Descriptions of Reared Larvae of Six Species of *Sebastes*

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ABSTRACT

This paper describes techniques used in rearing larvae obtained from field-caught females of six species of rockfishes (*Sebastes*). The early larval stages are described for three of these species (*S. entomelas*, *S. serranoides*, and *S. rubrivinctus*) and more complete larval series are described for three other species (*S. rufus*, *S. ovalis*, and *S. constellatus*). The larval taxonomic characters of these species are compared with those of other rockfish species. Experiments on yolk-sac larvae of *S. rubrivinctus* showed that sinking rates decrease with decreasing yolk volume and point to the precise timing of ontogeny and birth in *Sebastes*.

INTRODUCTION

Estimation of spawning biomass by sampling eggs and larvae has been accomplished for important fish stocks off California (Ahlstrom 1954, 1966, 1968; Smith 1972). Rockfishes are highly fecund livebearers whose newborn young are at a developmental stage similar to the first-feeding larvae of typical pelagic spawners (Moser 1967). Since their larvae are abundant and widespread over the CalCOFI (Calif. Coop. Oceanic Fish. Invest.) sampling area (Ahlstrom 1961; Ahlstrom et al. 1978), there is a potential for spawning biomass estimation from ichthyoplankton samples. This potential is confounded by the large number of species (62 off California; Hubbs et al. 1979) and the relative paucity of larval characters.

Identification of larvae of eastern Pacific rockfishes has proceeded slowly. Complete developmental series, from newborn individuals to the juvenile stage, are known for eight species: *S. aurora*, *S. cortezi*, *S. dallii*, *S. jordani*, *S. levis*, *S. macdonaldi*, *S. melanostomus*, and *S. paucispinis* (Moser et al. 1977; Moser and Ahlstrom 1978; Moser et al. 1985). These identifications have been accomplished by comparing the full-term larvae from identified females with the smallest larvae of distinct series obtained from plankton hauls. Also, newly transformed identifiable juveniles with remnants of larval pigmentation and morphological features were used, along with meristic characters, to identify larval series. Using the latter technique, Richardson and Laroche (1979) and Laroche and Richardson (1980, 1981) have described postflexion larvae and early juveniles of the widow rockfish (*S. entomelas*) and nine other species. This opens the possibility for estimation of recruitment, providing these stages can be sampled adequately. Our plankton samples are dominated by early larval stages (Fig. 1) and may allow estimation of spawning biomass when critical information on fecundity, mortality, and duration of the early pelagic phase becomes available.

Progress in the identification of rockfish larvae is dependent on rearing developmental species. Although Japanese workers have been successful in rearing *Sebastes* larvae (Table 1), the rearing of an eastern Pacific species to the juvenile stage has been accomplished only recently (Moser and Butler 1981). More recently Stahl-Johnson 1985) has reared the larvae of *S. caurinus* and *S. auriculatus*

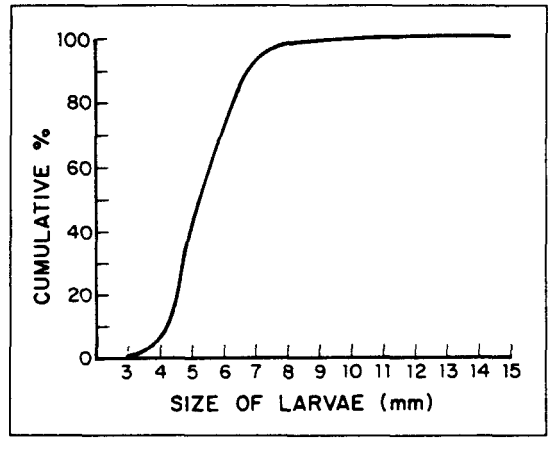

Figure 1.—Size composition of rockfish larvae in CalCOFI samples expressed in cumulative percent (N = 11,633).

Table 1—Summary of *Sebastes* rearing experiments.

Authors	Fujita	Fujita	Siokawa and Tsukahara	Tsukahara	Kusakari et al.	Moser and Butler
Date	1957	1958	1961	1962	1977	1981
Species	*S. pachycephalus*	*S. oblongus*	*S. pachycephalus*	*S. marmoratus*	*S. schlegeli*	*S. dallii*
Gestation period (days)	23	—	20	—	—	—
Rearing duration (days)	28	30	25	10	83	60
Food	*Artemia* nauplii	*Artemia* nauplii	*Artemia* nauplii	*Artemia* nauplii	*Brachionus* *Artemia* *Tigriopus*	Wild plankton
Feeding	yes	yes	yes	no	yes	yes
Source of larvae	Female spawned in aquarium	Female spawned in aquarium	Female spawned in aquarium	Female spawned in aquarium	Female spawned in aquarium	Female spawned in field
Initial size (mm)	6.9-7.0	7.25-7.50	6-7	3.5-4.5	5.3-7.9	5.4
Final size (mm)	9.75	14	13	5	50	24.3

Table 2—Dates and locality of capture and rearing information for *Sebastes* species.

Species	Date	Locality	Method of capture	Rearing temperature (°C)	Days reared	Diet
constellatus	4/16/78	60 Mile Bank	Hook-and-line	14.5-16.5	38	Wild plankton
entomelas[1]	3/06/81	Nelson Island Oregon	Midwater trawl	10	26	*Brachionus*, wild plankton
ovalis	1/27/78	60 Mile Bank	Hook-and-line	13.4-16.1	29	*Brachionus* and *Artemia* nauplii to day 13; wild plankton days 13-29
rubrivinctus	9/15/76	Tanner Bank	Bottom trawl	9.2-14.7	Cultured for 14 days	Not fed
rufus	2/01/78	60 Mile Bank	Hook-and-line	13.8-16.1	46	*Brachionus* and *Artemia* nauplii to day 5; *Tisbe* nauplii days 6-8; wild plankton days 8-46
rufus	1/20/79	60 Mile Bank	Hook-and-line	15.6-16.0	12	Wild plankton
serranoides	1/18/79	Tanner Bank	Hook-and-line	16.2-17.0	16	Wild plankton

[1]Information from G. W. Boehlert, Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, pers. commun.

through caudal fin formation, and G. W. Boehlert (NMFS Honolulu Lab., pers. comm.) has reared a partial series of *S. melanops*. This paper describes reared early larval stages of widow rockfish (*S. entomelas*), flag rockfish (*S. rubrivinctus*), and olive rockfish (*S. serranoides*) and more complete reared series of bank rockfish (*S. rufus*), speckled rockfish (*S. ovalis*), and starry rockfish (*S. constellatus*). Rearing was carried out at the Southwest Fisheries Center, La Jolla, California, except for the brood of *S. entomelas*, which was reared by G. W. Boehlert at the Marine Science Center, Newport, Oregon.

METHODS AND MATERIALS

Intraovarian rockfish larvae were obtained at sea by collecting near-term females with hook-and-line or by bottom trawling (Table 2). Rockfishes brought from depth often have expanded gas bladders which exert pressure on other internal organs and cause pregnant females to extrude their brood. Larvae from near-term females were collected in containers of seawater and brought back to the laboratory within one or two days for rearing. Free-swimming larvae were separated from dead ones and from those which were unable to swim off the bottom of the transport container and introduced into 100-L round black fiberglass rearing containers filled with filtered seawater. The containers were immersed in a water bath which maintained temperatures; an airstone was used to reduce stratification.

Larvae were fed cultured rotifers (*Brachionus plicatilis*), copepods (*Tisbe* sp.), wild plankton, or a combination of these (Table 2). Wild plankton was obtained by towing a 70-μm mesh net in Mission Bay, San Diego, Calif. The plankton was passed through a series of screens, and the 104-254 μm fraction, dominated by copepod nauplii, was used as food. Plankton densities in the rearing containers were maintained at 2-4 nauplii/mL, and a liter of dense algal culture, *Tetraselmis suesica* or *Duneliella* sp., was added daily as food for the plankton.

Larvae were removed from the culture tank and preserved in 3% buffered formalin to establish life history series for analysis of morphology and pigmentation. Terminology and methods of description follow those of Moser et al. (1977) and Moser and Ahlstrom (1978).

RESULTS AND DESCRIPTIONS

Sebastes entomelas

Rearing—According to G. W. Boehlert (NMFS Honolulu Lab., pers. comm.), extruded larvae were obtained on 6 March 1981 from females collected on the FV *Centurion* at Nelson Island, Oregon. Larvae were immediately placed in jars and buckets of filtered seawater and transported to the laboratory. Those swimming were pipetted into circular black plastic pots (10-L capacity) of UV-filtered seawater with salinity >30‰; all larvae were held in a constant temperature room at 10°C. Within 24 hours, moribund larvae were siphoned from remaining jars and buckets and swimming larvae were transferred into a dark green circular tank (120-L capacity). After three to five days in the laboratory, rotifers were introduced at densities from 2 to 4/mL along with a dense algal culture. Subject to availability, wild zooplankton was added to the rearing tanks. Mortality was minimal to day 11, increased rapidly from day 12 to 15, with 25% of the larvae surviving on day 13, and only one larva was left on day 26.

Morphology—Six preserved samples, from day 1 to day 10, were provided by G. W. Boehlert. Extruded larvae were 4.5-4.6 mm long; a yolk sac (0.55-0.60 mm in length) and oil globule were present. Prey items were present in the stomachs of specimens preserved on day 4, even though considerable yolk remained. The yolk sac and oil globule were absent in larvae sampled after day 7. Larvae did not show appreciable growth during the 10-day period (Table 3) and reached a state of development typical of full-term broods (Fig. 2).

Pigmentation—Larvae at day 10 had melanophores along the dorsal region of the gut, below the posterior gut region, and a series on the ventral midline of the tail. The tail series extended from the third or fourth postanal myomere to the 17th-19th postanal myomere, and contained 13-16 melanophores ($\bar{x}$ = 14.0±0.94 SD for 10 larvae counted). Pigment was present on the lower jaw in all specimens and melanophores were present on the brain, typically on each side of the cerebellum and optic lobes. A few specimens had 1-2 melanophores on the nape and scattered melanophores on the pectoral fin blade.

Sebastes rufus

Rearing—Larvae collected on 1 Feb. 1978 were 4.6-4.8 mm in length when stocked. The oil globule and a small yolk remnant were invested in the liver tissue. The yolk was utilized within four days; however, the oil globule persisted to the end of the first week. Larvae did not feed on *Brachionus* or *Artemia* nauplii provided through day 5. They began feeding when nauplii and copepodites of a laboratory culture of *Tisbe* were added to the tank on day 6. Within a day the *Tisbe* moved to the sides and bottom of the container and were unavailable to the larva. Beginning on day 8, wild plankton was provided and elicited feeding activity immediately. Larvae survived until day 46.

Larvae collected on 20 Jan. 1979 were 4.3-4.7 mm in length and had a conspicuous yolk mass about 0.6 mm in diameter. They began feeding on wild copepod nauplii added that day even though the yolk mass was about 0.5 mm in diameter and occupied the anterior half of the gut region. By day 5, the yolk mass and oil globule were confined to the liver tissue. Yolk utilization was complete by the end of one week; however, the oil globule persisted one or two days more. Larvae survived until day 12.

Morphology—Larvae of *S. rufus* lack distinctive morphological features (Tables 4, 5; Fig. 2). The 6.1-mm specimen (Fig. 2D) had developing caudal rays and hypural elements and a straight notochord; the largest specimen (7.6 mm) had a completely flexed notochord (Fig. 2E). The supporting elements of the dorsal and anal fins were forming in the 7.6-mm specimen. Head spine development is similar to that observed in other species (Moser and Ahlstrom 1978). At about 6.0 mm, the following spines were forming: third posterior preopercular, second and fourth anterior preopercular, pterotic, and parietal. In the 7.6-mm specimen, the second and fourth posterior preopercular spines were also present. The postocular spine was just beginning to form above the eye. The parietal spines were relatively short and flat against the head.

Pigmentation—Newborn larvae had one or two melanophores above the brain, one at the nape, a dorsal melanistic shield above the gut, and a short postanal series along the ventral midline (Fig. 2). The ventral midline series extended from the fifth and sixth postanal myomere to the 14th-18th postanal myomere and contained 8-13 melanophores ($\bar{x}$ = 10.3±1.54 SD for all specimens in growth series). Dorsal midline melanophores appeared soon after extrusion and increased in number in two stanzas up to the notochord flexion stage ($\bar{x}$ = 2.0±1.24 SD for specimens in 4.4 mm-5.2 mm range, and $\bar{x}$ = 9.4 ± 2.67 SD for specimens in the 5.5 mm-7.6 mm range).

The symphysis of the lower jaw was pigmented at 4.7-4.8 mm; the dorsal surface of the brain was solidly pigmented by 4.7 mm, except for the olfactory lobe region which was pigmented at 5.6 mm. Melanophores were added to the nape to produce a solid blotch by 4.7 mm, the 7.6 mm specimen had a melanistic streak on each side of the snout along the maxillaries, and the upper opercular region was pigmented.

At 4.7 mm, a melanophore was present on the medial surface of each pectoral fin base and small melanophores were scattered over the fin blade. The medial surface of the fin base was solidly

Table 3—Measurements (mm) of larvae of *Sebastes entomelas*.

Body length (age in days)	Yolk sac (length × width)	Snout-anus distance	Head length	Snout length	Eye diameter	Body depth	Pectoral fin Length	Pectoral fin Base depth
4.6 (1)	0.60 × 0.45	1.6	0.89	0.22	0.32	0.68	0.21	0.20
4.4 (2)	0.55 × 0.43	1.5	0.90	0.26	0.31	0.63	0.20	0.20
4.5 (4)	0.45 × 0.31	1.5	0.92	0.30	0.30	0.62	0.23	0.24
4.5 (7)	0.18 × 0.18	1.4	0.90	0.26	0.31	0.64	0.25	0.26
4.8 (10)	–	1.6	0.98	0.27	0.33	0.61	0.23	0.24
4.3 (10)	–	1.4	0.85	0.25	0.30	0.59	0.21	0.23

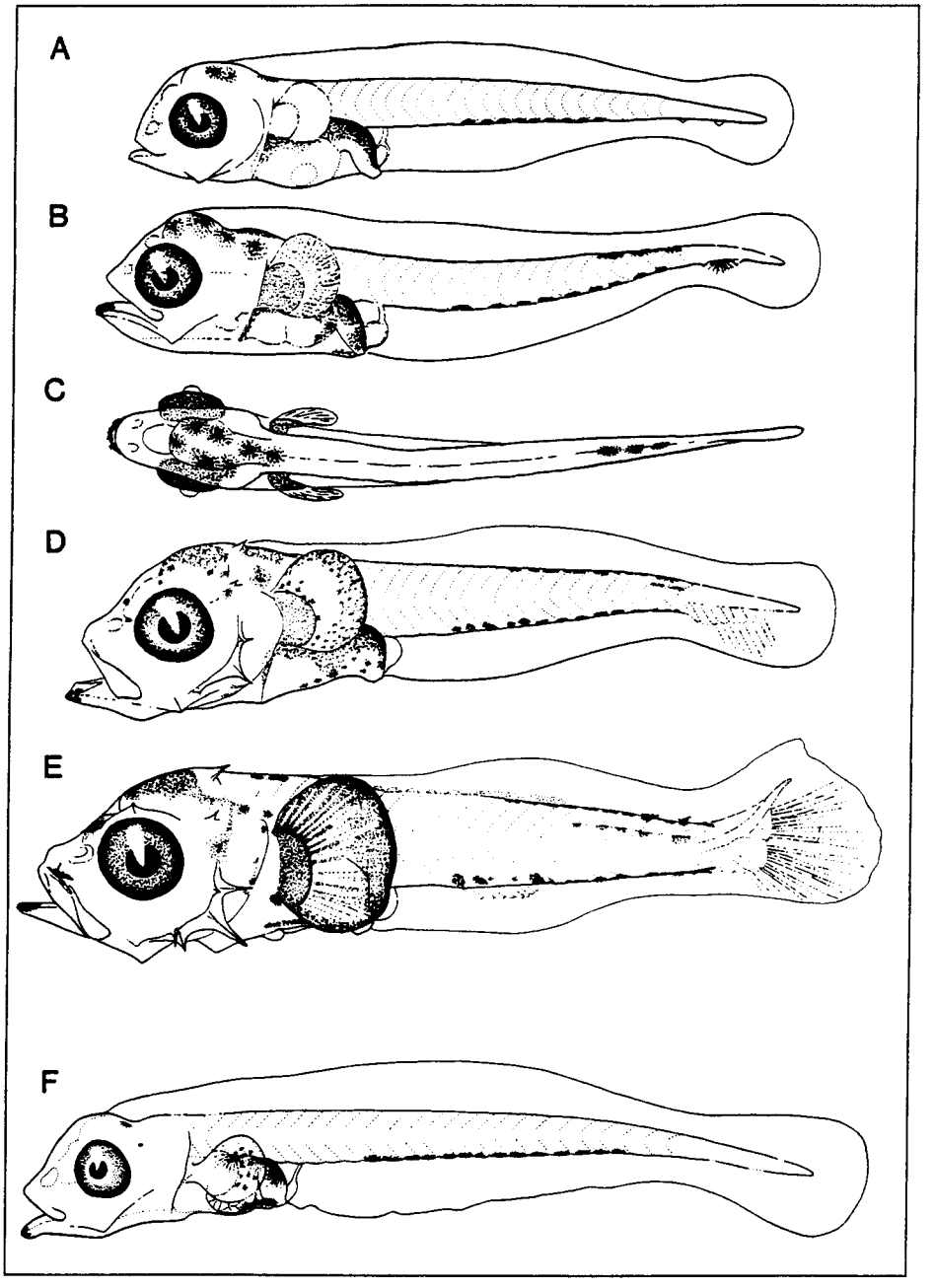

Figure 2—Larvae of *Sebastes rufus* (A-E) and *S. entomelas* (F). A. 4.8 mm, day 3; B. 4.9 mm, day 9; C. 4.9 mm, day 9 (dorsal view); D. 6.1 mm, day 22; E. 7.6 mm, day 35; F. 4.8 mm, day 10.

Table 4—Measurements (mm) of larvae of *Sebastes rufus*.

Body length (age in days)	Snout-anus distance	Head length	Snout length	Eye diameter	Body depth	Pectoral fin Length	Pectoral fin Base depth	Pelvic fin length
4.8 (3)	1.8	1.1	0.29	0.38	0.68	0.25	0.20	
4.8 (4)	1.9	1.2	0.26	0.43	0.81	0.26	0.26	
4.7 (6)	1.8	1.1	0.26	0.42	0.70	0.26	0.26	
4.6 (7)	1.8	1.1	0.31	0.40	0.68	0.25	0.26	
4.8 (8)	1.8	1.2	0.24	0.40	0.70	0.26	0.24	
4.9 (9)	1.9	1.2	0.30	0.48	0.82	0.27	0.34	
5.2 (13)	2.0	1.2	0.29	0.50	0.95	0.34	0.38	
5.6 (13)	2.1	1.2	0.30	0.47	1.0	0.37	0.34	
5.3 (19)	2.0	1.2	0.32	0.50	0.93	0.35	0.39	
5.7 (19)	2.2	1.4	0.44	0.57	1.1	0.48	0.50	
5.9 (19)	2.3	1.5	0.45	0.60	1.2	0.54	0.52	
6.1 (22)	2.6	1.6	0.45	0.66	1.3	0.59	0.52	
*7.6 (35)	3.3	2.2	0.58	0.81	1.7	0.93	0.82	0.05
*7.2 (46)	3.7	2.5	0.65	0.94	1.7	1.0	0.76	0.09

*Specimens undergoing notochord flexion

Table 5—Comparative morphometry (in mm) of preflexion larvae of nine *Sebastes* species ($\bar{x}$ ± SD/range).

Sebastes sp.	Snout to anus distance / Body length	Head length / Body length	Snout length / Head length	Eye diameter / Head length	Body depth / Body length	Pectoral fin length / Body length	Pectoral fin base depth / Body length
constellatus	37.8 ± 1.30	22.6 ± 0.89	28.0 ± 1.87	32.8 ± 2.49	15.8 ± 0.84	5.4 ± 0.55	6.8 ± 1.30
	36-39	22-24	26-30	29-35	15-17	5-6	5-8
dallii	42.4 ± 0.52	22.6 ± 1.06	25.6 ± 3.02	38.0 ± 1.85	17.6 ± 1.85	5.6 ± 0.52	5.9 ± 1.36
	42-43	21-24	19-29	35-41	15-20	5-6	3-7
jordani	36.5 ± 0.84	22.3 ± 1.51	26.8 ± 3.43	37.7 ± 0.82	17.0 ± 1.26	6.7 ± 0.52	6.5 ± 0.55
	36-38	21-25	23-31	36-38	16-19	6-7	6-7
levis	39.6 ± 2.30	24.7 ± 1.60	30.7 ± 2.63	33.1 ± 2.67	21.7 ± 1.11	17.4 ± 5.29	10.9 ± 1.57
	37-44	23-28	27-35	29-36	20-23	11-24	8-13
macdonaldi	42.4 ± 3.53	27.6 ± 2.25	30.6 ± 4.16	34.6 ± 2.34	23.1 ± 3.99	8.4 ± 1.21	9.8 ± 1.48
	36-47	24-31	25-36	31-37	13-27	6-10	8-12
ovalis	38.0 ± 3.00	23.7 ± 2.08	21.7 ± 2.08	38.0 ± 2.00	16.3 ± 1.53	6.0 ± 1.73	7.7 ± 1.15
	35-41	22-26	20-24	36-40	15-18	5-8	7-9
paucispinis	41.0 ± 2.74	26.8 ± 2.28	27.4 ± 3.21	32.8 ± 3.77	19.6 ± 1.67	16.4 ± 4.56	9.0 ± 0.71
	37-44	24-29	24-32	29-37	17-21	11-21	8-10
rufus	38.9 ± 1.44	23.9 ± 1.38	25.8 ± 3.19	38.6 ± 2.97	17.2 ± 2.18	6.7 ± 1.67	6.7 ± 1.67
	38-43	21-26	20-31	35-42	14-21	5-10	4-9
serranoides	36.5 ± 1.09	22.8 ± 1.40	28.3 ± 2.27	37.8 ± 1.90	15.9 ± 1.31	5.2 ± 0.62	6.2 ± 1.19
	35-38	20-26	25-32	35-41	14-18	4-6	5-8

pigmented by 5.6 mm and the pigment on the blade assumed a distinctive pattern (Fig. 2D, E). Late in the preflexion stage (ca. 6.0 mm), internal melanophores appeared above the dorsal surface of the notochord at the 17th-18th postanal myomeres and extended anteriorly to the 9th myomere in the 7.6-mm specimen (Fig. 2E). A few early larvae had a melanophore in the hypural region (Fig. 2B), but these melanophores did not persist.

Sebastes ovalis

Rearing—Larvae were 4.9-5.1 mm at extrusion and had the oil globule and a small amount of yolk invested in the liver tissue. The yolk persisted to day 5 and the oil globule to day 9. They did not feed on *Brachionus* and *Artemia* nauplii and experienced a massive die-off on day 11. The remaining few were fed wild plankton on day 13 and began to feed, with one specimen living to day 29.

Morphology—The larvae were similar to *S. rufus* (Fig. 3A-C; Tables 5, 6). In the 6.8 mm larva, the caudal rays were forming and the notochord was just beginning to flex. Head spines formed as in *S. rufus*, and the 6.8 mm larva had the following spines: pterotics, parietals, second and fourth anterior preoperculars, and the third posterior preopercular.

Pigmentation—Pigmentation was similar in pattern to that of *S. rufus* larvae but somewhat heavier. The youngest larvae sampled had a patch of 5-8 melanophores above the brain, several melanophores at the nape, a solid sheath above the gut, one or two spots on the medial surface of the pectoral fin base, scattered spots on the fin blade and dorsal and ventral postanal series. The ventral series extended from the fifth or sixth to the 18th or 19th postanal myomeres and contained 13-17 melanophores ($\bar{x}$ = 14.8 ± 1.68 SD for all specimens). The dorsal series was composed of two irregular rows containing 11-12 melanophores in the smallest larvae,

Table 6—Measurements (mm) of larvae of *Sebastes ovalis*, *S. serranoides*, and *S. constellatus*.

Body length (age in days)	Snout-anus distance	Head length	Snout length	Eye diameter	Body depth	Pectoral fin Length	Pectoral fin Base depth	Pelvic fin length	Snout anal fin distance
Sebastes ovalis									
5.1 (5)	1.8	1.1	0.23	0.40	0.79	0.26	0.35		
4.8 (9)	1.8	1.1	0.22	0.44	0.75	0.25	0.34		
6.8 (29)	2.8	1.8	0.44	0.68	1.20	0.54	0.60		
Sebastes serranoides									
4.9 (2)	1.7	1.0	0.31	0.40	0.77	0.25	0.24		
5.0 (2)	1.8	1.1	0.32	0.40	0.74	0.24	0.24		
5.0 (3)	1.8	1.1	0.31	0.40	0.72	0.25	0.25		
5.3 (5)	1.9	1.2	0.33	0.46	0.87	0.27	0.32		
5.2 (7)	1.8	1.2	0.31	0.42	0.71	0.22	0.28		
5.7 (7)	2.1	1.3	0.32	0.47	0.91	0.30	0.36		
5.6 (9)	2.1	1.3	0.36	0.52	1.0	0.33	0.40		
5.8 (12)	2.1	1.3	0.36	0.53	1.0	0.32	0.39		
5.7 (13)	2.1	1.3	0.40	0.50	1.0	0.30	0.40		
5.8 (14)	2.2	1.4	0.45	0.54	0.95	0.32	0.44		
5.8 (16)	2.2	1.5	0.43	0.56	0.95	0.35	0.45		
Sebastes constellatus									
4.5 (4)	1.7	1.0	0.30	0.32	0.75	0.24	0.29		
4.6 (6)	1.8	1.1	0.30	0.32	0.71	0.25	0.30		
4.6 (8)	1.8	1.0	0.26	0.35	0.67	0.27	0.34		
4.4 (9)	1.6	1.0	0.27	0.33	0.72	0.26	0.35		
4.6 (11)	1.7	1.0	0.30	0.35	0.73	0.25	0.35		
*7.1 (38)	3.5	2.3	0.78	0.77	2.0	1.0	0.71	0.30	4.2

*Specimen undergoing notochord flexion

increasing to 19-21 melanophores in the largest larvae (Fig. 3). Pectoral fin pigmentation was similar to that in *S. rufus*. The tip of the lower jaw became pigmented at about day 9.

Sebastes serranoides

Rearing—Larvae from the two females caught on 18 Jan. 1979 were markedly different in stage of development. Larvae from female #1 were 4.2-4.3 mm long, with a yolk mass of 0.6 mm diameter, and were premature. Larvae from female #2 measured 4.8-5.4 mm, had no yolk and only a remnant of the oil globule in the liver tissue. These larvae began feeding immediately on wild plankton whereas the premature brood began feeding on day 5, when only a remnant of yolk was visible in the liver tissue. Both groups had massive die-offs due to improper water circulation and stratification on day 9; however, a few larvae from both broods survived to day 16.

Morphology—The larvae were similar to *S. rufus* (Fig. 3D-F; Tables 5, 6). Caudal fin rays were not forming in the largest specimens, nor were head spines.

Pigmentation—Pigmentation was similar to that of *S. rufus*. In a sample of 30 newborn larvae from female #1, 17% lacked pigment over the brain, 73% had 1 or 2 melanophoes, and 10% had 3-4 melanophores above the brain. Nape melanophores were lacking in 57% of the larvae, 33% had one nape spot, and 10% had 2-3 spots. By day 5, melanophores covered the brain and nape. Newborn larvae had a melanistic shield over the gut and a distinct series of melanophores along the ventral midline below the gut. All newborn larvae had a melanophore at the future hypural region. The postanal ventral midline series extended from the third or fourth postanal myomere to the 18th-20th and contained 14-20 melanophores ($\bar{x}$ = 16.0±1.60 SD for the entire growth series). Of 100 newborn larvae examined, 67 lacked dorsal midline melanophores, 28 had a single melanophore, and 5 specimens had 2 melanophores at the 17th-19th postanal myomeres. At the end of the first week, additional melanophores appeared in the dorsal midline series and 9 to 14 day larvae had 7-16 ($\bar{x}$ = 13.2±3.70 SD) melanophores in the series.

At day 5, the tip of the lower jaw and the pectoral fins were pigmented. The medial surface of the pectoral fin base had a large melanophore and the outer half of the fin blade had a covering of fine melanophores. By day 9 the medial surface of the fin blade was fully pigmented and the fin blade had a distinct pigment pattern (Fig. 3E). Also, at this stage melanophores appeared on the snout, opercular region, and lateral nape region. At day 14 the medial surface of the fin base was totally pigmented.

Sebastes constellatus

Rearing—Newborn larvae of *S. constellatus* were 4.0-5.0 mm at extrusion, had a small remnant of the oil globule, and began feeding immediately on wild plankton. There was a massive die-off at the end of the first week and the single larva remaining alive at the end of the second week lived to day 38.

Morphology—Early larvae of *S. constellatus* were morphologically indistinct (Fig. 4A-C; Tables 5, 6). The 38-day specimen (7.1 mm) was similar to larvae of other species of the subgenus *Sebastomus* (Moser et al. 1977; Richardson and Laroche 1979), in having a relatively large head with strong spination and the following head spines: second and third anterior preopercular, second and fourth posterior preopercular, pterotics, posttemporals, postoculars, and parietals. Each postocular spine was borne on a prominent supraocular shelf, and the heavily serrated parietals were elongated compared with those of *S. rufus*. Also, in this specimen the dorsal and anal fin bases and the pelvic fins were beginning to form.

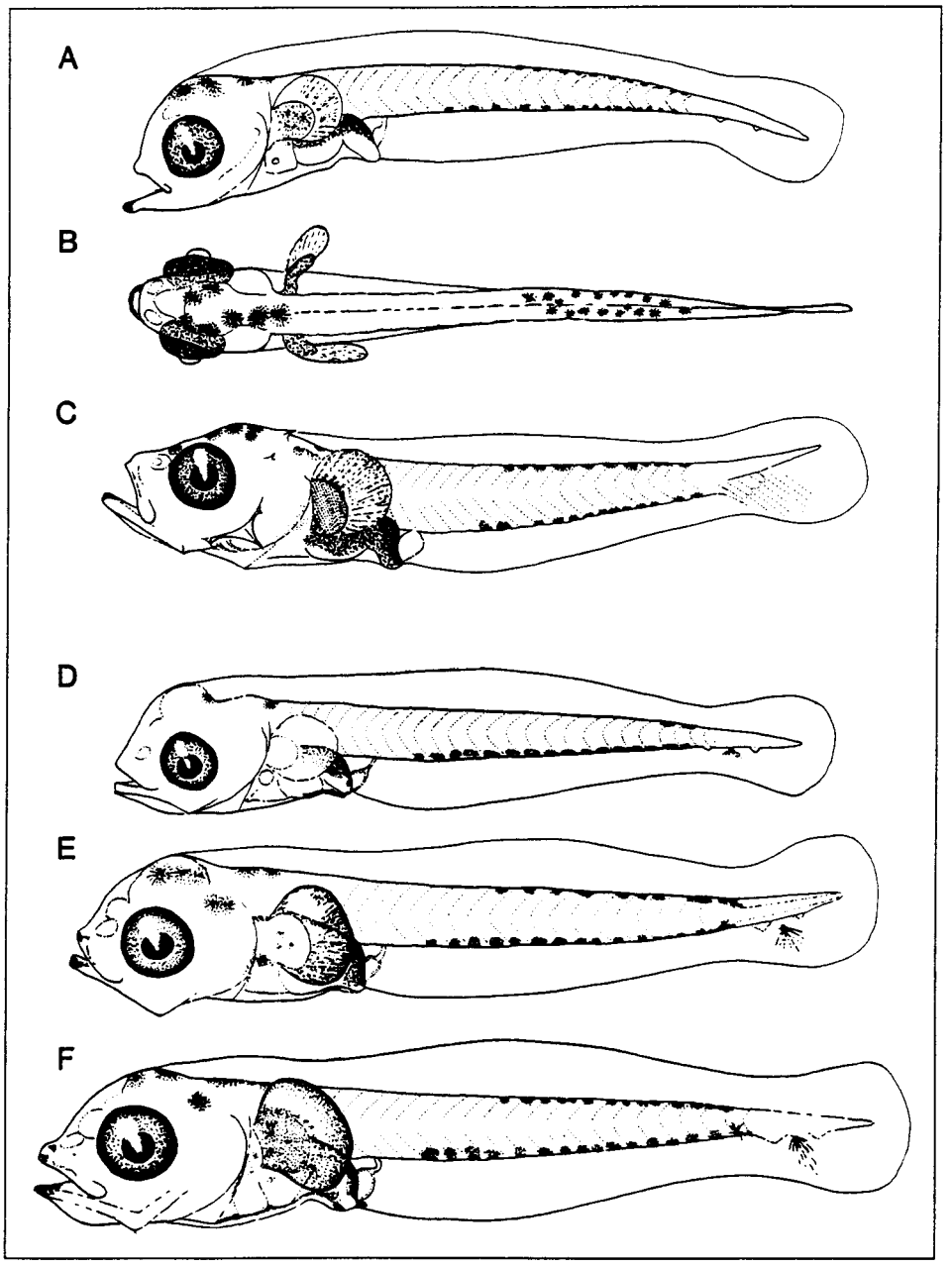

Figure 3—Larvae of *Sebastes ovalis* (A-C) and *S. serranoides* (D-F). A. 4.9 mm, day 9; B. 4.9 mm, day 9 (dorsal view); C. 6.8 mm, day 29; D. 5.0 mm, day 2; E. 5.6 mm, day 9; F. 5.8 mm, day 14.

Pigmentation—Pigmentation in early larvae of *S. constellatus* was similar to that known for other species of *Sebastomus*. The pigment pattern consisted of a spot at the tip of the lower jaw, a shield over the gut, a ventral midline series below the gut, and a postanal ventral series extending from the third to the 15th postanal myomere and containing 12-16 melanophores (Fig. 4). During the first week, the pectoral fin blade became covered with small melanophores that were denser at the distal margin. The 7.1-mm larva had snout pigment, a covering of melanophores above the brain, nape spots, a solidly pigmented pectoral fin-base, pelvic fin pigment, and a hypural spot (Fig. 4C). Dorsal midline pigment was not present.

Sebastes rubrivinctus

Rearing—The brood of larvae collected on 15 Sept. 1976 was held at two temperature ranges, 8.8-9.3°C and 14.4-15.0°C, to provide specimens for sinking rate experiments, and were not fed subsequently. After two weeks, the least advanced individuals were about 4.8 mm long, had a yolk sac measuring about 0.6 × 0.7 mm, and an oil globule about 0.23 mm in diameter; the most advanced specimens lacked yolk and had an oil globule 0.10-0.20 mm in diameter. Sinking rates ranged from 0.6 cm/s for the least advanced to 0.09 cm/s for the most advanced (Table 7, Fig. 5).

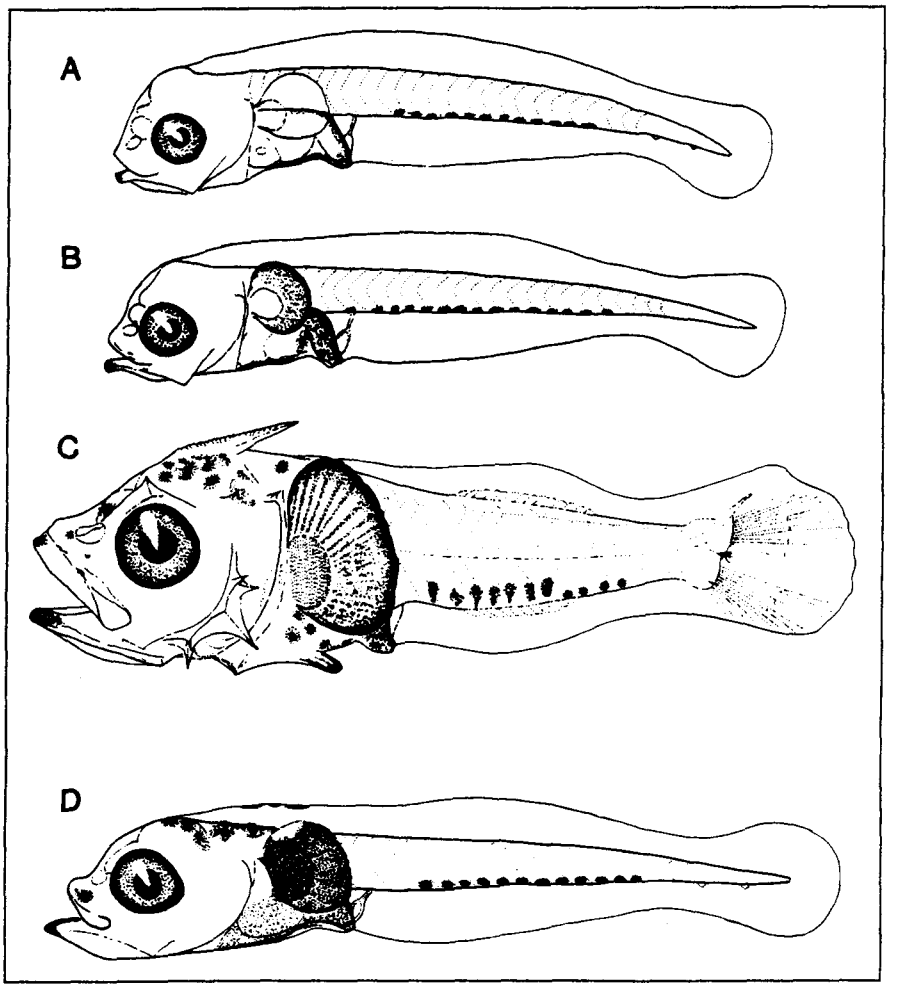

Figure 4—Reared larvae of *Sebastes constellatus* (A-C) and *S. rubrivinctus* (D). A. 4.5 mm, day 4; B. 4.6 mm, day 11; C. 7.1 mm, day 38; D. 5.1 mm, day 14.

Table 7—Sinking rates for anesthetized larvae of *Sebastes rubrivinctus* at different stages of yolk and oil globule utilization.

Specimen length (mm)	Yolk length (mm)	Yolk width (mm)	Yolk volume (mm^3)	Oil globule diameter (mm)	Sinking time (min:s)	Beaker height (cm)	Sinking rate (cm/s)
4.8	0.70	0.60	0.154	0.23	0:59.8	36.5	0.61
4.9	0.74	0.58	0.166	0.22	1:44.8	36.5	0.35
4.8	0.64	0.54	0.116	–	1:54.2	36.5	0.32
5.0	0.68	0.50	0.121	0.24	2:26.6	36.5	0.25
5.1	0.46	0.30	0.033	0.18	3:06.8	36.5	0.20
5.0	0.38	0.30	0.023	0.20	3:11.2	36.5	0.19
5.2	0.56	0.36	0.059	0.20	3:20.4	36.5	0.18
5.2	0.38	0.32	0.024	–	3:24.0	36.5	0.18
5.0	0.38	0.26	0.020	0.24	3:32.4	36.5	0.17
4.8	0	0	0	0.10	4:26.6	36.5	0.14
5.1	0	0	0	0.12	6:45.0	36.5	0.09
4.8	0.08	0.08	<0.001	0.20	7:05.8	36.5	0.09

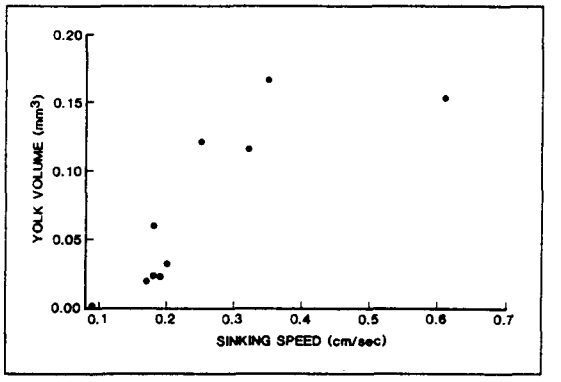

Figure 5—Sinking speed of larvae of *Sebastes rubrivinctus* at various stages of yolk utilization.

Pigmentation—In yolk-exhausted larvae, the head was heavily pigmented with melanophores covering the brain, nape, lower jaw, and with one or more melanophores in the snout (Fig. 4D). One to several melanophores were present at the margin of the dorsal finfold above the nape. Finfold pigmentation has not been reported in larvae of other species of *Sebastes*. The median surface of the pectoral fin base was covered solidly with melanophores as was the blade, except for a small dorsally located clear zone. The gut was pigmented solidly on all surfaces. Postanal pigmentation consisted of a ventral midline series of 13-23 melanophores ($\bar{x}$ = 16.4 ± 1.82 SD for 50 specimens) extending from the third or fourth postanal myomere to the 15th-16th.

DISCUSSION

Our ability to identify the early-stage larvae of rockfishes has progressed so that, for some species, standard plankton surveys may be used to determine the temporal and areal extent of spawning and relative larval abundance (Moser et al. 1977). These surveys also provide the possibility for estimation of spawning biomass when critical information on fecundity, larval mortality, and duration of the early pelagic phase becomes available. The species with identifiable larvae are only a fraction of the rockfish species which are currently or potentially important to fisheries. Larval series which have been described have distinctive morphological features, pigmentation, temporal and spatial distributions, or a combination of these characters, and are readily identifiable compared with the unidentified species which have more subtle larval characters. Rearing of larval series provides the means for increasing the number of identifiable species; however, rockfish are difficult to rear. We have not been able to duplicate the Japanese success with *Artemia* as a food (Table 1) largely because eastern Pacific species are smaller and comparatively less developed at birth (Table 1) and we have had to rely on freshly collected wild plankton. Indeed, in our rearing attempts, high concentrations of *Brachionus* have not elicited feeding behavior. The recent successful rearing of copper and brown rockfish (*S. caurinus* and *S. auriculatus*) larvae to the stage of caudal fin formation on a diet of *Brachionus* and *Artemia* (Stahl-Johnson 1985) suggests a diversity in larval food requirements among eastern Pacific species.

The number and arrangement of postanal midline pigment series have been emphasized as key characters in identifying rockfish larvae (DeLacy et al. 1964; Moser 1967; Westrheim 1975; Moser et al 1977). Previously, early-stage rockfish larvae have been divided into two groups: those with both dorsal and ventral midline series and those with only ventral series. Larvae of *S. rufus* and *S. serranoides*, described herein, represent a third type which has only a ventral midline series at birth (most specimens) but soon develops a substantial dorsal midline series to which melanophores are added gradually. This must also happen in *S. entomelas* and *S. flavidus*, since newborn larvae lack dorsal midline series (Westrheim 1975) but early postflexion larvae (Laroche and Richardson 1980, 1981) have well developed dorsal midline series. The usefulness of the postanal pigment series as a larval character will depend on knowing the composition and arrangement of these series at precise developmental stages, knowledge which can be obtained only by rearing each species.

The distribution of dorsal and ventral midline pigment may provide characters for systematic analysis. Barsukov (1981) has hypothesized that the widow rockfish (*S. entomelas*) is most closely related to the blue rockfish (*S. mystinus*) and that these two are part of a group that includes *S. flavidus*, *S. melanops*, and *S. serranoides*. Also, Barsukov proposed that the sister group to the *S. entomelas* group includes *S. rufus*, *S. ovalis*, and *S. hopkinsi*. Characters of first-feeding larvae are now known for all of the above species. In the former group and *S. rufus*, first-feeding larvae have only a ventral row of postanal midline pigment but develop a dorsal row during the preflexion larval stage (not known for *S. mystinus*). First-feeding larvae of *S. ovalis* and *S. hopkinsi* have both dorsal and ventral postanal midline pigment. More precise knowledge of the number and arrangement of postanal midline pigment is needed to test the utility of this character in species identification and systematic analysis.

The larvae of the starry rockfish, *S. constellatus*, show the suite of pigment and morphological characters described for other members of the subgenus *Sebastomus* (Moser et al. 1977; Richardson and Laroche 1979). Preflexion and postflexion larvae of this group have a postanal ventral midline series only and pigment on the dorsal head region, on the lower jaw, and on the pectoral fins (heaviest on the distal margin). Late in the postflexion stage, *Sebastomus* larvae develop a blotch on the caudal peduncle and a saddle beneath the spinous dorsal fin. It is likely that early larval stages of this group will not be identifiable to species. In groups

such as these, the late larval and pelagic juvenile stages could be used to estimate recruitment, depending on our ability to sample these stages adequately. Mid- and late-stage larvae are undersampled by plankton nets (Fig. 1) and juvenile habitats are diverse for the large array of *Sebastes* species. Those with distinct pelagic juvenile stages could be sampled with midwater trawls, surface nets, or small-mesh purse seines depending on their location in the water column (Moser and Ahlstrom 1978; Laroche and Richardson 1981). Those species which transform and quickly settle to soft-bottom habitats can be sampled by small-mesh bottom trawls; however, those which settle quickly to rocky habitats may be vulnerable only to traps.

An important aspect of the life history of rockfish was addressed by the sinking rate experiment on *S. rubrivinctus* larvae reported in this paper. The sinking rate in rockfish embryos and yolked larvae decreases with decreasing yolk volume (Fig. 5), whereas in species with pelagic eggs such as the plaice (Blaxter and Ehrlich 1974) and the northern anchovy (Hunter and Sanchez 1976) sinking rate increases with decreasing yolk volume. Whereas the newhatched larvae of fish species with pelagic eggs find themselves positioned or maintained in the upper water column by virtue of their buoyant eggs, all evidence indicates that rockfish larvae are extruded at the depth range of the adults and rise to the upper water column. Since prematurely born yolk-sac larvae would sink rapidly to the bottom and die, birth must be coordinated precisely with the time of yolk and oil globule exhaustion. Perhaps birth is initiated by behavioral or biochemical cues from the full-term larvae. If birth was initiated by the female, she would gain some latitude in the critical timing of extrusion, particularly if she were able to provide nutrition to the developing brood after yolk exhaustion. Indeed, maternal nutriton is suggested by the markedly greater rearing success of broods spawned spontaneously by captive females compared with broods taken from field-caught females. Recently, Boehlert and Yoklavich (1984) have demonstrated maternal nutrition in *Sebastes*.

Early mortality in *Sebastes* follows a vastly different path than in other fishes with a prolific larval stage. Rockfish have avoided the high mortality of the egg stage (e.g., 30-40%/day for northern anchovy reported by Stauffer and Picquelle 1980) since there is insignificant intraovarian mortality, even in species with brood sizes exceeding 2 million embryos (Moser 1967). The great reproductive potential inherent in being able to produce large numbers of fully-formed larvae that are ready to feed on zooplankters is balanced by the mortality encountered in the journey of these first-feeding larvae from their place of birth to the upper water column. This mortality is controlled to some degree by events during late intraovarian life since survival of newborn young depends on their state of organ development, energy reserves, and bouyancy. Studies on intraovarian physiology of *Sebastes* (Boehlert and Yoklavich 1984) and attention to brood condition in field-caught females will provide valuable insight into rockfish production.

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