

**Abstract.**—The larval development of three roughy species complexes, *Paratrachichthys* sp., *Aulotrachichthys* sp., and *Optivus* sp., is described and illustrated using larvae collected from Tasmanian and New South Wales waters. Larvae were identified using meristic and morphological characters and are characterized by differences in head and dermal spination, size at caudal flexion, and size and pigmentation of the pelvic fins. Head spination is well developed in *Aulotrachichthys*, and weak in *Optivus* and *Paratrachichthys*. Dermal spination is well developed in postflexion *Aulotrachichthys* and flexion *Optivus*, but absent in *Paratrachichthys*. Development of a luminous organ and anterior migration of the anus occur much earlier in *Aulotrachichthys* than *Paratrachichthys* and are notably absent in *Optivus*. The use of these larval characters in trachichthyid systematics, and the possible reasons for the absence in our samples of larvae attributable to orange roughy *Hoplostethus atlanticus*, are discussed.

## Larval development of three roughy species complexes (Pisces: Trachichthyidae) from southern Australian waters, with comments on the occurrence of orange roughy *Hoplostethus atlanticus*

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The family Trachichthyidae (order Beryciformes) consists of some 31 species, of which at least 15 occur in southern temperate waters of Australia (May & Maxwell 1986). Seven genera are known from Australian waters: *Hoplostethus*, *Paratrachichthys*, *Aulotrachichthys*, *Optivus*, *Gephyroberyx*, *Trachichthys*, and *Sorosichthys*. The various species inhabit depths from nearsurface to greater than 1200 m, with most occurring in depths greater than 200 m. There is considerable confusion regarding the taxonomy of the group, and a number of the species occurring in Australian waters are undescribed. The genus *Hoplostethus* comprises at least three Australian species—*H. intermedius*, *H. latus*, and orange roughy *H. atlanticus* (May & Maxwell 1986)—which supports a recently developed fishery. *Paratrachichthys* is represented in Australian waters by the sandpaper fish, *Paratrachichthys* sp., an undescribed species that is closely related to, and has only recently been distinguished from, the New Zealand

endemic *P. trilli* (M. Gomon, Mus. Victoria, Melbourne, pers. commun., Nov 1990). Specimens have been recorded from New South Wales, Victoria, South Australia, Tasmania, and southern Western Australian waters (May & Maxwell 1986).

*Aulotrachichthys* and *Optivus* each contain two closely-related undescribed Australian species (M. Gomon, pers. commun.). *Aulotrachichthys* sp.1 occurs in shallow waters of South Australia, whereas *Aulotrachichthys* sp.2 occurs in deeper water off the east coast (May & Maxwell 1986). Similarly, *Optivus* has both eastern and western Australian representatives: *Optivus* sp.1 along the east coast as far north as southern Queensland, and *Optivus* sp.2 off southern Western Australia (May & Maxwell 1986). The remaining three genera are monotypic, represented by *Gephyroberyx darwini*, *Trachichthys australis*, and *Sorosichthys anannassa*.

Little is known about the ecology or early life history of trachichthyids, and there is nothing in the literature on the early life history of Aus-

tralian species. Parr (1933) and Johnson (1970) described 19mm and 21.5mm juvenile *Korsogaster*, respectively, a genus subsequently synonymized with *Hoplostethus* by Woods & Sonoda (1973). Crossland (1981) illustrated a trachichthyid larva, possibly *Optivus elongatus*, from northeastern New Zealand. Robertson (1975) described an egg tentatively ascribed to *Paratrachichthys trailli*. Kotlyar (1984) described juveniles of four species of *Hoplostethus* (including a 36mm *H. atlanticus*), the smallest of his specimens being a 15mm *H. melanopterus*. Okiyama (1988) figured and briefly described single specimens of an unidentified *Hoplostethus* (10.7mm), *Gephyroberyx japonicus* (11.0mm), and *Paratrachichthys prosthemi* (27.5mm).

Comparatively little is known of trachichthyid larval characters; however, common characters include precocious pelvic fin development, heavy pigment, a stocky body form approaching the shape of adults (in larger larvae), a myomere count of 26–30, and the presence of minute spines over the body surface (Keene & Tighe 1984, and references therein).

Recent commercial interest in the orange roughy *Hoplostethus atlanticus* has emphasized the need for information on the early life history of this species. As yet, despite considerable effort in ichthyoplankton sampling, no *H. atlanticus* larvae have been reported from Australian waters. The current study describes the larval development of three trachichthyid species complexes—*Paratrachichthys* sp., *Aulotrachichthys* sp., and *Optivus* sp.—in specimens obtained from plankton samples collected primarily in Tasmanian and New South Wales coastal waters from 1984 to 1986. These descriptions are presented in order to further define larval characters that may be of use in trachichthyid systematics and future identification of other trachichthyid larvae, including *H. atlanticus*.

## Materials and methods

Specimens were largely obtained from ichthyoplankton samples collected in 1984–86 by the CSIRO Division of Fisheries, Hobart, Tasmania, as part of a study aimed at documenting the distribution and abundance of larval fishes in Tasmanian coastal and neritic waters. Details of sampling locations and protocol are provided by Thresher et al. (1989). Larvae were obtained from oblique tows to a depth of 200m (bottom depth permitting) at a series of stations covering shelf and slope waters, using a 1m diameter ring net (500 $\mu$  mesh). Additional material was obtained from samples collected with identical gear in New South Wales shelf and slope waters by A. Miskiewicz (Water Board, Environ. Proj. Group, PO Box A53, Sydney South, 2000).

Larval samples were fixed in either 10% formalin buffered with sodium tetraborate, or 95% ethanol. Morphometric analysis and illustrations were based on formalin-fixed specimens of *Paratrachichthys* and *Optivus*. However, only ethanol-fixed material was available for *Aulotrachichthys*. No allowance was made for shrinkage or distortion in preservative.

Larvae were examined using a Wild M5 dissecting microscope, and all drawings were made with the aid of a camera lucida. Larvae were identified using existing literature (Keene & Tighe 1984, Okiyama 1988) by comparison with juvenile and adult features of identified species, and by the establishment of developmental series. Comparisons with similar larvae (e.g., zeids) were made with material from the CSIRO samples.

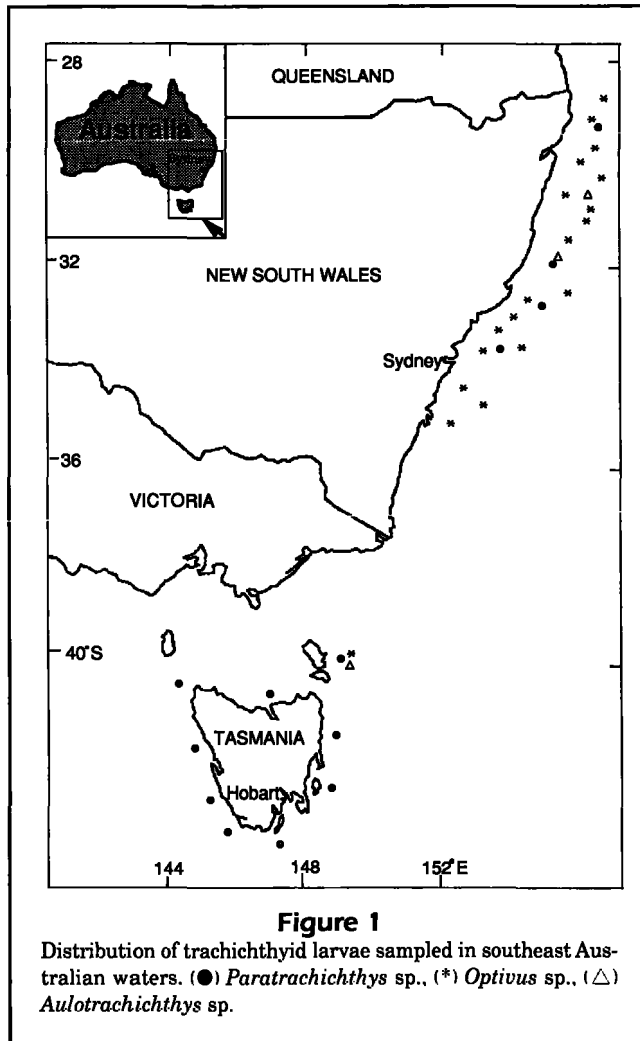
All unspecified body lengths refer to notochord length in preflexion and flexion larvae, and to standard length in postflexion larvae and juveniles. We define **snout to anal-fin length** as the horizontal distance from the tip of the snout to the anterior origin of the anal fin or anal-fin anlagen. **Body depth at anus** is the vertical distance between body margins through the center of the anal opening. **Body depth at pectoral** is equivalent to 'body depth' of Leis & Rennis (1983). Other definitions, such as body shape, follow Leis and Trnski (1989). Nomenclature of head spination follows that of Moser & Ahlstrom (1978). Larval measurements were made using an ocular micrometer. Juveniles were measured with vernier calipers.

## Results

During 18 months of sampling, 119 *Paratrachichthys*, 147 *Optivus*, and 25 *Aulotrachichthys* larvae were collected. The distribution of larvae is detailed in Figure 1. No larvae that could be attributed to *Hoplostethus* were collected. A representative series of each species was deposited in the ISR Munro Fish Collection (CSIRO, Hobart, Tasmania). Reference numbers: *Optivus*, CSIRO L179-184; *Paratrachichthys*, CSIRO L185-190; *Aulotrachichthys*, CSIRO L191-196.

## Identification

In larger specimens of two of the series, the anus is located between the pelvic fins. Only three trachichthyid genera have this character: *Paratrachichthys*, *Aulotrachichthys*, and *Sorosichthys* (May & Maxwell 1986). *Sorosichthys* is separated easily on the basis of a pelvic count of 1,5, compared with the 1,6 of the other two genera (Table 1). The only character reported in the literature to distinguish adults of *Aulotrachichthys* from *Paratrachichthys* is the presence in



the former of striated silvery tissue on the bases of the pectoral fin, on the isthmus beneath the gill cover, and in a narrow strip along the ventral edge of the body (May & Maxwell 1986). However, examination of juvenile and adult specimens also reveals a difference in anal fin-ray counts: *Paratrachichthys* with a count of

III,10 and *Aulotrachichthys* with III,8. Both series had a pelvic count of I,6. An anal count of III,8 and striated pectoral tissue occurred in the largest specimen of only one series; on that basis, we assign the series with the largest specimen to *Aulotrachichthys* and the other to *Paratrachichthys*. We were unable to determine whether or not the *Aulotrachichthys* and *Optivus* series represented more than one species. *Optivus* larvae were distinguished on the basis of a dorsal count of IV,11, an anal count of III,9, and the position of the anus, which remains static, immediately anterior to the anal fin.

### Larval development

#### *Paratrachichthys* sp. (Fig. 2)

**Morphology** Head length is about equal to body depth at pectoral until flexion, after which body depth increases to approximately 50% of body length (Table 2). The mouth is large, reaching to approximately the center of the eye in our smallest specimen (3.2 mm) and beyond the eye in larvae greater than 4.5 mm (Fig. 2A-C). The body depth at anus increases markedly during flexion, associated with the anterior migration of the anus during this period. The gas bladder is inflated and prominent in all specimens. There are 27–29 myomeres.

Initially the gut is straight and tube like. It quickly thickens, coils, and becomes triangular by approximately 5.0 mm. The anus begins to migrate anteriorly by 6.5 mm and is in the adult location (between the pelvics) by 7.8 mm (Fig. 2E). The light organ surrounding the anus first appears in 5.4 mm larvae as an unpigmented, thickened ring. By 6.1 mm the light organ is lightly pigmented; by 6.9 mm the organ is heavily pigmented and rugose. Notochord flexion commences at about 5.9 mm and is complete by 7.6 mm.

**Fin development** Development of the pelvics is precocious. Slight swellings on either side of the gut are present in our smallest specimen (3.2 mm). Distinct buds are present by 3.9 mm. The pelvics develop rapidly, having a full complement of 7 elements by 5.6 mm, and reaching up to 34% body length by 7.6 mm. Anlagen of both dorsal and anal fins are present by 4.3 mm. The anlagen first appear as hyaline zones within the fin folds, connected to the body by a series of filamentous extensions inserted at each myoseptum (Fig. 2B). Bases of the anal and dorsal fins are present by 4.7 mm, and posterior incipi-

**Table 1**

Meristic characters of trachichthyid genera present in southern Australian waters.

	D	A	P1	P2	Vertebrae
<i>Paratrachichthys</i>	V,13	III,10	12–14	1,6	27–29
<i>Aulotrachichthys</i>	V,13	III,8	12–14	1,6	27–29
<i>Optivus</i>	IV,11	III,9	10–12	1,6	27–29
<i>Hoplostethus</i>	V–VIII,12–18	III,9–11	12–20	1,6	25–30
<i>Gephyroberyx</i>	VIII,13–14	III,11	14	1,6	26–27
<i>Sorosichthys</i>	IX–X,8–9	II,8	13	1,5	Unknown
<i>Trachichthys</i>	IV,10–14	III,9–11	11–14	1,6	27

Table 2

Body proportions of larvae and juveniles of *Paratrachichthys* sp. (expressed as mean proportions of body length with standard deviations in parentheses). Specimens between dashed lines were undergoing notochord flexion. Characters lacking standard deviation are based on one individual only.  $n$ =number of individuals.

Size range (mm)	$n$	Snout to anal fin	Preanal length	Body depth (at pectoral)	Body depth (at anus)	Head length	Eye diameter	Pelvic fin length
3.32	1	—	0.62	0.19	0.10	0.22	0.13	—
3.90	1	—	0.68	0.22	0.09	0.28	0.12	0.06
4.01–4.50	5	—	0.59(0.03)	0.26(0.02)	0.12(0.01)	0.29(0.01)	0.12(0.01)	0.11(0.04)
4.51–5.00	7	0.63(0.02)	0.62(0.02)	0.28(0.03)	0.14(0.01)	0.30(0.01)	0.14(0.01)	0.18(0.02)
5.01–5.50	8	0.63(0.02)	0.62(0.02)	0.34(0.02)	0.19(0.04)	0.31(0.02)	0.14(0.01)	0.25(0.03)
5.51–6.00	3	0.61(0.02)	0.57(0.01)	0.35(0.02)	0.26(0.04)	0.33(0.02)	0.15(0.01)	0.27(0.02)
6.01–6.50	2	0.60(0.05)	0.54(0.07)	0.38(0.03)	0.29(0.05)	0.33(0.01)	0.15(0.01)	0.29(0.01)
6.95	1	0.70	0.55	0.43	0.39	0.35	0.14	0.30
7.60	1	0.74	0.43	0.53	0.43	0.41	0.17	0.34
10.00	1	0.71	0.48	0.42	0.42	0.34	0.17	0.26
35.80	1	0.58	0.38	0.38	0.38	0.34	0.14	0.18
39.70	1	0.60	0.37	0.39	0.39	0.36	0.12	0.18

ent rays first appear above these bases by 5.4 mm. Incipient rays appear in the pectoral fin shortly thereafter (5.5 mm). Ossification of dorsal, anal, pelvic, and pectoral fins occurs during flexion, with full complements in all fins present by 7.8 mm.

**Spination** *Paratrachichthys* larvae have only weakly developed head spination. A low supraocular ridge is present at 3.3 mm, developing 1–2 spines by 3.9 mm (Fig. 2A). The number of supraocular spines increases to 2–3 by 4.0 mm, reaching a maximum of 5–6 just prior to flexion. During flexion, the supraocular spines disappear.

The single opercular spine is present by 6.9 mm and is retained in the adult. Similarly, single preopercular and posttemporal spines are present by 8.7 mm and are retained. Cranial ridges are present by 5.4 mm; however, even by 10.0 mm these have not yet become denticulate as they are in juveniles and adults.

**Scalation** Juvenile and adult *Paratrachichthys* have small, adherent, ctenoid scales covering the body and a series of strong ventral scutes between the anus and the anal fin (Woods & Sonoda 1973). Our largest larva (10.0 mm) has no sign of scalation and lacks the minute dermal spines of other trachichthyid genera, although a weak fleshy ridge develops along the ventral midline between the anus and the anal fin by 7.6 mm, probably a precursor to the characteristic ventral scutes of juveniles and adults. The 39.7 mm juvenile examined was, in effect, a miniature adult having completed scalation, including the ventral scutes.

**Pigmentation** *Paratrachichthys* larvae are moderately to heavily pigmented (with the exception of the last 2–8 myomeres, including the notochord tip) throughout the entire larval period. Pigment tends to be concentrated over the dorsal and ventral surfaces of the body and the dorsal surface of the gut. Otherwise, there are few useful distinguishing features based on patterns of pigmentation.

The pelvic fins are heavily pigmented by 4.2 mm and remain so in our largest postflexion larva (10.0 mm). Some variation was introduced by the obviously faded pigment of certain specimens, the result being a series of heavily-pigmented and a series of moderately- to lightly-pigmented individuals. Because the major pigment concentrations, morphology, and meristic information were otherwise identical for the two series, it is unlikely that variations in the intensity of pigmentation indicate the presence of more than one species.

### *Aulotrachichthys* sp. (Fig. 3)

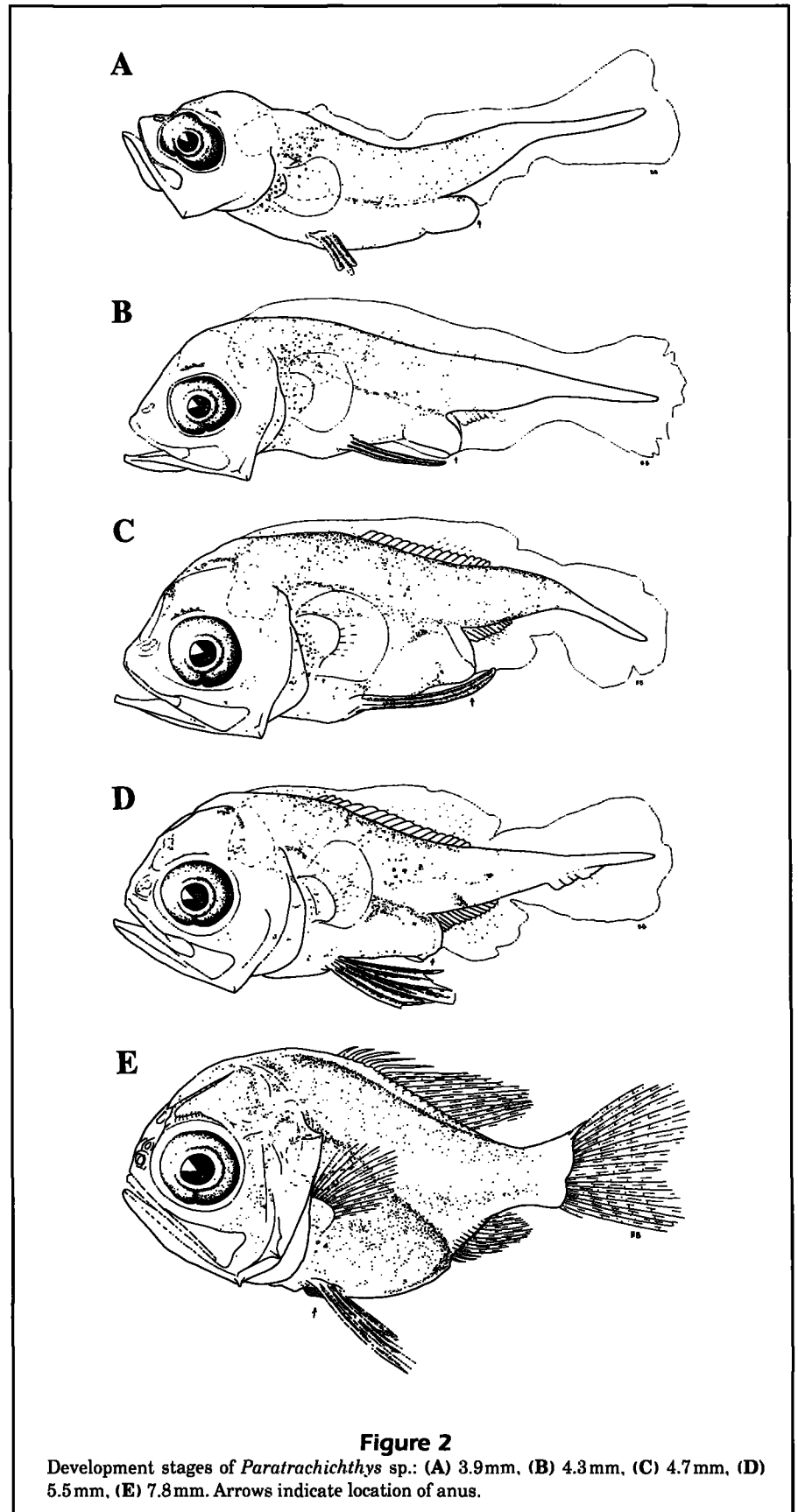
**Morphology** Head length is about equal to body depth at the pectoral fin until flexion, after which body depth increases to 50% body length (Table 3). The mouth is moderately large, reaching to the posterior margin of the eye in our smallest specimen (2.8 mm), falling to just short of the margin in our largest specimen (7.9 mm). The body depth at the anus increases markedly prior to flexion as the anus migrates anteriorly. The gas bladder is inflated and prominent in all speci-

mens. There are 27–29 myomeres.

The gut is a convoluted tube in our smallest specimen (2.8 mm). It quickly thickens, coils, and becomes triangular by 4.4 mm. The anus begins to migrate by 3.9 mm and is in the adult location (between the pelvic fins) by 4.9 mm (Fig. 3C,D). A light organ that surrounds the anus first appears in 3.6 mm larvae and is well developed, rugose in appearance, and heavily pigmented by 4.4 mm. Ventral striated tissue, characteristic of adults, is present in the 7.9 mm specimen.

Insufficient specimens were available to fully document flexion; however, flexion was just about to commence in a 4.9 mm specimen, was well underway in a 5.7 mm specimen, and had been completed in a 7.9 mm specimen.

**Fin development** Development of the pelvic fins is precocious. Even our smallest specimen has a full pelvic complement of 7 elements (although ossification is not completed until 4.4 mm). The pelvic fins are large, up to 35% body length at 4.9 mm, and reach beyond the anal-fin origin in all specimens. The limited number of specimens precluded documenting initial dorsal- and anal-fin anlagen development; however, the separation from the body of the posteriormost anal base in our 4.1 mm specimen suggests a finfold development similar to *Paratrachichthys*. Both dorsal and anal bases are present by 3.9–4.1 mm, and incipient rays appear above these bases by 4.4 mm. Incipient rays appear in the pectoral fin shortly thereafter (4.9 mm). Ossification of the dorsal, anal, and pectoral fins commences in flexion-stage larvae, with a full complement in all fins present by 7.9 mm.



**Figure 2**

Development stages of *Paratrachichthys* sp.: (A) 3.9 mm, (B) 4.3 mm, (C) 4.7 mm, (D) 5.5 mm, (E) 7.8 mm. Arrows indicate location of anus.

**Table 3**

Body proportions of larvae of *Aulotrachichthys* sp. (expressed as mean proportions of body length with standard deviations in parentheses). Specimens between dashed lines were undergoing notochord flexion. Characters lacking standard deviation are based on one individual only.  $n$ =number of individuals.

Size range (mm)	$n$	Snout to anal fin	Preal anal length	Body depth (at pectoral)	Body depth (at anus)	Head length	Eye diameter	Pelvic fin length
2.51–3.00	5	—	0.59(0.05)	0.25(0.03)	0.14(0.02)	0.24(0.02)	0.11(0.01)	0.23(0.01)
3.01–3.50	3	—	0.63(0.01)	0.25(0.01)	0.14(0.01)	0.27(0.02)	0.13(0.01)	0.27(0.03)
3.51–4.00	3	—	0.60(0.03)	0.34(0.03)	0.18(0.04)	0.31(0.02)	0.13(0.01)	0.33(0.03)
4.01–4.50	2	0.62(0.01)	0.54(0.01)	0.34(0.02)	0.22(0.02)	0.31(0.01)	0.13(0.01)	0.31(0.00)
4.91	1	0.59	0.38	0.39	0.37	0.34	0.13	0.35
5.66	1	0.64	0.30	0.35	0.51	0.30	0.16	0.28
7.85	1	0.72	0.44	0.50	0.50	0.43	0.17	0.31

**Spinination** *Aulotrachichthys* larvae have well-developed head spinination. Our smallest specimen has a low supraocular ridge with a single spine. The number of supraocular spines increases to 3–4 by 4.4 mm (Fig. 3C); they become quite robust and reach a maximum number of 8–9 during flexion. Generally, the posterior group of these spines are the largest and are recurved. Preopercular spines are present by 4.4 mm, with an anterior preopercular series added by 4.9 mm. By 5.7 mm, preopercular spinination is quite robust, with secondary ridging and branching of the largest spines (particularly at the angle) (Fig 3D). Nuchal, supracleithral, and posttemporal spines, as well as nasal and cranial ridges, are developed prior to 5.7 mm. During flexion a hard bony plate forms in the region of the posttemporal, extending posteriorly to the level of the opercular margin. This plate extends beyond the opercular margin by 7.9 mm, and is retained in the adult. Available specimens are insufficient to determine if this plate results from the fusion of the supracleithral and posttemporal series. During flexion, spines also develop on the dentary and infraorbital. Several cranial and opercular ridges appear at this stage.

A single spine is present immediately posterior to the anus by 4.9 mm. Dermal spines are present on the pelvic bases by 5.7 mm, and by 7.9 mm a cluster of spines is also present immediately anterior to the anus. The 7.9 mm specimen has well developed dermal spinination in longitudinal rows over the entire body surface and on the dorsal- and anal-fin bases, although there is no sign of scalation. Additionally, this specimen has a row of strong spines extending posteriorly along the ventral midline from the anus towards the

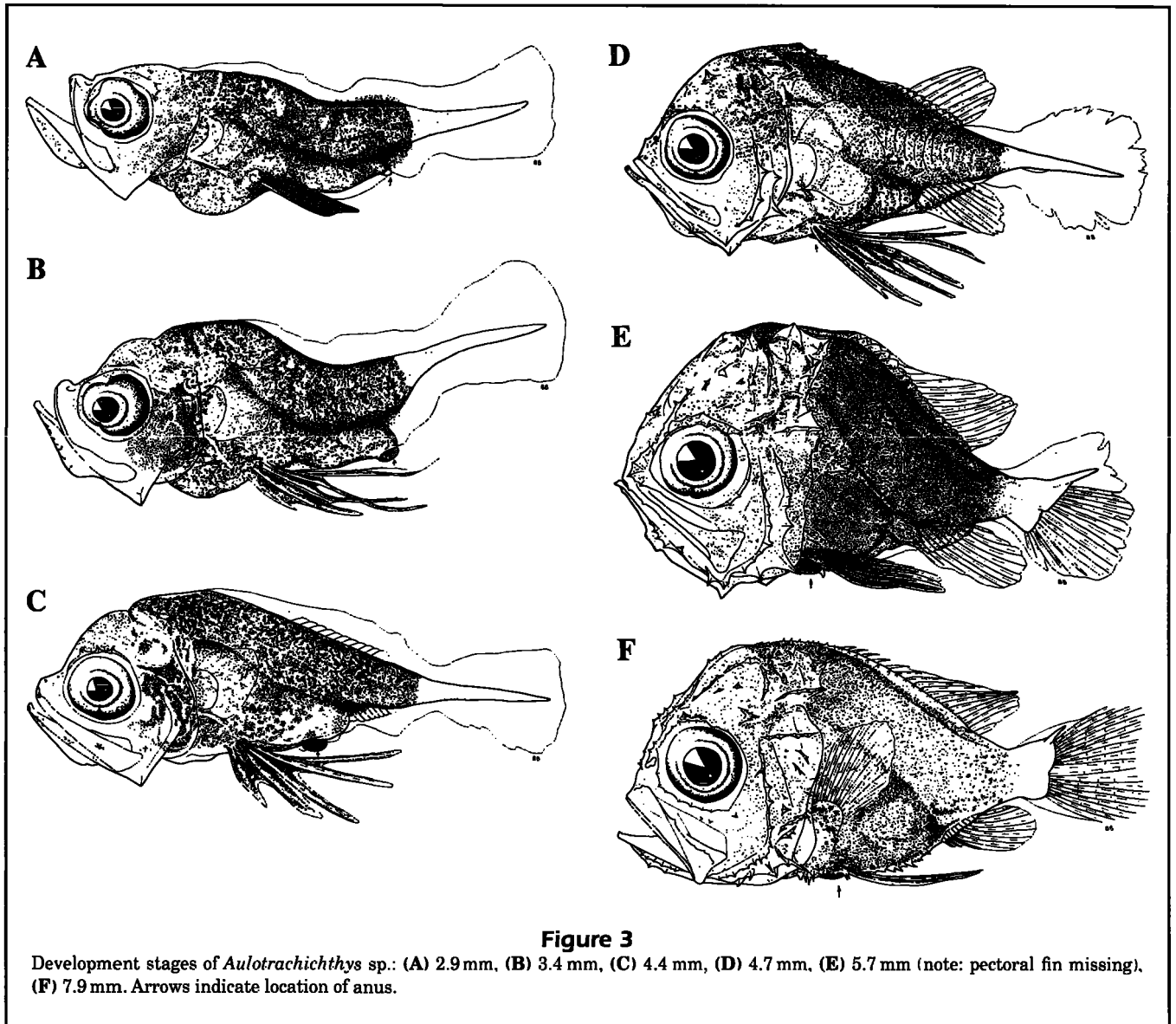
anal fin, probably precursors to the ventral scutes of adults. Fine villiform teeth are present in both jaws.

**Pigmentation** *Aulotrachichthys* larvae are heavily pigmented (with the exception of the posteriormost 5–6 myomeres, including the notochord tip) throughout the larval period. The pelvic fins are heavily pigmented in the smallest specimen and remain so in the 7.9 mm specimen. *Aulotrachichthys* larvae are more heavily pigmented than *Paratrachichthys*, although, as with *Paratrachichthys*, there are few useful distinguishing characters based on pigment pattern.

#### ***Optivus* sp. (Fig. 4)**

**Morphology** Body depth increases to a maximum of 49% body length during flexion (Table 4). Body depth at anus increases only slightly compared with *Paratrachichthys* and *Aulotrachichthys*, because the anus position in *Optivus* remains static. Head length increases from 36% body length in preflexion larvae to 44% in juveniles. Eye diameter remains relatively constant. The mouth is moderate to large, reaching to the center of the eye in our smallest specimen (2.5 mm) and beyond the eye in larvae greater than 4.0 mm. The gut, which is initially straight, quickly thickens, coils, and becomes broadly triangular by 3.5 mm. *Optivus* larvae do not develop a light organ. Notochord flexion commences at about 4.0 mm and is complete by 7.1 mm. There are 27–29 myomeres.

**Fin development** Pelvic fins first appear in larvae of 3.0 mm as slight swellings on either side of the gut,



and these develop rapidly. Distinct buds are present by 3.2 mm, and the developing fin reaches up to 25% body length by 6.2 mm (Fig. 4A-C). Ossification commences by 5.1 mm, and a full complement of seven elements is present by 8.0 mm. Anlagen of both dorsal and anal fins are present by 2.7 mm and appear as hyaline zones located within the median finfolds, as in *Paratrachichthys*. Bases are first visible in both fins by 3.5 mm, and incipient rays are present by 4.0 mm. Incipient rays appear in the pectoral fin by 4.5 mm. Ossification of the dorsal, anal, and pectoral fins commences in early-flexion-stage larvae, with a full complement in all fins present by 7.1 mm.

**Spination** Head spination is only weakly developed in preflexion *Optivus* larvae. A low supraocular ridge is present by 2.7 mm, with 4–5 spines developing by 3.4 mm (Fig. 4A). By 4.5 mm, these supraocular spines have disappeared. Cranial ridges are present by 4.7 mm, and a series of spines develops on the preopercular margins by 5.1 mm. The preopercular, opercular, and posttemporal spines characteristic of adults are present by 23.0 mm (Fig. 4E).

**Scalation** Small dermal spines appear on the body by 4.7 mm and develop in longitudinal rows over the entire body and dorsal- and anal-fin bases by 5.1 mm. By 8.0 mm the base of each single dermal spine has trans-

Table 4

Body proportions of larvae and juveniles of *Optivus* sp. (expressed as mean proportions of body length with standard deviations in parentheses). Specimens between dashed lines were undergoing notochord flexion. Characters lacking standard deviation are based on one individual only.  $n$  = number of individuals.

Size range (mm)	$n$	Snout to anal fin	Preanal length	Body depth (at pectoral)	Body depth (at anus)	Head length	Eye diameter	Pelvic fin length
2.51–3.00	3	0.66(0.03)	0.68(0.04)	0.34(0.01)	0.18(0.01)	0.36(0.01)	0.13(0.01)	–
3.01–3.50	8	0.66(0.03)	0.66(0.03)	0.38(0.03)	0.20(0.02)	0.35(0.02)	0.14(0.01)	0.05(0.01)
3.51–4.00	9	0.69(0.08)	0.65(0.05)	0.40(0.05)	0.20(0.02)	0.36(0.03)	0.14(0.02)	0.08(0.02)
4.01–4.50	11	0.67(0.04)	0.65(0.04)	0.44(0.05)	0.24(0.04)	0.40(0.03)	0.15(0.02)	0.12(0.02)
4.51–5.00	5	0.69(0.04)	0.67(0.04)	0.45(0.04)	0.26(0.05)	0.40(0.04)	0.15(0.01)	0.14(0.01)
5.01–5.50	3	0.74(0.01)	0.70(0.04)	0.45(0.04)	0.30(0.03)	0.45(0.04)	0.14(0.04)	0.20(0.02)
6.01–6.50	2	0.72(0.03)	0.69(0.06)	0.49(0.01)	0.29(0.02)	0.46(0.01)	0.16(0.02)	0.25(0.02)
7.15	1	0.71	0.70	0.48	0.30	0.43	0.15	0.20
8.00	1	0.72	0.69	0.47	0.31	0.45	0.15	0.20
10.01–10.50	2	0.70(0.07)	0.69(0.08)	0.44(0.02)	0.30(0.01)	0.44(0.01)	0.15(0.01)	0.21(0.03)
15.00	1	0.62	0.60	0.39	0.28	0.36	0.13	0.23
17.40	1	0.63	0.61	0.37	0.28	0.36	0.13	0.19
17.80	1	0.62	0.60	0.38	0.27	0.36	0.13	0.20
18.40	1	0.65	0.64	0.38	0.27	0.35	0.14	0.21
19.60	1	0.63	0.62	0.37	0.27	0.34	0.13	0.18
23.00	1	0.65	0.63	0.37	0.27	0.35	0.12	0.19

formed into a small ctenoid scale (Fig. 5A). Not all scales develop spines at the same stage; by 10.2 mm, scales have 1–3 spines (Fig. 5B). Three spines appear to be present on all scales by 23.0 mm. A row of larger spines appear on the ventral surface between the anus and the pelvic fins by 7.2 mm and form the characteristic ventral scutes of juveniles and adults by 15.0 mm.

**Pigmentation** Pigmentation in preflexion *Optivus* larvae is moderate and concentrated on the dorsal surface of the gut, as well as the dorsal and ventral surfaces of the trunk. Pigment is absent from the posteriormost 5–6 myomeres (including the notochord tip) as in *Paratrachichthys* and *Aulotrachichthys*. During flexion, the entire body and head become moderately pigmented and the dorsal surface of the gut becomes heavily pigmented. The entire body and head is evenly pigmented in the largest specimen (23.0 mm, Fig 4E). The pelvic fins are moderately pigmented by 4.7 mm; the pigment contracts towards each base during flexion and disappears by 23.0 mm.

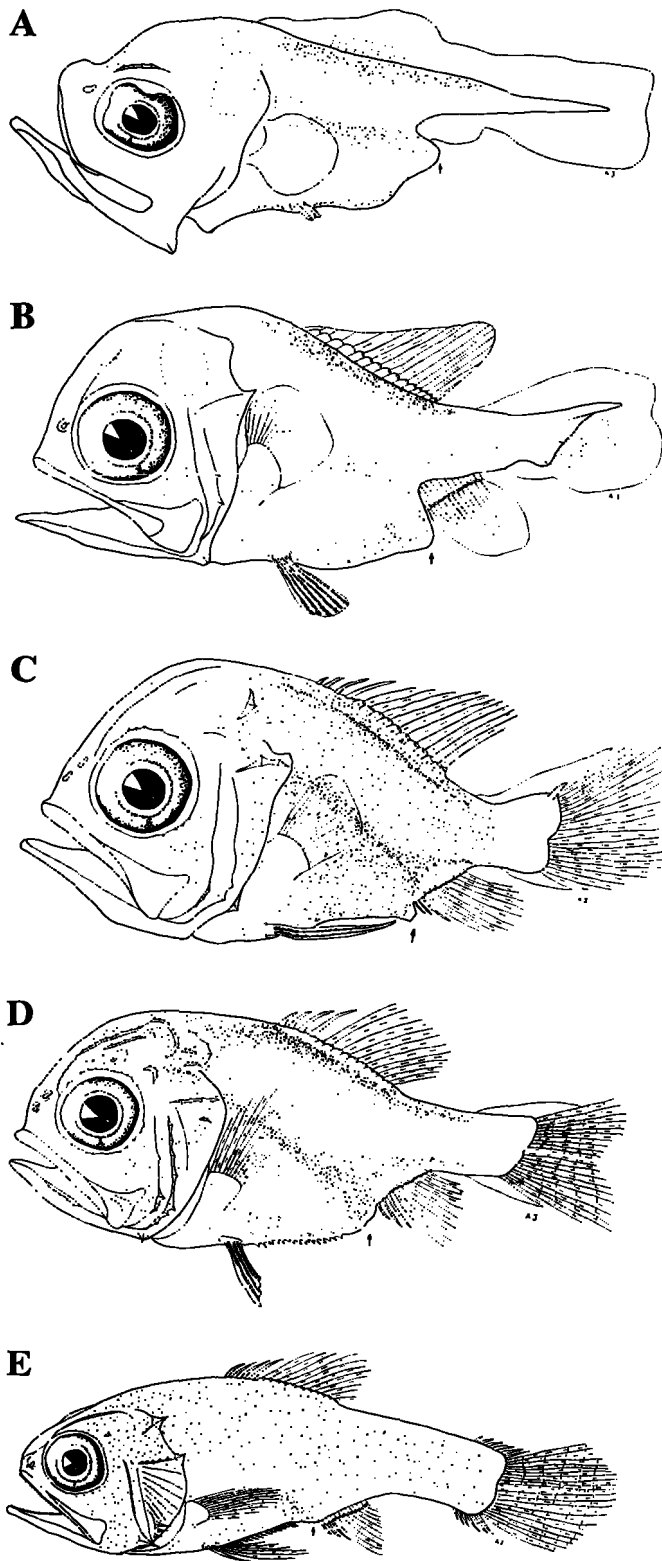
## Discussion

Considerable confusion exists in the systematics of beryciform fishes at the species level. Current classifications are based almost entirely on adult characters.

Keene & Tighe (1984) noted the usefulness of including early-life-history characters in these studies, but the lack of such data at that time for ten of the beryciform families precluded an adequate appraisal. The three genera featured here together share characters common to other described trachichthyid larvae, including moderate to heavy pigment, a moderate to large mouth, a stocky body form, precociously-developing and heavily-pigmented pelvic fins, cranial ridges, opercular spination, and a myomere count of 26–30. Pelvic-fin pigmentation is most pronounced in *Aulotrachichthys* and *Paratrachichthys* and is least developed in *Optivus*. Dermal spination is well developed in *Aulotrachichthys* and *Optivus*, although absent in *Paratrachichthys*. Cranial ridges and opercular spines are present in all of our series; however, *Aulotrachichthys* develops by far the most pronounced head spination of the three and perhaps of any reported trachichthyid larva.

Small trachichthyid larvae can be confused with zeids and some gadoid larvae that also have precocious, heavily-pigmented pelvic fins. However, zeid larvae are more evenly pigmented, have pigment extending into the finfolds in small larvae, generally have a higher myomere count (29–42, Tighe & Keene 1984), and have a more tightly coiled gut with consequently a longer postanal length. The sequence in which fin-ray ele-





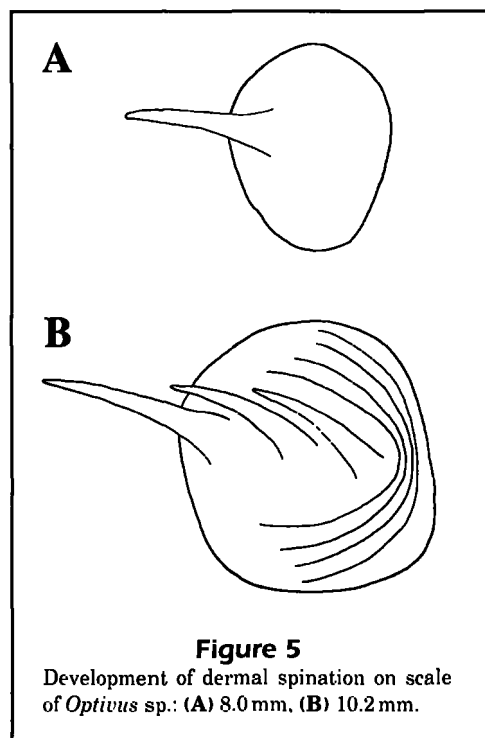
**Figure 4**

Development stages of *Optivus* sp.: (A) 3.4 mm, (B) 4.7 mm, (C) 5.1 mm, (D) 7.2 mm, (E) 23.0 mm (note: scale spination not figured). Arrows indicate location of anus.

ments form also distinguishes zeid larvae. In zeid larvae examined during this study, the anteriormost bases and rays were the first dorsal-fin elements to form. In trachichthyids, however, the middle or posterior elements are the first to form. When present, supraocular spination was also a useful feature to distinguish trachichthyids from zeids (zeids examined did not develop supraocular spines until after flexion). Although this may be useful locally, some zeid species (e.g., *Zeus faber*) have supraocular spines at sizes similar to trachichthyid larvae (Sanzo 1931). Larger zeid larvae are easily distinguished from trachichthyid larvae by their longer dorsal- and anal-fin bases, often with elongate anterior rays, a larger mouth, and a rhomboid, laterally-compressed body shape.

Small gadoid larvae with precocious, heavily-pigmented pelvics (e.g., *Gaidropsarus*) differ from trachichthyids in having a higher myomere count (>40), pelvics set higher on the body, and a more slender post-anal body form. Larger gadoid larvae are easily distinguished by morphology, fin meristics, and pigment (see Dunn & Matarese 1984, for details).

*Hoplostethus* species, and in particular orange roughy *H. atlanticus*, are by far the most abundant trachichthyids in Tasmanian waters. Despite extensive sampling throughout the year covering pelagic environments from nearshore to mesopelagic and epipelagic zones (see Thresher et al. 1989, for details), no larvae of the genus *Hoplostethus* have been identified. New Zealand researchers also have been unable to locate *H. atlanticus* larvae (Pankhurst & Conroy 1987), even though spawn-



**Figure 5**

Development of dermal spination on scale of *Optivus* sp.: (A) 8.0 mm. (B) 10.2 mm.

ing aggregations have been located (Beardsell 1984)

The 26 mm *Hoplostethus atlanticus* specimen, caught in a demersal trawl at 400–950 m off St. Patricks Head, eastern Tasmania (CSIRO H1141), represents the smallest *H. atlanticus* reported to date (Fig. 6). Kotlyar (1984) previously recorded a 36 mm *H. atlanticus* taken by bottom trawl in the Atlantic Ocean at a depth of 965–990 m. The

26 mm juvenile has characters that are common to the other trachichthyids identified, such as a deep body, large mouth, cranial ridges and opercular spination, heavily-pigmented gut and pelvic fins, and distinct anal- and dorsal-ray bases. It is highly likely that such characters are retained in the larvae of *H. atlanticus*, and *Hoplostethus* larvae in general.

Several scenarios may explain why *Hoplostethus atlanticus* larvae have not yet been located.

1 Bimonthly sampling frequency is too coarse to capture larvae during their pelagic stage. Although this cannot be discounted due to the lack of information on larval duration, the likelihood of completely missing all larvae seems low.

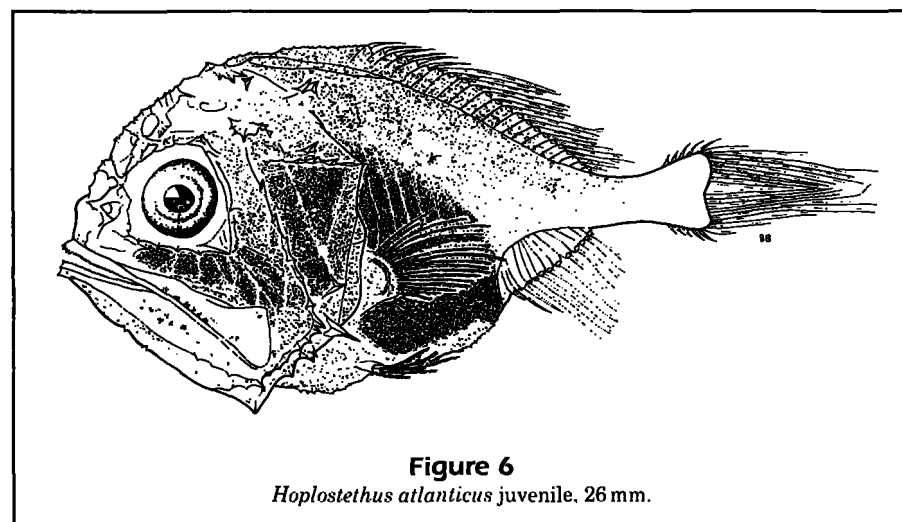
2 Larvae occur further off the shelf or slope than sampled (>18 km from the shelf break).

3 Larvae may occur in greater depths than those sampled in 'standard' ichthyoplankton surveys. This may be the most reasonable scenario, and has previously been suggested by Kotlyar (1984) for *Hoplostethus* less than 15–19 mm (based on the capture of three *H. melanopterus* juveniles 15.0–18.2 mm in Isaacs Kid trawls at 1000–1500 m in the Sulu Sea). Larvae may also occur close to the bottom on the continental slope, as supported by the capture of our 26 mm specimen and that by Kotlyar (1984).

*Hoplostethus atlanticus* adults occur in depths of 500–1200 m (May & Maxwell 1986). Spawning has been confirmed from both the east coast of Tasmania (Lyle et al. 1989) and New South Wales (Williams 1989). *Hoplostethus atlanticus* eggs (2.12–2.45 mm in diameter with a conspicuous orange oil droplet) have been collected in plankton tows above 400 m in Tasmanian (Lyle et al. 1989) and New Zealand waters (Beardsell 1984), and are presumably buoyant. The lack of larvae in surface waters, however, suggests that egg density, the presence of a thermocline, or a combination of both factors may confine eggs and larvae to deep water. Although deep-water plankton sampling is logistically more difficult than shallow-water sampling, such sampling should be carried out if we are to fully understand the early life histories of certain deep-water species.

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**Figure 6**

*Hoplostethus atlanticus* juvenile, 26 mm.

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