

**Larvae and Pelagic Juveniles of Blackgill Rockfish,
Sebastes melanostomus, Taken in Midwater Trawls
off Southern California and Baja California**

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Examination of 217 midwater trawl samples from the coastal basins off southern California and Baja California revealed a recurring group of rockfish species. The late larvae and pelagic juveniles of the blackgill rockfish, *Sebastes melanostomus*, constituted 16% of the total number of rockfish specimens. The life-history stages of this species are described, with emphasis on the pelagic juvenile stage. Late stage larvae and pelagic juveniles develop a distinctive pattern of melanophore bands which, by disrupting the body outline, may help conceal the young during their midwater existence. Evidence from midwater trawl collections suggests that 30-mm pelagic juveniles migrate or are carried shoreward at a depth of ~200 m to the appropriate habitat for settling. The high relative abundance of blackgill rockfish pelagic juveniles in midwater trawl samples suggests that this species may represent a potential resource.

Key words: blackgill rockfish, *Sebastes melanostomus*, larvae, pelagic juveniles, midwater trawls, developmental stages, melanophore patterns, life-history strategy, head-spine development

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L'examen de 217 échantillons prélevés au chalut mésopélagique dans les bassins côtiers au large de la Basse-Californie et du sud de la Californie a permis de mettre en évidence la réapparition d'une espèce de sébaste dans cette région. Des stades larvaires avancés et des juvéniles pélagiques de *Sebastes melanostomus* constituaient 16% du nombre total de spécimens de sébastes. Nous décrivons les stades du cycle biologique de cette espèce, en mettant l'accent sur le stade juvénile pélagique distinctif. Le stade larvaire avancé et les juvéniles pélagiques se distinguent par leurs bandes de mélanophores qui, en brisant le contour du corps, peuvent contribuer à dissimuler les jeunes durant leur vie pélagique. Certaines données recueillies grâce au chalut portent à croire que les juvéniles pélagiques de 30 mm migrent vers le rivage ou y sont transportés jusqu'à une profondeur d'environ 200 m, où ils trouvent leur habitat définitif. L'abondance relative élevée des juvéniles pélagiques de *Sebastes melanostomus* dans les échantillons de chaluts mésopélagiques porte à croire que cette espèce pourrait représenter une ressource exploitable.

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IN recent years the rockfishes, now referred to the genus *Sebastes*, have become increasingly important as a commercial and recreational resource in coastal waters from Mexico to Alaska. In California, for example, rockfishes increased from 29 to 71% of the party-boat catch during the 10-y period from 1965 to 1974 (McAllister, 1976). During this same period the commercial landings of rockfishes in California more than doubled and increased fivefold in value (Greenhood and Mackett 1967; McAllister 1976). Along the entire Pacific coast

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commercial landings of rockfishes, excluding *Sebastes alutus*, increased from 18.8 to 28.9 million pounds (8535 to 13 120 tonnes (t)) over the same period (Verhoeven 1976).

The Pacific ocean perch (*S. alutus*) has presented a striking example of overexploitation. Until 1960, the northeastern Pacific stocks of this species were fished only by United States and Canadian trawlers, who took fewer than 5000 t annually and only fished in the southernmost portion of the range of commercially abundant stocks (southern Oregon to central British Columbia). By 1965, however, the Russians and Japanese, who had entered the fishery in 1960 off

Alaska, had expanded their fishery southward to southern Oregon. In 1965 their total catch peaked at 520 000 t (Chikuni 1975). Thereafter the fishery declined rapidly and stabilized at about one-fourth that of the peak catch. The overexploitation of *S. alutus* demonstrates the need for effective management of other rockfish species, which are subjected to increased fishing pressure. The problem is complicated by the large species complement (about 70), difficulties in identification, and inadequate knowledge of the life histories of many species.

Sampling the planktonic larvae of *Sebastes* is one of the potential means of estimating year-class abundance at an early age; however, the early developmental stages are known for only a few species (Moser et al. 1977). At the end of the larval period the species of *Sebastes* follow divergent strategies. Some, like *S. paucispinis*, move to inshore nursery areas such as eelgrass beds (Moser 1967). Others, like *S. diploproa* and *S. rubrivinctus*, spend their early juvenile life in masses of floating kelp and flotsam (Mitchell and Hunter 1970; Boehlert 1977). Still others, such as *S. macdonaldi*, have an extended pelagic juvenile stage (Moser 1972).

A study of the *Sebastes* larvae and juveniles taken by midwater trawl in the deep-water basins off southern California and Baja California revealed a recurring group of a few common types. One of these, the black-gill rockfish (*S. melanostomus*), has a striking pigment pattern and could be assembled into a continuous developmental series from 6.2 to 46.2 mm. In this paper we describe this series and point out the potential of using the pelagic juvenile stages of certain species of *Sebastes* in resource assessment.

Materials and Methods

A total of 217 midwater trawl collections containing *Sebastes* larvae and juveniles was examined; of these, 202 were provided by the Los Angeles County Museum of Natural History, 6 by the Scripps Institution of Oceanography (SIO) Fish Collection, and 9 by the National Marine Fisheries Service, La Jolla. Of the Los Angeles County Museum collections all but 20 were made with an open 10-ft (3-m) Isaacs-Kid midwater trawl. Two were made with an open 30-ft (9-m) midwater trawl, 1 was made with a 6-ft (1.8-m) ring net, and 17 were discrete depth samples made with an acoustically operated 6-ft (1.8-m) Tucker opening-closing net. The open midwater trawls were fished horizontally at maximum depth for 2 h. Maximum depths ranged from 10 to 1350 m (Table 1) over a range of bottom depths of 210–4389 m ($\bar{x} = 2225 \pm 973$ SD). Depths sampled by the opening-and-closing nets are listed in Table 1.

A total of 1310 larvae and juveniles of *Sebastes* was examined of which 211 (16%) represented *S. melanostomus* (Table 2). The distribution and size frequency of *S. melanostomus* are shown in Fig. 1 and 2. Newborn larvae obtained from a pregnant female of this species, caught on March 13, 1975 and identified with the characters of Barsukov (1968), Tsuyuki and Westrheim (1970), and

TABLE 1. Maximum depths (m) of midwater trawls used in this study (Los Angeles County Museum material).

Open trawls				Discrete depth trawls	
Depth range	No. of tows	Depth range	No. of tows	Depth	No. of tows
0–50	25	601–650	5	200	6
51–100	31	651–700	11	225	1
101–150	7	701–750	1	250	1
151–200	4	751–800	3	300	1
201–250	8	851–900	7	350	3
251–300	5	901–950	6	450	1
301–350	25	951–1000	1	525	1
351–400	4	1051–1100	4	550	1
401–450	7	1151–1200	6	650	1
451–500	6	1251–1300	10	800	1
501–550	3	1301–1350	1		
551–600	4	Unknown	1		

TABLE 2. Composition of *Sebastes* identified in midwater trawl samples from southern and Baja California.

<i>Sebastes</i> type	No. of specimens	% total
<i>S. aurora</i>	16	1
<i>S. diploproa</i> (juveniles)	25	2
<i>S. levis</i>	2	<1
<i>S. macdonaldi</i>	4	<1
<i>S. melanostomus</i>	211	16
<i>S. paucispinis</i>	6	<1
<i>S. rubrivinctus</i>	51	4
Subgenus <i>Sebastomus</i>	585	45
<i>S. spp.</i>	410	31
Total	1310	

Miller and Lea (1972), were raised to the point of yolk depletion. These larvae helped confirm the identification of the trawl-caught series and were used in the description of the larvae. The descriptive methods follow those of Moser et al. (1977). Terminology of the head spines follows that of Eschmeyer (1969), Moser (1972), and Poss (1974).

The terminology of specimen length requires special explanation. Standard length is defined as the distance between the tip of the snout and the posterior edge of the hypural plate. In larvae that have not completed notochord flexion, and therefore do not have the posterior edge of the hypural plate in a vertical position, we measure the body length from the tip of snout to the tip of the notochord. Notochord flexion in *S. melanostomus* is completed at a length of 7.5 mm and specimen length in larvae larger than this is referred to as standard length.

Fresh specimens for aging were obtained from the stomach contents of albacore (*Thunnus alalunga*) taken in August 1977 about 80 miles (129 km) south-southwest of San Diego, Calif. The otoliths were prepared and analyzed according to the methods of Brothers et al. (1976).

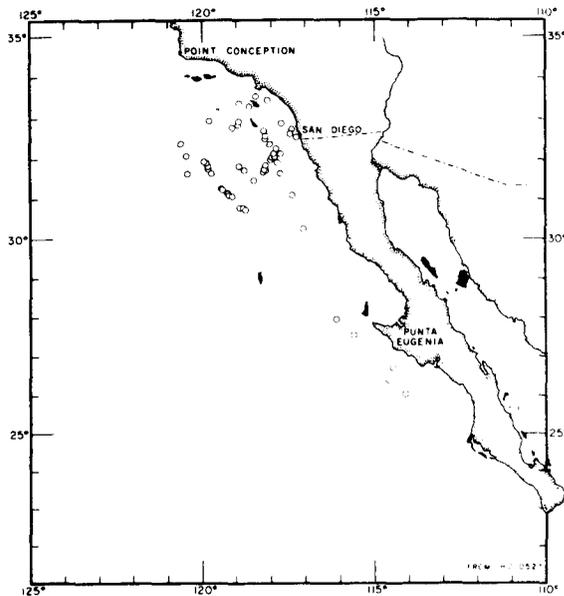


FIG. 1. Distribution of midwater trawl samples containing larvae and pelagic juveniles of *Sebastes melanostomus*.

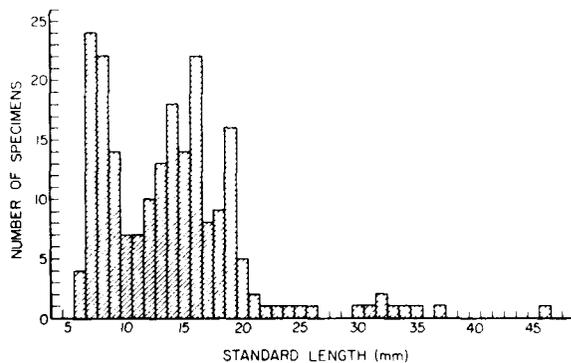


FIG. 2. Length frequency of total midwater trawl catches of *S. melanostomus* taken off southern and Baja California.

Results and Discussion

DISTINGUISHING FEATURES

Larvae of *S. melanostomus* are extruded at a length of about 4.5 mm. Although there is a gap in our series between 4.5 and 6.2 mm (Table 3), some of the pigment present on the smallest trawl-caught specimens is also evident on newborn larvae. Newborn larvae have a single row of melanophores (mean of 8 melanophores for 27 specimens counted) on the ventral midline of the tail, a patch above the brain, a heavy blotch at the tip of the lower jaw, a streak along the posterior region of the upper jaw, a pattern of minute melanophores on the pectoral fins, and a group along the dorsal and

lateral surfaces of the gut (Fig. 3). A large blotch that appears on the opercle at about the completion of notochord flexion, along with the upper jaw streak that has moved anteriorly, helps to distinguish larvae of this size. Older larvae and pelagic juveniles develop a striking banding, which is retained in benthic juveniles and even to some extent in adults (Fig. 3-5). Larvae and pelagic juveniles develop unusually prominent head spination. The beginning of the pelagic juvenile stage is marked by the appearance of anterior lateral-line scales in 16.0-mm specimens. The largest pelagic juvenile examined measures 46.2 mm, and the smallest demersal juvenile 36.0 mm.

MORPHOLOGY

Body proportions for larvae and pelagic juveniles of *S. melanostomus* and of four other species of *Sebastes* studied previously (Moser et al. 1977) are listed in Table 4. Larvae and pelagic juveniles of *S. melanostomus* are comparatively deep-bodied, big-headed, and have eyes of moderate size. Relative head length is considerably greater in flexion-stage larvae of *S. melanostomus* than in the other species.

The development of prominent head spines is the outstanding morphological feature of *S. melanostomus* larvae. The sequence of development of head spines in early larvae of *Sebastes* has been described for *S. macdonaldi* (Moser 1972). The more complete series of late-stage larvae and pelagic juveniles of *S. melanostomus* provides an opportunity to describe the development of these spines in greater detail. Their development and eventual fate is described in relation to the bones that bear them in the approximate sequence of their appearance (Table 5, Fig. 6 and 7).

Parietal—Parietal bones bear serrated ridges that terminate in prominent spines. Posterior to each parietal spine is a nuchal spine. Initially the nuchals are small and subjacent to the parietals; however, during larval development the nuchals enlarge in relation to the parietals and eventually equal them in size (Fig. 7B). Both spines are retained in adults.

Frontal—The frontal bone, which forms a shelf above the eye, eventually bears two spines. Initially the postocular spine forms directly above the eye but gradually moves posteriorly with development to assume a rearward position above the orbit at the end of pelagic life. The second spine to develop on the shelf is the supraocular. Initially it is located forward but moves posteriorly with development to a position above the center of the orbit. Supraocular and postocular spines are retained in adults. At the beginning of the pelagic juvenile stage the tympanic spine begins to form on the upper rim of a sensory-canal opening. The spine enlarges to eventually obscure the opening at the end of pelagic life. On the largest stained pelagic juvenile examined a single coronal spine is present on the right side

TABLE 3. Measurements (mm) of larvae of *Sebastes melanostomus*. Specimens between dashed lines are undergoing notochord flexion and those between solid lines are pelagic juveniles.

Specimen length	Snout-anus distance	Head length	Snout length	Eye diam	Body depth	Pectoral fin length	Pectoral fin base depth	Pelvic fin length	Snout-anal fin interval
4.5	1.7	0.96	0.28	0.36×0.39	1.0	0.25	0.23		
6.2	3.7	3.0	1.0	0.92×0.96	2.2	1.2	0.79	0.64	4.0
6.8	3.8	3.4	1.0	1.0×1.1	2.4	1.3	0.80	0.77	4.2
7.2	3.8	3.2	1.0	1.0×1.1	2.5	1.3	0.84	—	4.3
7.6	4.4	3.4	1.2	1.1×1.1	2.9	1.8	0.87	1.1	4.8
7.8	4.7	3.4	1.2	1.1×1.1	3.0	1.6	0.90	1.0	4.9
8.2	4.5	3.2	1.0	1.2×1.2	3.4	1.6	1.0	1.2	5.1
8.5	4.8	3.7	1.2	1.2×1.2	3.2	1.9	1.0	1.3	5.2
9.0	5.2	3.8	1.2	1.2×1.2	3.4	1.9	1.2	1.3	5.4
10.1	5.8	4.0	1.2	1.4×1.4	4.2	2.2	1.2	1.5	6.1
11.3	6.7	4.7	1.4	1.6×1.6	4.4	2.6	1.2	1.8	6.8
12.3	7.6	5.0	1.6	1.7×1.7	4.5	2.6	1.3	2.0	8.2
13.5	8.0	5.2	1.6	1.8×1.8	5.2	2.9	1.3	2.2	8.6
14.5	9.1	5.7	1.9	1.9×1.9	5.6	3.1	1.4	2.4	9.8
15.7	9.7	6.2	1.8	2.0×1.9	5.9	3.6	1.6	3.1	10.1
16.2	9.8	6.5	2.2	2.1×2.0	6.2	3.5	1.5	3.1	10.3
17.4	10.6	6.2	1.9	2.2×2.2	6.5	5.0	1.7	3.3	11.0
18.6	11.5	7.2	2.3	2.3×2.2	6.7	4.4	1.8	3.5	12.3
19.8	12.7	7.9	2.7	2.3×2.3	7.2	4.7	1.8	3.8	13.4
20.7	13.0	8.0	2.7	2.4×2.4	8.0	5.2	2.1	4.2	13.5
21.4	13.2	7.8	2.2	2.5×2.5	8.5	5.7	2.2	4.0	13.7
23.3	14.5	8.6	2.4	2.7×2.7	8.7	6.2	2.3	4.8	15.4
24.0	16.6	10.1	2.8	2.8×2.8	9.0	6.2	2.3	—	16.9
25.2	16.7	10.1	—	3.0×3.0	9.2	6.2	2.3	4.9	17.2
26.4	16.9	10.0	2.9	2.9×2.9	9.9	6.9	2.7	5.2	17.7
30.1	19.6	12.0	3.2	3.3×3.3	10.3	8.1	2.7	6.0	19.5
32.7	20.7	12.7	3.3	3.2×3.2	12.0	8.8	3.0	6.7	21.7
33.5	23.3	13.2	3.3	4.2×4.2	12.7	9.1	3.3	7.1	24.4
34.5	21.6	13.2	3.6	3.8×3.8	11.8	9.3	3.3	6.9	22.7
37.2	24.3	14.0	3.5	4.1×4.1	12.5	10.1	3.3	7.0	25.5
46.2	29.5	15.7	4.2	4.7×4.7	17.2	13.0	4.4	9.5	31.1
36.0 ^a	22.5	12.8	2.7	4.0×4.0	13.7	10.1	3.4	7.5	24.7
42.1 ^a	27.2	15.7	4.8	4.3×4.3	14.7	11.3	3.8	8.8	29.0
60.6 ^a	37.9	22.0	5.2	7.5×7.5	21.4	16.9	5.8	11.8	41.1

^aBenthic juvenile.

of the interorbital region. They are present on no other pelagic juveniles in our collection and are only occasionally reported in adults.

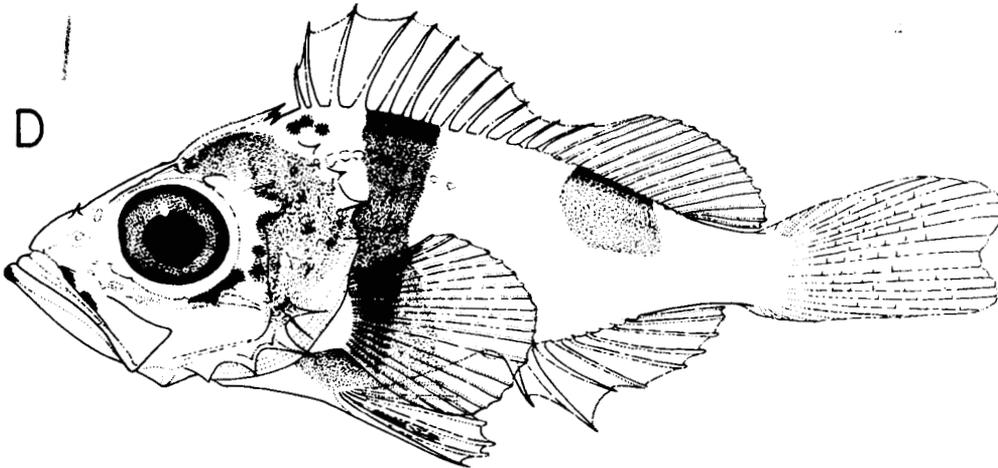
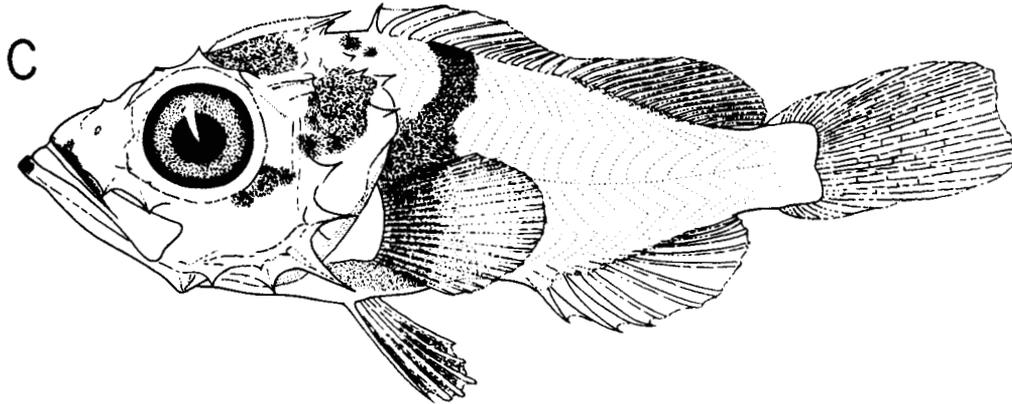
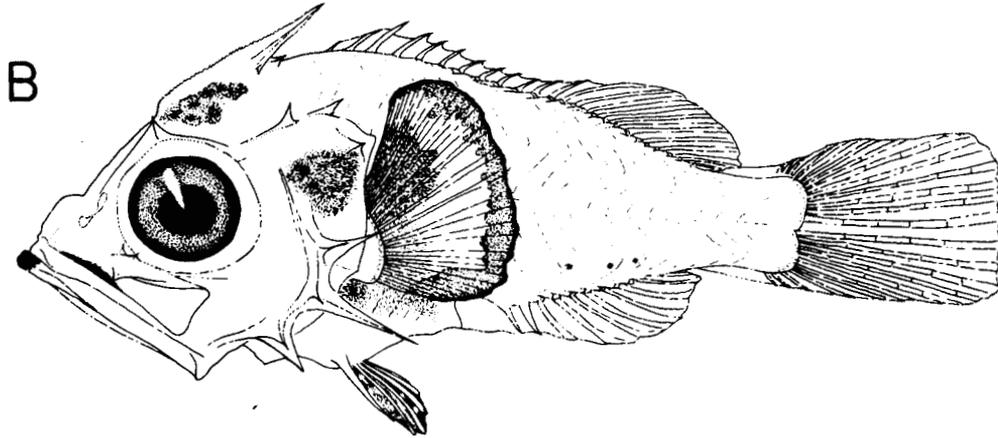
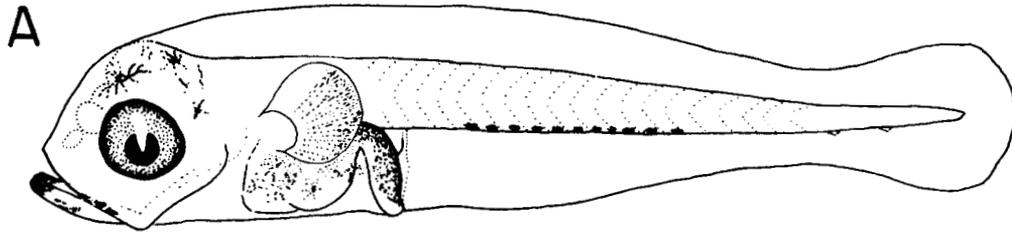
Pterotic — The large spine on the pterotic bone forms early in the larval period and remains prominent until it disappears at the end of pelagic life.

Preopercle — The spines on the preopercle form early and become highly conspicuous. Two series are formed: a posterior series of large backward-projecting spines and an anterior series of small laterally project-

ing spines. In the smallest stained larva the 2nd, 3rd, and 4th spines of the posterior series have already developed, and each bears in the anterior series a small spine projecting outward from its base. The 3rd posterior spine is the largest in the series and remains so until the end of the pelagic phase. The 3rd and 4th posterior spines are both serrated. The 1st and 5th posterior spines begin to form in the 6.8-mm larva and with continued enlargement during larval development become equal in size to the others. All five spines in the posterior preopercular series are retained in adults.

The spines in the anterior series do not persist. The

FIG. 3. Developmental series of *S. melanostomus*. A, 4.4-mm larva reared from pregnant female; B, 8.2-mm larva; C, 12.3-mm larva; D, 17.4-mm pelagic juvenile.



A



B



C



FIG. 4. Pelagic juveniles of *S. melanostomus*. A, 26.4 mm; B, 31.5 mm; C, 46.2 mm.

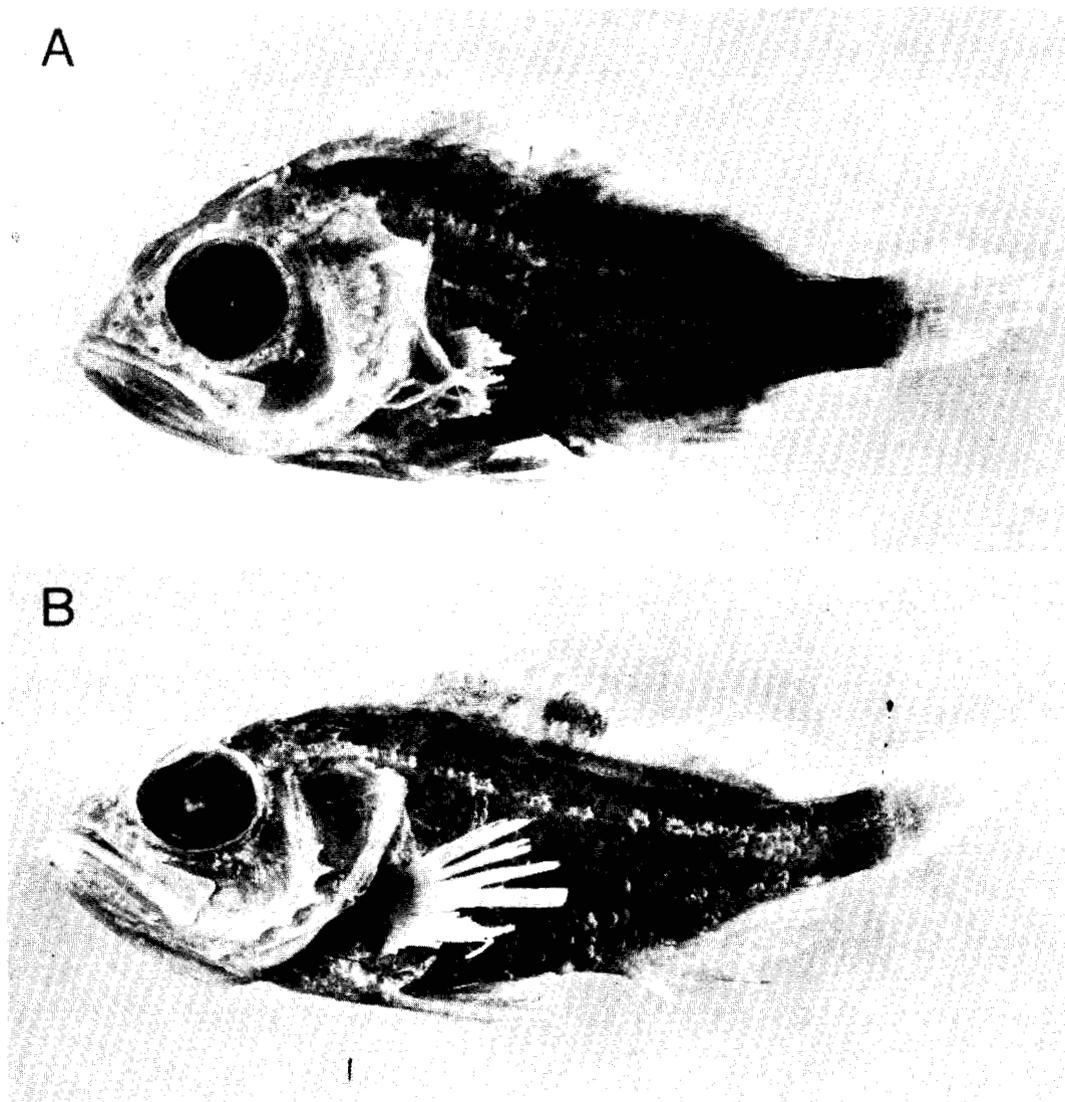


FIG. 5. Benthic juveniles of *S. melanostomus*. A, 36.0 mm; B, 42.1 mm.

one at the base of the 3rd spine of the posterior series is weakly developed or variously lacking on one or both sides until 13.5 mm, after which it is never evident. The ones at the bases of the 2nd and 4th posterior spines gradually diminish in size and are absent in individuals larger than 20.3 mm.

Opercle — A prominent spine is present on the upper posterior edge of the opercle in the smallest stained larva. This upper opercular spine has a long rod-like support that slants ventroposteriad from its point. A second opercular spine with a weaker and shorter supporting rod develops ventral to the former at about 8.8

mm. Upper and lower opercular spines are retained in adults.

Infraorbitals — Confusion and inconsistency mark the nomenclature of the series of bones that underlie the orbit of scorpaeniform fishes. Poss (1974) reviewed the historical aspects of this problem and suggested a rational terminology that we adopt here. The most anterior bone in the series, usually called the lacrymal bone by recent workers, is referred to as infraorbital 1. The next bone posterior to it, usually referred to as suborbital 1, is here termed infraorbital 2. Posterior to it the bone that bears the projection extending to the

TABLE 4. Comparative morphometry of five species of *Sebastes* (A = larvae undergoing notochord flexion, B = postflexion larvae, C = pelagic juveniles). Values given for each body proportion expressed as percentage of head length: mean, standard deviation, and range.

	Snout-anus distance		Head length		Snout length		Eye diam		Body depth		Pectoral fin length		Pectoral fin base depth		Pelvic fin length	
	Body length	Head length	Body length	Head length	Head length	Head length	Body length	Body length	Body length	Body length	Body length	Body length	Body length	Body length	Body length	Body length
<i>S. jordani</i>																
A	42.4 ± 1.67 (41-45)	28.4 ± 2.19 (26-30)	35.5 ± 1.29 (34-37)	32.2 ± 2.50 (29-35)	21.0 ± 1.00 (20-22)	8.4 ± 1.14 (7-10)	7.8 ± 0.45 (7-8)	1.4 ± 0.55 (1-2)								
B	51.0 ± 2.86 (46-54)	32.3 ± 1.44 (31-36)	34.4 ± 1.98 (31-39)	29.3 ± 2.10 (27-34)	23.8 ± 1.19 (22-26)	16.8 ± 3.25 (11-20)	7.9 ± 1.0 (7-10)	9.0 ± 3.62 (3-13)								
C	53.3 ± 1.03 (52-55)	31.2 ± 1.94 (28-33)	34.0 ± 2.83 (30-38)	26.5 ± 1.52 (24-28)	22.2 ± 0.84 (21-23)	20.5 ± 1.05 (19-22)	7.0 ± 0.00 (7)	13.5 ± 1.22 (12-15)								
<i>S. lewis</i>																
A	48.9 ± 3.44 (45-56)	30.5 ± 1.85 (28-33)	34.8 ± 0.89 (34-36)	32.5 ± 1.77 (30-35)	28.5 ± 3.51 (24-35)	34.9 ± 6.96 (24-46)	12.9 ± 0.64 (12-14)	6.1 ± 3.27 (2-12)								
B	59.2 ± 2.87 (57-63)	35.0 ± 2.00 (34-38)	30.2 ± 2.22 (28-33)	30.5 ± 1.73 (28-32)	34.0 ± 1.41 (33-36)	45.0 ± 3.74 (41-50)	11.2 ± 0.96 (10-12)	21.0 ± 4.76 (16-26)								
C	63.0 ± 0.82 (62-64)	33.8 ± 0.96 (33-35)	30.5 ± 2.38 (28-33)	27.0 ± 3.37 (25-32)	35.0 ± 1.41 (34-37)	40.8 ± 7.09 (32-47)	10.2 ± 0.96 (9-11)	24.2 ± 2.87 (22-28)								
<i>S. macdonaldi</i>																
A	51.8 ± 3.56 (48-56)	35.6 ± 1.52 (34-38)	34.0 ± 4.00 (30-38)	32.0 ± 1.41 (31-34)	31.6 ± 2.07 (30-35)	13.0 ± 1.22 (12-15)	—	5.8 ± 2.39 (3-9)								
B	60.3 ± 3.06 (55-64)	37.5 ± 1.84 (34-41)	32.9 ± 3.00 (29-37)	33.0 ± 1.33 (31-35)	34.4 ± 1.17 (33-36)	19.3 ± 3.65 (15-26)	—	14.3 ± 3.77 (10-21)								
C	64.2 ± 2.44 (61-68)	35.1 ± 2.37 (32-38)	27.9 ± 2.09 (25-32)	30.7 ± 2.74 (26-34)	31.4 ± 1.59 (30-34)	30.4 ± 1.74 (28-34)	—	21.9 ± 1.36 (21-25)								
<i>S. melanostomus</i>																
A	56.6 ± 2.99 (53-60)	46.8 ± 2.75 (44-50)	32.0 ± 2.58 (29-35)	32.5 ± 1.00 (32-34)	35.8 ± 1.50 (35-38)	20.0 ± 2.71 (18-24)	12.0 ± 0.82 (11-13)	11.7 ± 2.08 (10-14)								
B	59.1 ± 2.69 (55-63)	40.9 ± 2.02 (39-44)	31.5 ± 1.72 (29-35)	33.6 ± 2.07 (31-38)	38.9 ± 1.52 (37-42)	21.5 ± 0.97 (20-23)	11.3 ± 1.06 (10-13)	15.7 ± 1.89 (13-20)								
C	63.9 ± 2.67 (60-70)	38.4 ± 1.97 (36-42)	29.0 ± 3.21 (25-34)	30.1 ± 2.29 (25-35)	36.9 ± 1.75 (34-40)	26.1 ± 1.75 (22-29)	9.6 ± 0.50 (9-10)	19.7 ± 0.80 (19-21)								
<i>S. paucispinis</i>																
A	44.8 ± 3.70 (40-49)	29.6 ± 1.95 (27-32)	30.6 ± 1.82 (29-33)	30.2 ± 1.64 (29-33)	23.0 ± 1.41 (21-24)	27.2 ± 2.49 (25-31)	9.0 ± 0.71 (8-10)	13.6 ± 9.29 (9-26)								
B	57.3 ± 3.82 (51-61)	37.1 ± 1.07 (36-39)	32.2 ± 0.98 (31-33)	31.3 ± 1.70 (28-33)	29.6 ± 0.98 (28-31)	35.7 ± 1.25 (34-37)	7.6 ± 0.53 (7-8)	35.1 ± 2.79 (31-39)								
C	62.3 ± 2.73 (60-66)	36.2 ± 1.72 (33-38)	30.5 ± 2.95 (26-33)	27.8 ± 1.72 (26-30)	27.3 ± 0.52 (27-28)	28.2 ± 3.4 (25-34)	6.0 ± 0.89 (5-7)	25.2 ± 2.71 (22-30)								

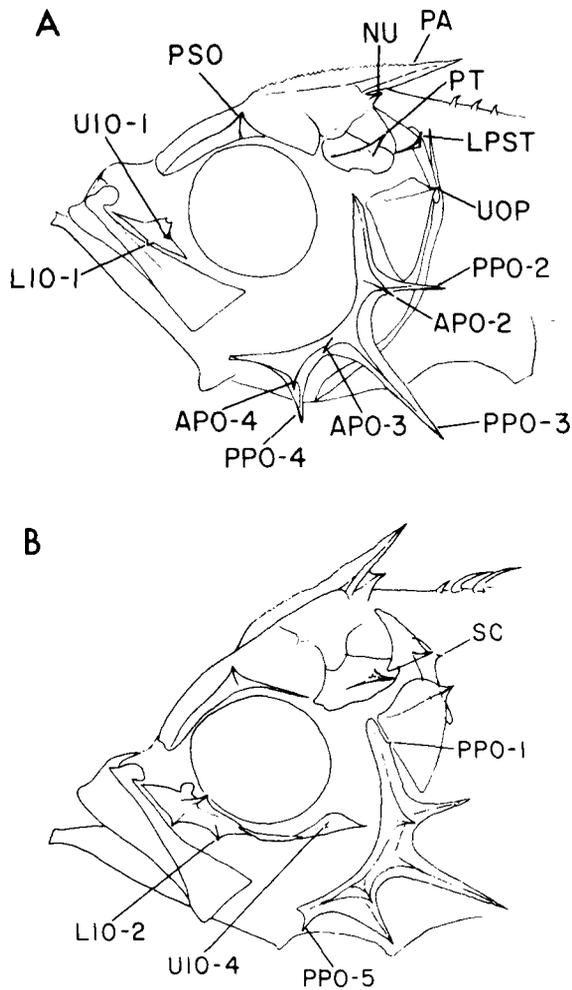


FIG. 6. Head spines in 6.2 mm (A) and 8.2 mm (B) stained larvae of *S. melanostomus*. Abbreviations of head spines: APO-2, 2nd anterior preopercular; APO-3, 3rd anterior preopercular; APO-4, 4th anterior preopercular; CL, cleithral; IOP, interopercular; LIO-1, 1st lower infraorbital; LIO-2, 2nd lower infraorbital; LOP, lower opercular; LPST, lower posttemporal; NA, nasal; NU, nuchal; PA, parietal; PPO-1, 1st posterior preopercular; PPO-2, 2nd posterior preopercular; PPO-3, 3rd posterior preopercular; PPO-4, 4th posterior preopercular; PPO-5, 5th posterior preopercular; PRO, preocular; PSO, postocular; PT, pterotic; SC, supracleithral; SPO, supraocular; TM, tympanic; UIO-1, 1st upper infraorbital; UIO-2, 2nd upper infraorbital; UIO-3, 3rd upper infraorbital; UIO-4, 4th upper infraorbital; UOP, upper opercular; UPST, upper posttemporal.

preopercle and has usually been referred to as suborbital 2 is termed the infraorbital 3.

All three bones develop spines in larvae of *Sebastes*. In our smallest stained larva of *S. melanostomus*, infraorbital 1 bears an outward-projecting spine on its upper

edge and a downward-projecting one on its ventral edge. At 8.2 mm a second spine appears posteriorly on the ventral edge of the bone, and at 9.0 mm a second outward-projecting spine forms posterior to the one on the upper edge of the bone. The two upper spines develop as projections on a serrated shelf below the orbit. They become progressively reduced during pelagic life and are obsolete in benthic juveniles and adults. The two lower spines progressively enlarge with development, becoming prominent in juveniles and adults. A single outward-projecting spine develops on the upper lateral face of infraorbital 3 at 7.2 mm. As development proceeds the spine projects from a serrated shelf that rims the orbit. The spine is reduced toward the end of pelagic life and is lost in benthic juveniles. The last spine to appear in the infraorbital series projects outward from the upper edge of infraorbital 2. With development it becomes a projection of the serrated shelf below the orbit, but remains inconspicuous and disappears at the end of the pelagic period.

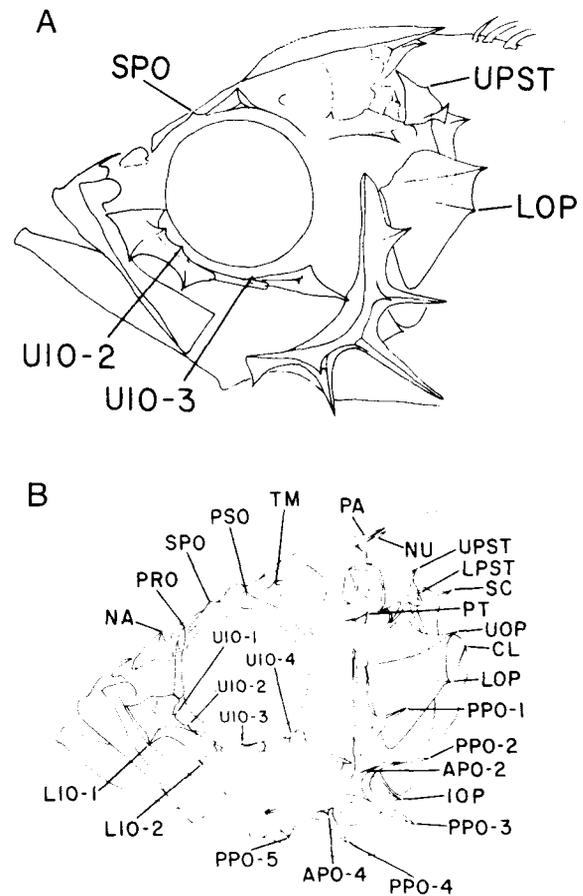


FIG. 7. Head spines in 10.0 mm (A) and 16.0 mm (B) stained larvae of *S. melanostomus*. Abbreviations as in Fig. 6.

Lateral ethmoid — The lateral ethmoid bone begins to form at the anterior rim of the orbit early in the larval period. Late in the larval period (13.2 mm) the preorbital spine begins to form as a dorsal projection from the bone. Inconspicuous at first, it enlarges to become a prominent spine in juveniles and adults.

Nasal — The nasal spine begins to form at about 12.8 mm as a dorsal projection of the nasal bone. It becomes pronounced with further development and is a prominent spine in juveniles and adults.

Posttemporal — The posttemporal bone forms two spines. In the smallest stained larva a strong spine projects outward from the ventral margin of the bone. It remains conspicuous throughout the larval period but as the lower region of the bone begins to curve inward in pelagic juveniles the spine recedes, becomes barely discernible in early benthic juveniles, and then disappears. A second spine begins to form above the lower spine on the posterior edge of the bone at 10.0 mm. In contrast to the lower posttemporal spine, the upper spine becomes progressively larger with development. It projects dorsoposteriad from the bone and is retained in juveniles and adults.

Supracleithrum — A backward-projecting spine appears on the posterior edge of the supraclathrum at 8.2 mm. It enlarges progressively with development to equal the upper posttemporal spine in size and is retained in adults.

Cleithrum — A small spine appears on the upper posterior margin of the cleithrum at 14.7 mm. It remains throughout the pelagic period, is retained in small benthic juveniles, and then lost.

Interopercular — Late in the larval period a supporting rod begins to develop at the upper margin of the interopercular, where the bone faces the subopercular. At 15.7 mm this rod projects backward as a spine which is retained throughout the remainder of the stained series. It is variously present or absent in benthic juveniles and adults.

Subopercular — In some pelagic juveniles a spine projects from the lower margin of the subopercular, where the bone faces the interopercular. In the largest stained specimen (32.2 mm) a second spine is present just above the one at the lower margin. Like the interopercular spine, these spines are variously present or obsolete in benthic juveniles and adults.

A notable feature of head-spine development in *Sebastes* is the gradual ontogenetic appearance of most of the major spines found in other scorpaenid genera. Of the 22 spines that Eschmeyer (1969) has listed for the Scorpaenidae, 19 occur in the larvae and pelagic

juveniles of *Sebastes*. In genera of the subfamily Scorpaeninae, the spines that develop in larvae and pelagic juveniles are retained and typically become more prominent in adults. In *Sebastes* (subfamily Sebastinae) a number of spines gradually become reduced toward the end of the pelagic juvenile stage and are lost soon after the fish settle. Among the spines that degenerate are the infraorbitals (which are, however, retained in *S. alcutianus*, *S. macdonaldi*, and *S. phillipsi*), the anterior preoperculars, the lower posttemporals, and the pterotics. Apart from the ontogenetic appearance and loss of these spines, other spines of the complement known for *Sebastes* are lost or reduced in adults of some species (Phillips 1957). Generally spine reduction and loss is more pronounced in species that have a convex interorbital region and a streamlined head, and usually do not live directly on the bottom. This trend culminates in semipelagic species such as *S. goodei*, *S. jordani*, and *S. paucispinis*, which have little or no spination atop the head. Interestingly, spination appears to be adaptive at one life-history stage and nonadaptive at another; i.e. sebastine larvae and pelagic juveniles develop almost the complete ancestral complement of head spines, probably as an adaptation for flotation and defense. As adults, the evolutionary direction of sebastines is toward a pelagic existence that contrasts with the sedentary mode of existence of most scorpaenines and, for this, the reduction and loss of head spines is adaptive in adults and is reflected in the loss of spines during ontogeny. In concert with this, the connection between the preopercle and infraorbital 3 is reduced to allow the flexibility and streamlining that would appear to be adaptive for semipelagic life. In scorpaenines, infraorbital 3 is a broad bone that fuses with the preopercle, whereas in *Sebastes*, infraorbital 3 is T-shaped and sends a narrow projection to the preopercle but does not fuse with it.

FIN DEVELOPMENT

In comparison with other *Sebastes* species, the pectoral fins of *S. melanostomus* are of moderate length. They increase in relative length during development (Table 3). The pectoral fin base is relatively deep as in *S. levis*. The smallest stained specimen has 17 pectoral rays, which falls within the adult complement of 17–20 (Table 6). For the remainder of the series the modal count is 19.

The pelvic fin is also of moderate length in comparison with other species and further enlarges during development (Table 3). The adult complement of 1 spinous and 5 soft pelvic rays is evident in the smallest stained specimen. In this specimen, 3 of the anterior spinous dorsal rays and 7 of the soft rays are forming. The full complement of 13–14 spinous rays is achieved in all larvae longer than 8.2 mm. Although the 13th spinous ray cannot be differentiated anatomically from the 1st soft-ray until the middle of the larval period, it is distinguished by its relative height. The most posterior

TABLE 6. Meristics from cleared and stained larvae of *S. melanostomus*.

Length (mm)	Procurent caudal fin rays		Pectoral fin rays		Gill rakers (right arch)		Anal fin rays	Dorsal fin rays	Vertebrae
	Superior	Inferior	Left	Right	Upper limb	Lower limb			
6.2 NL	2	2	17	17	2	15	0,5	III,7	23 ^a
6.8	2	—	19	19	3	15	III,7	XIII,12	26
7.2	2	3	19	19	2	15	II,7	XII,11	24 ^a
7.5 SL	3	3	19	19	3	16	III,7	XIII,12	26
7.7	3	4	20	20	3	15	III,7	XIII,11	26
8.2	4	5	17	17	4	17	III,7	XIII,13	26
8.8	5	6	18	18	6	16	III,7	XIII,13	26
9.0	5	6	19	19	6	17	III,7	XIII,13	26
9.4	5	6	18	19	5	17	III,7	XIII,13	26
10.0	7	8	19	19	7	20	III,7	XIII,13	26
10.6	7	7	19	19	7	18	III,7	XIII,14	26
11.8	8	8	19	19	8	20	III,7	XIII,14	26
12.0	8	9	20	20	8	19	III,7	XIII,13	26
12.8	8	8	19	19	8	21	III,7	XIII,13	26
13.2	9	9	19	19	8	20	III,7	XIII,13	26
13.5	9	9	19	19	8	21	III,7	XIII,13	26
13.8	9	9	19	19	8	19	III,7	XIII,14	26
14.2	9	9	20	20	8	21	III,6	XIV,14	26
14.7	9	10	19	19	8	20	III,7	XIII,13	26
15.7	9	10	19	19	8	21	III,7	XIII,13	26
16.0	9	9	19	19	8	21	III,7	XIII,14	26
16.9	9	9	19	19	7	20	III,7	XIII,14	26
17.7	10	10	19	19	8	21	III,7	XIII,13	26
18.4	10	11	19	19	8	21	III,7	XIII,13	26
18.9	9	10	19	19	8	21	III,6	XIII,13	26
19.5	9	10	19	18	9	22	III,7	XIII,14	26
20.3	9	10	19	19	8	21	III,7	XIII,14	26
21.1	10	10	19	19	8	21	III,7	XIII,14	26
22.4	9	9	19	19	9	22	III,7	XIII,13	26
26.9	—	—	19	19	9	22	III,7	XIII,13	26
32.2	—	—	20	19	8	21	III,7	XIII,13	26

^aIncomplete vertebral count.

rays are the last to appear, and the ultimate ray is distinguishable by its bifid condition.

The smallest stained specimen has no spinous anal rays, but all specimens 7.5 mm and longer have the full complement of 3. As in the dorsal fin the most posterior spinous ray can be identified by its relative height. The full complement of 6–7 soft rays is present in larvae 6.8 mm and larger. As in the dorsal fin, the ultimate soft ray is bifid. All but 2 of the 30 specimens had 7 soft rays.

Formation of the caudal fin had already begun in our smallest specimens which are undergoing notochord flexion. Flexion is complete at 7.5 mm. Although juveniles have 2 superior and 2 inferior hypurals the more primitive complement of 3 + 3 hypurals is evident during the larval stage. In juveniles, the superior hypurals consist of a broad inner and a small upper bone; the inferior hypurals comprise a broad inner bone and a narrow lower bone, the parhypural, which we have included in our count of hypurals. These broad inner bones each start from two centers of ossification. In the superior group, the three hypurals start to ossify in-

dependently. The uppermost, a small hypural, forms rather late, since it was first observed as a cartilage at 10.6 mm and was not ossified until about 12.8 mm. The other two hypurals are evident on the smallest stained specimen, 6.2 mm. They remain as distinct bones on 6.2- to 7.7-mm specimens and then fuse, initially at their distal margins and then gradually inward toward the ural centrum; fusion was complete by ~17 mm. The inferior group also forms from three centers. On the 6.8-mm specimen, all three bones are separate and ossifying. The two inner bones are fused at their distal margins on a 7.2-mm specimen, and mostly fused along their lengths by ~8.2 mm; however, complete fusion can be delayed until ~17 mm. All hypurals are autogenous (separate from the ural centrum). In that it retains a hemal arch and has a pair of long, thin "parhypuropophyses," the lower hypural of the inferior group could be characterized as a typical "parhypural."

The 8+7 principal caudal rays, countable on the smallest specimen, are supported exclusively by the hypural bones; the superior hypurals support the 8 rays

TABLE 7. Change in the mean number and range of ventral midline melanophores in larvae of *S. melanostomus* from mid-water trawl collections.

Size range (mm)	No. specimens	$\bar{x} \pm SD$	Range
6.0-6.9	12	7.3 \pm 1.30	4-9
7.0-7.9	26	5.2 \pm 2.53	1-10
8.0-8.9	16	3.8 \pm 2.81	0-9
9.0-9.9	9	2.3 \pm 1.87	0-5
10.0-10.9	10	1.8 \pm 1.99	0-5
11.0-11.9	4	2.8 \pm 2.63	0-5
12.0-12.9	13	0.5 \pm 0.97	0-3
13.0-13.9	15	0.1 \pm 0.26	0-1

of the upper lobe and the inferior hypurals support the 7 rays of the lower lobe.

The procurrent caudal rays form gradually. Two dorsal and 2 ventral procurrent rays were detectable on the 6.2-mm specimen; the lower value for the full complement of procurrent rays, 9 dorsal and 9 ventral, was developed on a 13.2-mm specimen, and the more usual complement of 9 dorsal and 10 ventral rays on a 14.7-mm specimen. The range in larger specimens is 9 or 10 dorsal and 9-11 ventral. The ventral procurrent caudal rays are supported by the spatulate elongated hemal spines of the two vertebrae immediately anterior to the ural; the dorsal procurrent caudal rays are supported by the three epural bones and the spatulate, elongated neural spine of the second vertebra anterior to the ural. The reduced neural spine of the vertebra adjacent to the ural forms at 10.6 mm but is too short to enter into support of the procurrent rays. Note that both hemal spines that support ventral procurrent caudal rays develop autogenously, separate from their centra, but appear to be secondarily ossified to their centra in later life-history stages.

The ural centrum, a long moderately tapered bone with a truncate termination, is beginning to ossify on the 6.2-mm specimen. On this specimen, all vertebral centra except the three immediately anterior to the ural centrum are ossifying; by 7.5 mm all 26 vertebral centra are ossifying. The three epurals are first seen as cartilage on a 9.4-mm specimen and are ossified on a 13.2-mm specimen. The single pair of uroneurals appears on a 10.6-mm specimen and is well developed by 13.2 mm.

PIGMENTATION

The initial pigment pattern of *S. melanostomus* larvae is known from specimens reared in the aquarium (Moser et al. 1977). The dorsal and lateral surfaces of the gut are covered with melanophores. A ventral midline row on the tail contains fewer melanophores than in any other species presently known (mean of 8, with a range of 4-11, for 27 specimens counted). The pectoral fin is partially covered with a patch of fine melanophores. Most specimens examined had one or two spots on the nape, as many as 8 melanophores on the dorsal aspect

of the head, and a strong patch at the mandibular symphysis, often extending onto the gular region. About half of the reared specimens had a linear patch of melanophores at the posterior aspect of the jaw, a unique placement for the species of *Sebastes*, insofar as presently known.

With further development, the number of melanophores in the ventral midline is reduced (Table 7) and they are lacking in larvae longer than 14.0 mm. The pigment over the gut is augmented and forms a solid sheet over the gut. Pigment is added to the brain and forms a solid covering in larvae longer than 11.0 mm. The blotch at the symphysis of the lower jaw enlarges to cover the oral valve and remains prominent throughout the larval period. It becomes diffuse and gradually weaker in pelagic juveniles and is absent occasionally in specimens longer than 18.0 mm. The pigment streak originally posterior to the jaw becomes more pronounced and becomes located above the anterior half of the maxillary throughout the larval and pelagic juvenile stages. A distinctive patch of melanophores begins to form on the upper region of the opercle in 6-mm larvae. The patch enlarges throughout the larval period. In pelagic juveniles it covers the entire opercle and becomes confluent with the dorsal head pigment. Pigment develops on the cheek at the posteroventral corner of the orbit in larvae as short as 10.8 mm. It is variously present or absent in larvae as long as 13.0 mm and present, usually as a triangular patch, in specimens up to 19.0 mm. In larger pelagic juveniles the patch usually extends anteriorly beneath the eye. Pigment patches in the nasal region are present in about half the larvae longer than 13.0 mm. In pelagic juveniles the patches enlarge and become diffuse over the entire nasal region.

The most striking pigmentation is the pattern of melanistic bars that develops on the body. The anterior bar begins to form in larvae as short as 11.3 mm. Either a patch of melanophores that extends upward from the gut region or a patch that extends downward from the base of the dorsal fin, or both, are present. Although the smallest larvae in which these patches become confluent to form a complete band measures 12.3 mm, larvae as long as 14.7 mm may not have a complete band. The band has a consistent width, extending ventrad in a zone between the 3rd or 4th to the 7th or 8th spinous dorsal. A bar begins to form beneath the soft-dorsal fin in larvae as short as 14.4 mm. It is present in about half of the larvae between 14.4 and 16.0 mm as a patch of melanophores or saddle extending ventrad from the fin base. It was observed in all but 4 of 21 pelagic juveniles between 16.0 and 18.2 mm long and in all specimens longer than this. There is a gradual ventrad progression of the saddle, and in late pelagic juveniles a complete band is formed with pigment developing dorsad from the anal fin base. A third band begins to form on the caudal peduncle in pelagic juveniles as short as 20.7 mm. Initially it is a lateral blotch but enlarges to form a complete band in specimens longer than 32.2 mm.

The development of background pigment on the unbanding regions of the trunk is a gradual process that begins in larvae as short as 13.5 mm in which one to several melanophores appear forward of the anterior band. These melanophores become more extensive in later larvae, and the entire area anterior to the band begins filling in with pigment in pelagic juveniles to become solidly covered in most specimens longer than 19.0 mm. The gradual filling in of the unpigmented areas between the posterior bands begins at ~32.5 mm long and progresses so that the largest pelagic juvenile is completely pigmented with the bands merely accentuated.

The fins are also characteristically pigmented. In newborn larvae the pectoral fin blades are evenly covered with fine melanophores. As the fin rays develop, the melanophores become distributed on the interradial membranes, with heavier pigmentation on the distal margins of the blades. The medial surfaces of the fin bases are heavily pigmented. At ~7.5 mm an unpigmented zone begins to form between the distal margin and the proximal half of the fin blade. At ~9.0 mm the pigment at the distal margin begins to diminish while pigment remains in an arc-shaped basal zone that extends onto the dorsal margin of the fin. At the beginning of the pelagic juvenile stage the pigment along the dorsal margin of the fin begins to recede, leaving a basal bar that becomes accentuated in late-stage pelagic juveniles. In early larvae the membranes between the pelvic rays become covered with melanophores, and the distal margins of the fins are accentuated. At ~9.0 mm the pigment begins to recede from the margins and with further development becomes restricted to the proximal region of the fins.

Characteristic blotches develop on the dorsal and anal fins of pelagic juveniles. At the beginning of the pelagic juvenile stage a large blotch develops as a dorsal extension of the anterior pigment bar and at its maximum development in late-stage pelagic juveniles occupies the basal half of the fin in a zone extending from the 3rd to the 6th spinous ray. Concomitantly, a small blotch develops anteriorly on the membrane between the 1st and 3rd spinous rays. At ~26.0 mm a large blotch develops as a dorsal extension of the posterior pigment bar and another blotch forms between the 9th and 12th spinous dorsal rays. At ~30.0 mm a blotch forms on the anal fin and at maximal development extends from the 2nd spinous ray to the 7th soft ray.

DISTRIBUTION

Confusion surrounds our knowledge of the latitudinal range of *S. melanostomus*. Miller and Lea (1972) listed the southern limit as Cedros Island, Baja California (28°15'N). Our records extend this southward to off Punta Abreojos (26°06'N, 114°05'W). On the basis of biochemical identification Tsuyuki and Westrheim (1970) suggested that the northern limit lies to the

south of British Columbia. Barsukov (1968) reported this species from the Bering Sea and synonymized it with the Japanese species *S. iracundus*. If he is correct, *S. melanostomus* has the greatest latitudinal range of any species of *Sebastes*. Tsuyuki and Westrheim (1970) pointed out the taxonomic complexities of the *S. melanostomus* species group and their estimate of the northern limit of this species may well be correct.

Little is known about the bathymetric distribution of *S. melanostomus*. Depth range for 10 benthic collections of juveniles and adults made off southern and Baja California was 183–448 m with a mean weighted to catch rate of 302 m (SIO Fish Collection). Miller and Lea (1972) listed the maximum known depth of *S. melanostomus* as 549 m, making this one of the deepest living of all *Sebastes*. For this reason, blackgill rockfish are rarely taken by commercial and recreational fishermen off southern California. Their comparative abundance in midwater trawl samples in this area (Table 1) suggests that the small catches of adults may not reflect true abundance and that blackgill rockfish may represent a potential deep-water fishery.

The frequent and widespread occurrence of larvae and pelagic juveniles in midwater trawl samples taken over deep coastal waters (Fig. 1) and their need to reach more shoreward shallow areas for settling suggests a distinct life-history strategy for *S. melanostomus* and for the other rockfish species taken with it.

The peak month for birth of *S. melanostomus* larvae off southern California is February (J. LaGrange personal communication). Like other species of *Sebastes*, larvae of *S. melanostomus* inhabit the upper mixed layer and are seldom taken below 100 m (Ahlstrom, 1961). After completing larval development at ~16 mm long they transform into pelagic juveniles and live in the midwaters over coastal basins during summer. Large *S. melanostomus* larvae appear in midwater trawls from April to August (Fig. 8). Pelagic juveniles begin to appear in June and are found in increasingly larger sizes through October. Examination of daily growth rings on the otoliths of specimens taken from albacore stomachs revealed an age of 47 d for a 15.0-mm larva and 101 d for a 30.4-mm pelagic juvenile, the largest one available (Fig. 9). Pelagic juveniles are therefore ~34 mo old when they approach the size for settling. The size threshold for settling to the bottom is ~36.0 mm, judging from a newly transformed specimen of that size taken in an otter trawl off Scripps Institution of Oceanography (La Jolla, Calif.) at 265–356 m. Pelagic juveniles of this size appear in midwater trawls in September and October and either migrate or are transported shoreward to water of appropriate depth for settling. Two discrete depth tows, one at 200 m in August and another at 250 m in October, contained pelagic juveniles of 30.1 and 32.5 mm, respectively, suggesting that horizontal migration or transport of pelagic juveniles occurs in this depth range. This strategy appears to be shared with *S. aurora* and a number of

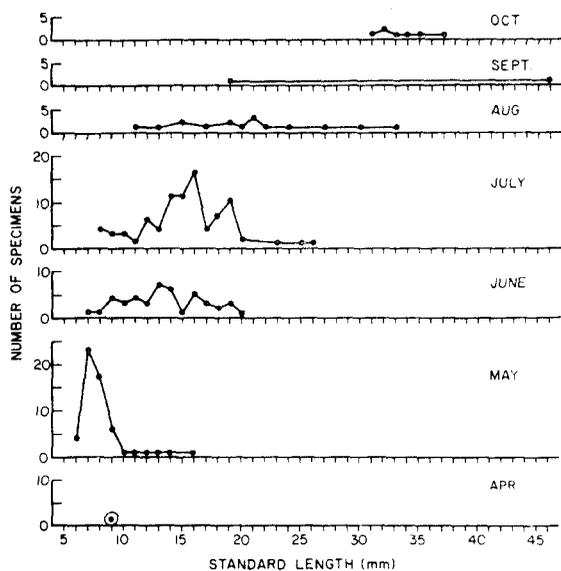


FIG. 8. Composite monthly size frequencies for larvae and pelagic juveniles of *S. melanostomus* from midwater trawls.

species of the subgenus *Sebastes*. Interestingly, all of these species have strong dark bands alternating with almost transparent regions on their bodies, possibly a protective pattern that serves to break up their body outline during their pelagic life. A similar strategy involving a midwater pelagic juvenile stage is found in *Sebastes altivelis*; however, adults of that species inhabit the deep coastal basins and juveniles can reach the adult habitat by descending vertically (Moser 1974).

A different strategy is employed by the splitnose rockfish, *Sebastes diploproa* (Mitchell and Hunter 1970; Boehlert 1977). Larvae are released from February to July and appear in surface waters upon reaching a length of ~10 mm. They are recruited to drifting masses of kelp and flotsam where they grow to a maximum of 50 mm long. These juveniles develop a solid background pigmentation with faint bars, and the fins have contrasting dark and clear areas that would appear to disguise them in the kelp and midwater habitat. Since the smallest benthic specimens are ~30 mm long, emigration from surface waters must occur in a length range of 30–50 mm. Catches from discrete midwater hauls indicate that emigrating pelagic juveniles descend to a depth of 200–250 m and migrate horizontally until they reach bottom, at which time they are ~1 yr old.

The bocaccio, *S. paucispinis*, exhibits a third strategy (Moser 1967). Planktonic larvae attain a size of ~30 mm and then migrate shoreward to their early juvenile habitat in kelp and eelgrass beds. Juveniles from these habitats have a striking pattern of irregular bars and pigment saddles that provide a mottled appearance. At the end of their 1st yr they begin to move into deeper

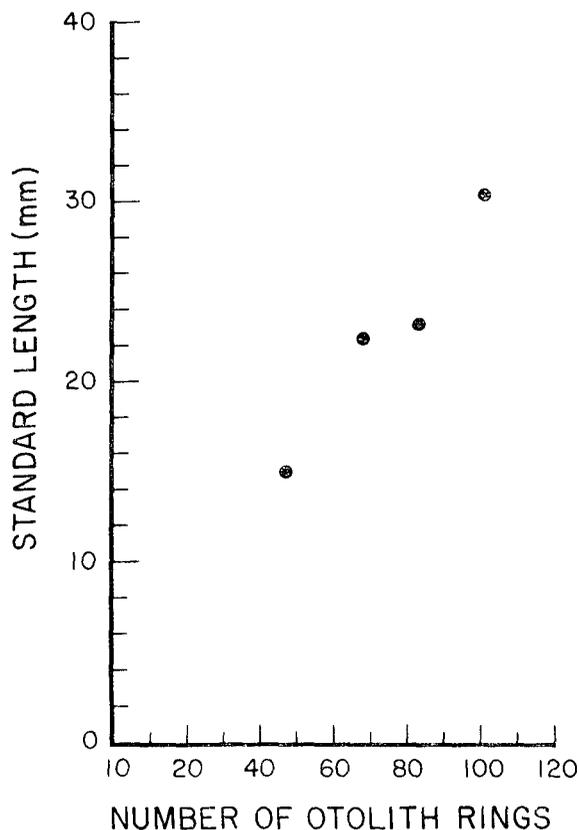


FIG. 9. Age-length relationship of *S. melanostomus* based on counts of daily growth rings of sagittae.

water, and a pattern of small spots has replaced the mottling.

The life-history strategies described here are probably only a fraction of those utilized by wide-ranging planktonic larvae of rockfishes to reach appropriate habitat for settling. At present the larvae of only about a half dozen species can be identified from plankton samples and, with present techniques, the larvae of a substantial number of species will not be differentiable. Estimation of spawning biomass from ichthyoplankton surveys will therefore be limited to a portion of the rockfish fauna. Likewise, the commercial and recreational fisheries sample a limited number of species or a portion of their habitat. An alternative is to sample juvenile stages. Because of the diversity of strategies and habitats, each species may be vulnerable to collection at some time during the juvenile period, either by trawl, trap, or predator. Additionally, sampling of juvenile stages provides the potential for predicting year-class strength. *Sebastes melanostomus* provides a clear example of a species with a special pelagic juvenile stage that is vulnerable to sampling by midwater trawl. Re-

search on the life histories of other rockfish species may provide similar opportunities for resource assessment.

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