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Ontogenetic Larval Characters of Three Leiognathid Species in Kagoshima Bay, Southern Japan

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Abstract A total of 13,597 leiognathid larvae collected from 303 larval net collections in Kagoshima Bay during October 1983 and October 1990 were examined and sorted into three species. The larvae of *Leiognathus rivulatus* (12,677 specimens, 1.2–5.6 mm SL) and *L. nuchalis* (420 specimens, 1.1–4.4 mm SL) were distinguished from each other mainly by the following characters: in larvae less than about 3.0 mm SL, elongated (*L. rivulatus*) or dot- or wedge-shaped (*L. nuchalis*) melanophores along the ventral contour of the tail; in larvae larger than about 3.0 mm SL, presence (*L. nuchalis*) or absence (*L. rivulatus*) of melanophores on the head above the eye. Larvae of the third species (500 specimens, 1.0–3.5 mm SL) were easily recognised by the presence of a melanophore at the symphysis of the lower jaw, being tentatively classified as *L. elongatus* owing to their morphological similarity to the genus *Leiognathus* and the common occurrence of adult *L. elongatus* in Kagoshima Bay.

The family Leiognathidae comprises three genera (*Leiognathus*, *Gazza* and *Secutor*) with at least 30 nominal species (Seigel, 1982). According to Senou (1993), two genera and nine species of Leiognathidae occur around Japan, three of these (*L. rivulatus*, *L. nuchalis* and *L. elongatus*) being reported as adults from Kagoshima Bay (Imai and Nakahara, 1969). The larvae of three Japanese leiognathid species have been described. Mito (1966) described two *L. rivulatus* larvae (2.70 and 6.60 mm in total length) from the Seto Inland Sea and Kinoshita (1988) described the larvae of *L. rivulatus*, *L. nuchalis*, and a third species collected from the Ryukyu Islands and believed to be *G. minuta*.

From 1983 to 1993, the Laboratory of Fisheries Biology, Faculty of Fisheries, Kagoshima University, conducted ichthyoplankton surveys in Kagoshima Bay, leiognathid larvae being among the 20 most abundant taxa in most years. In this paper, the early ontogenies of *L. rivulatus*, *L. nuchalis* and *L. elongatus* (tentative identification) are described, including reliable diagnostic characters.

Materials and Methods

The specimens used in this study were collected in Kagoshima Bay fortnightly or monthly from October 1983 to October 1990 by the R/V *Shiranami* (1.5 tons), principally at 14 fixed stations (Fig. 1). In total, 1171 collections from 93 cruises were available for the study.

A cylindrical-conical type net (1.3 m diameter) was towed in step hauls using 50 and 100 m rope lengths (5 min for each) at a speed of about 2 knots. The samples were fixed in approximately 5% buffered sea water formalin immediately after collection, the larvae later being sorted and preserved in 70% ethyl alcohol in the laboratory. A total of 13,597 leiognathid larvae were identified to species. In addition, two *L. rivulatus* (4.6 and 4.7 mm SL) and three *L. nuchalis* (5.5, 7.0 and 12.0 mm SL) (collected from oceanic and estuarine waters of Tosa Bay, southern Japan, respectively) were borrowed from Dr. I. Kinoshita, Marine Fisheries Laboratory, Faculty of Agriculture, Kyoto University, for comparative purposes.

The larvae were examined under a dissecting microscope and measured using an ocular micrometer. Some larvae were stained with methylene blue for clear observation of spines and fin rays. Standard lengths (SL) were measured from the tip of the snout to the end of the notochord.

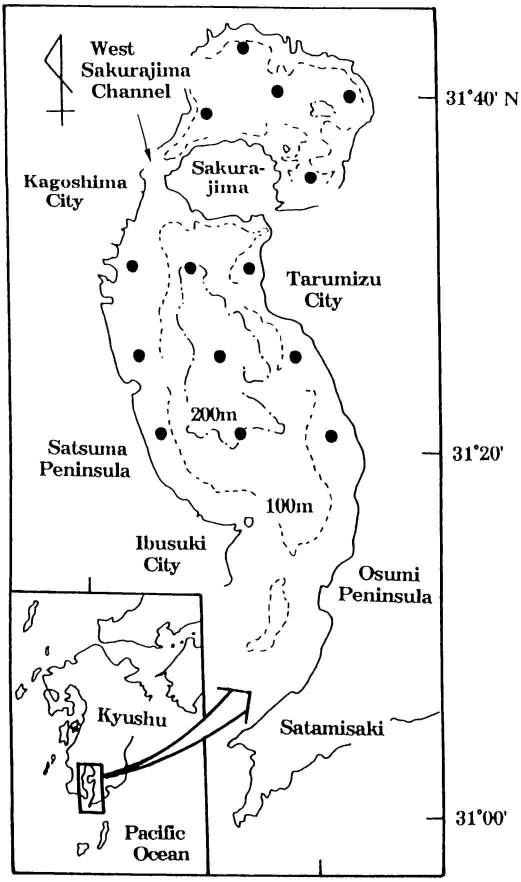

Fig. 1. Ichthyoplankton sampling stations in Kagoshima Bay.

Results

Identification

Most of the following characters of leiognathid larvae were given by Kinoshita (1988) and Leis and Trnski (1989): 23–25 myomeres; body moderate to deep, strongly compressed laterally; large, round head; small mouth; preanal length short, less than 50% of SL; a series of spines on inner and outer edges of preopercle; supraoccipital crest and supraocular ridge with spines; large ascending premaxillary process; body lightly pigmented; a row of small pigments on ventral contour of tail. These characters enabled complete separation of leiognathid larvae from other ichthyoplankton in the samples.

Leiognathid larvae occurred in 303 collections (38 cruises), being mainly small specimens, 1.0–5.6 mm SL, which could not be accurately classified using only the diagnostic characters given by Kinoshita (1988). After careful examination, they were here assigned to three species: *Leiognathus rivulatus*, *L. nuchalis*, and tentatively *L. elongatus*.

Common features of early ontogeny

Together with meristic characters, leiognathid larvae, especially those of the genus *Leiognathus*, are very similar to each other in appearance. Therefore, the characters common to the early ontogeny of the present species are given below, with those peculiar to each species in that species description.

Early ontogeny progresses rapidly. The smallest larvae examined were about 1.0 mm SL, being already devoid of yolk. Notochord flexion began at about 3.0 mm SL, ending at about 4.0 mm SL. According to Leis and Trnski (1989) all of the fin rays are formed at about 10.0 mm SL.

Body form.—Body strongly compressed laterally. Tail slender before notochord flexion, deep thereafter (Figs. 2, 4, 5). Head large, about 30% of SL, remarkably rounded; forehead wide before completion of median fin rays (about 5.0 mm SL), moderate thereafter (Figs. 2, 4, 5). Eyes large, round in smaller larvae (46% of HL at about 2.0 mm SL), becoming moderate in larger larvae (26% of HL at 5.5 mm SL). Mouth small, never exceeding a vertical from anterior edge of eye, extremely protrusible; a large, conspicuous ascending premaxillary process developing prior to notochord flexion.

Teeth.—Teeth developing on both jaws at about 3.0 mm SL, remaining small throughout early ontogeny.

Head spination.—Small to moderate spines developing progressively on preopercle, supraoccipital crest, supraocular ridge, supracleithrum, posttemporal (Figs. 2 and 4). Outer edge of preopercle bearing spines in smallest larvae; largest spine at angle, thereafter size decreasing upwards and anteriorly. Small, equally-sized inner spines appearing on surface of preopercle at about 1.5 mm SL. Spines appearing on supraoccipital crest at about 2.0 mm SL, subsequently increasing in number. A few, inconspicuous spines appearing on supraocular ridge in specimens greater than 2.0 mm SL. A small spine developing on supracleithrum at about 3.0 mm SL, subsequently increasing in number (a few only) (Leis and Trnski, 1989). A small posttemporal spine appearing at about 3–4mm SL.

All of the spines progressively degenerate after the beginning of the juvenile stage (Leis and Trnski, 1989).

Fin formation.—No significant differences in fin formation were found among the present species.

Principal rays (9+8) of caudal fin completed at about 4.0 mm SL. Spines and rays of dorsal (VIII, 16) and anal (III, 14) fins completed at about 5.0 mm SL (*L. rivulatus* and *L. nuchalis*). Pectoral fin rays (16–21) completed at about 7.9–10.5 mm SL (Leis and Trnski, 1989), not observed in the present, smaller-sized larvae. Pelvic fin rays completed at 8.6–10.0 mm SL (Leis and Trnski, 1989), their anlagen not observed in the present larvae.

Pigmentation.—Body lightly pigmented (Figs. 2, 4 and 5). Small melanophores in a series along ventral contour of tail, varying in number, size and shape with development and among species; all embedded in younger larvae, subsequently dividing into three parts. Anteriormost three to five melanophores remain embedded, disappearing prior to notochord flexion (about 3.0 mm SL). Posteriormost melanophores on caudal peduncle differing in number among species, moving partially onto anal finfold just before notochord flexion, thereafter becoming embedded and fixed in number. Remaining melanophores along anal fin base moving completely onto anal finfold, thereafter gradually decreasing in number and changing shape as anal fin develops. After loss of melanophores on anal fin spines, a single melanophore only associated with each soft ray pterygiophore (fixed number of melanophores along ventral contour of tail 14 (i.e., number of soft rays) + number of melanophores on caudal peduncle – fixed at onset of notochord flexion). A single, distinct melanophore present at angle of lower jaw and cleithral symphysis. Pigment also present above gas bladder, above and below anus, and at middle of ventral contour of abdomen. A few melanophores on finfold below tip of notochord, being slightly larger than those along ventral contour of tail, become located on base of lower caudal fin rays after flexion.

Leiognathus rivulatus (Temminck and Schlegel) (Fig. 2)

Materials examined. 12,677 specimens, 1.2–5.6 mm SL, from Kagoshima Bay and 2 of 4.6 and 4.7 mm SL, from Tosa Bay.

Diagnostic characters. No pigmentation on lower jaw symphysis; preflexion larvae with vertically elongated melanophores along ventral contour of tail; no melanophores on head above eye in flexing and postflexion larvae; postflexion larvae with one or two spines on supraocular ridge and flat melanophores along anal fin base.

Early ontogeny. Supraocular ridge bearing one or two spines in largest larvae, the first appearing at about 2.2 mm SL, and (usually) a second at greater than 4.5 mm SL (Fig. 3). Two spines present on outer margin of preopercle in smallest larvae (1.2 mm SL), subsequently increasing to nine. Two spines appearing on inner margin of preopercle at about 1.5 mm SL, remaining unchanged throughout development. A few spines developing on supraoccipital crest at about 2.0 mm SL, being uniformly pointed upwards; subsequently increasing in number but decreasing in relative size: four at 2.2 mm SL, seven at 2.7 mm, eight or nine at 3.2 mm and nine or ten beyond 5.0 mm. A single supracleithral spine appearing at about 3.0 mm SL, two at 5.6mm SL.

Melanophores along ventral contour of tail thin and vertically elongated until beginning of notochord flexion. Prior to notochord flexion, anteriormost four or five melanophores disappear, middle melanophores moving to anal finfold, becoming slightly thickened, remaining five to seven melanophores on caudal peduncle moving partially onto anal finfold. During simultaneous occurrence of notochord flexion and appearance of anal fin base, middle melanophores flatten, those on caudal peduncle becoming re-embedded. In postflexion larvae, middle melanophores enlarge and flatten, being located at anal fin pterygiophores; posteriormost elongated melanophores becoming closely crowded. Number of ventral melanophores decreasing as follows: 44–34 at 1.2–2.0 mm SL, 34–25 at 2.0–3.0 mm SL, 31–22 at 3.0–4.0 mm SL and 26–19 at 4.0–5.6 mm SL (Fig. 3). Since the fixed number of ventral melanophores is theoretically 19 to 21 (comprising 14 on anal soft ray bases plus 5 to 7 on caudal peduncle), such were not finalised in some larvae of 4.0–5.6 mm SL in the present material (Fig. 3). A small, internal melanophore appearing on occiput at about 1.5 mm SL, becoming invisible due to covering of muscle beyond 2.0 mm SL. At about 5.0 mm SL, a single melanophore appearing at upper edge of

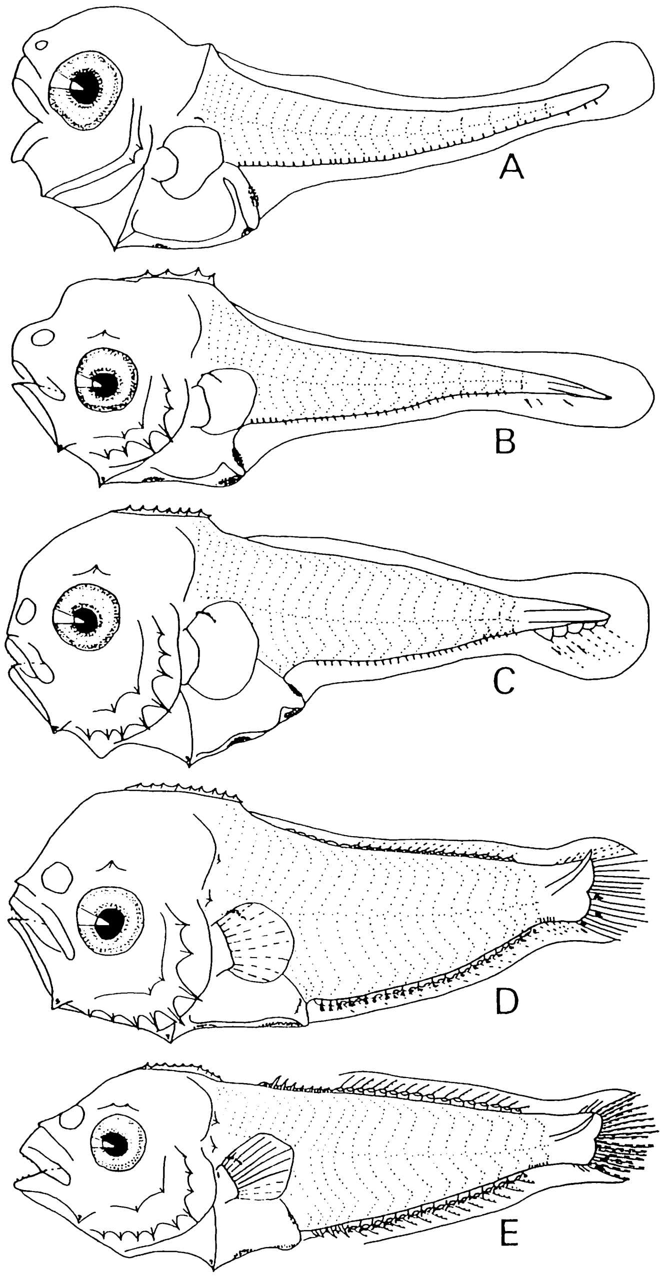

Fig. 2. Larvae of *Leiognathus rivulatus.* A) 1.2 mm SL; B) 2.2 mm SL; C) 2.7 mm SL; D) 3.2 mm SL; E) 5.0 mm SL.

pectoral fin base.

Two specimens, 4.6 and 4.7 mm SL from Tosa Bay were identical with those of Kagoshima Bay in all characters, especially in lacking melanophores at the lower jaw symphysis and above the eye, and having one or two supraocular spines, and 26 and 22 (not complete—see above) melanophores along the ventral contour of the tail, comprising 19 and 15 flattened melanophores along the anal fin base, respectively, and 7 embedded, elongated melanophores on

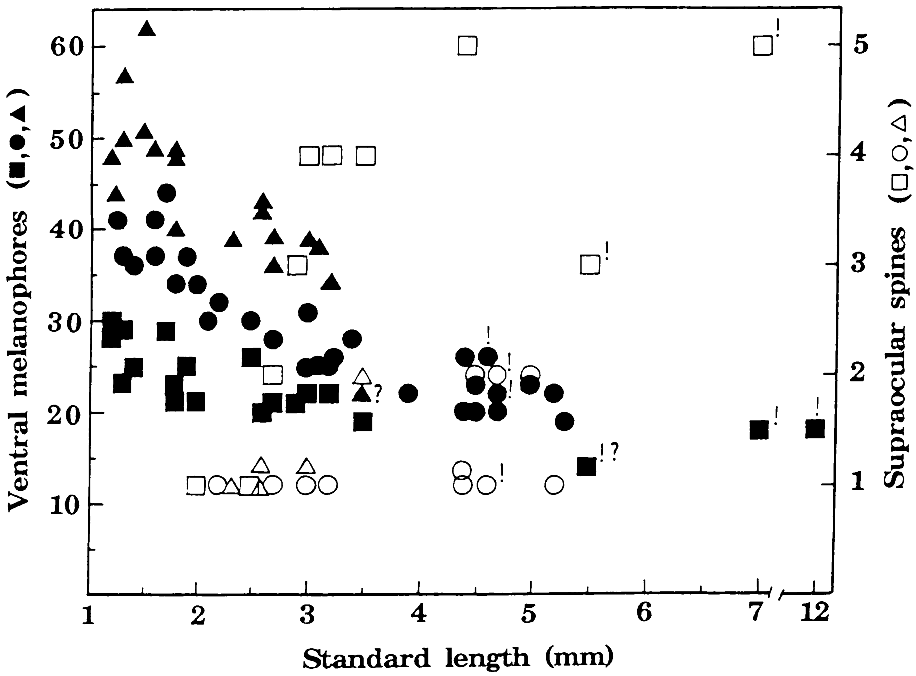

Fig. 3. Number of melanophores on ventral contour of tail and supraocular spines in relation to standard length in three *Leiognathus* species. Symbols: *L. nuchalis* (■,□); *L. rivulatus* (●,○); *L. ?elongatus* (▲,△); exclamation marks, reference specimens (see text); partially damaged specimens(?).

the caudal peduncle.

Leiognathus nuchalis (Temminck and Schlegel)
(Fig. 4)

Materials examined. 420 specimens, 1.1–4.4 mm SL, from Kagoshima Bay and 3 of 5.5, 7.0 and 12.0 mm SL, from Tosa Bay.

Diagnostic characters. No pigmentation on lower jaw symphysis; preflexion larvae with dot- or wedge-shaped melanophores along ventral contour of tail; a few melanophores on head above eye during and after flexion; postflexion larvae with five spines on supraocular ridge and slightly embedded, wedge-shaped melanophores along anal fin base.

Early ontogeny. Supraocular ridge bearing five inconspicuous spines in largest larvae, the first appearing at about 2.0 mm SL, two at about 2.5 mm SL, four at 3.0 mm SL and five at greater than 4.0 mm SL (Fig. 3). Three spines on outer margin of preopercle in smallest larvae (1.1 mm SL), subsequently increasing to nine. Two spines appearing on inner margin of preopercle at about 1.5 mm SL, remaining unchanged. A few spines developing on supraoccipital crest at about 2.0 mm SL, being upwardly pointed and larger posteriorly; subsequently increasing in number but decreasing in relative size: four at 1.9 mm SL, seven at 2.7 mm SL, eight at 3.0 mm SL and ten at greater than 4.4 mm SL. Irrespective of these changes, the supraoccipital spines are larger than those of *L. rivulatus* (Figs. 2 and 4) throughout development.

At preflexion, melanophores along ventral contour of tail dot-shaped (less than about 2.0 mm SL), thereafter wedge-shaped. Prior to notochord flexion, anteriormost three or four melanophores disappear, middle melanophores moving to anal finfold, remaining three to four melanophores on caudal peduncle enlarging (remaining dot-shaped) and moving partially onto anal finfold. After completion of flexion, middle wedge-shaped melanophores enlarge, being partially embedded at the anal fin pterygiophores; slightly elongated, posteriormost melanophores become re-embedded, being moderately separated. Number of ventral melanophores decreasing as follows: 30–21 at 1.1–2.0 mm SL, 26–20 at 2.0–3.0 mm

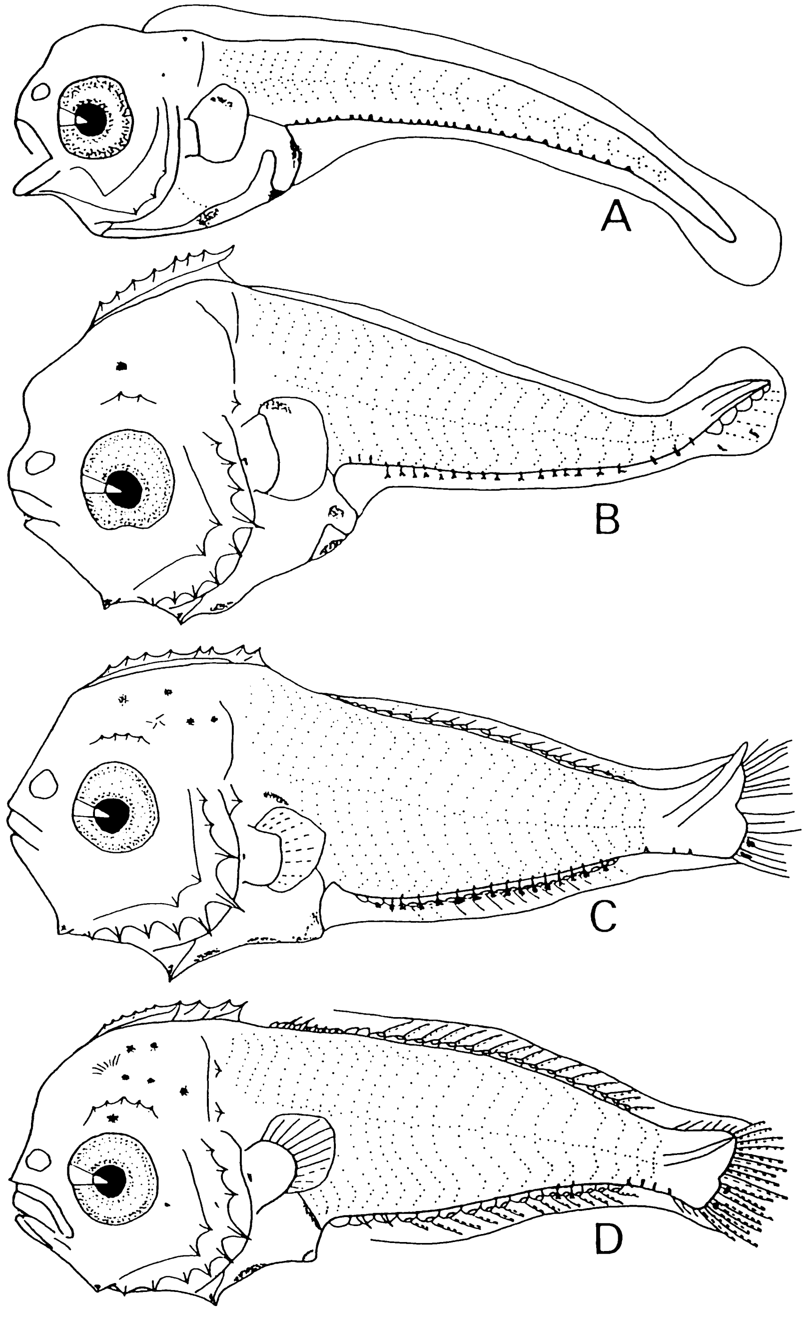

Fig. 4. Larvae of *Leiognathus nuchalis.* A) 1.2 mm SL; B) 2.7 mm SL; C) 3.4 mm SL; D) 4.4 mm SL (melanophores on anal fin base partially damaged).

SL, 22–19 at 3.0–4.0 mm SL (damaged in Fig. 4D) and 18–17 beyond 7.0 mm SL (Fig. 3). Since the fixed number of ventral melanophores is theoretically 17 or 18 (comprising 14 on anal soft ray bases plus 3 or 4 on caudal peduncle), such were not finalised in any Kagoshima Bay specimens (maximum size 4.4 mm SL), but were so in the 7.0 mm larva and 12.0 mm juvenile from Tosa Bay (Fig. 3). A minute

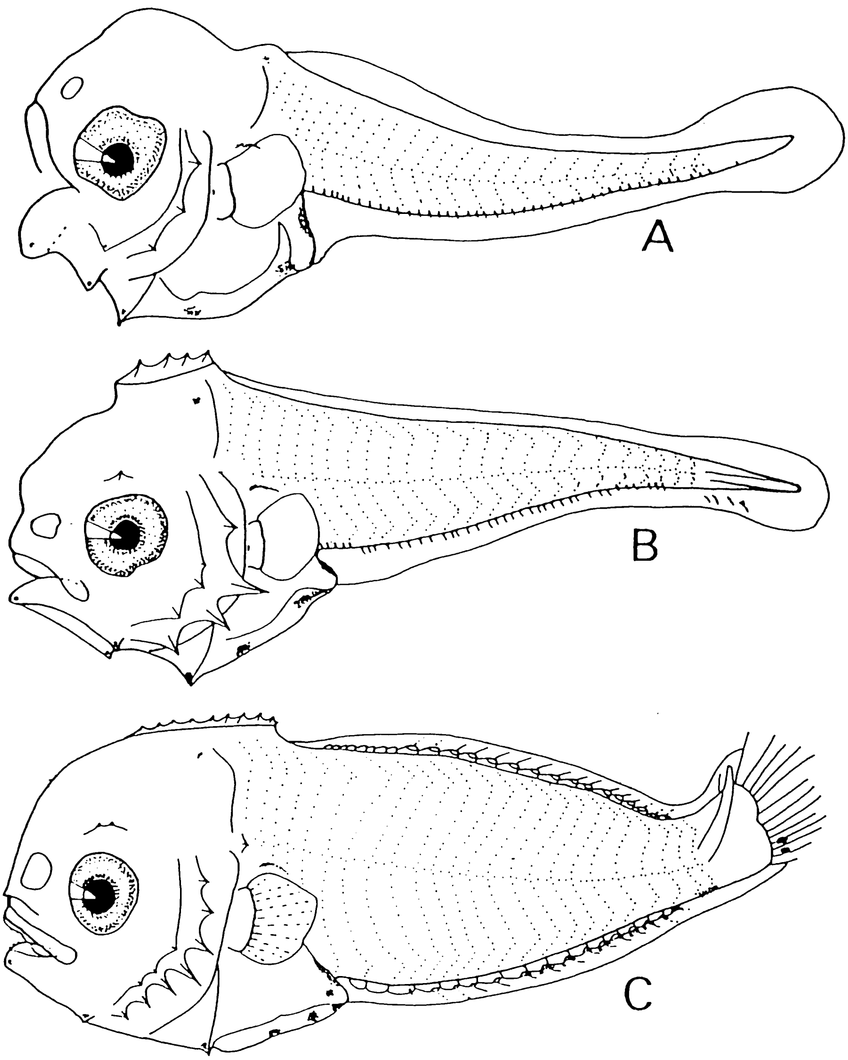

Fig. 5. Larvae of *Leiognathus ?elongatus.* A) 1.2 mm SL; B) 2.3 mm SL; C) 3.5 mm SL.

melanophore appearing on occiput above hind brain in smallest larvae (about 1.0 mm SL), disappearing beyond 1.5 mm SL. A single melanophore appearing on mid-lateral portion of brain at about 2.2 mm SL, subsequently increasing to about seven, both externally and internally over mid- and hind-brain. At about 2.5 mm SL, a single small melanophore appearing on middle of pectoral fin base, remaining throughout early ontogeny. A few small melanophores appearing on cheek at about 4.4 mm SL.

Of the three Tosa Bay specimens, the 5.5 mm SL larva possessed 14 inconspicuous, wedge-shaped melanophores along the anal fin base, but three instead of five supraocular spines, and lacked melanophores above the eye and black spots on the dorsal spines. Since the possibility exists that the supraocular spines and melanophores above the eye were damaged, this larva was recorded as *L. nuchalis*, owing to the presence of wedge-shaped melanophores along the anal fin base. The 7.0 mm SL larva and 12.0 mm SL juvenile bore the adult character of black spots on the dorsal fin spines, the former being identical with Kagoshima Bay *L. nuchalis* larvae in all characters. In addition, the juvenile specimen possessed many melanophores on the head and body, including both jaws, along the isthmus, and over the cheek and lateral surface of the body, but retained the larval character of 14 wedge-shaped melanophores along the anal fin base and four embedded, slightly elongated melanophores on the caudal peduncle. The supraocular spines had disappeared.

Leiognathus ?elongatus (Günther)
(Fig. 5)

Materials examined. 500 specimens, 1.0–3.5 mm SL, from Kagoshima Bay.

Diagnostic characters. A small melanophore present on lower jaw symphysis.

Early ontogeny. Supraocular ridge bearing two spines in 3.5 mm SL larvae (larger specimens unavailable), the first appearing at about 2.3 mm SL, two at greater than 3.0 mm SL (Fig. 3). Three spines on outer margin of preopercle in smallest larvae (1.0 mm SL), subsequently increasing to seven. Two spines appearing on inner margin of preopercle at about 1.5 mm SL, usually a third at greater than 2.3 mm SL. A few spines developing on supraoccipital crest at about 2.0 mm SL, being uniformly pointed upwards; subsequently increasing in number but decreasing in relative size: four at 2.3 mm SL, six at 2.6 mm SL, eight at 3.0 mm SL and nine at 3.5 mm SL.

The melanophores along ventral contour of tail are thin and vertically elongated on preflexion larvae, and the number is the highest among the present three species (Fig. 3). Prior to notochord flexion, anteriormost four or five melanophores disappear, middle melanophores moving to anal finfold, remaining seven to ten melanophores on caudal peduncle moving partially onto anal finfold. At about completion of notochord flexion, middle melanophores widen, becoming flattened, being located along anal fin base. Those on caudal peduncle shorten, becoming embedded and closely crowded. Embedded melanophores on caudal peduncle inconspicuous from lateral view, clearly visible ventrally. Number of ventral melanophores decreasing as follows: 62–40 at 1.0–2.0 mm SL, 43–36 at 2.0–3.0 mm SL and 39–34 at 3.0–3.2 mm SL (Fig. 3). Since the probable fixed number of ventral melanophores is theoretically 21 to 24 (comprising 14 on anal soft ray bases plus 7 to 10 on caudal peduncle), such were not finalised on any of the specimens (Fig. 3). The most developed larva (3.5 mm SL) (Fig. 5C) possessed seven melanophores on the caudal peduncle but only 15 along the posterior half of the anal fin base, most of the anterior half having apparently been damaged. A small, diagnostic melanophore present on the lower jaw symphysis in the smallest larvae (1.0 mm SL); present also in the largest (3.5 mm SL) specimen. At about 1.5 mm SL a second melanophore appearing at lower jaw symphysis in a few larvae, coalescing with initial melanophore at greater than 2.0 mm SL. A small, inconspicuous melanophore in middle of pectoral fin peduncle base on larvae smaller than 2.6 mm SL. A melanophore on occiput in smallest larvae examined (1.0 mm SL), subsequently enlarging, moving internally to above hind brain; still present in 3.5 mm SL specimen.

Discussion

In this study, the larvae of *Leiognathus rivulatus* and *L. nuchalis* were distinguished from each other using the characters summarized in Table 1. In addition, the melanophores along the ventral contour of the tail were apparently more numerous in *L. rivulatus* than in *L. nuchalis*. The larvae thus identified were classified to each species with the direct

Table 1. Sequence of diagnostic characters during early ontogeny of *Leiognathus rivulatus* and *L. nuchalis*. Diagnostic characters: A) shape and location of melanophores along ventral contour of tail; B) occurrence of melanophores on brain; C) number of supraocular spines

Standard length, mm		2		3	4
L. rivulatus	A	Elongated →		|	| Flat-shaped and external →
	B		| Absent →		
	C				| One or two →
L. nuchalis	A	Dot, then wedge shaped →			| Internal →
	B		| Present →		
	C				| Five →

comparison of the larvae classified by and borrowed from Dr. I. Kinoshita.

On the basis of the above results, Mito's (1966) two specimens (2.70 and 6.60 mm TL) described as *L. rivulatus* may have been *L. nuchalis*, since the melanophores along the ventral contour of tail were dot-shaped in the 2.70 mm larva and clearly internally positioned in the other, although melanophores above the eye were not mentioned and only two supraocular ridge spines were described (see below).

The classification of *L. nuchalis* and *L. rivulatus* in the present study followed that of Kinoshita (1988), with a direct comparison of larvae after completion of notochord flexion. The following differences between the present descriptions and those of Kinoshita (1988), inclusive of Mito (1966), are as follows: whereas the present study showed a maximum of five supraocular ridge spines in *L. nuchalis*, only two were described by Kinoshita and Mito (as *L. rivulatus*); supraoccipital ridge spines differed in shape between the two species in the present study, but were not so described by Kinoshita; melanophores above the eye of *L. nuchalis* were not mentioned by Kinoshita or Mito; specific differences in the number and shape of melanophores along the ventral contour of the caudal peduncle were not mentioned by Kinoshita; and the ratio of body depth/standard length was not used in the present study. Except for the last, the differences appeared due mainly to less than critical observation, since five supraocular ridge spines and melanophores above the eye were discernable (although with difficulty in the case of the former) both on the present and Kinoshita's larvae of *L. nuchalis*. Body proportion differences were not used in this study due to the variability between specimens and the presence of more reliable morphological characters.

Direct preflexion larval comparisons were not made between Kinoshita's (1988) material and the present specimens. Kinoshita (1988) illustrated a 3.0 mm SL larval *L. rivulatus*, describing the diagnostic characters as being about 30 dot-shaped melanophores along the ventral contour of the tail. Two larval *L. nuchalis* (2.9 and 3.3 mm SL) were described as having about 40 wedge-shaped melanophores. In the present study, the melanophores along the ventral contour of the tail were considered to be elongated in *L. rivulatus* and dot- or wedge-shaped in *L. nuchalis*, being more numerous in the former species. This indicated a subjective difference in the description of melanophore shape between the two studies. In Kinoshita's (1988) figures melanophores of a 2.9 mm SL larva classified as *L. nuchalis* appeared either elongated or wedge-shaped, being more numerous than those on a 3.0 mm SL larva classified as *L. rivulatus*. If in fact elongated, the melanophores indicated that the 2.9 mm SL larva should be regarded as *L. rivulatus*, and conversely, the 3.0 mm SL larva as *L. nuchalis*. The melanophores along the ventral contour of the tail of a 3.3 mm SL larva (figured as *L. nuchalis*) also appeared either elongated or wedge-shaped, but numbered only 21, indicating the larva to have most probably been *L. nuchalis*.

Although diagnostic characters exist for the above species care should be taken in the identification of larvae, because owing to the difficulty in discerning some characters, such as the supraocular ridge spines. Others, such as the melanophores along the ventral contour of the tail were incomplete in all larvae examined due to damage.

Larvae of the third species were tentatively classified as *L. elongatus* on the basis of their apparently belonging to the genus *Leiognathus* and the occurrence of adults of that species in Kagoshima Bay. Although leiognathids comprise three genera and at least 30 species (Seigel, 1982), larvae have been described for only three *Leiognathus* species and two others unnamed (Kinoshita, 1988; Leis and Trnski, 1989). The angular spine on the outer edge of the preopercle is smooth and moderately long in the former, but serrated and remarkably long in the latter, which seems to indicate a generic difference, as suggested by Kinoshita (1988). The larvae determined as *L. ?elongatus* have a smooth, moderately long angular spine. Imai and Nakahara (1969) reported three *Leiognathus* species, *L. rivulatus*, *L. nuchalis* and *L. elongatus*, from Kagoshima Bay. Recently Ozawa (1993) interviewed Kagoshima Bay fishermen regarding leiognathid fishes. Most fishermen mentioned adults of *L. elongatus* being sometimes caught en masse, instead of the target species *L. rivulatus*, with a single reference to the apparent occurrence of *L. fasciatus*.

Acknowledgments

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鹿児島湾におけるヒイラギ科3種の初期発育における形態的特徴

Muhammad M. Haque・小沢貴和

鹿児島湾において1983年から1990年にかけて行なった稚魚ネットによる303回の採集で13,597尾のヒイラギ科仔魚が採集され，3種が識別された．オキヒイラギ（体長1.2–5.6 mmの12,677尾）とヒイラギ（1.1–4.4 mmの420尾）仔魚は主に以下の特徴により識別された：体長約3.0 mm以下では，尾部腹面に沿う色素胞がオキヒイラギでは棒状，そしてヒイラギでは点あるいは楔状；体長約3.0 mm以上では，頭部眼上に色素胞がヒイラギでは存在し，オキヒイラギでは欠如する．三番目の仔魚（体長1.0–3.5 mmの500尾）は下顎癒合部に色素胞を有することにより識別され，ヒイラギ属に類似した形態と鹿児島湾での成魚の普遍的出現をもとに確定的ではないがヒメヒイラギと同定された．

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