Larval development of two sympatric flounders, *Paralichthys adspersus* (Steindachner, 1867) and *Paralichthys microps* (Gunther, 1881) from the Bay of Coquimbo, Chile

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Abstract.—Developmental series of two sympatric flounders of the genus *Paralichthys*, found in the Bay of Coquimbo, are illustrated and described. The series consist of yolksac to metamorphosed larvae of artificially-reared *Paralichthys adspersus* (1.7–13.0 mm SL) and *P. microps* (1.5–11.0 mm SL). Field-collected larvae correspond to the size ranges found in reared larvae. Degree of cephalic spination (in particular, sphenotic spines), pigmentation pattern, and number of elongated dorsal-fin rays are useful for identification of yolksac-to-postflexion larvae of both species.

During early metamorphosis the most valuable characteristics for identification are the number of elongated dorsal-fin rays, although after their reabsorption several morphometric relationships have to be used. *Paralichthys adspersus* preflexion larvae have two sphenotic spines and almost no pigmentation in the dorsal finfold, while *P. microps* larvae have only one sphenotic spine and a well-pigmented dorsal finfold. Beginning at notochordal flexion, the number of elongated dorsal-fin rays, six for *P. microps* and three for *P. adspersus*, can be used to identify the larvae. During late metamorphosis, morphometric relationships of SnL/HL, HL/SL, and BD/SL must be used to identify the larvae. Flexion is complete at 7.2 mm SL and metamorphosis at ~11.0 mm SL in *P. microps*, and at 8.6 mm SL and 13.0 mm SL in *P. adspersus*, respectively.

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Paralichthys is one of the most important genera of flatfish on both coasts of North and South America (Ginsburg 1952), considering number of species, geographic distribution, and economic importance. Seven species of the genus have been reported in Chilean waters (Bahamonde and Pequeño 1975), *Paralichthys adspersus* (Steindachner 1867) and *P. microps* (Gunther 1881) being the most abundant and most widely distributed. The former is found from the coast of Paita (Peru) to Lota (Chile) and Juan Fernández Island; the latter from Huacho (Peru) to the austral tip of South America (Chirichigno 1974). Because these two morphologically-similar species co-occur over most of their distributional ranges, adult and larval identifications have been difficult. Muñoz et al. (1988) described larvae of *P. microps*, but recognized the possibility that specimens of both species were included in their sample. They indeed have one *P. adspersus* larva (3.2 mm, Fig. 2b). Silva (1988) published photographs of the eggs and some larvae of *P. microps*.

In this paper, taxonomic characters which separate these two species during early-life-history stages, from yolksac larva to juvenile, are described.

Material and methods

Most of the material examined in the present study was obtained from several experiments, resulting from artificial fertilization of eggs and sperm from ripe specimens captured in the Bay of Coquimbo (29°59'S).

Larvae were cultured in 200 L conical tanks, with a daily 25% water renewal. From hatching through flexion, larvae were fed the rotifer *Brachionus plicatilis* in concentrations of 5/mL, and from flexion through metamorphosis were fed *Artemia salina* nauplii in concentrations of 10/mL. Temperature range during the experiment was 13–17°C (Silva 1988). Larvae, sampled with a Bongo net (1 m, 500 μ mesh) and an epibenthic trawl (500 μ mesh) at stations in Coquimbo Bay and adjacent coastal areas, were compared with cultured larvae.

A total of 49 larvae of *P. adspersus* and 46 of *P. microps* were used; of these, 39 larvae of both species were cleared and stained using Potthoff's (1984) method to determine the sequence of development of the axial skeleton. Pterygiophores and rays were counted when present, regardless of their state of development. Larvae were anesthesized with MS-222 before fixing in 5% formalin, and were later preserved in 3% buffered formalin.

Specimens were divided into developmental stages following the definitions of Ahlstrom et al. (1976).

Table 1

Morphometric relationships in *Paralichthys adspersus* and *P. microps* larvae. *N* = number of specimens; measurements in mm; length = NL for preflexion-flexion stages, SL for postflexion-juvenile.

	Preflexion			Flexion		
Measure	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range
Paralichthys adspersus						
N		21			11	
Length	5.52	1.12	(3.6–7.0)	7.80	0.55	(6.9–8.6)
PAL/SL	41.40	1.32	(40.5–43.5)	39.60	3.08	(31.9–42.0)
BD/SL	13.90	3.80	(13.0–18.1) 17*	22.80	5.08	(17.4–31.4)
BD†/SL						
HL/SL	18.20	1.13	(16.7–20.0)	21.50	2.53	(18.6–26.7)
UJL/HL	37.30	4.52	(29.4–39.4) 17*	37.90	2.32	(33.3–41.7)
LJL/HL	46.30	3.08	(41.2–51.8) 19*	48.10	3.15	(44.7–54.7)
SnL/HL	22.10	2.22	(18.3–26.8)	21.10	1.02	(18.9–22.4) 10*
ED/HL	28.00	2.36	(24.8–33.3)	26.80	1.50	(24.7–28.9)
Paralichthys microps						
N		22			8	
SL	4.17	0.95	(2.95–6.0)	6.86	0.35	(6.2–7.2)
PAL/SL	41.15	1.83	(38–44)	40.90	3.27	(35–45)
BD/SL	13.30	2.16	(10–18)	25.60	6.40	(19–37)
BD†/SL						
HL/SL	18.10	1.48	(15–20)	21.60	3.70	(17–28)
UJL/HL	34.60	3.60	(29–37) 11*	44.50	4.20	(38–50)
LJL/HL	51.98	4.50	(43–59) 20*	57.10	3.86	(50–62)
SnL/HL	22.90	3.56	(16–31) 20*	23.90	2.88	(20–28)
ED/HL	30.10	4.10	(23–43) 21*	26.80	1.70	(24–29)

	Postflexion			Metamorphosis			Juvenile		
Measure	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range
Paralichthys adspersus									
N		7			6			4	
SL	8.90	0.35	(8.4–9.4)	10.00	0.53	(9.2–10.2)	13.60	1.04	(12.3–15.0)
PAL/SL	40.80	2.76	(37.6–45.2)	37.60	3.17	(33.9–43.5)	34.40	0.68	(33.3–35.0)
BD/SL	35.80	1.77	(33.7–38.2)	39.50	1.42	(36.6–41.3)	37.90	0.72	(37.2–39.0)
BD†/SL				41.90	2.90	(36.4–45.8)	35.30	0.83	(34.4–36.2)
HL/SL	30.60	2.35	(27.6–33.7) 6*	32.00	1.69	(29.7–34.7)	35.10	0.38	(34.7–35.7)
UJL/HL	34.10	1.71	(31.5–37.3)	34.50	1.49	(31.7–36.5)	34.40	0.94	(33.3–35.6)
LJL/HL	45.60	2.61	(41.7–50.5)	45.90	1.35	(42.9–48.4)	46.80	1.50	(44.4–48.1)
SnL/HL	20.70	2.55	(17.5–25.8)	18.30	1.66	(15.6–20.3) 5*	14.30	1.76	(11.5–16.3)
ED/HL	25.50	1.07	(24.1–26.8) 6*	25.00	2.57	(21.4–28.6)	28.70	2.09	(26.3–32.0)
Paralichthys microps									
N		4			8			4	
SL	6.90	0.77	(6–7.8)	9.30	0.67	(8.10–10.6)	15.20	1.95	(13.0–18.0)
PAL/SL	42.20	3.40	(37–46)	39.40	2.47	(36.2–43.5)	35.30	0.83	(34.4–36.2)
BD/SL	44.70	6.20	(35–46)	40.00	1.39	(37.7–42.0)	37.40	0.86	(36.2–38.5)
BD†/SL				46.50	1.03	(45.4–48.9)			
HL/SL	37.30	5.10	(32–46)	39.10	2.68	(35.8–43.0)	37.40	1.19	(36.3–39.4)
UJL/HL	38.90	2.10	(35–41)	37.80	2.09	(34.7–39.7) 6*	35.60	1.47	(34.3–38.0)
LJL/HL	50.70	4.30	(42–56)	47.90	2.70	(44.2–51.7) 6*	45.80	1.86	(43.1–46.9)
SnL/HL	23.20	1.90	(20–25)	23.30	1.73	(21.3–26.6) 6*	16.70	1.39	(15.5–19.0)
ED/HL	24.40	0.70	(23–25)	25.10	1.32	(23.0–26.6)	28.80	1.99	(25.4–30.2)

**N* differs from number indicated above.

BD Body depth
BD† Body depth measured at anus
ED Eye diameter
HL Head length
LJL Lower jaw length
PAL Preanal length
SL Standard length
SnL Snout length
UJL Upper jaw length

Morphometric measurements follow the definitions of Gutherz (1970) and were made with an ocular micrometer (to 0.01 mm). Notochordal length (NL) was used for yolksac larvae through flexion: from then on, standard length (SL) was utilized. In preflexion and flexion larvae, body depth (BD) is defined as the vertical distance across the body at the anus including the dorsal-fin pterygiophores. After flexion, it is defined as the vertical distance across the body at the pelvic fin, from its base to the base of dorsal-fin rays. Head length (HL) is defined as the distance from the snout to the cleithrum, until and through flexion, and thereafter from snout to the opercle edge. The total number of myomeres and vertebrae does not include the urostyle. Drawings were made from a compound microscope equipped with a camera lucida.

Linear regression models were fitted to six morphometric relationships of the larvae, comparing the preflexion stages with flexion, postflexion, and metamorphosis, to separate larvae of both species. An F test (Neter and Wasserman 1974) was used to compare the morphometric relationships of these two groups of larvae within and between species.

Determination of *Paralichthys* adults was based on

Table 2

Osteological development sequence of fins in *Paralichthys adspersus* and *P. microps* larvae. Length = NL preflexion, SL postflexion.

	Paralichthys adspersus						*Paralichthys microps*					
	Rays + Pterygiophores		Rays + Radials		Rays		Rays + Pterygiophores		Rays + Radials		Rays	
SL	Dorsal	Anal	Pelvic	Pectoral	Caudal	Vertebrae	Dorsal	Anal	Pelvic	Pectoral	Caudal	Vertebrae
4.1							–	–	–	–	–	–
4.5							–	–	–	–	–	–
4.7	–	–	–	–	–	–						
4.8	–	–	–	–	–	–						
5.4	–	–	–	–	–	–						
5.5							0+1	–	–	–	–	–
5.9							0+2	–	–	–	–	–
6.1		–	–	–	–	–	2+2	–	–	–	–	–
6.2							3+3	–	–	–	–	–
6.2							3+3	–	–	–	–	–
6.5							3+4	–	–	–	–	3
6.5							4+5	0+20	–	–	–	27+-
6.7	2+3	–	–	–	–	–						
6.9	3+3	–	–	–	–	–						
7.0							9+60	24+49	–		6+7	29+-
7.1							64+62	53+51	3+0		8+7	30+-
7.2							69+68	?+53	5+0		1+9+8+1	34
7.7	3+3	–	–	–	–	9	71+69	57+55	5+0		1+10+8+1	34
7.7	3+4	–	–	–	–	26						
7.8							71+71	53+53	5+0		1+10+9+0	34
8.1	5+4	–	–	–	–	32	73+72	57+54	6+0		0+10+8+0	34
8.1	6+30	0+23	–	–	–	33						
8.1	10+60	0+48	–	–	–	33						
8.2	13+48	0+42	–	–	9+8	33						
8.5	45+64	38+51	3+0	–	9+9	33						
8.6	56+65	30+51	3+0	–	1+9+8+1	33	73+73	58+57	6+0	–	1+9+9+1	34
8.6	64+66	50+51	4+0	–	1+9+8+1	33						
8.6	69+67	55+53	5+0	–	1+9+8+1	33						
8.8	73+72	55+55	5+0	–	1+10+9+1	33						
9.2	71+71	57+57	5+0	–	1+9+9+1	32	75+75	60+59	6+0	0+2	1+10+8+1	34
9.7				–			75+75	64+61	6+0	3+0	1+10+8+1	35
10.1	74+72	59+57	6+0	–	1+9+9+1	34	72+71	58+56	6+2	6+3	1+10+9+1	33
10.2	70+70	54+53	6+0	0+3	1+9+9+1	33						
10.9	71+70	57+55	6+2	7+4	1+9+9+1	33						
11.3							70+68	59+57	6+3	14+4	1+9+9+1	34
12.3	68+66	55+54	6+3	14+4	1+10+9+1	33						
12.7							73+72	59+56	6+3	14+4	1+9+9+1	33
14.0	70+69	57+56	6+3	13+4	1+9+8+1	33						

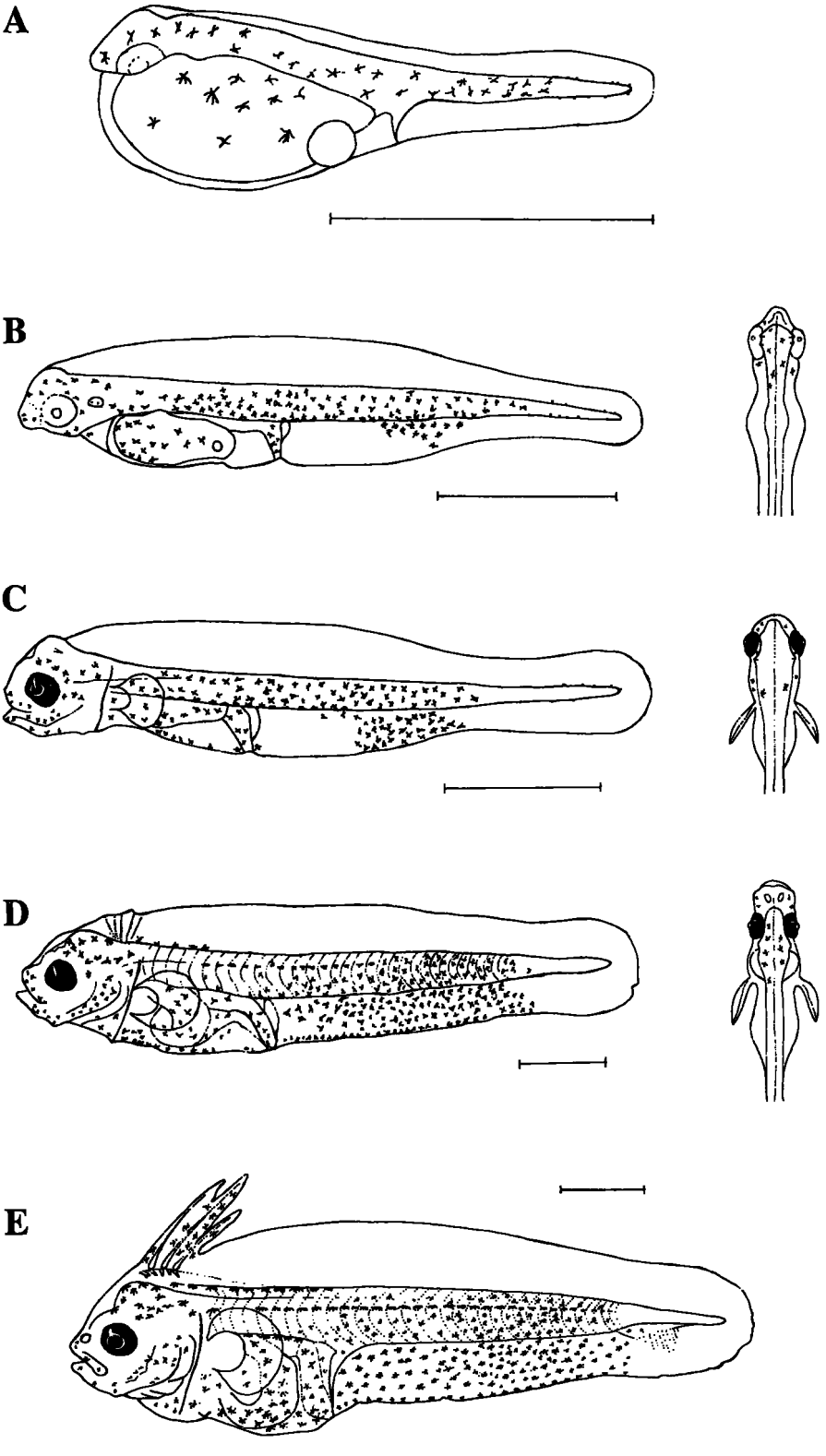

Figure 1

Paralichthys adspersus larvae. (A) Early yolksac, 1.7 mm NL; (B) late yolksac, 3.4 mm NL; (C) early preflexion, 3.9 mm NL; (D) late preflexion, 6.8 mm NL; (E) flexion, 7.7 mm NL. Drawings at right are dorsal head views.

the criteria of Ginsburg (1952), who observed that the origin of the dorsal fin in *P. microps* was over the center of the upper eye, while in *P. adspersus* it was over the eye's anterior margin. Furthermore, the number of gill rakers over the lower portion of the first arch is larger in *P. microps* (18–23) than in *P. adspersus* (15–19). An additional criterion found by Zuñiga (1988) referring to the size of the nostrils was also used.

Description

Paralichthys adspersus

Hatching occurs ~60 hours after fertilization. Larvae are ~1.7 mm NL; yolksac is more than half the body length; a small oil globule (0.13 mm) is present posterior to the yolksac (Fig. 1A).

Diagnosis The most important distinguishing features of preflexion *P. adspersus* larvae are the presence of two sphenotic spines (Fig. 2) and the lack of pigmentation in the dorsal finfold (Fig. 1). This last character may be useful through postflexion. Starting at notochord flexion, the presence of two groups of numerous opercular and preopercular spines, as well as 2–3 elongated dorsal-fin rays, is diagnostic. This last feature is useful until metamorphosis. Beyond metamorphosis, diagnosis should be based mostly on morphometric relationships.

Pigmentation Eyes of yolksac larvae are not pigmented. Few, relatively-large melanophores are found on the head, trunk, and yolksac except at the ventral margin (Fig. 1A). A series of small melanophores is present near the tip of the notochord. Pigment forms

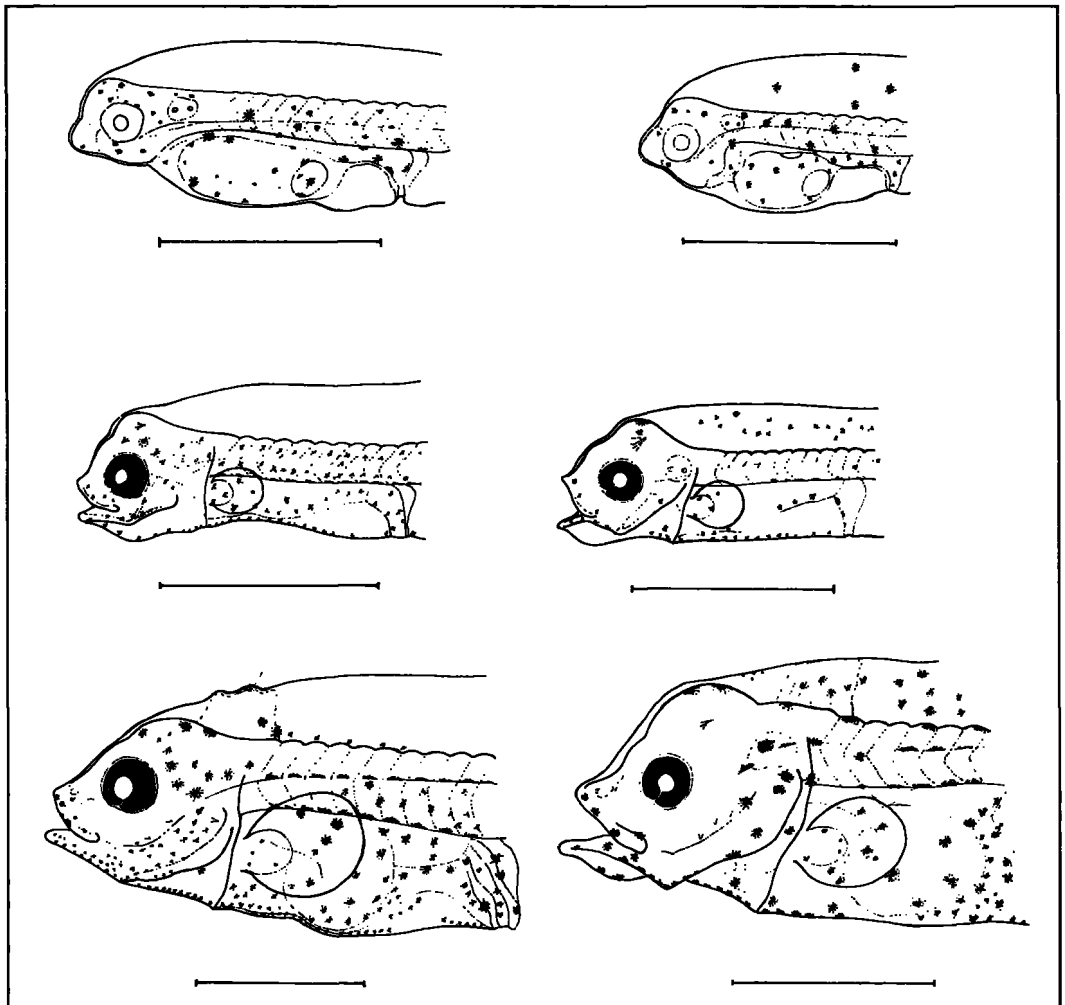

Figure 2
Heads of *Paralichthys adspersus* (left) and *P. microps* (right) larvae, showing number, size, and location of sphenotic, preopercular, and opercular head spines. Bars = 1.0 mm.

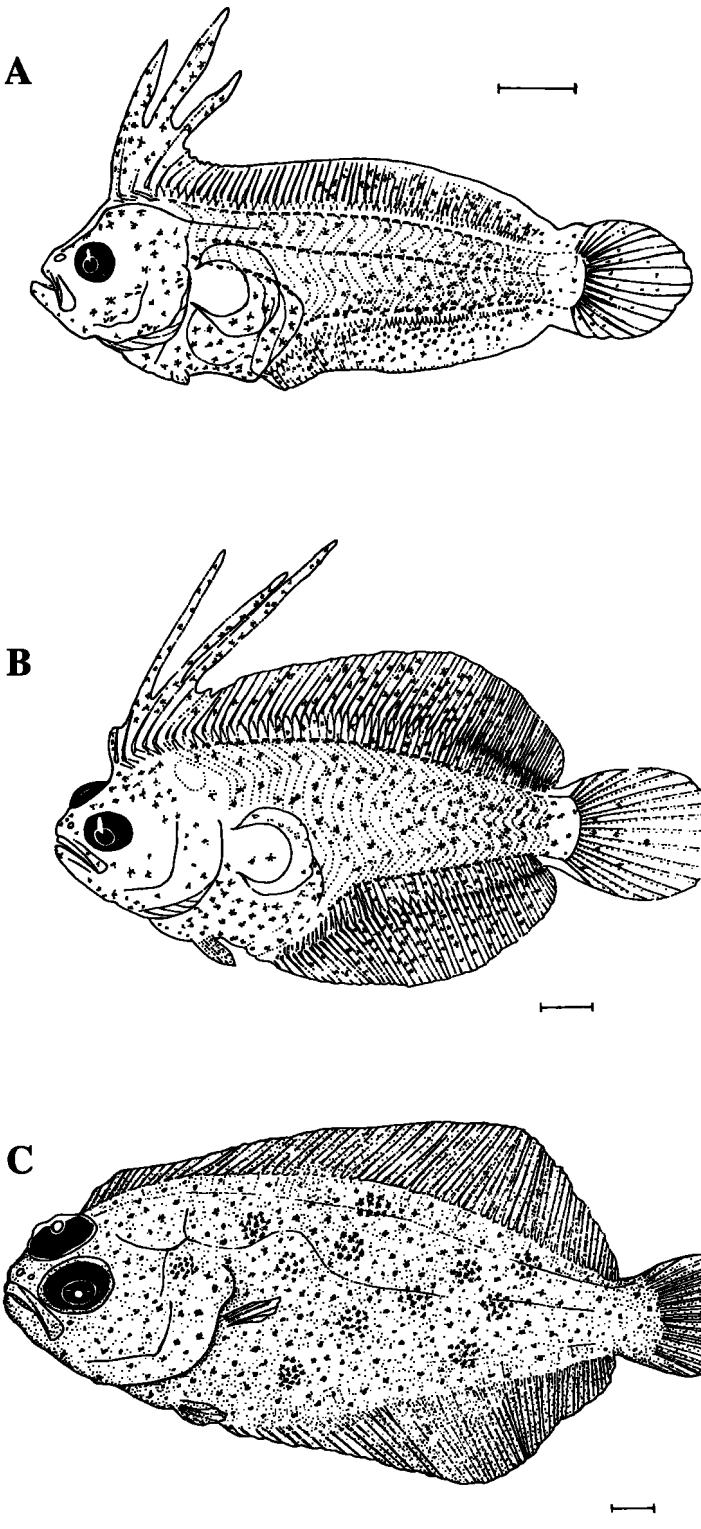

Figure 3
Paralichthys adspersus larvae. (A) Early postflexion, 8.8 mm SL; (B) early metamorphosis, 10.3 mm SL; (C) juvenile, 14.3 mm SL. Bars = 1.0 mm.

on the medial region of the pelvic fin. At the end of the stage (Fig. 1B), the eyes start to pigment.

During the preflexion stage (Fig. 1C, D), stellate melanophores are present on the head and over the anterior 2/3 of the body. Melanophores are absent on the dorsal finfold. At 3.5 mm NL, a series of melanophores forms on each side, slightly dorsal to the midline. At 4.0 mm NL, an embedded series of melanophores begins to develop dorsal to the notochord. A series of melanophores is present at the ventral margin of the body, from the gular region to the anus.

Head pigmentation consists of melanophores over both jaws, preopercle, opercle, and dorsal and lateral brain region. At about 5.0 mm NL, a melanophore is found internally above the palate, where it persists until metamorphosis.

At the beginning of the flexion stage (Fig. 3A), pigment intensifies in the tail region. The dorsal finfold generally remains unpigmented; however, a few melanophores appear in some specimens. A paired series of melanophores develops above the dorsum. Tail melanophores concentrate in the ventrolateral region, while the paired series dorsal to the notochord is less visible. The paired series dorsal to the gut becomes continuous with the gular–abdominal series. Head pigmentation increases. The interradial membrane of the elongated dorsal-fin rays becomes pigmented. Melanophores near the tip of the notochord persist but migrate as the caudal fin develops.

During postflexion (Fig. 3B), the melanistic pattern is similar to the previous stage except the paired dorsal series is more evident. The dorsal fin is pigmented, particularly in the posterior half, and the ventral region of the abdomen becomes pigmented.

During metamorphosis (Fig. 3C) pigmentation increases, especially on the left side of the body. Dorsal-fin pigmentation is concentrated in the posterior half of the fin. Groups of melanophores are present on the interradial membrane of the anal fin. The pelvic fin is almost completely pigmented.

Fin development Dorsal-fin pterygiophores and rays begin to form simultaneously at ~6.5 mm NL, reaching their full complements at 8.8 mm SL (Table 2). The anal-fin pterygiophores appear in advance of their corresponding fin rays, at 8.1–8.6 mm NL. In both fins, development proceeds posteriad. The pelvic fin appears at 8.5 mm NL, and all six rays are present at 10.1 mm SL. The hypural complex develops between 8.1 and 8.6 mm NL. There are 18 caudal-fin rays, plus 2 procurrent rays.

Morphology With absorption of the yolk, the yolksac larva becomes slender; the gut, jaws, and pectoral fins develop; and two sphenotic spines begin to develop on each side of the head. At 3.5 mm NL (4–5 days posthatching), the yolk is exhausted, the mouth is functional, eyes are pigmented, and the pectoral fin is formed.

Two sphenotic spines appear at ~3.0 mm NL on each side of the head (Fig. 2); initially the upper one is the larger. Both spines are reabsorbed before development of elongated dorsal-fin rays, near the end of this stage. On some specimens, a third, smaller sphenotic spine can be found below the first two.

At about 4.5 mm NL, preopercular and opercular spines appear; the former are located along the posterior margin of the preoperculum and on the anterior preopercular ridge. Opercular spines are located at the upper portion of the bone and are more prominent than preopercular spines.

At ~6.5 mm NL, the elongated rays of the dorsal-fin crest begin to appear. Three rays (corresponding to the second, third, and fourth dorsal-fin rays of the adult) form the initial crest. At 6.2 mm NL the gut begins to coil. During preflexion, body depth is moderate (13.9% NL) and preanal distance is ~41.4% NL. These proportions remain relatively constant during later development (Table 1). There are 33 myomeres (11 preanal and 22 postanal) at the end of the stage.

The beginning of the flexion stage is characterized by an increase in body depth (22.8% NL) and development of the caudal fin. Preopercular spines are in two series in the upper and lower margins of the bone. Opercular spines are also in two groups: an upper group on the body of the operculum and a lower one along its margin. Elongated dorsal-fin rays remain, the middle one being the longest. At ~7.5 mm NL, the pelvic fins begin to form and, by the end of the stage, rays and pterygiophores of dorsal, anal and caudal fins are more evident.

Morphometric proportions are similar to those of the previous stage, except body depth which increases. A small increase in head length is also apparent (Table 1). There are 33 (9 preanal and 24 postanal) myomeres at the end of the stage.

During postflexion, body depth increases to 35.8% SL; head length reaches 30.6% SL (Table 1). Dorsal-crest fin rays increase in relative length; the second reaches 50% SL. The short dorsal-fin ray anterior to the crest begins to develop.

Preopercular and opercular spination increases in some specimens, but the spines begin to reabsorb at the end of the stage. The interocular region begins to change in preparation for eye migration. There are 33 (7–8 preanal and 25–26 postanal) myomeres at the end of the stage.

During metamorphosis, body depth continues to increase (39.0% SL), and snout length decreases (18.3% HL); however, other body proportions do not change substantially (Table 1). The second elongated dorsal-fin ray reaches its maximum length (~53.9% SL) before being reabsorbed. Migration of the right eye to the left side begins. Pectoral-fin rays form. Preopercular and opercular spines are lost, as are the elongated dorsal-fin rays. Eye migration is completed at ~13.0 mm. The smallest juvenile was 12.3 mm SL (Fig. 3C). There are 33 (4–6 preanal and 27–29 postanal) myomeres at the end of the stage.

Paralichthys microps

Hatching occurs 57–68 hours postfertilization; yolksac larvae are ~1.5 mm NL; one oil globule is present. Yolksac development is similar to *P. adspersus* yolksac larvae, except that melanophores form on the dorsal and anal finfold and a simple sphenotic spine begins to develop at yolk exhaustion (~3.2 mm NL, 4–5 days after hatching).

Diagnosis Distinguishing features of preflexion *P. microps* larvae are the presence of only one sphenotic spine (Fig. 2) and the dorsal finfold with pigmentation. After notochord flexion until metamorphosis, the most distinguishing feature is the presence of more than 3, and later 6, elongated dorsal-fin rays (Figs. 4E, 5). After reabsorption of these elongated rays, diagnosis is mostly based on morphometric relationships.

Pigmentation During the preflexion stage, the pigmentation pattern is similar to that of *P. adspersus*, but *P. microps* larvae have a different arrangement of body and finfold melanophores and less head pigment. Melanophores are relatively sparse over the trunk and

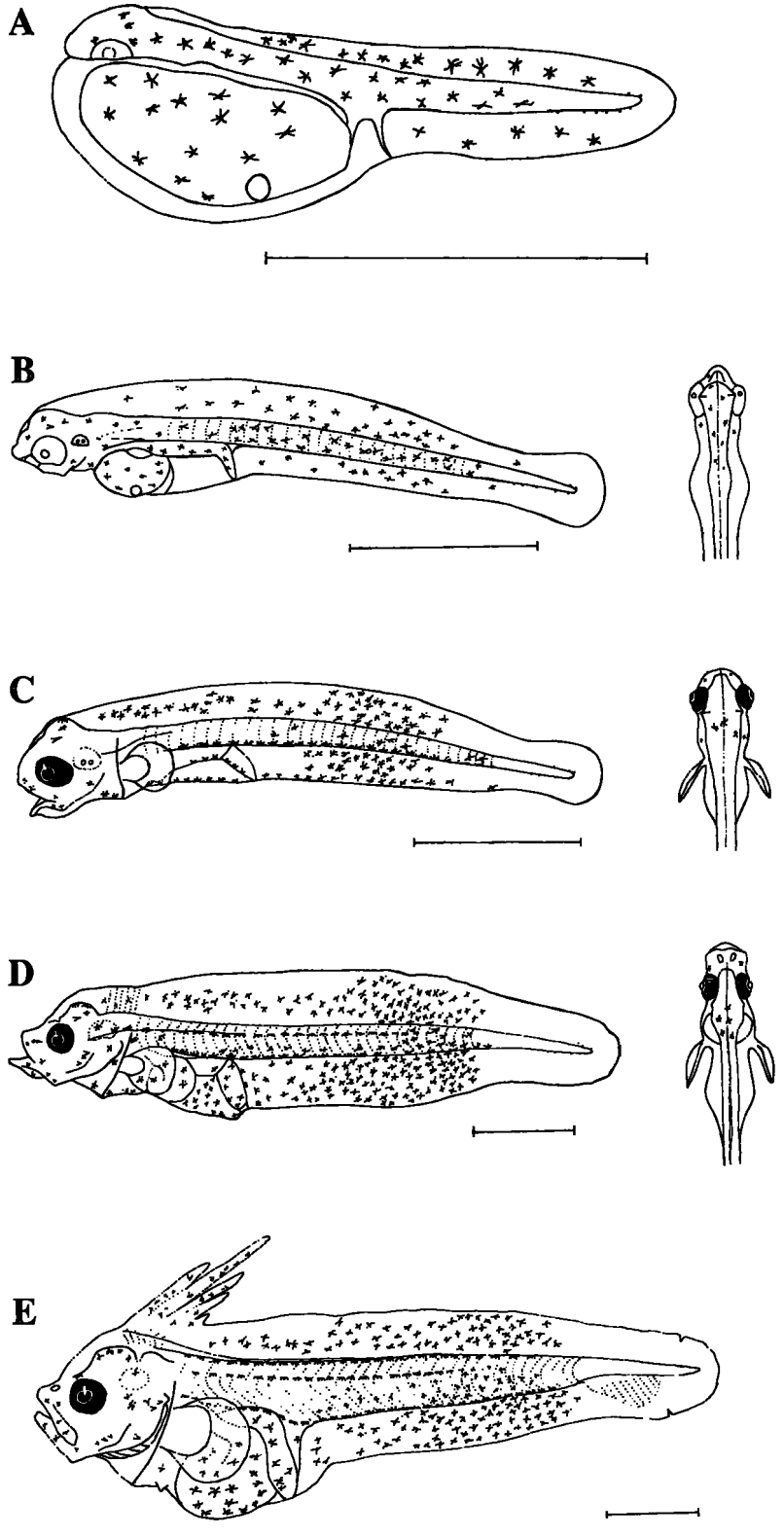

Figure 4

Paralichthys microps larvae: (A) Early yolksac, 1.5 mm NL; (B) late yolksac, 3.0 mm NL; (C) early preflexion, 3.4 mm NL; (D) middle preflexion, 5.3 mm NL; (E) late flexion, 7.0 mm NL. Drawings at right are dorsal head views. Bars = 1.0 mm.

anterior one-third of the tail. A dense zone of melanophores develops on the middle one-third of the tail and associated dorsal and ventral finfold regions (Fig. 4). Pigment is less dense on more anterior regions of the finfold and is absent on the posterior one-third of the tail and finfold. Head pigmentation is restricted to the jaws, dorsal brain, and opercle.

During the flexion stage, the melanistic zone on the tail and associated finfold region intensifies. The paired series along the dorsum and the epaxial region remains visible, while the embedded series dorsal to notochord is less visible due to the development of musculature. The number of ventral and ventrolateral abdominal melanophores increases. The ventral region of the gut has small melanophores, while those on the side of the gut are larger and stellate. The series above the gut and along its ventral midline are less apparent.

The pattern of melanophores on the head remains about the same, with brain melanophores the most conspicuous. Head pigmentation consists of small melanophores on the jaws, palate, preoperculum, operculum, and gular region, and larger and stellate melanophores in the brain region. The small melanophores located at the ventral margin near the tip of the notochord disappear with development of the caudal fin. Melanophores increase in number on the dorsal-fin crest and on the interradial membranes of the dorsal and anal fins during the postflexion stage (Fig. 5A).

Finally, during the metamorphosis stage (Fig. 5C) melanophores increase in numbers on the head and body, especially on the left side. Body melanophores are associated with myosepta. The paired dorsal series remains visible. Melanophores on the dorsal and anal fins are arranged in groups. The elongated dorsal-fin rays are covered with melanophores. The rear margins

of the hypural plates become pigmented, as do the bases of the caudal-fin rays.

Fin development Pterygiophores and fin rays of the dorsal fin appear at 5.5 mm NL; full complements are present at 7.7 mm SL (Table 2). Anal-fin pterygiophores and rays appear at 6.5 mm NL and have full complements at 7.7 mm SL. The pelvic-fin rays begin to develop at 7.0 mm NL and all are present at 8.1 mm SL; pterygiophores begin to develop at 10.1 mm SL and all are present at 11.3 mm SL. The first pectoral-fin rays appear at ~9.5 mm SL; full complements are present at 11.3 mm SL. The hypural complex develops between 6.2 and 7.2 mm NL. The number of caudal-fin rays is 18, plus 2 procurrent rays.

Morphology The sphenotic spine is more developed than in *P. adspersus* preflexion larvae (Fig. 2) (max. length is 24% eye diameter) and disappears with the appearance of the elongated dorsal-fin rays. At ~5 mm NL, up to 4 spines may be found at the preopercular margin; up to 3 spines are found in the upper region of opercle. At this size, the gut becomes coiled and the larva is moderately slender. Preanal distance is 41.2% NL; body depth (BD) is 13.3% NL, and upper jaw length (UJL) is 34.6% HL (Table 1).

At ~6 mm NL, three elongated rays appear on the dorsal fin crest. They correspond to the second, third, and fourth rays of the adult fin. The middle ray of the crest is the longest. There are 34 (11–12 preanal and 22–23 postanal) myomeres at the end of the stage.

The flexion stage is characterized by development of the hypural elements of the caudal fin. Body depth increases to 25.6%

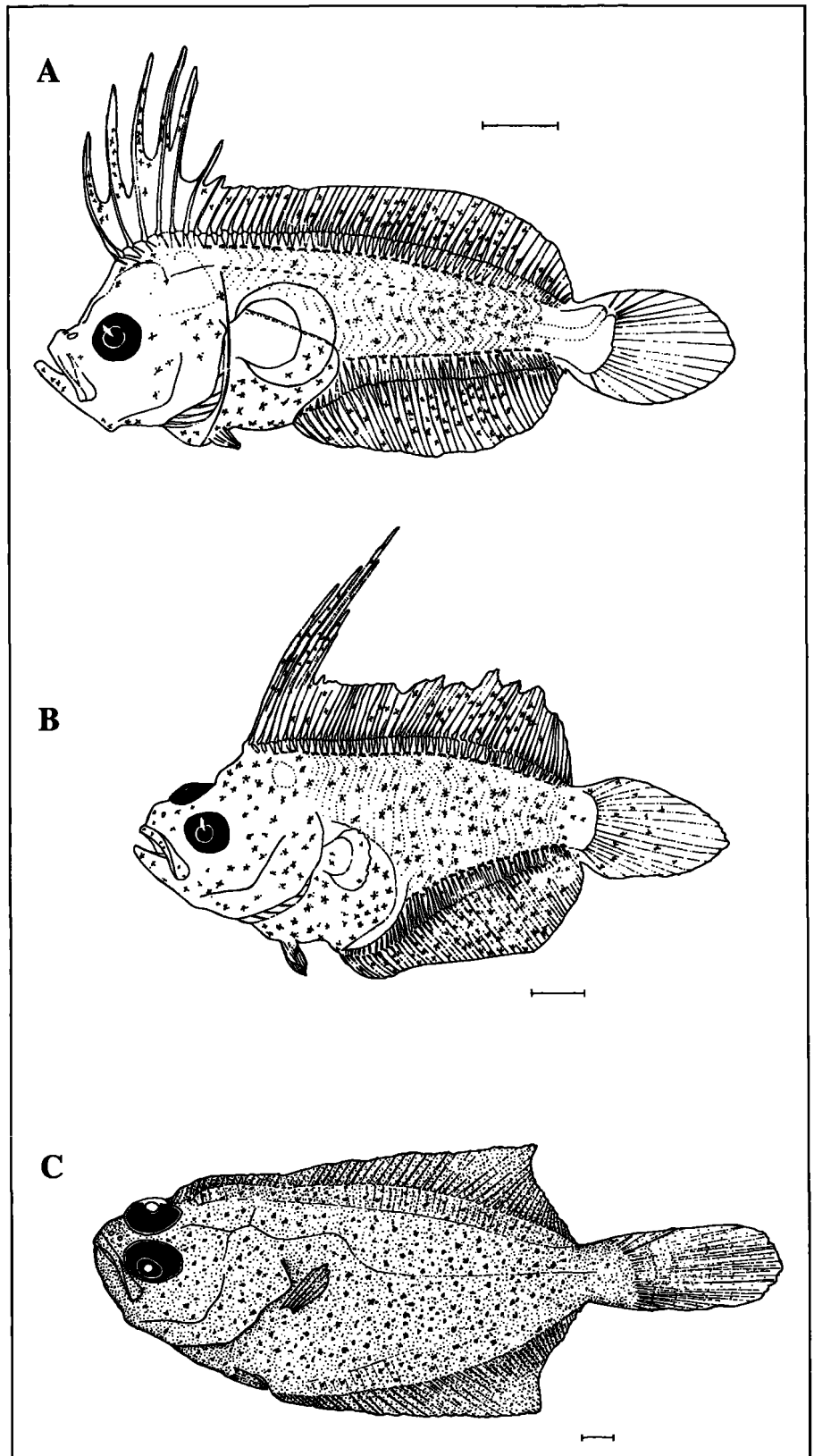

Figure 5
Paralichthys microps larvae. (A) early postflexion, 7.4 mm SL; (B) early to middle metamorphosis, 8.7 mm SL; (C) juvenile, 15.5 mm SL. Bars = 1.0 mm.

NL; upper and lower jaw lengths increase to 44.5% and 57.1% HL. Relative eye diameter decreases to 26.8% HL (Table 1).

The number and location of preopercular and opercular spines remain almost constant. The pelvic fin starts to develop at ~7.0 mm NL. Up to 6 elongated fin rays develop in the dorsal crest. There are 34 (9–11 preanal and 23–25 postanal) myomeres at the end of the stage.

The 6 (sometimes 7) fin rays of the dorsal crest continue to elongate during the postflexion stage. The fourth and fifth rays are more than half the body length; the first dorsal-fin ray is apparent but poorly developed. Rays and pterygiophores of median fins become more apparent.

By the end of this stage, preopercular and opercular spines start to disappear and the interocular region begins to deform in preparation for eye migration. Body depth increases (up to 44.7% SL) as does head length (up to 37% SL), with a corresponding decrease in relative jaw length and eye diameter (Table 1). There are 34 (7–9 preanal and 25–27 postanal) myomeres at the end of the stage.

Finally, during metamorphosis as the right eye migrates towards the left side of the body, the dorsal crest is lost, the mouth changes form, and pectoral-fin rays form (Fig. 5C).

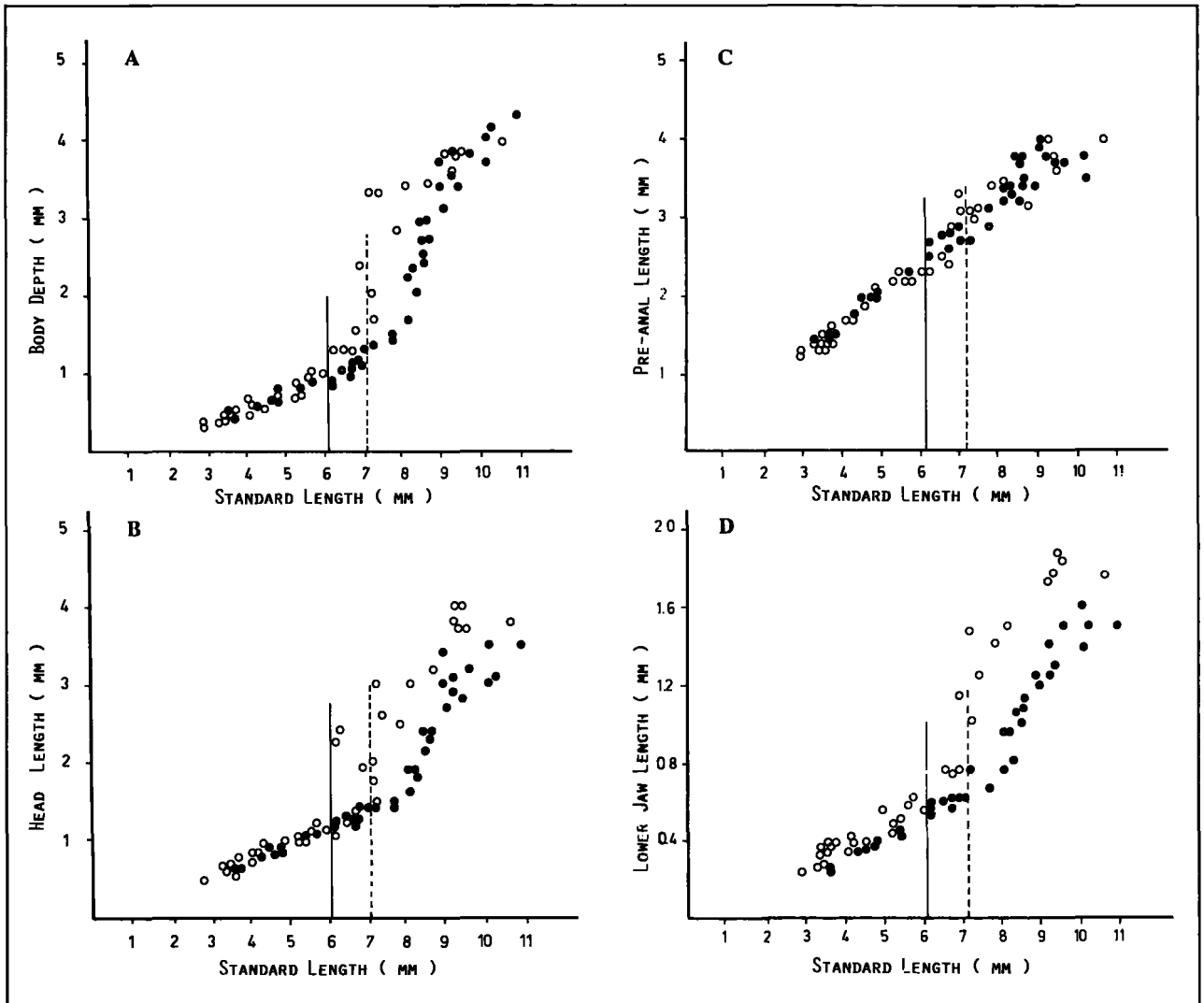

Figure 6

Morphometric relationships (vs. SL) of *Paralichthys adspersus* (●) and *P. microps* (○) larvae. (A) Body depth; (B) head length; (C) preanal length; (D) lower jaw length. Solid vertical line shows flexion of *P. microps*, and broken line flexion of *P. adspersus*.

Morphometrics

Six morphometric functional relationships are shown in Figures 6 and 7, and all linear regression models and their r^2 values are summarized in Table 3 (abbreviations as in Table 1). In general, all morphometric relationships were adequately described by the linear regression model, especially the preflexion *P. adspersus* larvae which always had higher r^2 values than those for other stages of the same species and all stages of *P. microps* (Table 3). The relationships are not so clear in *P. microps*, because the preflexion SnL/HL, PAL/SL, BD/SL, and HL/SL relationships had higher r^2 values than those of the other stages, while the relationships UJL/SL, LJL/SL, and ED/SL of other stages had higher values of r^2 than those from preflexion (Table 3).

F tests showed that models for all preflexion relationships and the PAL/SL of "other stages" could be considered statistically identical for both species, while all others were significantly different (Table 4). Regression models for all morphometric relationships (except SnL/HL and PAL/SL) between the two groups of developmental stages of *P. microps* were significantly different, while in *P. adspersus* all but SnL/HL, PAL/SL, and UJL/SL were significantly different (Table 5).

A summary of larval characters useful to identify larvae of both species during the different larval stages, including morphology, pigmentation, and morphometrics, is shown in Table 6.

Discussion

Characteristics of larval development of *P. adspersus* and *P. microps* are, in general, similar to those observed in other species of the genus (*P. dentatus* Smith and Fahay 1970; *P. olivaceus* Mito 1963, Okiyama 1967; *P. californicus*, Ahlstrom and Moser 1975). Important common characteristics are: presence of only one oil globule posteriad in the yolksac larvae; small size at hatching, notochordal flexion, and metamorphosis; presence of sphenotic spines; two groups of preopercular spines; elongated anterior dorsal-fin rays; a deep laterally-compressed body; and a large visceral mass. Opercular spines present in the two species described herein are uncommon in the family.

Length at hatching of Paralichthyid larvae varies between 1.5 and 3.7mmNL with a mean of 2.2mm, while the range described for the genus *Paralichthys* is 2.0–2.8mm (Ahlstrom et al. 1984). Thus, hatching sizes (1.5–1.7mm) of *P. adspersus* and *P. microps* larvae are smaller than any known congener. Lengths at flexion and metamorphosis of both species fall within

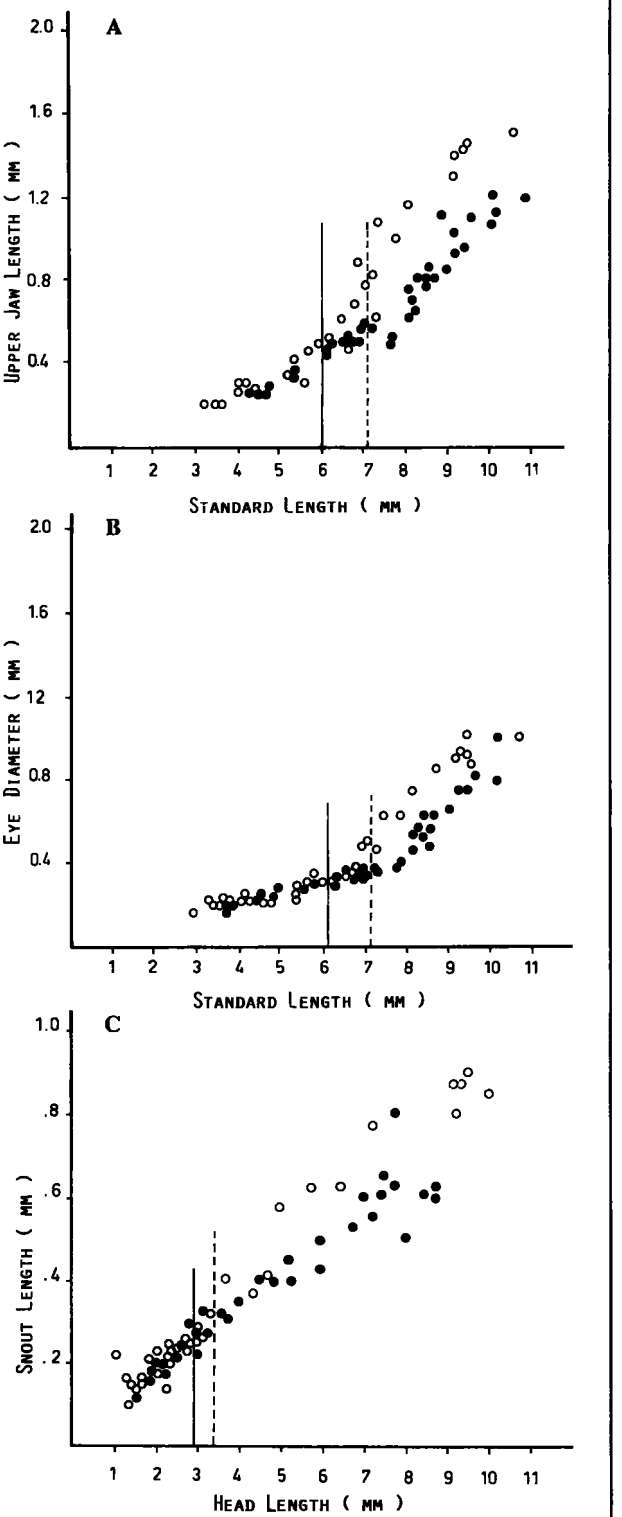

Figure 7
Morphometric relationships (vs. SL and HL) of *Paralichthys adspersus* (●) and *P. microps* (O) larvae. (A) Upper jaw length, (B) ocular diameter, (C) snout length. Symbols as in Fig. 6.

Table 3

Linear regression equations and r^2 values of selected morphometric relationships for preflexion and "other stages" larvae of *Paralichthys adspersus* and *P. microps*. Abbreviations as in Table 1.

	P. adspersus		*P. microps*	
Relationship	Preflexion	Other stages	Preflexion	Other stages
PAL/SL	0.091+0.397X r^2 0.975	0.652+0.328X r^2 0.557	0.088+0.388X r^2 0.957	0.534+0.338X r^2 0.772
BD/SL	−0.311+0.205X r^2 0.933	−5.446+0.944X r^2 0.873	0.328+0.214X r^2 0.901	−2.940+0.711X r^2 0.821
HL/SL	−0.189+0.218X r^2 0.971	−3.428+0.669X r^2 0.817	−0.149+0.217X r^2 0.937	−3.806+0.796X r^2 0.905
UJL/SL	−0.284+0.119X r^2 0.956	−1.012+0.215X r^2 0.701	−0.129+0.094X r^2 0.805	−1.060+0.258X r^2 0.889
LJL/SL	−0.137+0.110X r^2 0.974	−1.390+0.288X r^2 0.723	−0.034+0.104X r^2 0.815	−1.165+0.309X r^2 0.860
ED/SL	0.026+0.046X r^2 0.931	−1.114+0.199X r^2 0.911	0.047+0.042X r^2 0.785	−0.839+0.187X r^2 0.934
SnL/HL	−0.031+0.254X r^2 0.896	0.082+0.166X r^2 0.794	0.006+0.223X r^2 0.792	0.033+0.222X r^2 0.958

Table 4

Values of F for two regression models of morphometric relationships between preflexion and other developmental stages (flexion, postflexion, and metamorphosis) between *Paralichthys adspersus* and *P. microps*. Abbreviations as in Table 1.

	Preflexion			Other stages		
Relationship	F	df		F	df	
PAL/SL	1.18	(2, 41)	NS	0.05	(2, 38)	NS
BD/SL	0.66	(2, 38)	NS	11.24	(2, 38)	*
HL/SL	2.04	(2, 38)	NS	21.82	(2, 38)	*
UJL/SL	2.46	(2, 23)	NS	19.73	(2, 38)	*
LJL/SL	1.28	(2, 36)	NS	17.79	(2, 35)	*
ED/SL	0.67	(2, 38)	NS	34.97	(2, 33)	*
SnL/HL	1.25	(2, 38)	NS	14.81	(2, 35)	*

NS = Non-significant * Significant ($P<0.001$)

Table 5

F tests for two regression models of morphometric relationships between preflexion and other developmental stages (flexion, postflexion, and metamorphosis) within two species of *Paralichthys*. Abbreviations as in Table 1.

	P. adspersus			*P. microps*		
Relationship	F	df		F	df	
PAL/SL	0.79	(2, 43)	NS	1.48	(2, 36)	NS
BD/SL	50.90	(2, 41)	*	17.18	(2, 35)	*
HL/SL	22.90	(2, 41)	*	36.18	(2, 35)	*
UJL/SL	3.32	(2, 34)	NS	10.52	(2, 25)	*
LJL/SL	10.39	(2, 40)	*	18.03	(2, 35)	*
ED/SL	70.53	(2, 37)	*	51.96	(2, 34)	*
SnL/HL	2.14	(2, 40)	NS	0.83	(2, 33)	NS

NS = Non-significant * Significant ($P<0.001$)

the known range of the genus. *P. adspersus* is larger at metamorphosis than *P. microps* (9.6–13.0 mm SL vs. 8.0–11.0 mm SL, respectively) and is comparable to the 10.2–14.2 mm SL range for *P. olivaceus* (Okiyama 1967).

Early presence of elongated anterior dorsal-fin rays in *P. adspersus* and *P. microps*, at 6.5 and 6.0 mm SL, respectively, is common in *Paralichthys* and related genera of paralichthyids (*sensu* Ahlstrom et al. 1984). The six elongated dorsal-fin rays observed in *P. microps* fall within the described range (4–8) for *Paralichthys*, while *P. adspersus* only has 3, as in the related genus *Citharichthys* (Ahlstrom et al. 1984). The shape and size of these dorsal-fin rays is characteristic of the genus *Paralichthys* and not *Citharichthys*.

The melanistic pattern of the larvae of both species is very similar to that described for the genera *Paralichthys* and *Pseudorhombus* (*sensu* Ahlstrom et al. 1984); however, the pigment series along the horizontal septum described for other species

Table 6

Summary of larval characters which distinguish larvae of *Paralichthys adspersus* and *P. microps* during different larval stages. Abbreviations as in Table 1.

Developmental stage	*P. adspersus*	*P. microps*
Preflexion	Two sphenotic spines present before development of dorsal-fin rays. Dorsal finfold unpigmented. LJL/HL = 46.3%	One sphenotic spine present before development of dorsal-fin rays. Dorsal finfold pigmented. LJL/HL = 52.0%
Flexion	Dorsal finfold unpigmented. LJL/HL = 48.1% 2–3 elongated dorsal-fin rays.	Dorsal finfold pigmented. LJL/HL = 57.1% 3–6 elongated dorsal-fin rays.
Postflexion	Dorsal fin poorly pigmented. HL/SL = 30.6%; BD/SL = 35.8% 3 elongated dorsal-fin rays. 33 myomeres.	Dorsal fin pigmented. HL/SL = 37.3%; BD/SL = 44.7% 6 elongated dorsal-fin rays. 34 myomeres.
Metamorphosis	3 elongated dorsal-fin rays (before reabsorption). SnL/HL = 18.3%; HL/SL = 32.0%; BD†/SL = 41.9% 33 myomeres.	6 elongated dorsal-fin rays (before reabsorption). SnL/HL = 23.3%; HL/SL = 39.1%; BD†/SL = 46.5% 34 myomeres.
Juvenile	33 vertebrae. Meristics (see Table 7).	34 vertebrae. Meristics (see Table 7).

BD† measured at the anus.

is not present in *P. adspersus* or *P. microps*. Reared and field-caught specimens of *P. adspersus* lack pigmentation in the dorsal finfold during the first half of their larval development, a unique feature among described paralichthyid larvae.

In flounders, the main change in body shape occurs during flexion, with an increase in body depth and head length. This stage is characterized by development of skeletal structures and by a change in swimming and feeding (Balart 1984). After flexion, the rate of growth of the head, snout, and jaws is comparatively greater in *P. microps*, while the rate of increase in body depth is greater in *P. adspersus*.

Preflexion larvae of *P. adspersus* and *P. microps* are statistically indistinguishable using morphometrics. After flexion and loss of the elongated dorsal-fin rays, separation is based mostly on morphometric characteristics, especially SnL/HL and HL/SL. After metamorphosis, during the juvenile stage when all fin rays are already developed, the adult range of meristic counts can be used (Table 7).

Table 7

Meristics of adult *Paralichthys adspersus* and *P. microps* of use in identifying juveniles.

Character Norman (1937)	*P. adspersus* Ginsburg (1952)	*P. microps*	
Origin of dorsal fin	Between anterior margin of eye and pupil (7–12 cm). Over anterior margin of eye or near it (20–39 cm).	Over or slightly anterior to center of eye.	
Gill rakers			
Upper	15–19	18–23	
Lower	7–8 ($\bar{x}$ 7)	9–10	Chirichigno (1974)
Total	22–27 ($\bar{x}$ 25–26)	27–33	
Fin rays			
Dorsal	68–76	68–80	
Anal	54–61	56–65	
Pectoral	11–13	11–12	

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