.4			7.8	48.6			7.8
NL										
1.00–2.99	Formalin	6	38.5–50.8	19.6–23.0	19.1–24.0	12.8–16.3	44.6	21.7	20.7	15.1
	EtOH	5	38.4–50.0	17.9–21.2	17.5–23.8	9.3–14.7	43.2	19.6	20.2	12.0
3.00–3.99	Formalin	10	43.7–54.6	19.6–28.8	22.8–31.3	15.2–20.3	49.1	24.2	26.7	18.0
	EtOH	3	45.6–48.1	24.1–27.6	27.6–31.4	15.1–20.5	47.0	25.5	28.9	17.8
4.00–5.50	Formalin	5	39.0–51.8	21.2–30.4	23.2–37.4	16.3–20.7	45.8	25.0	30.6	18.4
	EtOH	3	36.5–50.1	23.7–31.7	30.6–46.4	18.4–21.1	45.3	28.1	36.6	19.4
FL										
4.50–5.99	Formalin	4	46.4–51.6	27.6–33.9	33.9–42.3	17.7–20.9	47.8	30.5	38.9	19.6
	EtOH	3	48.6–55.7	29.1–37.6	46.0–47.5	21.0–22.1	51.2	34.8	46.5	21.4
6.00–6.99	Formalin	3	44.6–48.0	25.0–28.4	30.2–39.5	15.2–16.0	45.7	26.7	36.1	15.7
SL										
6.00–6.99	Formalin	8	40.2–50.7	28.7–35.9	44.6–53.8	16.8–19.4	47.0	31.9	48.2	18.0
7.00–7.99	Formalin	10	42.9–51.5	30.5–33.9	42.7–54.2	15.7–18.4	47.0	32.3	47.5	16.9
8.00–8.99	Formalin	10	38.5–48.1	30.8–33.3	40.9–49.4	15.1–18.0	44.0	32.2	45.1	16.6

Table 5

Meristics of *Xystreurys liolepis* based on double-stained larvae.

		Fins						
Length	Vertebrae	Dorsal	Anal	Caudal	Pelvic	Pectoral	Branchiostegals	Gill raker
3.7 mm NL	–	–	–	–	–	Bud	–	–
3.9 mm NL	–	–	–	–	–	Bud	3	–
4.3 mm NL	–	–	–	–	–	Bud	2	–
4.4 mm NL	–	4	–	4	–	Bud	5	–
5.1 mm NL	–	4	–	2	–	Bud	4	–
5.1 mm FL	4 + 15	5	–	8	Bud	Bud	6	–
5.6 mm FL	11 + 26	63	55	8 + 8	4	Bud	7	4
6.7 mm SL	11 + 27	75	60	9 + 8	5	Bud	7	5
7.5 mm SL	11 + 26	71	57	10 + 8	6	Bud	7	5
8.4 mm SL	11 + 26	78	58	10 + 8	6	Bud	7	5

in the ventral finfold towards the end of the stage (Fig. 7E). Pigment is present on the elongate dorsal fin rays of flexion larvae and in the medial finfolds and fin anlagen in an area between about one-half and three-quarters the distance from snout to tail tip. Melanophores are also found at the anteriormost portion of the anal-fin anlage (Fig. 8A). Postflexion larvae are pigmented on the elongate dorsal fin rays, between about the 30th and 50th dorsal elements, and along most of the length of the medial fin bases. Melanophores are also present on the first few rays and near the midpoint of the anal fin (Fig. 8C).

Yolksac larvae are heavily pigmented at the tail tip with a few other melanophores found on the head and body (Figs. 7A, B). Scattered rows of dorsolateral and ventrolateral pigment form on the trunk and tail in the preflexion stage, but pigment along the dorsal and ventral margins does not form continuous double rows (one on either side of the margin) until late in the preflexion stage (Figs. 7D, E). Heavy dorsal midline

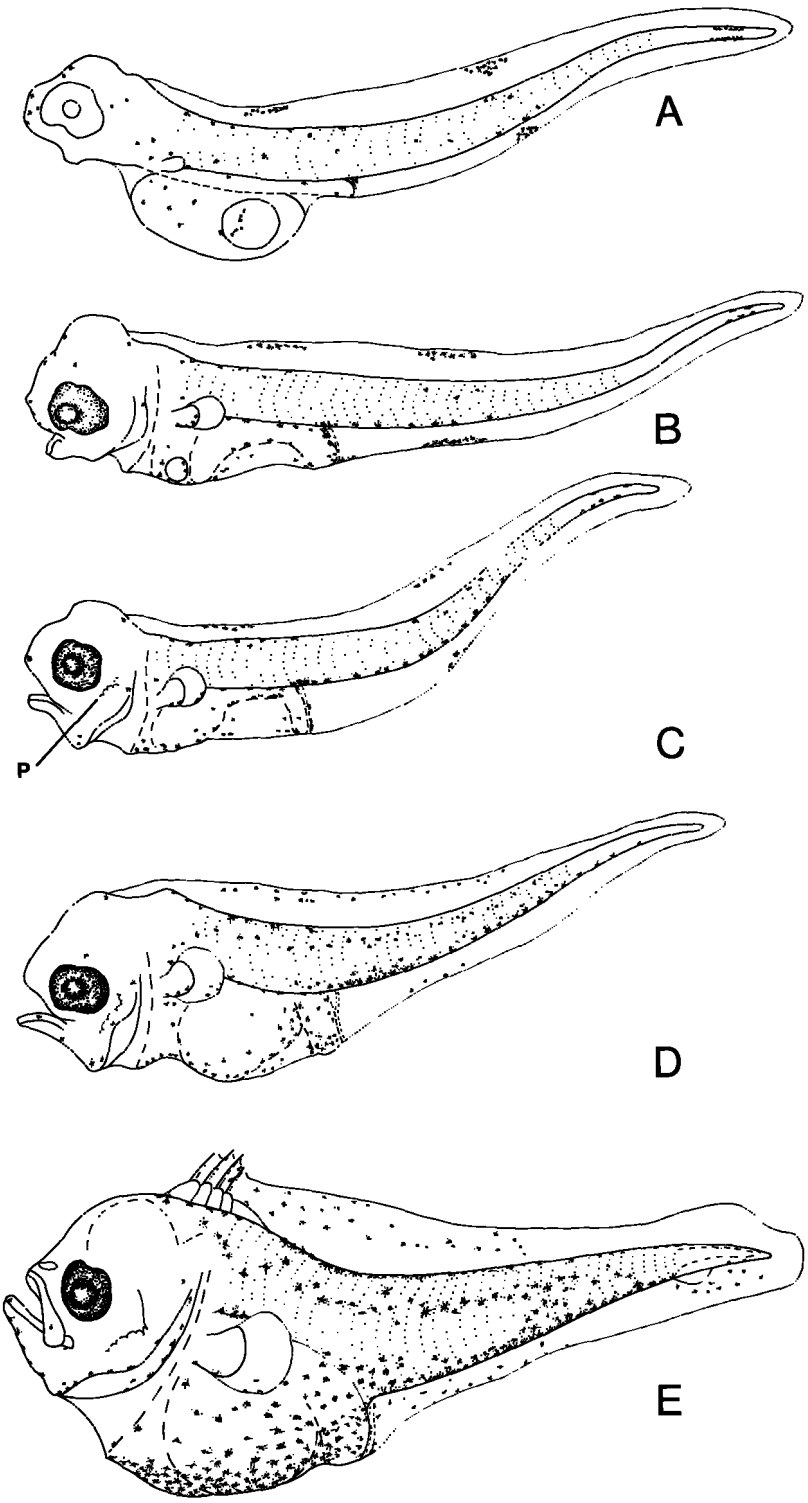

Figure 7

Xystreurys liolepis larvae (P = preopercular spines): (A) 2.0 mm YS (LACM 044 OB 15 OB 02P), (B) 2.1 mm YS (050 87 22 OB 02S), (C) 2.2 mm NL (LACM 044 87 36 OB 02S), (D) 2.8 mm NL (LACM 044 OB 22 OB 01S), (E) 4.2 mm NL (LACM 050 87 22 OB 02S).

and scattered dorsolateral melanophores of flexion larvae extend from about the first to the 29th or 30th myomere. Ventrolateral melanophores are located from approximately the 10th to the 30th myomere, and concentrated pigment along the postanal ventral margin is found from the vent to the last myomere (Fig. 8A). Dorsolateral and ventrolateral melanophores spread over the trunk and tail of postflexion larvae on all but the last six to eight myomeres, and several dense melanophores form posteriorly along the lateral midline (Figs. 8B,C).

Internal melanophores form on the dorsal surface of the notochord during the preflexion stage, but this pigment is obscured by thick musculature and heavy external pigmentation.

Pigment typically is present along the peritoneum and ventral midline of the gut at the end of the yolksac period. The gut of late-stage preflexion larvae is heavily pigmented, especially along the ventral margin from the cleithrum to the anus (Fig. 7E). Ventral margin pigment extends anterior to the cleithra in postflexion larvae (Fig. 8B).

Yolksac and preflexion larvae have few melanophores on the head and snout. Pigment develops on the upper and lower jaws, and upper palate of flexion stage larvae.

Larval comparisons Myomere or vertebral counts (34–36, *Paralichthys californicus* and 37–39, *Xystreurys liolepis*) will separate the larvae of *P. californicus* and *X. liolepis*, but these counts can be difficult to make, especially on small or damaged specimens. Morphological and pigment characters that will facilitate separation of the larvae of the two species until metamorphosis are given in Table 6. Visiblity of internal notochord pigment is the primary character for separation of post-yolksac larvae. Presence of sphenotic spines and

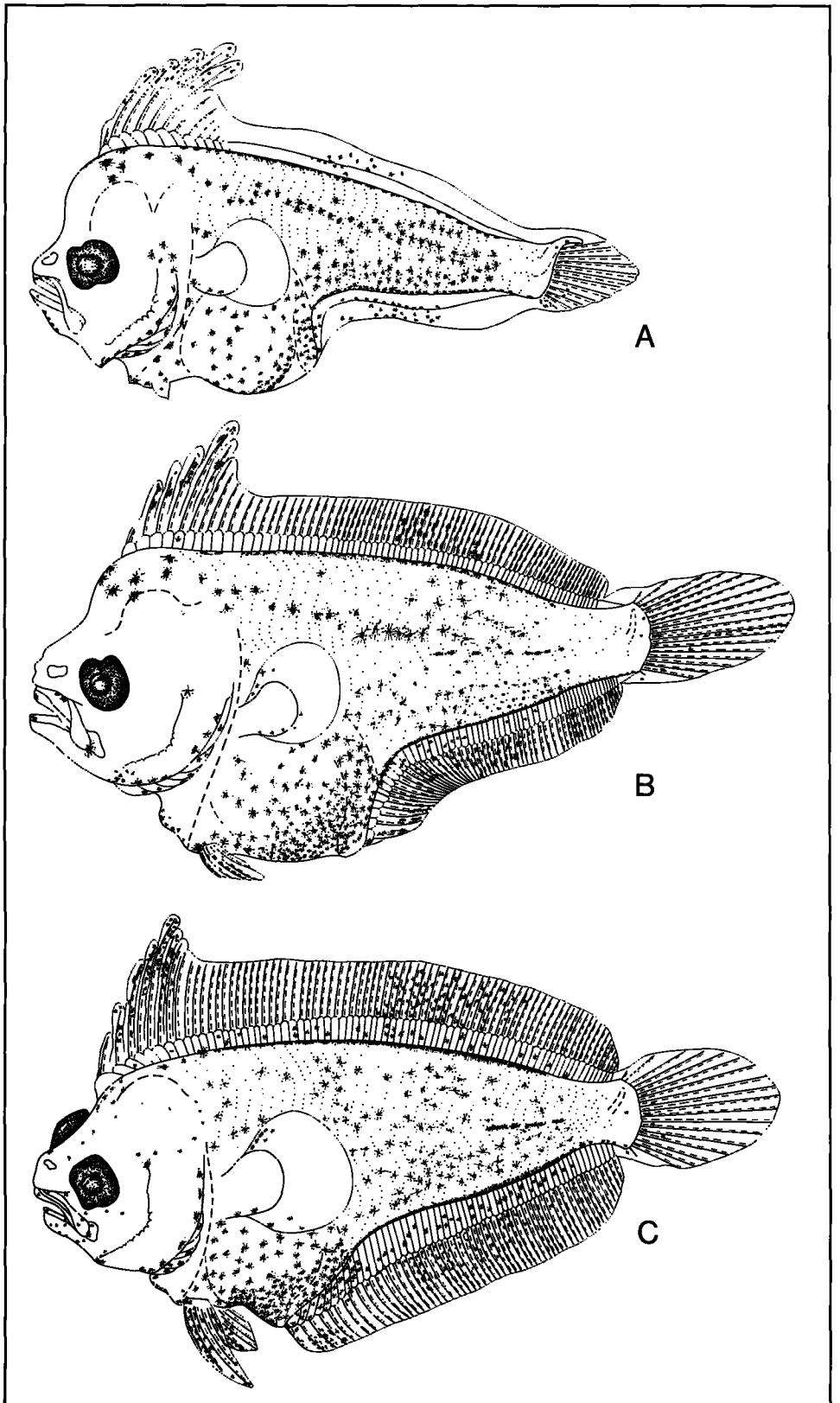

Figure 8
Xystreurys liolepis larvae: (A) 5.0 mm FL (LACM 051 88 36 OB 02P), (B) 6.3 mm SL (LACM 045 87 22 OB 01S), (C) 8.0 mm SL (LACM 037 OB 22 OB 02S).

Table 6
Comparison of larval characters: *Paralichthys californicus* and *Xystreurys liolepis*.

Paralichthys californicus (34–36 myomeres)	*Xystreurys liolepis* (37–39 myomeres)
Yolksac larvae (~2.0–2.5 mm NL)	
1. Sphenotic spines present	1. Sphenotic spines absent
2. Diffuse tail and finfold pigment	2. Concentrated patches of tail and finfold pigment
3. Many melanophores along the postanal ventral midline	3. Few melanophores along the postanal ventral midline
4. Late stage: Development of internal pigment along the notochord	4. Late stage: Internal pigment along the notochord obscured
Preflexion larvae (~2.5–4.5 mm NL)	
1. Presence of visible internal pigment along the notochord	1. Lack of visible internal pigment along the notochord
2. Sphenotic spines present	2. Sphenotic spines absent
3. Continuous row of postanal ventral midline pigment throughout the stage	3. Early to mid stage: Broken row of postanal ventral midline pigment
4. Mid to late stage: Body laterally compressed	4. Mid to late stage: Body robust
5. Mid to late stage: Row of external ventrolateral melanophores and external pigment at ~3/4 body length	5. Mid to late stage: Row of external dorsolateral and ventrolateral melanophores
6. Mid to late stage: Many ventral finfold melanophores	6. Mid to late stage: Few ventral finfold melanophores
7. Mid to late stage: Ventral midline pigment anterior and posterior to the cleithrum	7. Mid to late stage: Ventral midline posterior to the cleithrum
Flexion stage (~4.5–6.5 mm FL)	
1. Visible internal pigment along the notochord	1. Lack of visible internal pigment along the notochord
2. Body shape is laterally compressed	2. Body shape is robust
3. About 14 small gill rakers form on the first lower gill arch	3. About 4 gill rakers form on the first lower gill arch
4. Ventral finfold and anal fin anlage pigment along entire length	4. Ventral finfold and anal fin anlage pigment concentrated in patches
5. Ventrolateral row of trunk and tail pigment, little other lateral pigment	5. Dorsolateral and ventrolateral rows of trunk and tail pigment
6. Dorsal midline and lateral pigment extends to last myomere	6. Last 6–7 myomeres unpigmented laterally and along the dorsal midline
Postflexion larvae (~6.5–10 mm SL)	
1. Visible internal pigment along the notochord	1. Lack of visible pigment along the notochord
2. Body shape is laterally compressed	2. Robust body shape
3. Some external dorsolateral and ventrolateral pigment	3. Heavily pigmented externally
4. About 12–15 gill rakers on the first lower arch	4. About 4–5 gill rakers on the first lower arch
5. Dorsal midline and lateral pigment extends to the last myomere	5. Last 6–8 myomeres unpigmented laterally and along dorsal midline
6. 66–76 dorsal fin rays and 49–59 anal fin rays	6. 73–80 dorsal fin rays and 57–62 anal fin rays

finfold pigmentation will distinguish yolksac larvae. The more compressed shape of *P. californicus* and the robust, heavily pigmented body of *X. liolepis* are important characters for preflexion through postflexion stages. Material is lacking in the LACM collections to evaluate metamorphosed individuals, but meristic counts (i.e., gill rakers, dorsal fin rays, and ventral fin rays) will serve to separate juveniles.

Descriptions of the two species are based on field-collected material, but reared material was also examined. Pigmentation patterns of yolksac larvae were similar in reared and field material for both taxa. Pigmentation of reared larvae was heavier than that of field material in post-yolksac larval stages. Differences between reared and field-collected larvae of *Paralichthys californicus* increased as development

proceeded (reared specimens of *Xystreurys liolepis* older than early preflexion were not available for study). Reared specimens of *P. californicus* usually reflected the characteristic pigmentation patterns described from the field material, but the melanophores occurred in greater numbers and typically were more dendritic and heavily expressed. The eyed side of reared late-postflexion *P. californicus* larvae was covered with large dendritic melanophores obscuring most of the pigmentation characteristic of the field-collected larvae; however, the patterns were visible on the blind side. Furthermore, it appeared that reared larvae acquired pigmentation characteristics at an earlier developmental stage than did their field-collected counterparts.

The larval stages of three other species of *Paralichthys*—*P. dentatus* (Smith and Fahay 1970), *P. microps* (Munoz et al. 1988), and *P. olivaceus* (Pertseva-Ostroumova 1961, Okiyama 1967)—have been described. Larvae of *P. dentatus* and *P. olivaceus* hatch, undergo flexion, and transform at larger sizes than *Paralichthys californicus*. Larval size at hatching and at eye migration are similar for *P. californicus* and *P. microps*. All four species share the development of approximately five elongate, pigmented dorsal rays. *Paralichthys olivaceus*, *P. dentatus*, and *P. californicus* develop a series of sphenotic and preopercular spines. Opercular spines, not reported for *P. dentatus*, are present on both *P. olivaceus* and *P. californicus*. (Sphenotic and opercular spines were not reported in the description of *P. microps*.)

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