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U.S. DEPARTMENT OF COMMERCE
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National Oceanic and Atmospheric Administration
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National Marine Fisheries Service
Rolland A. Schmitten, Assistant Administrator for Fisheries

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GUILLERMO MORENO

P. O. Box 450
Moss Landing Marine Laboratories
Moss Landing, CA 95039

ABSTRACT

About 72 species of *Sebastes* (Family Scorpaenidae) are found along the eastern Pacific coast of North America, some of which are heavily exploited by both commercial and sport fisheries. Because of the large number of species, the identification of early life stages has progressed slowly. The objectives of this study were 1) to rear the larvae of four species of rockfish (*Sebastes mystinus, S. carnatus, S. atrovirens,* and *S. rastrelliger*); and 2) to describe the larvae using morphometric measurements, pigmentation patterns, and head spination.

Pigmentation was the most useful feature for identification purposes. Two general patterns were found: 1) a short row of ventral midline melanophores on the tail, and none or very little postero-dorsal pigmentation (*S. mystinus*); and 2) complete ventral midline pigmentation on the tail, and anterior and postero-dorsal melanophores (*S. carnatus, S. atrovirens,* and *S. rastrelliger*). With the exception of very early stages of *S. carnatus* and *S. atrovirens,* these species can be readily identified. Morphometric proportions and head spination did not show major differences among species.

Because of the great similarities found among species in this genus, descriptions from field studies are uncertain to some extent. Laboratory rearings, although difficult, can at least provide early larvae from known species which allow precise identification as well as an estimation of variability of characters (e.g., pigmentation) within and between broods.

Introduction

The genus *Sebastes* (Rockfishes; Family Scorpaenidae) is an abundant and diverse group of fishes along the Pacific coast of North America (Love and Westphal, 1981) including about 72 species in 11 nominal subgenera (Kendall, 1991). The group is an important part of the commercial and sport catches off California, Oregon, Washington, Canada, and Alaska (Moser et al., 1977; Gunderson and Lenarz, 1980; Lenarz, 1987). In California, rockfishes represent one third of the recreational fish catch; *S. mystinus, S. melanops,* and *S. flavidus* compose up to 30% of this proportion. *Sebastes mystinus* is also an important component of the commercial rockfish catch (Lenarz, 1987).

Species identification of early life history stages is critical for systematics as well as for studies using larval abundance for population estimates. In the genus *Sebastes,* many larval characters are shared by many closely related species, making determination and evaluation of the importance of characters difficult (Moser et al., 1977; Moser and Ahlstrom, 1978; Barsukov, 1981; Kendall and Lenarz, 1987). Larval rearing can provide essential identification information and permit an evaluation of variation in diagnostic characters of larvae from different ages, broods, and species. The relative importance of these diagnostic characters may then be evaluated.

Rockfishes are viviparous, extruding a few hundred thousand to over two million larvae (e.g., *S. paucispinis*; Moser, 1967) during an annual spawning season. The newly extruded larvae are born with little yolk, but with well-developed eyes and mouths that allow immediate feeding (Boehlert and Yoklavich, 1984).

Partial descriptions are available for the larvae of 51 eastern Pacific rockfish species (Matarese et al.,

Present address: School of Biological Sciences, Zoology/A08, The University of Sydney, New South Wales 2006, Australia.

lin, and then transferred after 30 days to a dehydrating series of isopropanol (25–50%) and ethanol (70%), allowing a week between each alcohol change. Initially, measurements were taken before and after fixation and dehydration to determine possible shrinkage. No changes were noted so subsequently larvae were measured only after preservation.

Morphometric and pigmentation analyses were conducted on dehydrated larvae for 0.5–mm SL size classes within the available size range (e.g., 3.0–7.9 mm) for each species. Morphometric measurements included standard length (SL); snout-anus length (SA); head length (HL); snout length (SnL); eye diameter (ED); and body depth at pectoral fin base (BD) (Moser et al., 1977; Moser and Ahlstrom, 1978). Body proportions (SA/SL; HL/SL; SNL/HL; ED/HL; BD/SL) were calculated and means, standard deviations, and ranges were obtained for each size group of each species.

A modification of the pigment scheme of Kendall and Lenarz (1987) of melanophore presence or absence at 26 loci was used. Pigmentation analysis of 33 loci (Fig. 1) assessed the presence and number of melanophores for loci 4, 6, 18, and 19, and the presence (given as proportions) of melanophores for the rest of the loci. Loci 4, 6, 18, and 19 were treated differently because melanophores at these loci could be counted with confidence. It was also possible to count the number of melanophores in loci 22 and 23 for *S. mystinus*. The other loci had tightly packed melanophores that made counts impossible in most cases. Because of the large observed variability in

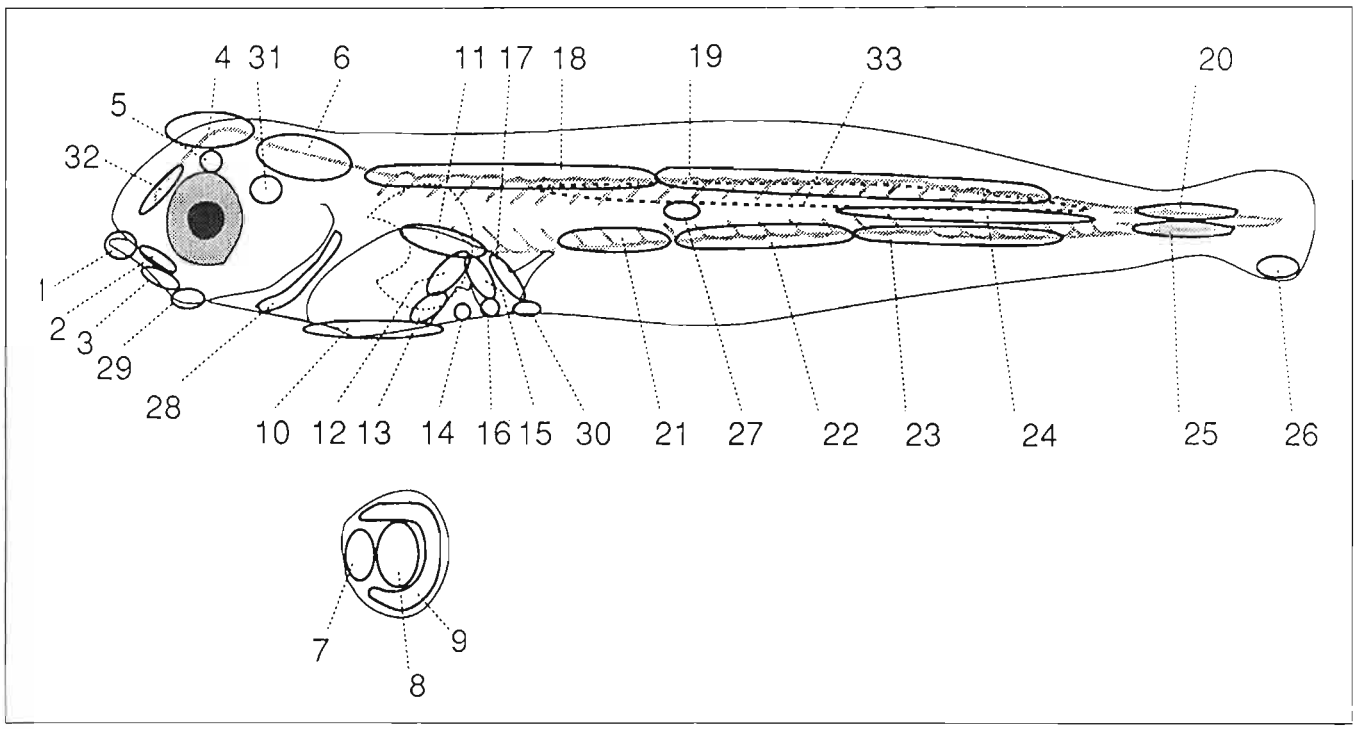

Figure 1

Diagram of 33 melanophore positions found on *Sebastes* larvae. Positions are as follows (pectoral fin loci (7, 8, and 9) are shown separately): Locus: **1** = symphysis of the lower jaw; **2** = upper jaw; **3** = lateral aspect of the lower jaw; **4** = dorsal surface of the brain from the front to the back of the eye; **5** = lateral surface of the brain from the front to the back of the eye; **6** = dorsal surface from the back of the eye to the front of the cleithrum; **7** = base of the pectoral fin; **8** = blade of the pectoral fin; **9** = margin of the pectoral fin; **10** = ventral aspect of the gut; **11** = dorsal aspect the gut; **12** = postero-dorsal surface of the gut; **13** = postero-ventral surface of the gut; **14** = ventral membrane between anus and gut; **15** = inside surface of the anus; **16** = border of the anus; **17** = outside surface of the anus; **18** = dorsal midline from above the cleithrum to the the 3rd postanal myomere; **19** = from the postanal myomere to the last myomere; **20** = from the last myomere dorsally along the notochord to the hypural plates (if present); **21** = first to 3rd or 4th postanal myomere; **22** = third or 4th to 6th or 7th postanal myomere; **23** = 7th to 19th postanal myomeres; **24** = lateral aspect of the body from the 6th or 7th to the 19th postanal myomere; **25** = from the last myomere ventrally along the notochord to the hypural plates (if present) or to the end of the notochord; **26** = ventral aspect of the caudal fin; **27** = lateral aspect of the body from the 1st to the 5th postanal myomere; **28** = cleithral symphysis; **29** = lower jaw symphysis; **30** = fin fold behind the anus; **31** = otic area; **32** = olfactory lobe; **33** = internal locus above the dorsal surface the notochord from the 3rd to the 19th postanal myomere. (Modified after Kendall and Lenarz, 1987.)

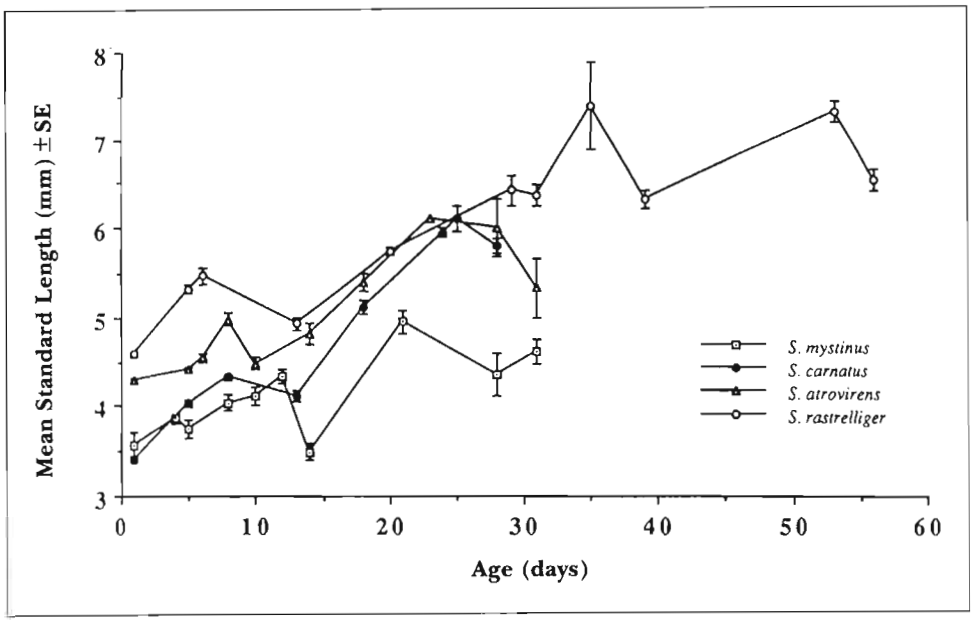

Figure 2
Mean standard length (± SE) vs. age of larvae of *Sebastes mystinus* (*n*=4), *S. carnatus* (*n*=3), *S. atrovirens* (*n*=2), *S. rastrelliger* (n=1). *n*= number of females that gave birth.

Table 1
Proportions of *Sebastes mystinus* larvae with melanophores present at loci 1–33 (see Fig. 1 for loci description).

SL (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
3.0–3.4	1.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	1.0	0.3	1.0	0.3	0.0	0.8	0.3	1.0	1.0
3.5–3.9	0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.4	1.0	0.0	0.0	0.2	0.1	1.0	1.0
4.0–4.4	0.6	0.0	0.0	0.4	0.0	0.4	0.0	0.4	0.6	0.6	1.0	0.1	0.0	0.3	0.0	0.9	1.0
4.5–4.9	1.0	0.0	0.0	1.0	0.2	0.8	0.0	0.7	1.0	0.8	1.0	0.3	0.2	0.5	0.3	0.8	1.0
5.0–5.4	1.0	0.0	0.0	1.0	0.2	1.0	0.0	1.0	1.0	1.0	1.0	0.2	0.2	0.0	0.2	1.0	1.0

SL (mm)	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	*n*
3.0–3.4	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.5	0.0	0.0	4
3.5–3.9	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	38
4.0–4.4	0.1	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.2	0.0	0.0	21
4.5–4.9	0.0	0.3	0.2	0.0	1.0	1.0	0.0	0.5	0.5	0.0	0.8	0.0	0.3	0.3	0.0	0.0	6
5.0–5.4	0.0	0.4	0.6	0.0	1.0	1.0	0.0	0.4	0.4	0.0	1.0	0.0	0.0	0.8	0.0	0.0	5

the longest surviving brood at 23 days. These leeches were attached (one per larva) on the left side of the head and detached themselves when the larvae were disturbed. The parasite was probably introduced by an infected female.

The range in standard length of these larvae was 3.1 mm at birth to 6.2 mm at 28 days. The mean standard length of yolk-sac larvae was 3.4 mm (SD=0.1) at birth and 5.8 mm (SD=0.2) at 28 days (Fig. 2). The full-term larvae were 4.4–mm (SD=0.3) mean standard length at birth. The pectoral fin reached to just in front of the anus by the time a mean standard length of 4.3 mm (day 13) was attained (Fig. 6).

The yolk-sac larvae showed little pigmentation (Table 2; Fig. 6A). However, complete ventral (loci 21–23) and dorsal midline (loci 18 and 19) pigment series were present (Fig. 5) along with a few melanophores scattered laterally on the yolk-sac and a prominent antero-lateral tail melanophore (locus 27). Melanophores on the dorsal surface of the gut (locus 11), anus (loci 16 and 17), and the antero- and postero-dorsal aspect of the tail (loci 18 and 19) were also quite frequent. All individuals in the 5.0–5.4 mm

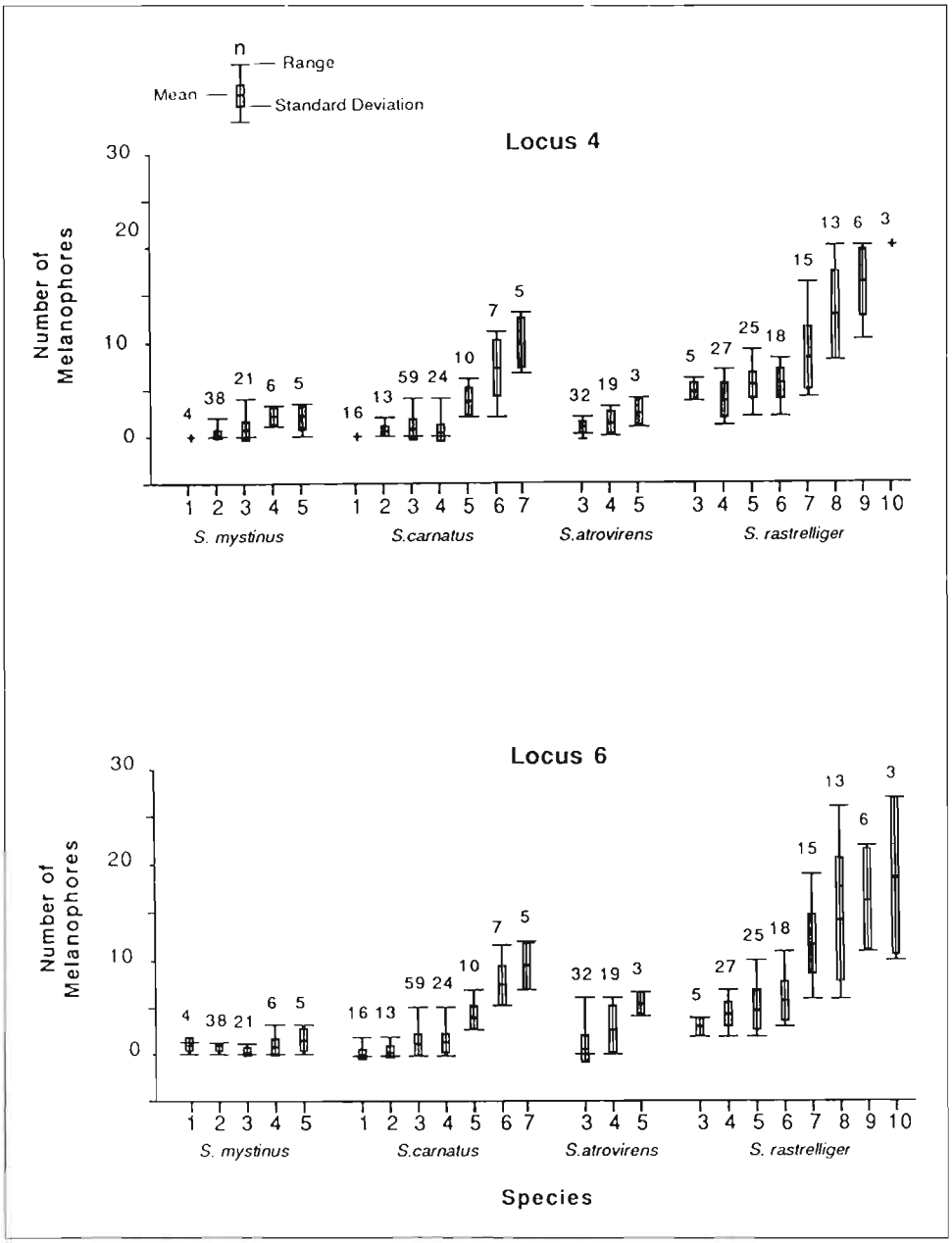

Figure 4

Melanophore densities (mean number per larva) at locus 4 and locus 6 of each size class for all species. 1= 3.0–3.4 mm; 2= 3.5–3.9 mm; 3= 4.0–4.4 mm; 4= 4.5–4.9 mm; 5= 5.0–5.4 mm; 6= 5.5–5.9 mm; 7= 6.0–6.4 mm; 8= 6.5–6.9 mm; 9= 7.0–7.4 mm; 10= 7.5–7.9 mm.

At birth, *S. atrovirens* larvae were similar to *S. carnatus* with pigmentation on the ventral and dorsal aspects of the gut (loci 10 and 11), the anus (locus 16), posterior aspect of the hindgut (locus 17), postero-dorsal midline of the tail (locus 19), and a complete ventral midline series (loci 21–23) (Table 3; Fig. 7). With development, increasing proportions of larvae showed pigmentation on the lower jaw (locus 1), forebrain (locus 4), nape (locus 6; Fig. 4), anterior dorsal midline (locus 18; Fig. 5), and otic capsule (locus 31) . With continued growth, pigmentation appeared on the posterior and postero-ventral surfaces of the gut (loci 12 and 13), cleithrum (locus 28), and lower jaw (locus 29). The pigmentation patterns of *S. atrovirens* and *S. carnatus* remained extremely similar throughout all stages (see Pigmentation in Species Comparisons Section for explanation of differences). No head spine development was apparent during the 30 days (Fig. 7D).

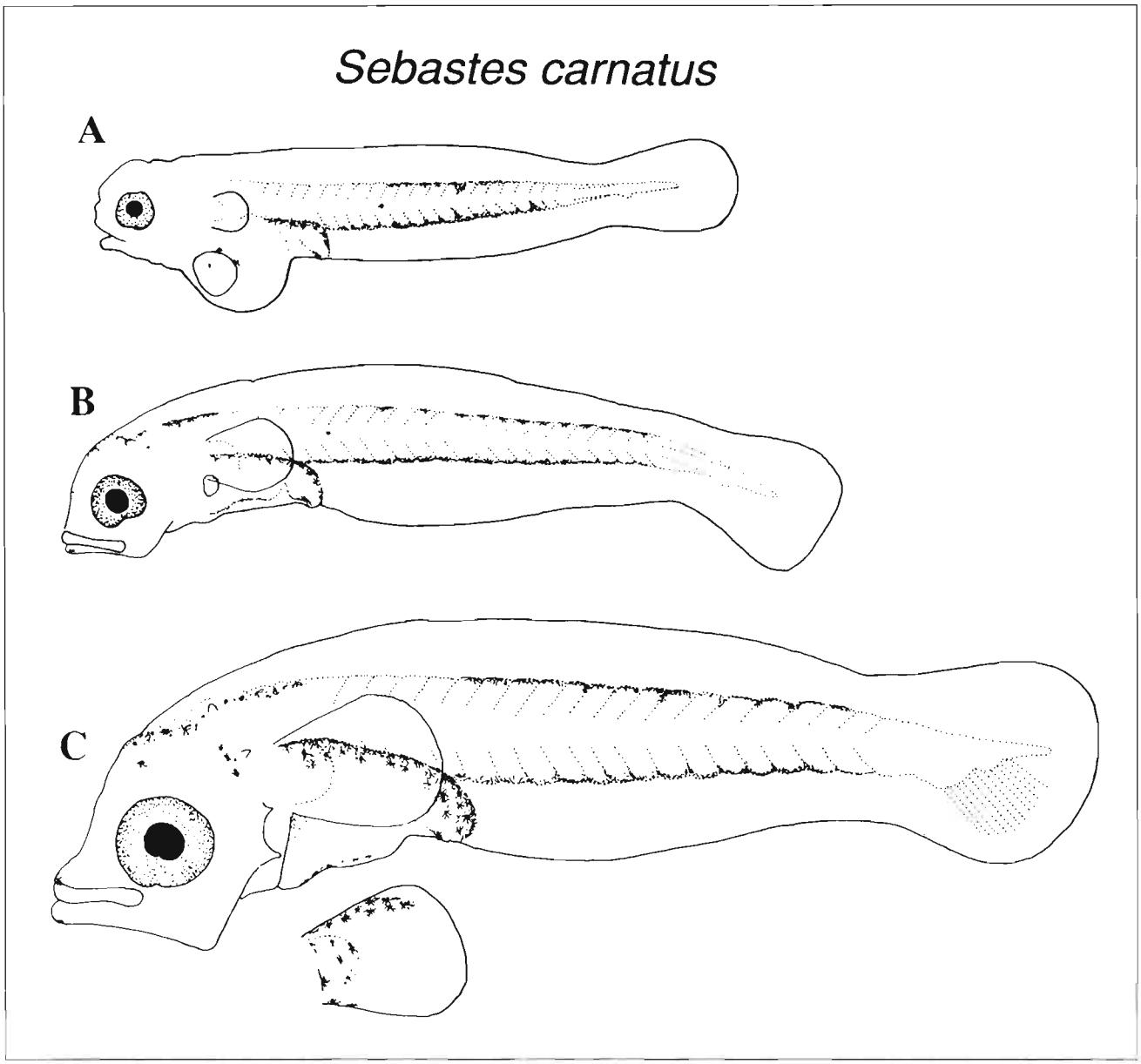

Figure 6

Sebastes carnatus larvae. (**A**) 3.5-mm SL yolk-sac larva; (**B**) 4.3-mm SL preflexion larva; (**C**) 6.0-mm standard length preflexion larva.

mm length was reached (Table 4). Melanophore density in the antero-dorsal midline series (locus 18) increased from 3.6 to 15.7. The postero-dorsal midline series (locus 19) also increased, from a mean of 44 to >44 at 7.5–7.9 mm (Fig. 5). Because of the dense arrangement of melanophores, it was not possible to quantify their exact number at this locus. Distinctive postero-lateral tail pigment (loci 24 and 33) was present on most 5.0–5.4 mm larvae and present in all 6.5–6.9 mm larvae. This pigmentation was also seen on similar-sized *S. carnatus* larvae.

Spination was present on larvae of 6.3–mm mean standard length at 29 days: the parietal, pterotic, second and third anterior preoperculars, second, third, and fourth posterior preoperculars, upper opercular, and postocular spines were present (Fig. 8C). By 7.4–mm mean standard length at 34 days the parietal, pterotic, first, second, and third anterior preoperculars, second, third, and fourth posterior preoperculars, upper opercular, and postocular spines were observed (Fig. 8D). Hypural elements were developed on 7.4–mm mean standard length larvae (34 days old).

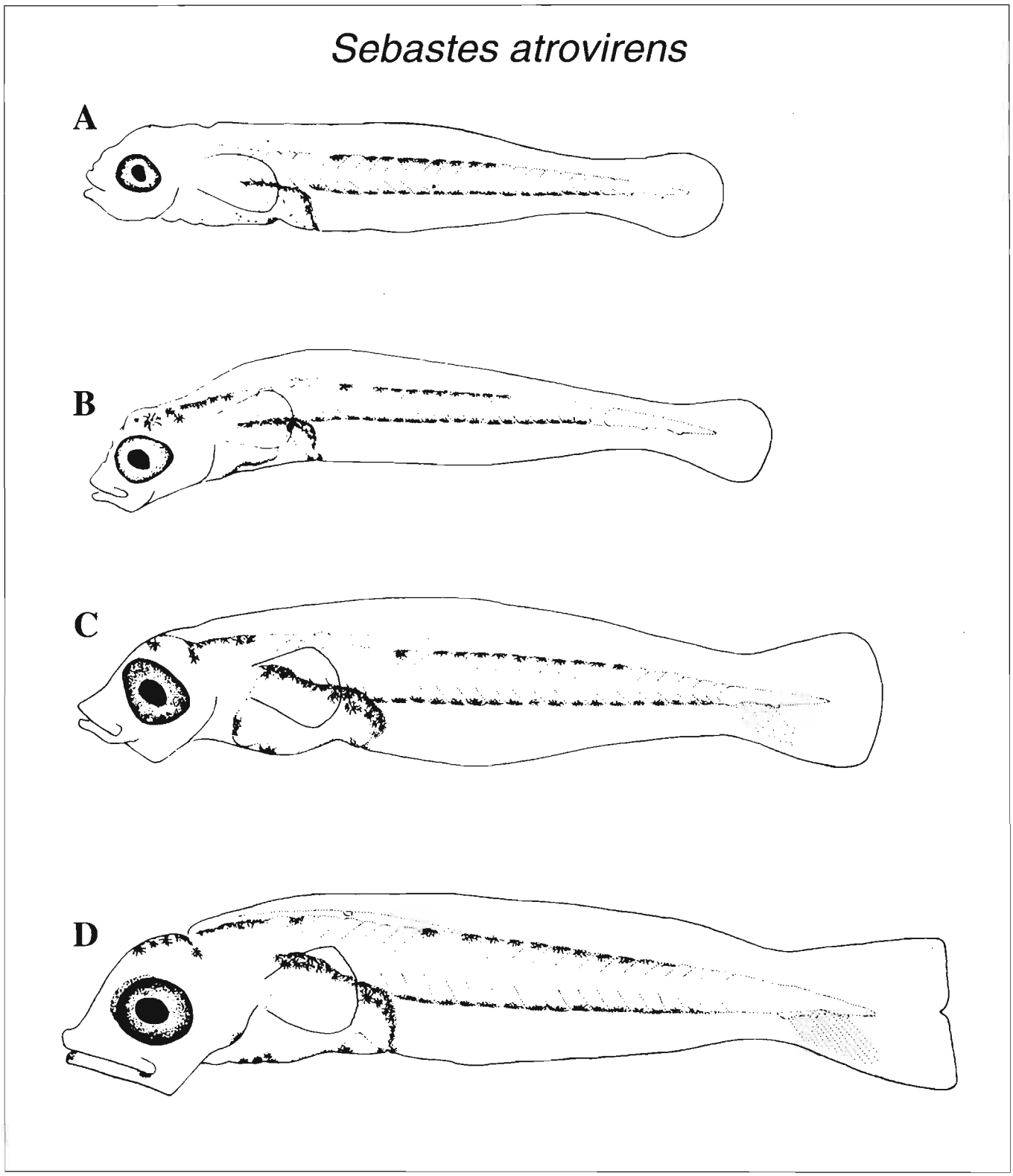

Figure 7

Sebastes atrovirens larvae. (**A**) 4.4-mm SL preflexion larva; (**B**) 4.6-mm SL preflexion larva; (**C**) 5.4-mm SL preflexion larva; (**D**) 5.9-mm SL preflexion larva.

Table 4
Proportions of *Sebastes rastrelliger* larvae with melanophores present at loci 1–33 (see Fig. 1 for loci description).

SL (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
4.0–4.4	0.6	0.4	0.4	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.4	1.0
4.5–4.9	0.3	0.2	0.3	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.1	0.1	0.4	1.0
5.0–5.4	1.0	1.0	0.8	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.2	0.0	0.0	0.0	0.7	1.0
5.5–5.9	1.0	0.9	0.9	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.3	0.8	1.0
6.0–6.4	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.9	1.0	0.0	0.1	0.0	0.3	1.0	1.0
6.5–6.9	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.4	1.0	1.0
7.0–7.4	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.3	0.0	0.0	0.3	0.5	1.0
7.5–7.9	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.7	1.0

SL (mm)	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	*n*
4.0–4.4	1.0	1.0	0.0	1.0	1.0	1.0	0.6	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.4	0.0	5
4.5–4.9	1.0	1.0	0.0	1.0	1.0	1.0	0.6	0.0	0.0	0.3	0.7	0.3	0.0	0.3	0.3	0.0	27
5.0–5.4	1.0	1.0	0.0	1.0	1.0	1.0	0.9	0.0	0.0	0.1	1.0	0.8	0.0	0.7	0.9	0.0	25
5.5–5.9	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.8	0.0	0.9	0.9	0.8	18
6.0–6.4	1.0	1.0	0.0	1.0	1.0	1.0	0.9	0.0	0.0	0.1	1.0	0.8	0.0	0.9	0.9	0.8	15
6.5–6.9	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.9	0.0	0.9	1.0	1.0	13
7.0–7.4	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	1.0	1.0	1.0	6
7.5–7.9	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.7	1.0	1.0	3

Table 5
Morphometric proportions of *Sebastes mystinus* larvae. Mean ± standard deviation, with the ranges in parentheses. SA/SL = snout-anus length/standard length; HL/SL = head length/standard length; SNL/HL=snout length/head length; ED/HL = eye diameter/head length; BD/SL = body depth/standard length.

SL (mm)	SA/SL	HL/SL	SNL/HL	ED/HL	BD/SL	*n*
3.0–3.4	39.4±1.9 (38.2–40.6)	24.2±1.9 (21.8–26.4)	37.8±3.9 (33.3–42.8)	37.8±3.9 (33.3–42.8)	18.9±1.6 (17.6–21.2)	4
3.5–3.9	34.9±2.2 (28.2–38.8)	19.4±1.6 (15.3–23.0)	42.1±5.1 (33.3–57.1)	37.8±6.9 (25.0–50.0)	16.5±1.3 (12.8–19.4)	38
4.0–4.4	34.9±1.7 (31.7–39.5)	20.6±1.7 (18.6–25.0)	37.2±5.1 (25.0–45.4)	35.8±3.4 (25.0–40.0)	15.9±2.0 (12.1–19.5)	21
4.5–4.9	37.7±1.4 (35.5–39.1)	22.6±2.0 (20.0–26.0)	46.0±5.4 (40.0–54.5)	30.5±5.5 25.0–40.0)	17.2±1.9 (15.2–19.5)	6
5.0–5.4	37.2±1.0 (36.0–38.4)	22.7±1.0 (21.5–24.0)	48.3±4.9 (41.6–54.5)	34.5±1.6 (33.3–36.3)	17.6±1.5 (16.0–20.0)	5

cus 19; Fig. 5) in larger specimens; and 3) presence of pigment on the pectoral fins (loci 8 and 9) with melanophores scattered over the fin rays and concentrated on the margin (Fig. 3).

Sebastes carnatus (Fig. 6) and *S. atrovirens* (Fig. 7) can be differentiated from *S. mystinus* (Fig. 3) by 1) presence of a long ventral midline melanophore series (loci 21–23); and 2) a greater number of melanophores on the dorsal midline (loci 18 and 19; Fig. 5). They can be differentiated from *S. rastrelliger* (Fig. 8) by the overall more pronounced pigmentation on the latter. *Sebastes carnatus* can be differentiated from similarly pigmented *S. atrovirens* by the following characters: 1) presence (up to 0.9) of antero-lateral tail pigment (locus 27; Tables 2 and 3); 2) presence of melanophores on the base and anterior margin of the pectoral fins (loci 7 and 9); and 3) presence of melanophores on the mid-upper and mid-lower jaw (loci 2 and 3; Table 2; Fig. 6).

Sebastes rastrelliger can be differentiated by the following patterns: 1) heavily pigmented head (loci 1–4 and 6; Figs. 4 and 8) with presence of melanophores

Table 8

Morphometric proportions of *Sebastes rastrelliger* larvae. Mean ± standard deviation, with the ranges in parentheses. SA/SL = snout-anus length/standard length; HL/SL = head length/standard length; SNL/HL=snout length/head length; ED/HL = eye diameter/head length; BD/SL = body depth/standard length.

SL (mm)	SA/SL	HL/SL	SNL/HL	ED/HL	BD/SL	*n*
4.0–4.4	34.2±2.1 (31.8–36.5)	19.9±1.7 (18.1–21.9)	30.0±4.5 (25.0–33.3)	37.2±4.5 (33.3–44.4)	16.1±1.3 (14.6–18.1)	5
4.5–4.9	34.5±2.1 (29.7–37.5)	18.9±1.3 (16.3–21.2)	28.8±5.2 (22.2–37.5)	36.8±5.4 (30.0–55.5)	15.6±1.4 (12.5–17.7)	25
5.0–5.4	35.3±1.8 (31.4–38.0)	19.6±2.3 (16.6–25.9)	30.2±4.9 (20.0–36.3)	35.8±5.2 (27.2–44.4)	14.7±1.4 (11.1–16.7)	25
5.5–5.9	38.0±2.8 (32.7–41.0)	20.3±1.9 (17.5–25.4)	32.8±4.1 (25.0–41.6)	39.1±4.8 (30.7–46.1)	15.9±1.9 (12.0–18.6)	18
6.0–6.4	40.1±1.7 (37.5–43.3)	24.4±2.4 (20.9–28.3)	30.0±4.1 (26.6–42.8)	35.3±4.8 (26.6–42.8)	17.4±1.9 (14.7–20.9)	15
6.5–6.9	40.2±2.4 (34.8–43.0)	24.7±1.3 (22.7–26.4)	30.8±2.4 (25.0–33.3)	37.3±3.7 (31.2–43.7)	17.9±1.9 (15.4–21.4)	13
7.0–7.4	40.5±2.2 (37.1–43.0)	25.0±1.7 (22.8–27.7)	30.9±3.3 (25.0–33.3)	44.4±5.0 (38.8–50.0)	20.3±1.2 (18.5–22.2)	6
7.5–7.9	42.8±1.4 (41.5–44.3)	26.3±0.4 (25.9–26.6)	32.8±6.3 (28.5–40.0)	39.3±1.2 (38.0–40.0)	19.8±2.2 (17.3–21.5)	3

and *S. caurinus* (Stahl-Johnson, 1985) show great similarities and are difficult to differentiate from each other.

Of the 51 species of eastern Pacific *Sebastes* larvae previously described, only nine descriptions have been based on reared specimens (Moser and Butler, 1981, 1987; Stahl-Johnson, 1985; Kendall, 1989; Wold, 1990) mainly because of the difficulty of rearing larvae past yolk-sac to juvenile stage. Such difficulties arise from the relatively small size, early developmental level at birth, feeding problems and importantly, slow larval growth rates shown for eastern Pacific species (Moser and Butler, 1987).

A major concern in rearing *Sebastes* is the need for healthy full-term larvae (Westrheim, 1975). Most information on the early larval stages of rockfishes comes from descriptions of pre-extrusion larvae. However, pigment patterns are not well established in yolk-sac *Sebastes* larvae, making these descriptions unreliable for the identification of more advanced stages (Westrheim, 1975). Because of the use of SCUBA-aided capture techniques, premature birth was alleviated for the nearshore *Sebastes* species described here.

The months of parturition observed for two (*S. mystinus, S. carnatus*) of the four species were similar to those reported by Wyllie-Echeverria (1987). There is no published information on parturition periods of *S. atrovirens* or *S. rastrelliger*. *Sebastes* species seem to have two major seasons of larval extrusion, winter and spring-summer (Phillips, 1964). *Sebastes mystinus* and *S. rastrelliger* gave birth in the winter season (November–March), and *S. atrovirens* in the spring-summer season (April–July). *Sebastes carnatus* overlapped both seasons with March–May parturitions.

Only the larvae of *S. rastrelliger* were maintained past the preflexion stage. These larvae lived for up to 56 days and went through flexion but did not reach postflexion. The data presented here for the other three species are still useful since small, preflexion forms (e.g., ≤7 mm) generally dominate (>90%) the *Sebastes* larvae caught off California by net sampling operations (Moser and Butler, 1987).

To describe these larvae, it was necessary to choose a character, either age or size, to allow an evaluation of variability, and a determination of useful specific identifying characters. As in most studies of *Sebastes* larvae, size was used instead of age. This was done because 1) grouping by age is a slow and expensive process in field studies and 2) size rather than age appears to be a better indicator of development, although there is variability in both. Policansky (1982) found that size (length), and not age, was the single

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