LARVAL DEVELOPMENT OF PACIFIC TOMCOD, *MICROGADUS PROXIMUS*, IN THE NORTHEAST PACIFIC OCEAN WITH COMPARATIVE NOTES ON LARVAE OF WALLEYE POLLOCK, *THERAGRA CHALCOGRAMMA*, AND PACIFIC COD, *GADUS MACROCEPHALUS* (GADIDAE)

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ABSTRACT

A developmental series from yolk-sac larvae through juveniles (2.7-46.6 mm SL) of *Microgadus proximus* from the northeast Pacific Ocean is described and illustrated. Larvae hatch at approximately 2.7 mm SL and the yolk is absorbed by 3.0 mm SL. Notochord flexion begins between 8.0 and 10.0 mm SL, is completed at 15.0 mm SL, and transformation occurs between 22.0 and 28.0 mm SL. Larvae have specific pigment patterns, particularly in the postanal region where melanophores are arranged in two bars, anterior and posterior. At 5.0-6.0 mm SL, the anterior bar is located at 41-53% SL and the posterior bar is at 61-74% SL. Melanophore patterns on the head, gut, and caudal region also distinguish *M. proximus*. The occurrence of larvae taken within 18 km of shore off Oregon during plankton surveys in 1971-72 is discusssed, and data indicate a winter-spring spawning period.

A combination of pigmentation characters, primarily the length and position of the anterior and posterior pigment bars, and meristic counts can distinguish larvae of *M. proximus* from *Theragra chalcogramma* and *Gadus macrocephalus*. The anterior bar is located at 47-55% SL in *T. chalcogramma* and at 40-57% SL in *G. macrocephalus*. The posterior bar is located at 69-79% SL in *T. chalcogramma* and at 59-81% SL in *G. macrocephalus*. Both *T. chalcogramma* and *G. macrocephalus* have 4 rays on the superior hypural element while *M. proximus* has 5 rays. Other characters useful in separating the three species include head, gut, mediolateral, postanal, and caudal pigment and stripe continuity.

Problems have been encountered in distinguishing larvae of Pacific tomcod, *Microgadus proximus* (Girard); walleye pollock, *Theragra chalcogramma* (Pallas); and Pacific cod, *Gadus macrocephalus* (Tilesius), in samples from the northeastern Pacific Ocean where these three species might cooccur (Waldron 1972; Dunn and Naplin[3]). Larvae of *T. chalcogramma* were described by Gorbunova (1954) and Yusa (1954). Larvae of *G.* (*morhua*) *macrocephalus* larvae were described by Gorbunova (1954), Uchida et al. (1958), and Mukhacheva and Zviagina (1960). In this report we provide the first published description of the larvae of *M. proximus* and comparative material on larvae of *T. chalcogramma* and *G. macrocephalus* that should enable workers to identify larvae of these three gadids in mixed samples. Eggs and larvae of the Atlantic tomcod, *Microgadus tomcod*, were described by Booth (1967), but eggs of *M. proximus* are unknown.

The geographic range of *M. proximus* extends from off central California (Isaacson 1965) to the Gulf of Alaska and Unalaska Island (Wilimovsky 1964). Their presence in the Bering Sea remains unconfirmed, although they were reported to occur in the Bering Sea by Tanner (1894) and Hart (1973). *Microgadus proximus* was not captured in the eastern Bering Sea during extensive multivessel groundfish surveys in 1974 (Pereyra et al.[4]) or in 1976 (Bakkala and Smith[5]). *Microgadus proximus* is found from near-surface waters to ap-

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[3]Dunn, J. R., and N. A. Naplin. 1974. Fish eggs and larvae collected from waters adjacent to Kodiak Island, Alaska, during April and May, 1972. Unpubl. manuscr., 61 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[4]Pereyra, W. T., J. E. Reeves, and R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Unpubl. manuscr., Vol. 1, 619 p.; Vol. 2, 534 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

[5]Bakkala, R. G., and G. B. Smith. 1978. Demersal fish resources of the eastern Bering Sea: Spring 1976. Unpubl. manuscr., Vol. 1, 234 p.; Vol. 2, 404 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

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proximately 220 m (Miller and Lea 1972). Planktonic larvae of *M. proximus* were the dominant gadid and fourth most abundant taxon in a coastal assemblage of fish larvae occurring off Yaquina Bay, Oreg., in 1971-72 (Richardson and Pearcy 1977).

Information on the biology and taxonomy of *M. proximus* is limited. Schultz and Welander (1935) presented counts of meristic structures and morphological measurements of *M. proximus*. Svetovidov (1948), in his review of Gadiformes, provided some meristic data and a brief osteological description of *M. proximus* based on two skeletons. Brief notes on the biology of the species are included in Clemens and Wilby (1961), Miller and Lea (1972), and Hart (1973). It is not of commercial importance in part because of its small size (to 30 cm) but it is taken in recreational catches (Beardsley and Bond 1970; Hart 1973).

METHODS

Specimens

Several hundred larvae of the three species were examined in the course of this study. *Microgadus proximus* larvae and juveniles were obtained from plankton and trawl samples collected off Oregon in 1971-1973 and 1979, by the School of Oceanography, Oregon State University (OSU), Corvallis, and off Washington in 1972 by the Northwest and Alaska Fisheries Center (NWAFC). Additional specimens were obtained from plankton collected in Puget Sound, Wash., in 1977-79 by the Fisheries Research Institute (FRI), University of Washington, Seattle; and in 1978 by Ecology Consultants, Inc., Fort Collins, Colo. Larvae were also collected from near Kodiak Island, Alaska, in 1977-79 by FRI.

Theragra chalcogramma larvae were collected in the eastern Bering Sea (1971, 1976-78) and off Kodiak Island (1972, 1977-78) by NWAFC. Additional specimens from Puget Sound, Wash., (1977, 1978) were provided by FRI and by Ecology Consultants, Inc., and from off Kodiak Island (1978) by FRI.

Gadus macrocephalus larvae were collected near Kodiak Island in 1978 by NWAFC and FRI and from Puget Sound, Wash., in 1977-79 by FRI.

Radiographs were examined of juvenile and adult *M. proximus* and *G. macrocephalus* specimens in the collections in the Department of Fisheries and Wildlife, OSU, and NWAFC, and of adult *T. chalcogramma* specimens at NWAFC and from the Institute of Animal Resource Ecology, University of British Columbia, Vancouver.

Illustrations of larvae were made with the aid of a camera lucida. All specimens had been preserved in either 3-5% Formalin,[6] buffered with sodium borate, or 95% ethanol. Illustrations of caudal fin development were drawn from cleared and stained specimens.

Measurements

The following measurements were made on 72 unstained larvae and juveniles (2.7-46.6 mm SL) of *M. proximus* using an ocular micrometer in a stereomicroscope:

Standard length (SL)—Snout tip to notochord tip prior to development of caudal fin, then to posterior margin of hypural element. (All body lengths in this study are standard lengths.)

Head length (HL)—Snout tip to posterior edge of opercle (to pectoral fin base in yolk sac and very small larvae before opercular margin is visible).

Snout length—Snout tip to anterior margin of orbit of left eye.

Upper jaw length—Snout tip to posterior margin of maxillary.

Eye diameter—Greatest diameter of left orbit.

Body depth at pectoral—Vertical distance from dorsal to ventral body margin at pectoral fin base.

Body depth at anus—Vertical distance from dorsal to ventral body surface at center of anal opening.

Snout to anus—Distance along body midline from snout tip to vertical through center of anal opening.

Snout to first dorsal fin—Distance along the body midline to vertical through origin of anteriormost dorsal fin ray of first dorsal fin.

Snout to second dorsal fin—Distance along body midline to vertical through origin of anteriormost fin ray of second dorsal fin.

Snout to third dorsal fin—Distance along body midline to vertical through origin of anteriormost fin ray of third dorsal fin.

Snout to first anal fin—Distance along body midline to vertical through origin of anteriormost fin ray of first anal fin.

[6]References to trade names do not imply endorsement by the National Marine Fisheries Service, NOAA.

Snout to second anal fin—Distance along body midline to vertical through origin of anteriormost fin ray of second anal fin.

Meristic Structures

Counts of meristic structures were made on 128 stained *M. proximus* larvae and juveniles. Sixty-six specimens (3.1-41.1 mm SL) were cleared and stained with Alizarin Red S (Taylor 1967), and 62 larvae (5.1-23.4 mm SL) were stained with Alizarin Red and Alcian Blue (Dingerkus and Uhler 1977). Both series of stained samples were used to make counts of meristic structures and to determine the onset and sequence of ossification as indicated by the uptake of Alizarin Red. Structures, including teeth, were considered ossified even if only slightly stained with Alizarin Red.

Counts on stained larvae and early juveniles were made of first, second, and third dorsal fin rays, first and second anal fin rays, caudal fin rays, left pectoral and pelvic fin rays, branchiostegal rays, gill rakers, abdominal and caudal vertebrae (including the postural centrum), and neural and haemal spines. Counts were made of premaxillary and dentary teeth on 12 specimens (11.9-41.1 mm SL).

Counts of meristic structures of juveniles and adults of *M. proximus*, *T. chalcogramma*, and *G. macrocephalus* were made from radiographs. Counts were made of first, second, and third dorsal fin rays, first and second anal fin rays, caudal fin rays, and abdominal and caudal vertebrae (including the postural centrum).

IDENTIFICATION OF *MICROGADUS PROXIMUS*

A developmental series of *M. proximus* specimens ranging from late yolk-sac larvae to early juveniles was linked by pigment patterns, myomere counts, fin development, and meristic counts in larger specimens. They were identified as gadids based on three criteria: 1) Distinctive pigment patterns, which in small larvae consist of an anterior and posterior pigment bar, each composed of a dorsal and ventral stripe. With further growth of larvae, these bars diffuse into dorso- and ventrolateral rows of pigment accompanied by development of a mediolateral line of melanophores. 2) Relatively high (54-58) myomere counts. 3) Presence of a "pseudocaudal" fin (Ahlstrom and Counts 1955) at about 8.5 mm SL, as indicated by the development of dorsal and ventral procurrent caudal rays before the development of hypurals.

Considering the collection locations (coastal Oregon and Washington) and the range of myomere counts, the specimens could have been one of only three potential species, *M. proximus*, *T. chalcogramma*, or *G. macrocephalus*. Meristic characters in the literature (e.g., Svetovidov 1948; Miller and Lea 1972; Hart 1973) are inadequate to separate all three species. Additional counts obtained in this study, particularly caudal vertebrae and fin rays on the superior hypural (Tables 1, 2), enabled positive identification of the series as *M. proximus*.

DEVELOPMENT OF *MICROGADUS PROXIMUS*

Pigment Patterns (Figures 1, 2)

Pigmentation varies in *M. proximus* larvae but basic trends persist and are useful in distinguishing the larvae. The importance of these pigment patterns is stressed by Russell (1976) for the entire family Gadidae. He feels many of the early larvae can be identified exclusively by specific pigment patterns. We follow his terminology by referring to the postanal pigment as bars according to their position, anterior and posterior. Russell's use of the term "bar" can be confusing, however, when referring to specific areas within a bar. We define bar as: anterior and posterior pigment area each composed of a dorsal and ventral stripe. Descriptions of pigment patterns for *M. proximus* are based primarily on 49 (2.7-31.0 mm SL) recently preserved (<2 yr) specimens in which fading was minimal.

Head Region

Pigment on the head of the smallest larvae (2.7-3.6 mm SL) is limited to a spot posterior to the pigmented eye and some melanophores on the lower jaw (Figure 1A). By 4.0 mm SL, 6 or 7 melanophores appear on the nape, 5 or 6 on the lower jaw, and a few internal as well as external melanophores on the forebrain. By 5.0 mm SL, added pigment occurs between the eyes, on both jaws and at the jaw angle, and internally, posterior to the eye (Figure 1B). Snout pigment appears at 8.0 mm SL (Figure 1C), and by 10.0 mm SL, pigment is added over the dorsal region of the head (Figure 1E). Pigment is added to these areas with

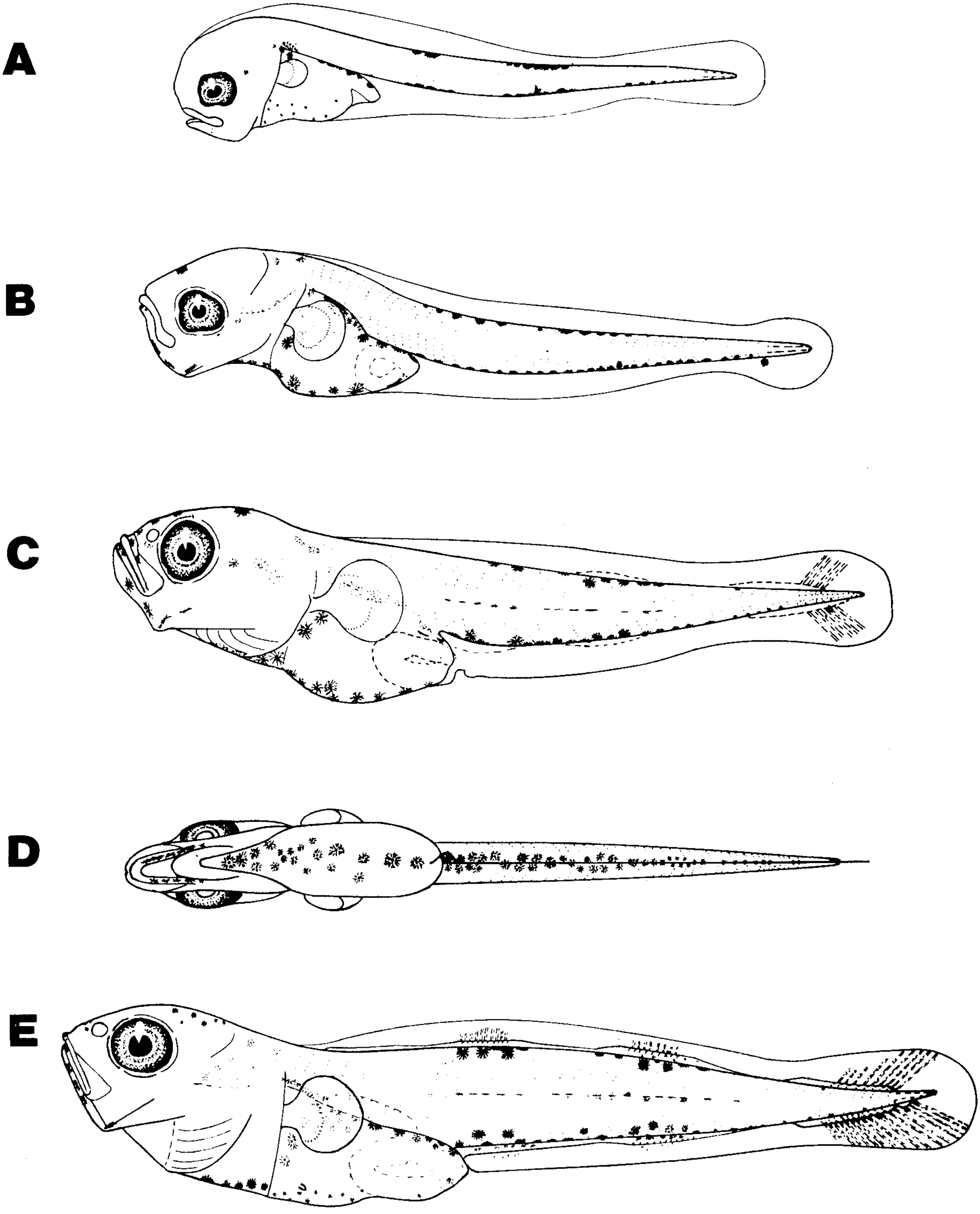


FIGURE 1.—Larval stages of *Microgadus proximus*: A. 3.6 mm SL; B. 5.7 mm SL; C. 8.4 mm SL; D. 8.4 mm SL (ventral view); E. 10.7 mm SL.

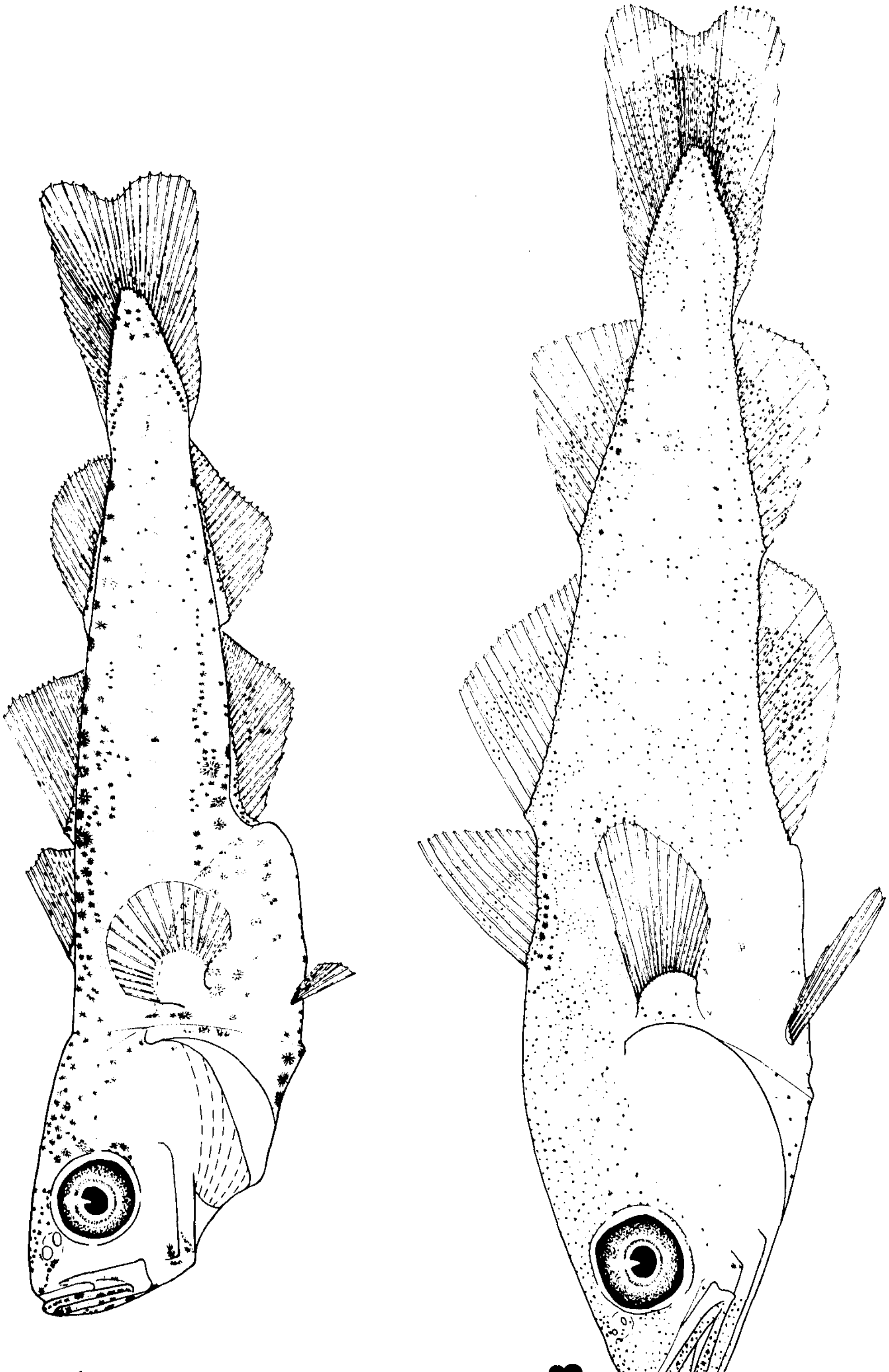


FIGURE 2.—*Microgadus proximus*: A. larva, 16.0 mm SL; B. early juvenile, 27.0 mm SL.

TABLE 1.—Summary of adult meristic counts for *Microgadus proximus*, *Theragra chalcogramma*, and *Gadus macrocephalus*. Data for *T. chalcogramma* is after Wilimovsky et al. (1967)[1] except where noted.

Species	Fin rays: First dorsal	Second dorsal	Third dorsal	First anal	Second anal	Vertebrae: Total	Precaudal	Caudal
M. proximus:								
Sample size	37	38	39	38	38	38	38	38
Mean	12.8	18.8	20.7	25.2	22.9	55.7	19.3	36.4
Range	9-15	16-21	17-24	22-28	20-28	54-58	17-20	34-38
T. chalcogramma:								
Sample size	242	229	235	237	237	98	[2]49	[2]49
Mean	11.7	14.6	17.7	18.9	18.8	49.8	18.7	32.6
Range	10-14	12-18	15-21	16-22	16-23	48-52	18-20	31-34
G. macrocephalus:								
Sample size	40	41	42	42	41	40	40	40
Mean	12.4	15.6	15.4	19.7	17.2	53.2	19.9	33.3
Range	10-15	11-22	10-20	17-27	12-25	49-56	18-21	31-35

[1]From Wilimovsky, N. J., A. Peden, and L. Peppar. 1967. Systematics of six demersal fishes of the North Pacific Ocean. Fish. Res. Board Can., Tech. Rep. 34, 95 p.
[2]From this study.

TABLE 2.—Distribution of caudal rays on the superior hypural element in *Microgadus proximus*, *Theragra chalcogramma*, and *Gadus macrocephalus* (Walters[1] and this study).

Species	No. of specimens	Percentage of caudal rays on superior hypural: 3	4	5	6
M. proximus	1,335	0.0	8.0	92.0	<0.1
T. chalcogramma	241	0.0	99.0	1.0	0.0
G. macrocephalus	87	0.3	97.0	0.0	0.0

[1]G. E. Walters, College of Fisheries, University of Washington, Seattle, WA 98115, pers. commun. January 1979.

development, and by 16.0 mm SL it becomes more concentrated on the jaws, jaw angle, snout, between the eyes, and over the head extending to the nape (Figure 2A). Several melanophores appear ventrally along the median cartilage between the dentaries and urohyal. With transformation (completion of fin development) at 22.0-28.0 mm SL, small and densely concentrated melanophores are added to the jaws and dorsal head (Figure 2B). The opercular area is unpigmented.

Gut Region

Melanophores line the dorsal surface of the gut cavity in the smallest larva (2.7 mm SL), and several spots are on the ventral abdominal surface anteriorly. The isthmus is pigmented by 4.0 mm SL. Melanophores increase in number on the dorsal and ventral gut surface with development. Melanophores are added laterally, occurring first anteriorly near the base of the pectoral fin at 5.0 mm SL (Figure 1B). The melanophores on the ventral surface of the gut extend more posteriorly, forming a rough line nearly to the anus by 8.0 mm SL (Figure 1C, D). Gut pigmentation changes little through transformation, except for additional melanophores on the lateral surface (Figure 2A). In early juveniles, the lateral pigment is more internal than external and the overlying skin is unpigmented (Figure 2B). Along the ventral surface of the gut is a single row of small melanophores. The base of the pectoral fin is pigmented.

Postanal Region

Pigment in the postanal region is an important diagnostic character for *M. proximus* larvae. The smallest larvae (2.7-3.6 mm SL) have two pigment bars, anterior and posterior. The stripes within the pigment bars are double rows of melanophores with pigment on both sides of the body along the dorsal and ventral midline. At first, the dorsal stripes consist of only 1 or 2 melanophores on each side, but increase to 2 or 3 anteriorly and 6-8 posteriorly by 3.6 mm SL (Figure 1A). The ventral stripes on each side have 4 or 5 spots anteriorly and 7 or 8 spots posteriorly by 3.6 mm SL (Figure 1A). At 3.6 mm SL the anterior bar is located at 42-50% SL (myomeres 16-22) and the posterior bar is at 59-72% SL (myomeres 29-37). With development, melanophores are added along the ventral stripes between the bars, becoming continuous with them by 5.7 mm SL (Figure 1B). The two dorsal stripes remain separate until 15.0 mm SL, although occasionally a few melanophores may be seen between them. Pigment is added along the body midline, externally at 7.5 mm SL and internally at 9.5 mm SL (Figure 1C, E). Postanal pigmentation changes are minimal for larvae between 10.0 and 14.0 mm SL, except for the addition of some spots laterally and in the dorsal and anal fin folds. By 15.0-16.0 mm SL, additional melanophores occur along the dorsolateral and ventrolateral surface, but those in the bars remain enlarged and distinctive (Figure 2A). After transformation, the larval pigment bars are no longer visible and the entire lateral area is pigmented, as are the dorsal and anal fins (Figure 2B).

Posterior to the second pigment bar, melanophores occur in the caudal region along the ventral body margin in the smallest larvae, connect with the ventral stripes by 5.7 mm SL (Figure 1B), and extend to the notochord tip by 6.2 mm SL. Caudal melanophores are smaller and less dendritic than those in the bars and appear as a single ventral midline row (Figure 1D). Several melanophores are added on the dorsal body margin posterior to the second pigment bar by 10.0 mm SL and, eventually, to the caudal fin fold ventrally and posteriorly by 15.0 mm SL. By 16.0 mm SL the dorsal and ventral midlines are distinctively lined with melanophores, and the lateral midline pigment, both internal and external, extends to the tail tip (Figure 2A). The proximal portion of the caudal fin is pigmented. After transformation pigment covers most of the fin (Figure 2B).

Morphology (Tables 3, 4)

Larvae of *M. proximus* are moderately elongate with the greatest body depth, about 19% SL, occurring at or near the pectoral fin base. The body tapers slightly toward the anus and then narrows abruptly posterior to the anus. The gut is only moderately long. The distance from snout to anus ranges from 41% to 48% SL in larvae and declines to 45% SL in juveniles. In our smallest yolk-sac larva (2.7 mm SL), the vent opens laterally to the right near the ventral fin fold and does not become vertical until the larvae reach about 7.5-8.5 mm SL. This lateral position of the anus in small gadid larvae was reported by Marak (1967) and Russell (1976). All yolk is absorbed by 3.0 mm SL. Notochord flexion is protracted, beginning at about 8-10 mm SL and ending at about 15 mm SL. Transformation begins at about 22 mm SL and is completed at about 27-28 mm SL. The largest pelagic specimen collected was 46.6 mm SL.

Head length as a proportion of standard length increases from 22% SL in preflexion larvae to 32% SL in transforming specimens. It declines to 30% SL in pelagic juveniles. Eye diameter as a proportion of head length decreases from 35% HL in preflexion larvae to 25% HL in pelagic juveniles, whereas snout length/head length increases from 18% HL to 29% HL. Upper jaw length/head length and body depth at pectoral fin base/standard length remain relatively constant, increasing only slightly from preflexion larvae to the pelagic juvenile stage. Depth at anus/standard length increases from 11% SL in preflexion larvae to 19% SL in juveniles.

The distance from the snout to the origin of the first dorsal fin as a proportion of standard length decreases slightly during development while the distance from the snout to the second dorsal fin/standard length remains nearly constant. The length from the snout to the origin of the third dorsal fin/standard length increases slightly during development.

Distances from the snout to the origin of the first anal fin/standard length decreases slightly from 47% SL in larvae undergoing notochord flexion to 45% SL in pelagic juveniles, whereas the snout to second anal fin distance/standard length increases slightly from 63% SL in larvae undergoing notochord flexion to 68% SL in pelagic juveniles.

Meristic Structures (Tables 5, 6; Figure 3)

Considerable variation occurs in the development of meristic structures as the size at which bones ossify varies from specimen to specimen (Table 5). The following discussion approximately parallels the sequence of development of meristic characters in *M. proximus*. Terminology of bones follows Ahlstrom and Counts (1955) and Ahlstrom.[7]

Head and Axial Skeleton

Branchiostegals can be discerned in some specimens as small as 3.9 mm SL. Ossification begins in some larvae at 8.1 mm SL, but the full complement of seven branchiostegals is not consistently ossified until the larvae are about 19 mm SL. The sequence of ossification of branchiostegals is from upper to lower.

Teeth begin ossifying on the dentary in 11.9 mm SL larvae (Table 6). Initially, the number of teeth

[7]E. H. Ahlstrom, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, La Jolla, CA 92038, pers. commun. July 1979. (Deceased.)

TABLE 3.—Morphometric measurements, in millimeters, of larvae and juveniles of *Microgadus proximus*. Specimens between dashed lines are undergoing notochord flexion.

Standard length	Head length	Eye diameter	Snout length	Upper jaw length	Depth at pectoral	Depth at anus	Snout to anus	Snout to first dorsal	Snout to second dorsal	Snout to third dorsal	Snout to first anal	Snout to second anal
2.7	0.6	0.2	0.1		0.5	0.3	1.0					
2.9	0.6	0.2	0.1		0.5	0.3	1.1					
3.4	0.7	0.3	0.1		0.4	0.3	1.4					
3.8	0.8	0.3	0.1		0.5	0.4	1.4					
4.1	0.8	0.3	0.1		0.6	0.4	1.7					
4.2	0.7	0.3	0.2	0.5	0.9	0.5	1.5					
4.5	1.2	0.3	0.1	0.3	1.1	0.5	1.9					
4.7	0.9	0.4	0.1	0.3	0.8	0.5	2.0					
5.1	1.2	0.4	0.2		0.9	0.6	2.3					
5.4	1.0	0.4	0.1		0.9	0.5	2.0					
5.5	1.2	0.4	0.2	0.3	1.0	0.5	2.4					
5.9	1.5	0.5	0.2	0.4	1.0	0.6	2.6					
6.1	1.5	0.5	0.3	0.4	1.1	0.7	2.4					
6.6	1.6	0.5	0.3	0.6	1.1	0.7	2.9					
6.9	1.4	0.5	0.4	0.6	1.2	0.8	2.6					
7.1	1.7	0.6	0.4	0.7	1.3	0.9	3.3					
7.3	1.8	0.5	0.4	0.7	1.3	0.9	3.1					
7.5	1.6	0.5	0.4	0.6	1.2	0.8	3.3					
7.9	1.7	0.6	0.4	0.6	1.3	0.9	3.4					
8.1	2.0	0.7	0.5	0.7	1.6	1.2	3.6					
8.3	2.1	0.7	0.6	0.9	1.6	1.2	3.6					
8.7	2.0	0.7	0.4	0.9	1.6	1.3	4.0					
8.9	2.3	0.7	0.6	0.8	1.6	1.3	4.1					
9.0	2.2	0.7	0.6	1.0	1.6	1.2	4.0					
9.2	2.2	0.7	0.6	1.0	1.7	1.2	4.0					
9.3	2.3	0.7	0.6	1.0	1.9	1.5	4.1	3.3	4.2	6.0		
9.6	2.2	0.7	0.6	0.9	1.8	1.4	4.4					
9.7	2.5	0.7	0.7	1.0	1.8	1.5	4.5					
10.1	3.0	0.8	0.9	1.2	2.1	1.9	4.8	3.6	4.8	6.7	4.9	6.7
10.2	2.2	0.8	0.6	1.0	1.8	1.4	4.4					
10.5	2.8	0.9	0.7	1.2	2.1	1.7	4.8	3.6	4.9		4.9	
10.8	2.9	0.9	0.7	1.2	2.1	1.7	4.6	3.7	4.9		4.7	
11.4	2.9	0.9	0.7	1.3	2.1	1.9	5.2	4.1	5.1		5.3	
11.7	2.8	0.9	0.8	1.2	2.1	1.9	5.1	3.9	5.2	7.4	5.2	
12.0	3.0	1.0	0.8	1.2	2.3	2.1	5.3	3.9	5.3	7.8	5.3	
12.5	3.4	1.0	0.8	1.2	2.5	2.2	5.8	4.5	6.0		6.0	
12.7	3.5	1.2	0.9	1.4	2.6	2.2	6.0	4.4	6.0	8.4	6.0	8.6
12.9	3.5	1.2	0.9	1.4	2.6	2.6	6.3	4.7	6.4	8.8	6.5	8.8
13.5	3.5	1.1	1.0	1.4	2.6	2.4	6.3	4.7	6.2	8.6	6.4	9.1
13.7	3.8	1.2	1.1	1.4	2.6	2.5	6.6	4.9	6.4	9.2	6.6	9.8
14.0	3.8	1.1	1.0	1.7	2.8	2.8	6.5	4.7	6.2	9.0	6.5	9.3
14.2	4.0	1.2	1.0	1.5	2.8	2.5	6.7	5.0	6.7	9.2	6.7	9.3
14.5	4.3	1.3	1.3	1.7	3.0	2.7	7.2	5.3	7.0	9.7	7.2	9.8
14.7	4.5	1.3	1.3	1.7	3.0	2.7	7.3	5.7	7.3	10.5	7.5	10.2
15.2	4.5	1.3	1.2	1.7	3.0	2.7	7.2	5.2	6.8	10.0	7.2	10.0
15.3	4.5	1.3	1.2	1.8	3.3	3.0	7.5	5.7	7.3	10.8	7.5	10.5
15.5	4.3	1.3	1.3	1.7	3.0	2.8	7.3	5.7	7.5	10.2	7.5	10.2
16.2	5.0	1.4	1.4	1.8	3.5	3.3	7.8	5.8	7.8	10.7	8.0	9.2
16.5	4.7	1.3	1.3	1.7	3.5	3.2	8.0	5.8	7.7	11.0	8.2	10.8
17.0	4.8	1.4	1.4	1.8	3.4	2.7	8.5	6.2	8.0	11.5	8.7	11.3
18.3	5.3	1.5	1.7	2.0	3.8	3.3	8.8	6.7	8.8	12.3	9.0	12.5
19.0	5.5	1.5	1.7	2.0	3.5	3.5	9.3	6.5	9.5	12.8	9.5	12.7
20.0	5.7	1.6	1.7	2.2	4.2	3.7	9.3	7.2	9.5	13.6	9.5	13.2
21.0	6.2	1.7	1.8	2.3	4.3	4.2	10.0	7.5	10.3	14.7	10.0	14.7
[1]22.1	6.1	1.8	1.7	2.7	4.7	4.3	10.5	7.8	10.8	15.3	10.5	14.8
[1]23.5	6.8	1.9	2.0	2.7	4.8	4.5	10.6	8.2	10.8	16.0	10.8	16.2
[1]24.0	8.2	1.9	2.0	2.8	5.2	4.7	11.3	8.5	11.5	16.2	11.5	16.3
[1]25.2	7.8	2.1	2.3	3.0	5.5	5.2	11.8	8.8	12.2	17.5	12.0	17.5
[1]26.3	9.5	2.2	2.5	3.2	5.5	5.5	12.5	9.2	12.2	18.0	12.5	18.2
[2]27.3	8.2	2.2	2.5	3.3	5.7	5.3	13.5	9.5	12.9	18.3	13.7	20.0
[2]28.0	8.7	2.3	2.5	3.5	6.0	5.7	14.3	9.7	13.2	19.7	14.8	20.6
[2]29.3	9.2	2.3	2.7	3.7	6.3	5.7	14.2	10.3	13.8	20.5	14.2	20.3
[2]31.3	9.5	2.5	2.8	3.8	6.3	5.7	14.2	11.2	14.7	21.7	14.3	20.8
[2]32.1	9.7	2.5	2.8	3.7	6.5	5.8	14.2	11.2	14.7	21.3	14.5	22.0
[2]34.3	10.8	2.5	2.8	4.0	7.5	7.2	15.3	11.7	16.0	22.8	15.8	23.3
[2]36.7	10.8	2.7	3.0	4.5	7.7	7.3	15.2	11.7	16.8	24.6	15.7	24.6
[2]38.0	10.8	3.0	3.2	4.5	7.8	7.5	16.5	12.8	17.5	25.5	16.5	25.8
[2]38.2	11.0	2.7	3.5	4.5	7.8	7.2	15.5	13.0	17.8	25.7	16.2	25.8
[2]40.1	11.7	2.8	3.5	4.7	7.9	7.2	16.7	12.8	18.0	26.0	17.0	26.3
[2]41.1	11.2	2.9	3.5	3.3	8.2	7.2	17.3	13.3	17.8	25.8	17.3	24.0
[2]41.3	12.5	3.0	3.8	5.0	8.3	8.2	18.3	14.0	19.0	27.8	18.0	27.3
[2]46.6	14.0	3.3	4.0	5.8	9.7	9.5	20.0	15.0	21.0	31.5	20.2	32.1

[1]Transforming.
[2]Pelagic juvenile.

TABLE 4.—Body proportions of larvae and juveniles of *Microgadus proximus*. Values given for each body proportion are expressed as percentage of standard length (SL) or head length (HL): mean, standard deviation, and range.

Body proportion	Preflexion	Flexion	Postflexion	Transforming	Pelagic juvenile
Sample size	[1]19	[2]25	10	5	13
Standard length (mm)	5.3±1.6 (3-8)	11.2±2.1 (8-15)	17.4±2.1(15-21)	24.2±1.6(22-26)	35.7±5.9(27-47)
Snout to anus length/SL	41.2±3.3 (36-47)	45.9±2.0(43-50)	48.1±1.0(47-50)	46.8±1.0(45-48)	44.6±3.3(41-51)
Head length/SL	21.9±2.6 (17-27)	26.0±2.2(22-31)	29.0±0.9(28-31)	31.6±3.6(28-36)	29.9±1.2(27-32)
Eye diameter/HL	35.1±5.0 (25-44)	31.6±2.3(27-36)	28.4±0.9(27-30)	26.1±2.8(23-30)	25.3±1.4(23-28)
Snout length/HL	17.8±7.0 (5-29)	26.6±2.3(20-30)	29.0±1.8(27-32)	27.5±2.2(24-30)	29.4±1.5(26-32)
Upper jaw length/HL	36.8±12.7(25-71)	40.9±3.4(35-46)	37.7±1.4(36-40)	38.1±4.4(34-44)	39.3±3.2(30-42)
Body depth at pectoral fin base/SL	17.3±2.7 (12-24)	19.3±1.0(18-21)	20.4±1.0(18-22)	21.2±0.6(20-22)	20.7±0.7(20-22)
Depth at anus/SL	10.8±1.1 (9-13)	16.5±2.0(13-20)	18.6±1.3(16-20)	20.0±0.7(19-21)	19.3±1.1(18-21)
Snout to first dorsal fin/SL		35.2±1.5(33-39)	35.8±1.0(34-37)	35.1±0.2 (35)	33.8±1.3(31-36)
Snout to second dorsal fin/SL		46.6±1.8(44-50)	47.7±1.4(45-50)	47.5±1.3(46-49)	46.1±1.1(43-47)
Snout to third dorsal fin/SL		66.0±2.3(63-71)	67.5±1.7(66-71)	68.5±0.8(68-69)	67.2±2.0(63-70)
Snout to first anal fin/SL		47.3±2.2(44-51)	48.9±1.2(47-51)	47.3±0.7(46-48)	45.3±3.4(42-53)
Snout to second anal fin/SL		62.5±1.6(19-72)	66.0±3.6(57-70)	68.5±1.0(67-69)	67.7±3.7(58-74)

[1]Sample size is 12 for upper jaw length.
[2]Sample size is 16 each for distances from snout to first dorsal fin and snout to second dorsal fin; 12 for distance from snout to third dorsal fin; 15 for distance from snout to first anal fin; and 9 for distance from snout to second anal fin.

on the dentary exceeds the number on the premaxilla, but this is reversed at about 23 mm SL with the difference increasing with growth. A similar change in number and location of teeth was reported to occur on the Pacific whiting, *Merluccius productus* (Ahlstrom and Counts 1955).

In larval and transforming specimens (11.9-22.3 mm SL), teeth are irregularly spaced and clustered in groups. Some are caninelike and others are recurved. As the larvae grow, the teeth become more closely spaced as the numbers of teeth increase and approach biserialization in 34.3 mm SL juveniles, similar to that described for Pacific whiting (Ahlstrom and Counts 1955).

Gill rakers begin ossifying at 9.6 mm SL and all (3 + 20 = 23) gill rakers are ossified in a 24.3 mm SL larva.

Neural spines in the abdominal region begin to ossify at about 8.7 mm SL and all are ossified by 11 or 12 mm SL. Ossification generally proceeds posteriorly. Neural spines of the caudal region also begin ossifying at about 8.7 mm SL but ossification is not complete until specimens are 17 mm SL. The neural and haemal spines of the third to sixth vertebrae preceding the postural centrum begin to accept alizarin stain before other neural spines in the caudal region. Haemal spines ossify in a sequence similar to neural abdominal spines; all spines are ossified by 17 mm SL. The last neural and haemal spines to ossify are those associated with the terminal preural vertebrae. These spines are broadly flattened and ossify simultaneously with other bones of the caudal complex, as discussed later (Figure 3).

Vertebral centra in both the abdominal and caudal regions begin to ossify at about 8.7 mm SL and ossification is completed by 11 mm SL and about 19 mm SL. Ossification proceeds from anterior to posterior.

Fins

Median and paired fins showed some variation in development, with fin rays first forming at different body lengths in individual specimens (Table 5). Fin formation occurs in the sequence: larval pectoral fins; caudal fin; first anal fin; second anal fin; third, second, and first dorsal fins (nearly simultaneously); pelvic fins; and pectoral fins with rays.

The pterygiophores supporting anal and dorsal fin rays begin ossifying at 23.4 mm SL and ossification is complete by 31.1 mm SL. Too few specimens were available to follow the sequence of ossification.

Larval pectoral fins are present in our smallest specimen (2.7 mm SL). They consist of a fleshy base and an undifferentiated membrane. They persist until rays begin differentiating late in the larval period.

The caudal fin of *M. proximus* is associated with a complex of 16 centra (2 ural and 14 preural centra), 14 neural and haemal spines, 2 epurals, 1 superior hypural (HY 4-6), and 2 inferior hypurals (HY 2-3, HY 1) (Figure 3).

Caudal rays total 49-56, of which 22-25 are dorsal in origin, 22-26 are ventral in origin, and five are normally supported by the superior hypural. Principal caudal rays number 32-33; of these, 12 or 13 are dorsal in origin and 13 or 14 are ventral in origin. One each is attached to the two epurals, five are carried on the superior hypural, two on hypural 2-3, and one on hypural 1.

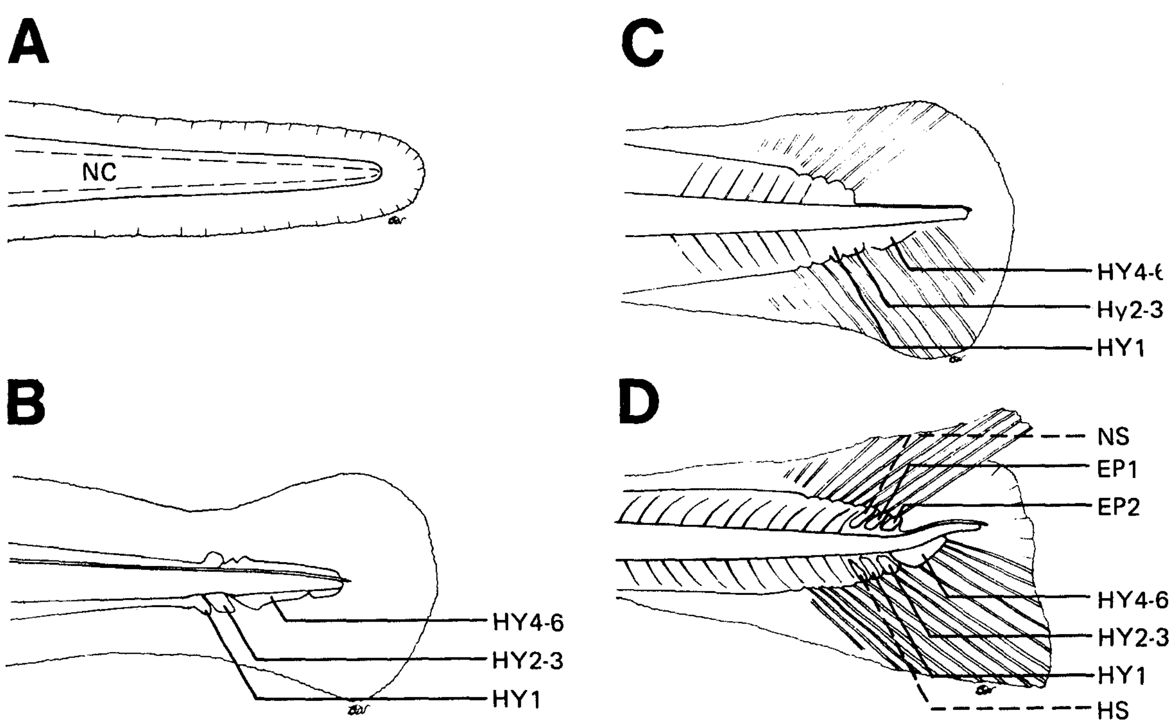
As with the Pacific whiting (Ahlstrom

and Counts 1955), some of the anterior caudal rays, both dorsally and ventrally, articulate with unmodified neural and haemal spines; other rays lie between the spines with no basal supports (Figure 3).

A symmetrical fin fold surrounds the tip of the notochord in specimens 3.1-5.5 mm SL (Figure 3). In 7.5 mm SL larvae, mesenchymal thickenings occur dorsal and ventral to the notochord. By 7.8 mm SL, the ventral thickening is differentiated into three cartilaginous plates constituting hypurals 1, 2, and 3 anteriorly, and hypurals 4-6 posteriorly (Figure 3B). In 9.5 mm SL specimens fin rays are considerably increased in number (Figure 3C). In 10.5 mm SL specimens the urostyle begins to flex, and the unossified hypurals 1, 2-3, and 4-6, as well as epurals 1 and 2 are differentiated (Figure 3D). Ossification proceeds rapidly during notochord flexion from anterior to posterior regions of the caudal complex. By 11.9 mm SL (Figure 3E), all preural centra are ossified, and all hypurals and both epurals have begun ossifying. Caudal fin rays have begun ossifying, beginning ventrally in the region of the inferior hypurals.

By 15.0 mm SL, all centra except the postural centrum are ossified; the hypurals and epurals are incompletely ossified (Figure 3F). Rays continue ossifying, proceeding posteriorly on the ventral margin and on the superior hypural and progressing anteriorly from epural number 2. By 19.4 mm SL all caudal rays posterior to preural centrum 12 are ossified. By 25.0 mm, the caudal fin is completely ossified (Figure 3G) and resembles in all details that of a 41.1 mm SL juvenile (Figure 3H).

We were unable to detect fusion of hypurals in the caudal fin of *M. proximus* during ontogeny. In the smallest larvae in which we could detect development of hypural elements (7.8-8.1 mm SL), only three hypurals could be observed. We believe, however, that these hypurals represent 1) an anterior, inferior hypural 1 (parhypural); 2) an inferior hypural representing a fusion of hypurals 2 and 3; and 3) a superior hypural representing a fusion of hypurals 4-6. This reasoning is predicated on 1) it is generally accepted that the evolutionary trend in fishes is toward a reduction in the number of hypurals, presumably by fusion of the constituent elements (Gosline 1961; Rosen and Patterson 1969; Marshall and Cohen 1973); 2) members of the family Moridae, generally considered a more primitive family than Gadidae (Svetovidov 1948; Greenwood et al. 1966; Rosen and Patterson 1969), possess three inferior and



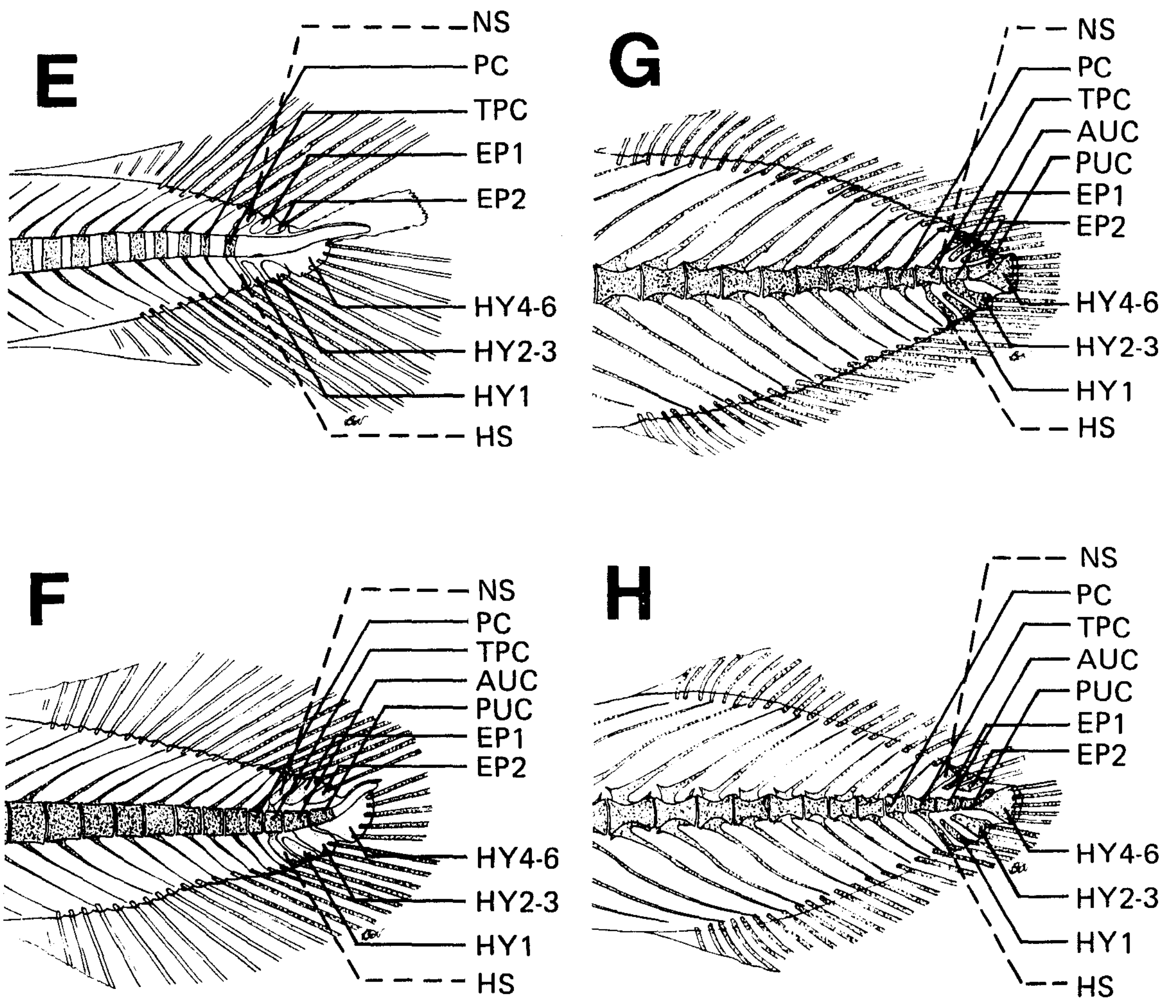


FIGURE 3.—Development of the caudal fin of *Microgadus proximus*: A. 5.2 mm SL; B. 7.8 mm SL; C. 9.5 mm SL; D. 10.5 mm SL; E. 11.9 mm SL; F. 15.8 mm SL; G. 25.0 mm SL; H. 41.1 mm SL. AUC = anterior ural centrum; EP = epural; HS = haemal spine; HY = hypural; NC = notocord; NS = neural spine; PC = preural centrum; PUC = postural centrum; TPC = terminal preural centrum. Ossified elements are stippled.

three superior hypurals (Fitch and Barker 1972); and 3) presumably more advanced families of fishes in the same evolutionary line as gadids (e.g., order Batrachoidiformes) have two hypurals, apparently representing fusion of component parts (Rosen and Patterson 1969).

Barrington (1937), who figured and described the development of the caudal fin in *G. morhua*, provides the only other description of caudal development in gadids. His illustrations also depict only three hypural elements. Barrington, however, considered it unlikely that fusion of hypural bones could occur without some evidence of compound origin remaining in the fused bones. Our terminology of the caudal fin bones differs from that used by Barrington (1937) for *G. morhua*. We consider his ventral radial as hypural 1 and his dorsal radials 1 and 2 to be epurals 1 and 2.

Also we found no evidence of a uroneural in the development of the caudal fin of *M. proximus*. Rosen and Patterson (1969) consider the presence of one uroneural as a characteristic of the Gadiformes.

An anlage of the first anal fin is evident by 8.7 mm SL and the base of the second anal fin is present at 9.3 mm SL. Rays in the first anal fin begin ossifying at about 11.9 mm SL and in the second anal fin at 12.7 mm SL. Ossification is

TABLE 5.—Meristic counts from larval and juvenile *Microgadus proximus*. Values given are means. Specimens between dashed lines are undergoing notochord flexion.

Length interval (mm SL)	Sample size	Dorsal fin rays			Anal fin rays		Pectoral fin rays	Pelvic fin rays	Branchi-ostegal rays	Gill rakers			Neural spines			Haemal spines	Centra		
		First	Second	Third	First	Second				Upper	Lower	Total	Abdominal	Caudal	Total		Abdominal	Caudal	Total
3.0- 3.9	5																		
4.0- 4.9	3																		
5.0- 5.9	6																		
6.0- 6.9	9																		
7.0- 7.9	10																		
8.0- 8.9	13								1.1				3.2	2.8	6.0	2.9	2.5	2.7	5.2
9.0- 9.9	14								1.2		1.2	1.2	5.8	7.4	13.2	7.9	5.4	7.3	12.7
10.0-10.9	16								3.0		1.0	1.0	10.6	11.5	22.1	11.3	11.6	10.6	22.2
11.0-11.9	4				4.8				4.5		1.5	1.5	19.3	24.3	43.6	24.5	19.3	27.0	46.3
12.0-12.9	8		0.8	0.6	2.9	1.0			5.0		5.6	5.6	19.1	28.1	47.2	29.0	19.1	29.0	48.1
13.0-13.9	[1]4	0.8	2.5	2.8	3.0	2.3			5.8		16.5	16.5	19.3	26.5	45.8	26.0	19.2	25.8	45.0
14.0-14.9	4	1.3	3.0	1.3	7.5	2.5		2.2	6.3				19.5	35.0	54.5	34.0	19.5	33.0	52.5
15.0-15.9	[2]4	1.3	4.3	2.8	4.5		1.3	0.5	6.5		6.5	6.5	19.5	32.3	51.8	31.0	19.5	31.8	51.3
16.0-16.9	3	1.3	1.3		3.7				6.3				18.7	21.0	39.7	19.3	18.7	28.0	46.7
17.0-17.9	[3]3	5.0	9.0	10.0	18.0	13.7	7.0	4.0	7.0	0.3	16.3	16.6	19.3	35.3	54.6	35.0	19.3	37.0	56.3
18.0-18.9	3	4.3	9.7	10.3	12.0	12.7	9.3	3.0	6.7	0.3	16.7	17.0	19.0	33.7	52.7	33.7	19.0	31.3	50.3
19.0-19.9	2	5.5	13.0	8.0	18.0	14.5	6.5	2.5	7.0	0.5	16.0	16.5	19.5	33.5	53.0	32.5	19.5	35.5	55.0
20.0-20.9	1	6.0	6.0		14.0	10.0			7.0	1.0	17.0	18.0	20.0	35.0	55.0	34.0	19.0	37.0	56.0
21.0-21.9	1	7.0	11.0	13.0	17.0	12.0			7.0	1.0	16.0	17.0	19.0	35.0	54.0	34.0	19.0	36.0	55.0
22.0-22.9	2	10.5	16.5	14.5	22.5	17.0	8.5	5.5	7.0	1.0	19.0	20.0	19.0	34.5	53.5	34.5	19.0	37.0	56.0
23.0-23.9	2	11.0	20.0	20.0	26.0	22.5	18.0	6.0	7.0	2.5	19.5	22.0	19.0	34.5	53.5	34.5	19.0	36.5	55.5
24.0-24.9	1	13.0	19.0	21.0	26.0	24.0	17.0	5.0	7.0	3.0	20.0	23.0	19.0	34.0	53.0	34.0	19.0	37.0	56.0
25.0-25.9	1	12.0	19.0	15.0	24.0	16.0	3.0	5.0	7.0	3.0	19.0	22.0	19.0	36.0	55.0	36.0	19.0	38.0	57.0
26.0-26.9	1	13.0	23.0	20.0	28.0	17.0	17.0	6.0	7.0	3.0	20.0	23.0	19.0	34.0	53.0	35.0	19.0	37.0	56.0
28.0-28.9	1	12.0	21.0	21.0	28.0	24.0	19.0	6.0	7.0	3.0	19.0	22.0	17.0	34.0	51.0	34.0	17.0	37.0	54.0
29.0-29.9	1	13.0	21.0	21.0	28.0	23.0	17.0	6.0	7.0	3.0	18.0	21.0	19.0	33.0	52.0	33.0	19.0	36.0	55.0
30.0-30.9	1	13.0	20.0	22.0	26.0	24.0	18.0	6.0	7.0	4.0	24.0	28.0	20.0	33.0	53.0	33.0	20.0	36.0	56.0
31.0-31.9	1	13.0	17.0	22.0	25.0	25.0	19.0	6.0	7.0	4.0	21.0	25.0	19.0	34.0	53.0	34.0	19.0	37.0	56.0
34.0-34.9	1	12.0	20.0	22.0	25.0	23.0	19.0	6.0	7.0	4.0	22.0	26.0	18.0	34.0	52.0	34.0	18.0	37.0	55.0
38.0-38.9	2	13.5	18.0	21.0	24.0	26.0	19.5	6.0	6.5	—	—	—	19.5	33.0	52.5	33.0	19.5	36.0	55.5
41.0-41.9	1	13.0	20.0	22.0	26.0	22.0	18.0	7.0	7.0	4.0	21.0	25.0	20.0	33.0	53.0	33.0	20.0	36.0	56.0

[1]Sample size is 3 for pectoral and pelvic fins.
[2]Sample size is 2 for second anal fin.
[3]Sample size is 2 for second dorsal fin and pectoral fin.

TABLE 6.—Numbers of teeth on premaxillary and dentary bones in selected sizes of larval and juvenile *Microgadus proximus*.

Size of specimen (mm SL)	Teeth on left side	
	Premaxilla	Dentary
Larvae:		
11.9	0	1
13.2	0	6
15.0	0	6
15.8	0	6
17.2	8	10
18.0	6	8
Transforming:		
22.3	10	14
23.4	30	24
24.3	32	27
Juveniles:		
28.6	36	24
34.3	44	35
41.1	49	38

complete in the first anal fin at 23.0 mm SL and in the second anal fin at 27 or 28 mm SL. Ray development within a fin proceeds anterior to posterior.

Dorsal fins develop in a manner analogous to the anal fins and the three dorsal fins develop almost simultaneously. Dorsal fins 2 and 3 commence ossification at 12.9 mm SL, and dorsal fin 1 begins accepting stain at 13.2 mm SL. Ossification is complete in the first and second dorsal fins at 22.0 mm SL and in the third dorsal at 28.0 mm SL. Rays ossify from anterior to posterior.

Pelvic buds appear at about 8.0 mm SL. Pelvic fins begin ossifying at about 14.0 mm SL and are consistently ossified in 26.0 mm SL early juveniles. Pectoral fins initiate ossification at 15.0 mm SL and reach their full complement of 18-20 rays in 28.0 mm SL juveniles.

Scales

Scales begin developing in the anterior portion of the body near the dorsal tip of the cleithrum in 28.6 mm SL specimens. Development appears to progress along the lateral line as the juveniles grow. Scale development was not complete in our largest specimen, 41.1 mm SL.

Occurrence of *Microgadus proximus* (Figure 4)

Although a number of ichthyoplankton studies have been conducted in the northeastern Pacific Ocean, data on occurrence of *M. proximus* are limited because of past difficulties in distinguishing the larvae from other gadids. Larvae of this species may be included under the broader category of Gadidae listed in some papers (e.g., Waldron 1972; Pearcy and Meyers 1974). Some data on distribution and seasonal abundance, however, are available.

Larvae of *M. proximus* are found in coastal waters off Oregon occurring mainly within 18 km of shore with abundance peaks at about 6 and 9 km (Richardson and Pearcy 1977; Richardson[8]). A few specimens have been reported as far as 74 km offshore (Richardson footnote 8).

The larvae have been collected in the plankton off Oregon from February through August with peak abundance from March through July (Richardson footnote 8). Misitano (1977) also collected four specimens, 5-61 mm SL, from March to July in the Columbia River mouth.

Monthly length frequencies and median lengths of larvae collected in 1971 and 1972 off Oregon indicate a winter-spring spawning period (Figure 4). Small larvae, ≤5 mm SL, were collected February through June.

Larvae of *M. proximus* were collected 24 km off coastal Washington (Cruise K-72-2-III) in early June 1972, by the NWAFC[9]. This species accounted for 22.2% of the total catch of fish larvae, and specimens ranged from 5.0 to 26.0 mm SL.

COMPARATIVE NOTES ON *THERAGRA CHALCOGRAMMA* AND *GADUS MACROCEPHALUS* (Figure 5, Table 7)

In the northeastern Pacific Ocean, larvae of *M. proximus* are similar to those of *T. chalcogramma* and *G. macrocephalus* at sizes <16.0 mm SL. Identification of all three species in mixed samples is difficult with previously available literature, which describes *T. chalcogramma* and *G. macrocephalus* from the northwestern Pacific Ocean (e.g., Gorbunova 1954; Uchida et al. 1958; Mukhacheva and Zviagina 1960). We have summarized characters which are useful to distinguish each species at sizes <16.0 mm SL based on our examination of specimens of all three species (Table 7).

The most useful character to separate the smaller larvae (hatching to 10.0 mm SL) of the

[8]Richardson, S. L. 1977. Larval fishes in ocean waters off Yaquina Bay, Oregon: abundance, distribution, and seasonality January 1971 to August 1972. Oregon State Univ., Sea Grant Coll. Program Publ. ORES-T-77-003, 73 p.

[9]Data on file for Cruise K-72-2 (III), 1972. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

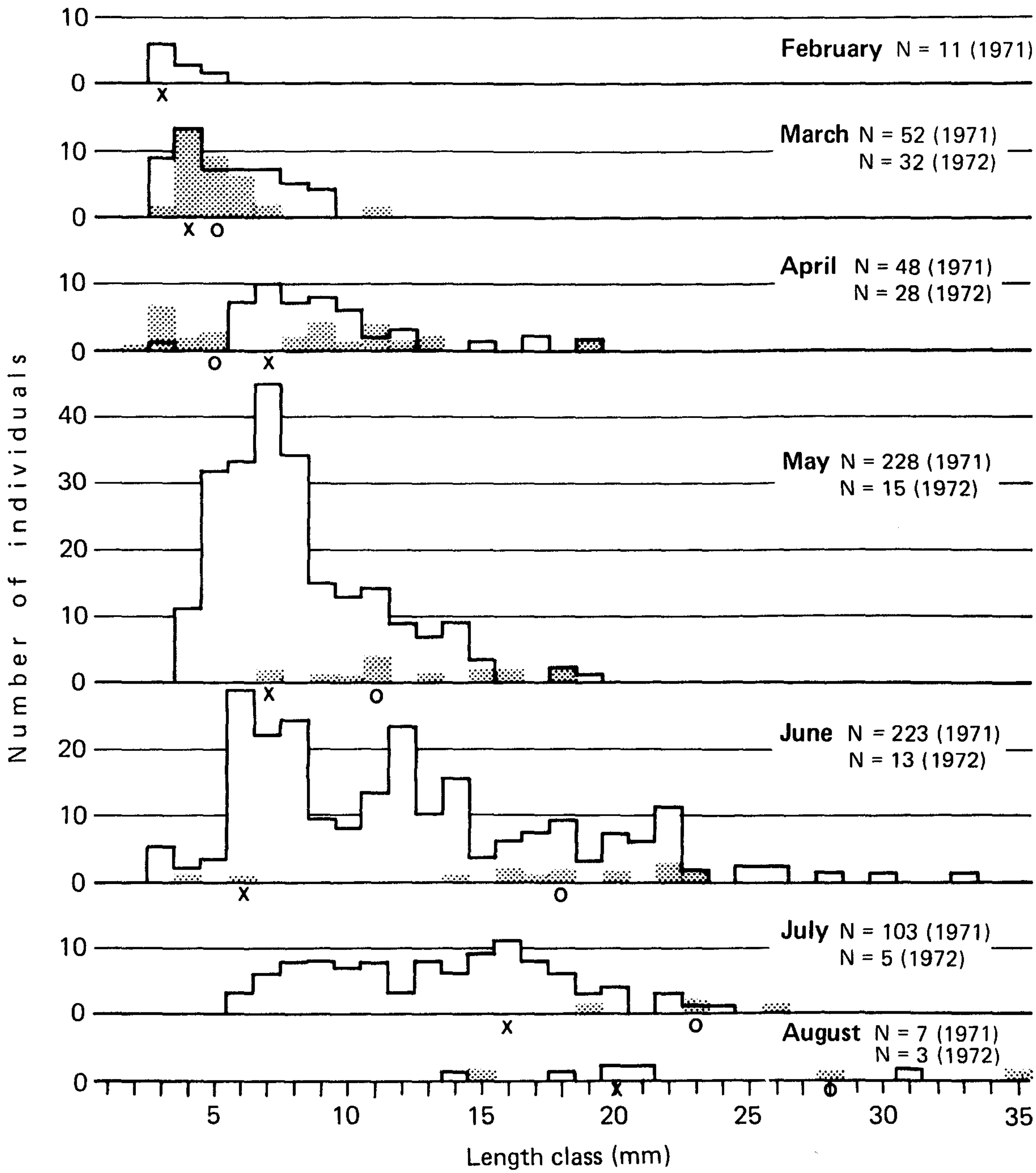


FIGURE 4.—Length-frequency histograms of *Microgadus proximus* larvae collected in 70 cm bongo nets off Oregon in 1971 (unshaded) and 1972 (shaded). X = median length class of larvae in 1971; O = median length class of larvae in 1972.

three species is the length and position of the anterior and posterior postanal pigment bars. In *M. proximus* larvae 5.0-6.0 mm SL (Figure 1B), the anterior bar begins just posterior to the anus at 41-53% SL (myomeres 14-23) and the posterior bar is at 61-74% SL (myomeres 28-39). In *T. chalcogramma* larvae of the same size range (Figure 5A), the anterior bar begins posterior to the anus at

47-55% SL (myomeres 21-26) and the posterior bar is at 69-79% SL (myomeres 36-43). The anterior bar begins posterior to the anus for similar size *G. macrocephalus* larvae (Figure 5C) at 40-57% SL (myomeres 16-26) and the posterior bar is at 59-81% SL (myomeres 26-42). Differences also exist in the number of melanophores in the stripe within a bar and associated bar length. This latter character, however, is only useful at small sizes (2.5-4.5 mm SL) because melanophores increase with development and the stripes become continuous. At 3.6 mm SL (Figure 1A), *M. proximus* larvae have on each side two dorsal and four ventral melanophores in the stripes within the small anterior bar, and seven melanophores each in the longer dorsal and ventral stripes within the posterior bar. Similar sized *T. chalcogramma* larvae (4.1 mm SL) have evenly sized stripes with five melanophores on both the dorsal and ventral stripe of the anterior bar, and five dorsal and seven ventral melanophores in each stripe of the posterior bar. *Gadus macrocephalus* larvae (4.4 mm SL) have longer stripes than the other two species, with 7 dorsal and 8 ventral melanophores on the anterior bar, and 11 dorsal and 10 ventral melanophores on the posterior bar.

With development these pigment stripes within the bars variously remain separate or become connected depending on the species. In *M. proximus* larvae the ventral stripes become continuous at 5.0-6.0 mm SL (Figure 1B) while the dorsal stripes remain separate until 13.0 mm SL. The dorsal stripes become continuous in *T. chalcogramma* larvae at 13.0 mm SL whereas the ventral stripes never connect. *Gadus macrocephalus* larvae have continuous dorsal and ventral stripes of melanophores by 5.0-6.0 mm SL (Figure 5C).

Other pigment differences may help in distinguishing species at certain size ranges. Early *G. macrocephalus* larvae (4.0-8.0 mm SL) have more head pigmentation than the other two species, particularly on the dorsal surface and in the snout area (Figure 5C). *Theragra chalcogramma* larvae (<13.0 mm SL) have much less lateral pigment on the surface of the gut than either *M. proximus* or *G. macrocephalus* larvae (Figure 5B). *Gadus macrocephalus* larvae (5.0-8.0 mm SL) have more mediolateral pigmentation between the postanal bars than the other two species in that size range (Figure 5C). Caudal pigment also differs and at sizes <10.0 mm SL can separate *M. proximus*. Only *M. proximus* larvae have a single row of ventral caudal melanophores posterior to the anal fin (Figure 1D) whereas both *T. chalcogramma* and *G. macrocephalus* larvae have isolated pigment spots (Figure 5B, D).

Also helpful in distinguishing *M. proximus* larvae from the other two species is the possession of five rays on the superior hypural compared with four rays for *T. chalcogramma* and *G. mac-*

TABLE 7.—Characters useful in separating larvae of *Microgadus proximus*, *Theragra chalcogramma*, and *Gadus macrocephalus* at specific size ranges.

Character	Size range (mm)	*Microgadus proximus*	*Theragra chalcogramma*	*Gadus macrocephalus*
Anterior pigment bar	5-6			
Percentage of SL		41-53	47-55	40-57
Located at myomeres		14-23	21-26	16-26
Posterior pigment bar	5-6			
Percentage of SL		61-74	69-79	59-81
Located at myomeres		28-39	36-43	26-42
Number of melanophores in each stripe of:				
Anterior bar	3-4			
Dorsal		2	5	7
Ventral		4	5	8
Posterior bar	3-4			
Dorsal		7	5	11
Ventral		7	7	10
Degree of stripe continuity:				
Anterior bar:				
Dorsal	5-13	Separate	Separate	Continuous
Ventral		Continuous	Separate	Continuous
Posterior bar:				
Dorsal	13-16	Separate	Continuous	Continuous
Ventral		Continuous	Separate	Continuous
Head melanophores	4-8	—	—	More on dorsal surface and snout
Melanophores on ventral surface of gut	>13	1-2 rows of spots	No spots or a few reduced spots	1-2 rows of spots
Lateral pigment on gut surface	<13	—	Much less	—
Mediolateral pigment in postanal region	5-8	—	—	More
Ventral caudal pigment	<10	Row of spots	Isolated spots	Isolated spots
Number of rays on superior hypural element	>13	5	4	4

A

B

C

D

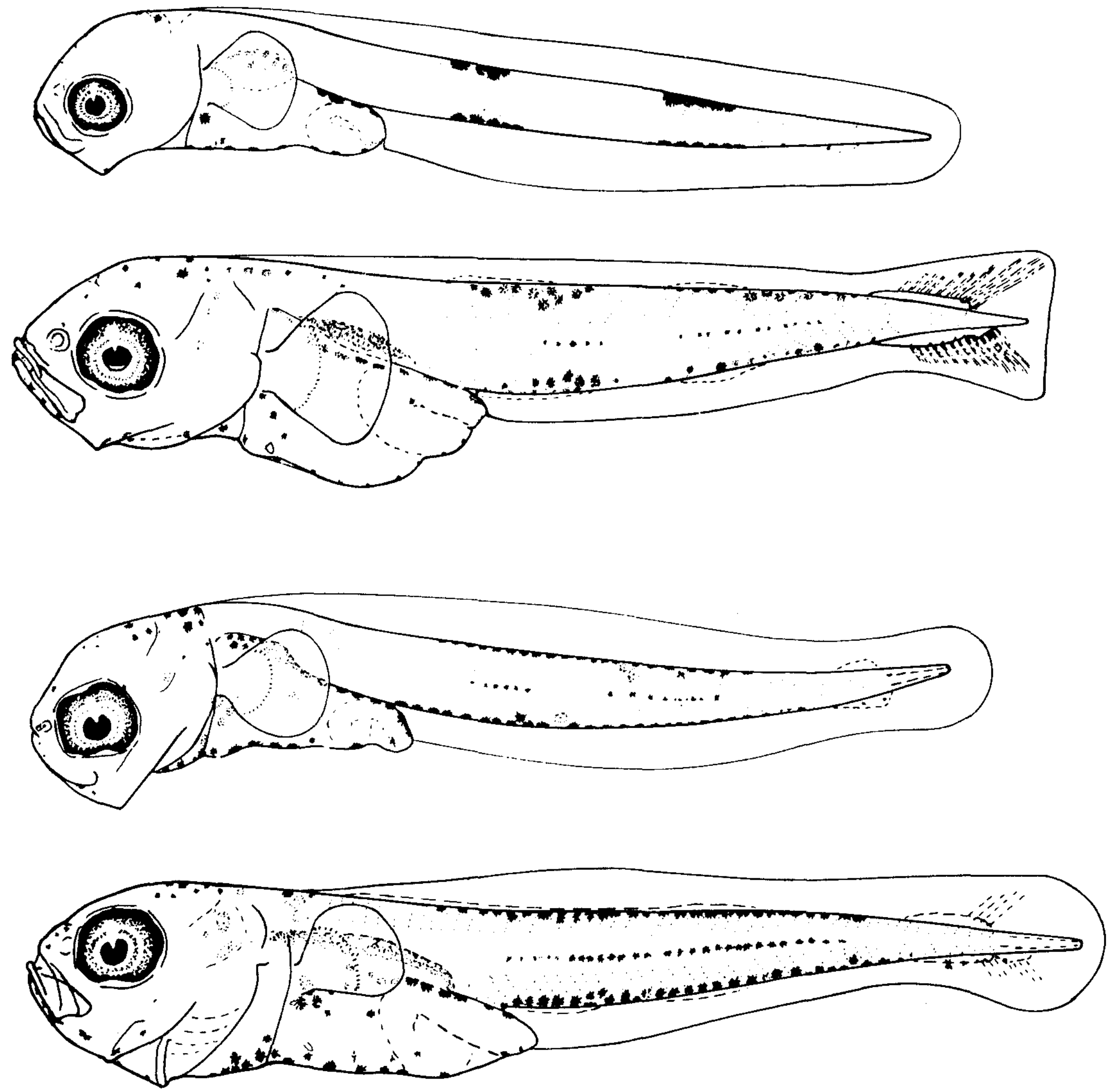


FIGURE 5.—Larvae of *Theragra chalcogramma* and *Gadus macrocephalus*: A. *T. chalcogramma*, 6.2 mm SL; B. *T. chalcogramma*, 9.8 mm SL; C. *G. macrocephalus*, 5.6 mm SL; D. *G. macrocephalus*, 8.5 mm SL.

rocephalus. This character can be useful in a size range (>13.0 mm SL) which may be troublesome when pigment patterns are no longer helpful and adult characters (e.g., barbel length, mouth and anus position, or shape of fins) are not fully developed. Larvae >20.0 mm SL may also be distinguished by a combination of meristic counts (Table 1).

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