Abstract.—Developmental series of larval and pelagic juvenile chilipepper, *Sebastes goodei*, collected off central California were described and illustrated. Pigment patterns were recorded on pre-extrusion larvae through fish in the pelagic juvenile stage, along with the number of dorsal-, anal-, and pectoral-fin rays. The number of gill rakers on the first gill arch, morphometric data, and the development of head spines were also recorded on selected specimens. In addition, otoliths were used to help confirm the identifications of early larvae given the distinctive pre-extrusion optical pattern found in *S. goodei*. For comparison, otoliths were examined on other *Sebastes* spp. commonly found in the region that had pigment patterns similar to, but slightly different from, those of *S. goodei*. Ages were obtained from *S. goodei* and other *Sebastes* spp. otoliths.

Early larvae of *S. goodei* were identified by their lack of pigment on the lower jaw, the cleithral region, and both the caudal and hypural areas, and by the presence of pigment on the cranium and the outer blade of the pectoral fin. Juvenile *S. goodei* were readily identified by their distinctive barred pattern. The distinctive pre-extrusion optical pattern was observed in 96% of *S. goodei* otoliths, as well as a significantly larger extrusion check radius than that in the otoliths of other *Sebastes* spp. Larval growth rates for *S. goodei* calculated from otolith age data appeared to be slower than those previously reported for pelagic juveniles.

Description of larval and pelagic juvenile chilipepper, *Sebastes goodei* (family Scorpaenidae), with an examination of larval growth

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The genus *Sebastes* (family Scorpaenidae) is a diverse group in the eastern Pacific Ocean comprising 72 species (Kendall, 1991), 59 species of which are known to occur off California alone (Eschmeyer et al., 1983). Off California, *Sebastes* spp. form a substantial portion of the groundfish fishery (PFMC[1]). Currently, the preflexion larvae of 51 species occurring off California have been described (Morris, 1956; Westrheim, 1975; Moser et al., 1977; Moser and Ahlstrom, 1978; Moser and Butler, 1981; Stahl-Johnson, 1985; Moser and Butler, 1987; Matarese et al., 1989; Wold, 1991; Moreno, 1993; Laroche[2]), but accurate identification of field-caught larvae is difficult owing to small interspecific differences and relatively large intraspecific variability (Moser et al., 1977; Kendall, 1991; Wold, 1991; Moreno, 1993). Descriptions are usually obtained from laboratory-reared larvae extruded from females of known identity or from a size series of field-caught specimens (Kendall and Lenarz, 1987; Kendall, 1991). Electrophoretic patterns have also been useful in the identification of larval *Sebastes* spp. (Seeb and Kendall, 1991). The ability to readily identify *Sebastes* larvae could facilitate their use in recruitment studies and

larval production biomass estimates (Moser and Butler, 1987; Hunter and Lo, 1993; Ralston et al.[3]).

Chilipepper, *Sebastes goodei*, is an important component of the groundfish fishery off California (mainly south of Cape Mendocino) (PFMC[1]). Individuals attain a maximum age of 21 years and a maximum size of 59 cm total length (TL); both males and females reach maturity from 3 to 6 years of age (Wilkins, 1980; Wyllie Echeverria, 1987). Spawning mainly occurs from November through March off northern and central California (Wyllie Echeverria, 1987). Partial descriptions currently exist for recently extruded larvae, 5.7 to 5.8

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[1] PFMC (Pacific Fishery Management Council). 1993. Status of the Pacific coast groundfish fishery through 1993 and recommended acceptable biological catches for 1994. Pacific Fisheries Management Council, Portland, OR, 96 p.

[2] Laroche, W. A. 1987. Guide to larval and juvenile rockfishes (*Sebastes*) of North America. P.O Box 216, Enosburg Falls, VT 05450. Unpubl. manuscr., 311 p.

[3] Ralston, S., J. R. Bence, M. B. Eldridge, and W. H. Lenarz. 1993. Estimating the spawning biomass of shortbelly rockfish (*Sebastes jordani*) in the region of Pioneer and Ascension Canyons using a larval production method. Southwest Fisheries Science Center, Natl. Mar. Fish. Serv., NOAA, 3150 Paradise Drive, Tiburon, CA 94920. Unpubl. manuscr., 32 p.

mm notochord length (NL)(Morris, 1956; Moser et al., 1977; Matarese et al., 1989; Laroche[2]), and for a 37.0-mm standard length (SL) pelagic juvenile (Matarese et al., 1989; Laroche[2]).

The purpose of this study is to describe the development of *S. goodei* from pre-extrusion larvae to the pelagic juvenile stage. In addition, the age and growth of early larvae were examined.

Methods

Specimens of larval and pelagic juvenile *S. goodei* were obtained from cruises conducted aboard the NOAA RV *David Starr Jordan* by using bongo nets with 0.505-mm mesh, a 5-m^2 Methot Isaacs-Kidd (MIK) trawl with 2-mm mesh and a 0.505-mm codend, and a 26 m × 26 m mid-water trawl with a 12.7-mm stretched-mesh codend liner. Bongo-net collections were made in February 1991 and 1993, MIK collections in March 1992 and 1993, and midwater trawl collections in May and June 1992 and 1993. Specimens from bongo and MIK collections were preserved in ethanol (EtOH) (80% for the 1991 bongo collection and 95% for all others), whereas midwater trawl specimens were frozen. Pre-extrusion larvae were collected from four adult females captured in January 1991 and were preserved in ethanol (initially 80%, but later transferred to 95%). Although preservation in ethanol causes shrinkage (Laroche et al. [1982] observed 3.2% shrinkage in larval English sole, *Pleuronectes vetulus,* preserved in 80% ethanol), the rate of shrinkage decreases with increased fish size (Radtke, 1989). Therefore, while discrepancies in SL due to different preservation methods could have occurred in using the frozen midwater trawl specimens along with the ethanol-preserved MIK trawl specimens, these fish were probably large enough (>24 mm SL) that the shrinkage rate was negligible relative to total size. All samples were collected off central California between Cypress Point (36°35'N latitude) and Salt Point (38°35'N latitude).

A total of 283 fish were examined, including 138 large specimens (>20 mm SL), 130 small specimens (<20.1 mm SL), and 15 pre-extrusion larvae. Large specimens were identified from meristic characters and pigment patterns (i.e. melanophore patterns, because other pigments such as xanthophores are not retained well in ethanol [Matarese et al., 1989]) as described previously in Chen (1986), Matarese et al. (1989), Moreland and Reilly (1991), and Laroche.[2] Small specimens were initially identified by using pigment patterns developed from a size series (Kendall and Lenarz, 1987) based on the pigment

patterns of pre-extrusion larvae and on the smallest individuals with complete meristic characters. Pigment patterns were recorded on each specimen examined. Dorsal-, anal-, and pectoral-fin ray counts were recorded on specimens >8.1 mm SL, and the number of gill rakers on the first gill arch were recorded on a subset of 50 large specimens.

Morphometric data, including head length, snout length, snout to anus distance, eye diameter, body depth at the pectoral fin base, body depth at the anus, and pectoral fin length, were taken on 20 specimens (all preserved in 95% ethanol) ranging in size from 5.3 mm NL to 22.0 mm SL. Measurements were recorded in mm by using a dissecting microscope connected to a video camera and computer. Terminology for morphometrics followed Richardson and Laroche (1979).

In order to examine the development of head spines, 20 specimens ranging in size from 6.1 mm NL to 22.0 mm SL were stained with Alizarin Red-S. In addition, because it is often used as a diagnostic character, the presence or absence of supraocular spines was noted in all large specimens. Terminology for head spination followed Richardson and Laroche (1979).

Otolith characters have recently been shown to be helpful in identifying late larval and pelagic juvenile *Sebastes* spp. (Laidig and Ralston, 1995). In particular, the otoliths of *S. goodei* develop a distinctive optical pattern (i.e. a dark inner ring surrounding a dark primordium) during the pre-extrusion larval stage (Laidig and Ralston, 1995). Consequently, otoliths were removed from 50 specimens (4.6 mm NL to 10.7 mm SL) to help confirm the initial pigment-based identifications of larval *S. goodei.* For comparison, otoliths were also removed from 52 larval *Sebastes* of unknown species (3.7 mm NL to 8.2 mm SL) that had pigment patterns similar to, but slightly different from, those of larval *S. goodei.* Otoliths of *S. goodei* and other *Sebastes* spp. were removed from specimens collected at the same sites to determine whether the pigment patterns described in this study were accurately distinguishing *S. goodei* from other *Sebastes* spp. Other *Sebastes* spp. were distinguished from *S. goodei* by one or all of the following characteristics: absence of pigment on the cranium and nape, presence of pigment on the tip of the lower jaw, presence of pigment on the cleithral region, and presence of pigment on the caudal area. *Sebastes jordani* and *S. paucispinis* were not included in the other *Sebastes* spp. category because they were easily identified on the basis of distinctive pigment patterns and morphometrics (Moser et al., 1977). Otoliths were examined under a compound microscope connected to a video camera and computer with a working magnification of 1,250×. The radius of the

extrusion check, the total radius, and the pre-extrusion optical pattern were recorded on all otoliths examined. Pre-extrusion optical patterns (as previously described in Laidig and Ralston, 1995) were recorded as being either "strong," "weak," or "absent." "Strong" patterns were readily visible and required very little focusing for resolution. In "weak" patterns, the dark inner ring surrounding the primordium was not readily visible without fine focusing. "Absent" patterns were devoid of the pre-extrusion optical pattern described for *S. goodei* (Laidig and Ralston, 1995). Ages were recorded only from otoliths with clear, distinct daily rings. Ages were obtained following the methods described in Laidig et al. (1991) and Woodbury and Ralston (1991).

Results

General development

Larval *S. goodei* were extruded at a size of 4.5 to 5.8 mm NL. Notochord flexion began at 5.7 to 6.5 mm NL and was complete at 8.1 to 8.8 mm SL. Meristic counts were similar to those reported by Chen (1986), Moreland and Reilly (1991), and Laroche[2] (Table 1). In late-stage flexion and recently flexed individuals a full complement of pectoral-fin rays was present, while the pelvic, dorsal, and anal fins had begun forming. By 9.0 mm SL, the full complement of pectoral-, pelvic-, dorsal-, and anal-fin rays had developed. Accurate gill-raker counts were obtained only on large specimens (>20 mm SL).

Changes in body shape in *S. goodei* were related to notochord flexion (Table 2). During flexion, body depth at the pectoral-fin base and at the anus increased substantially (Table 2). Also during flexion, pectoral-fin length increased with the development of the full complement of fin rays (Table 2). In addition, head length, snout length, snout to anus distance, and eye diameter all showed a marked increase during flexion (Table 2).

Head spines first appeared in *S. goodei* at approximately 6.1 mm NL; the pterotic and the second anterior and third posterior preoperculars were the first to form (Table 3). During late flexion (approximately 7.5 mm NL), the anterior and the second through fifth posterior preopercular series, the postoculars, and the parietals were evident (Table 3). The parietals were serrate and longer than the nuchals, which developed in postflexion individuals (approximately 8.5 mm SL). The first superior infraorbital also was evident in postflexion individuals (Table 3). The third spine of the posterior preopercular series was always the longest. By 14.0 mm SL, the opercular, inferior infraorbitals, supracleithral, and posttemporal spines had developed and by 20.0 mm SL the nasal and tympanic spines were evident (Table 3). Coronal spines were not observed on any of the specimens (Table 3). Supraocular spines, previously unrecorded in *S. goodei* (Moreland and Reilly, 1991; Laroche[2]), were observed on 11% of the large individuals (>20 mm SL)(Table 4). Specimens with supraocular spines ranged in size from 32.0 to 50.2 mm SL, indicating some variability in the occurrence of this characteristic in the pelagic juvenile stage (Table 4).

Pigment patterns

Pre-extrusion larvae ranging in size from 5.0 to 5.8 mm NL had a group of 6 to 12 melanophores on the cranial region, 2 to 5 melanophores on the nape, pigment on the dorsal region of the gut, and a series of 15 to 25 melanophores lining the ventral body that did not extend anteriorly beyond the third postanal myomere (Fig. 1A).

Recently extruded larvae (1 to 2 days old) ranging in size from 4.5 to 5.7 mm NL had more developed pigment on the cranium and nape than did pre-extrusion larvae and had pigment on the dorsal region of the gut and a series of 13 to 17 melanophores lining the ventral body that did not extend anterior to the fourth postanal myomere (Table 5). Pigment on the cranium persisted throughout development. By 5.7 to 6.1 mm NL (3 to 5 days old), pigment on the outer blade of the pectoral fin became evident (Table 5; Fig. 1B). During flexion, melanophores became

Table 1

Frequency of occurrence of dorsal-, anal-, and pectoral-fin ray, and gill-raker counts in chilipepper, *Sebastes goodei* .

Character	Count	Frequency of occurrence	Percent occurrence
Dorsal-fin rays	13	10	6.6
	14	106	70.2
	15	34	22.5
	16	1	0.7
Anal-fin rays	8	157	90.2
	9	17	9.8
Pectoral-fin rays	16	12	7.8
	17	138	90.2
	18	3	2.0
Gill rakers	33	1	2.0
	34	21	42.0
	35	14	28.0
	36	10	20.0
	37	4	8.0

Table 2

Morphometric measurements of chilipepper, *Sebastes goodei*, larvae of various size. All measurements are in mm. Specimens between the dashed lines were undergoing notochord flexion.

SL	Head length	Snout length	Snout to anus distance	Eye diameter	Body depth at pectoral base	Body depth at anus	Pectoral-fin length
5.3	1.06	0.27	1.73	0.39	0.85	0.45	0.35
5.4	1.07	0.28	1.80	0.45	0.90	0.47	0.33
5.6	1.03	0.33	1.83	0.44	0.97	0.43	0.38
5.8	1.05	0.30	1.98	0.47	0.98	0.45	0.41
6.0	1.16	0.32	1.95	0.47	0.98	0.48	0.42
6.1	1.12	0.30	2.03	0.48	1.00	0.44	0.43
6.6	1.40	0.32	2.45	0.49	1.15	0.57	0.74
6.7	1.43	0.36	2.50	0.56	1.16	0.57	0.78
6.8	1.45	0.39	2.50	0.58	1.17	0.59	0.75
7.3	1.80	0.52	2.77	0.67	1.46	0.84	1.01
8.0	2.56	1.00	3.99	0.80	1.99	1.18	1.60
8.1	2.70	1.07	4.20	0.95	2.10	1.60	1.75
8.3	3.00	1.05	4.25	1.01	2.15	1.57	1.88
8.7	3.18	1.13	4.65	1.10	2.51	1.72	1.92
9.1	3.45	1.33	4.75	1.24	2.40	1.90	2.07
9.6	3.61	1.21	5.12	1.38	2.79	2.08	2.28
12.2	4.50	1.35	7.34	1.65	3.16	2.37	3.34
13.9	4.92	1.76	7.97	1.75	3.55	2.72	3.54
20.1	6.50	2.04	10.40	2.40	4.85	3.88	5.28
22.0	8.46	2.73	12.34	2.54	5.71	4.92	6.02

evident on the dorsal surface anterior to the eyes (Table 5). None of the preflexion and flexion larvae were pigmented on the cleithral region or caudal area.
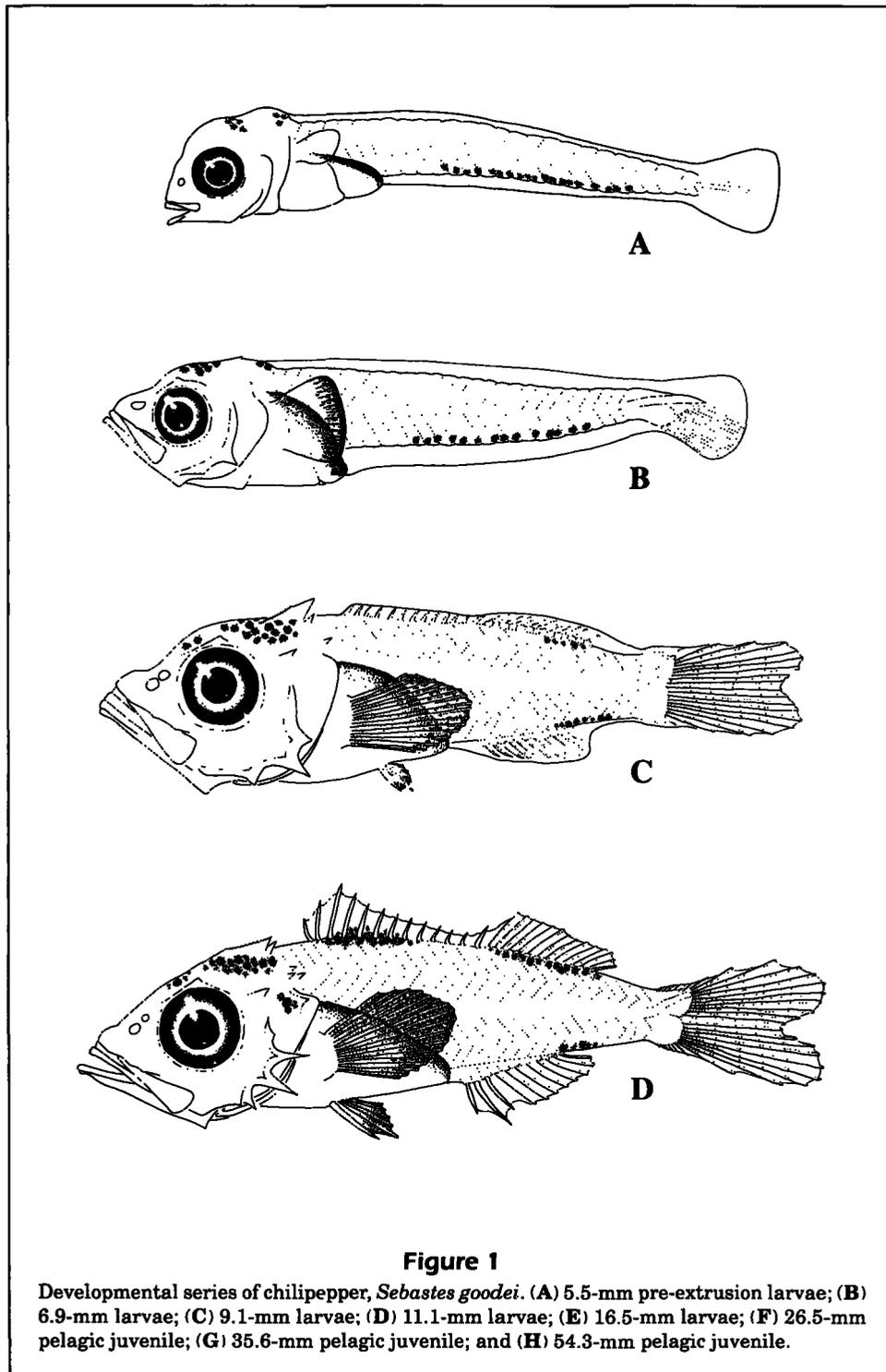
After flexion (>15 days old), pigment lining the ventral body was greatly reduced; approximately 8 melanophores were present either on or near the articulations of the anal-fin rays, and/or on the ventral midline of the caudal peduncle (Fig. 1C). In addition, nape pigment had become imbedded in postflexion individuals. Upon completion of flexion, melanophores had also begun to develop on the pelvic fin and along the posterior portion of the dorsal body surface underlying the soft dorsal fin (Table 5; Fig. 1C).

At 11.0 mm SL (>40 days old), additional melanophores had developed on the dorsal body surface underlying the spinous dorsal fin, and melanophores extended into the fin membranes (Table 5; Fig. 1D). In addition, pigment was evident along the blade of the pelvic fin, had covered the outer half of the pectoral fin, and had begun to develop on the surface of the operculum (Table 5; Fig. 1D). Pigment on the anterior tip of the lower jaw and on the hypural region had begun to occur at 11.8 mm SL, and pigment along the dorsal body surface continued to increase (Table 5).

By 12.0 mm SL, the melanophores lining the dorsal body surface had begun to form the first body bar

above the opercular region (Table 5). The first body bar and all subsequent body bars formed initially from the dorsal surface and extended ventrally with development. Pigment along the lateral midline of the body had begun to develop on the caudal region by 14.0 mm SL, and the second body bar had begun to develop underneath the spinous dorsal fin at 14.5 mm SL (Table 5; Fig. 1E). Pigment began to develop along the ventral and posterior regions of the eye orbit at 18.7 mm SL (Table 5).

By 28.0 mm SL, pigment on the ventral and posterior regions of the eye orbit, the dorsal surface anterior to the eyes, the surface of the operculum, the dorsal body surface, the lateral midline of the body, the hypural region, and on the membranes of the spinous dorsal fin were all well developed (Table 5; Fig. 1F). The ventral terminus of the first body bar was projected forward and the second body bar began to develop a similar pattern (Fig. 1F). In addition, the remaining three body bars had begun forming with the first appearance of the third body bar just anterior to the soft dorsal fin, with the fourth body bar directly under the soft dorsal fin, and with the fifth body bar on the caudal region (Table 5). Pectoral- and pelvic-fin pigment had become less prominent by 29.0 mm SL, with melanophores on only the

Figure 1

Developmental series of chilipepper, *Sebastes goodei*. (A) 5.5-mm pre-extrusion larvae; (B) 6.9-mm larvae; (C) 9.1-mm larvae; (D) 11.1-mm larvae; (E) 16.5-mm larvae; (F) 26.5-mm pelagic juvenile; (G) 35.6-mm pelagic juvenile; and (H) 54.3-mm pelagic juvenile.

outer quarter of the pectoral fin. Pigment along the ventral body surface was either absent or occurred sparsely (1 to 7 melanophores) on or near the anal-fin ray articulations and/or on the ventral surface posterior to the anal fin.

At 34.2 mm SL, individuals had begun to lose almost all their pectoral- and pelvic-fin pigment, while the third body bar had become almost fully developed (Fig. 1G). The second and third body bars had developed a forward projecting pattern similar to the
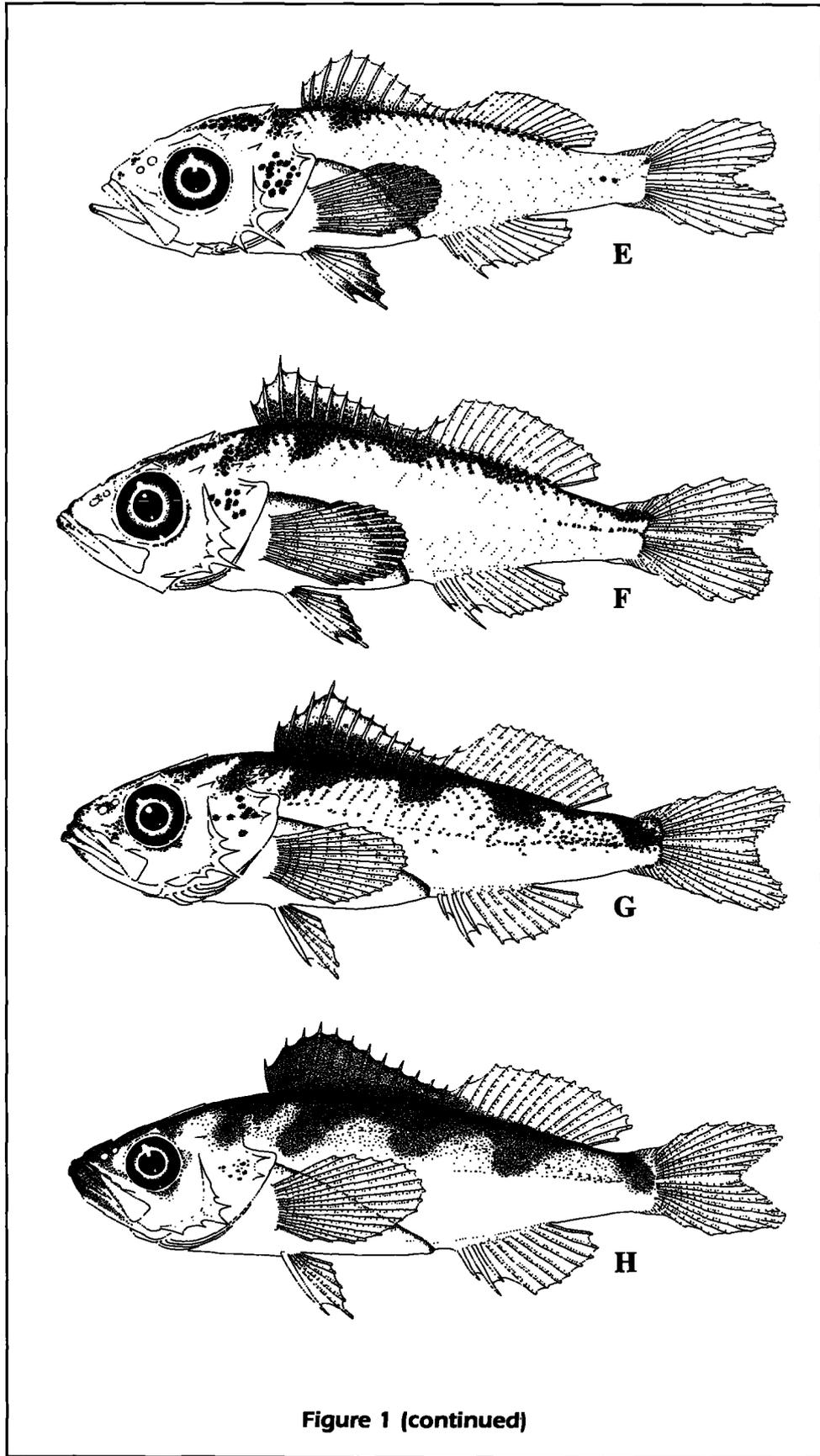
Figure 1 (continued)

Table 3

Development of head spines in chilipepper, *Sebastes goodei*. "1" indicates that spine is present and "0" indicates that spine is absent.

Spine	Standard length (mm)																			
	6.1	6.3	7.5	7.7	8.2	8.5	9.2	9.6	10.0	10.7	11.7	12.2	13.4	13.8	14.1	16.8	18.8	19.4	21.5	22.0
Pterotic	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Preoperculars																				
1st Anterior	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2nd Anterior	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3rd Anterior	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1st Posterior	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2nd Posterior	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3rd Posterior	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4th Posterior	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5th Posterior	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Preocular	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supraocular	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Postocular	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Parietal	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Infraorbitals																				
1st Inferior	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
2nd Inferior	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
3rd Inferior	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1
1st Superior	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2nd Superior	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
3rd Superior	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4th Superior	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
Nuchal	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Postemporals																				
Inferior	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Superior	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Supracleithral	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Operculars																				
Inferior	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Superior	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nasal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Tympanic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Coronal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

first body bar (Fig. 1G). By 38.3 mm SL, the fourth and fifth body bars were fully developed but did not develop the forward projecting pattern of the first three body bars (Table 5). In addition, pectoral- and pelvic-fin pigment had disappeared (Table 5).

The largest individual examined was 58.3 mm SL, which had all 5 body bars fully developed and well-developed pigment on the anterior tip of the lower jaw, the ventral and posterior region of the eye orbit, the dorsal surface anterior to the eyes, the hypural region, the entire dorsal body surface, and the spinous dorsal fin (Table 5; Fig. 1H). Pigment on the lateral midline surface had become indiscernible owing to the increased pigmentation of the lateral surface. The barred pattern had become slightly obscured by mottling over the dorsal lateral surface. Pectoral- and pelvic-fin pigments were recorded for a few of the larger individuals, but these were a result of 1 to 4 solitary melanophores located usually on one fin only (Table 5). Cheek bars and pigment on the anal fin were not observed on any of the specimens examined (Table 5).

Otolith analysis

The extrusion check radius in *S. goodei* otoliths was significantly larger than that of other *Sebastes* spp. (*S. goodei* mean=14.84 µ, SD=0.577; other *Sebastes* spp. mean=12.03 µ, SD=0.869; t=19.29, df=89, P=0.0001) (Fig. 2). In addition, "strong" patterns were observed in the majority of *S. goodei* specimens, which provided confirmation of the initial pigment-based identifications but which occurred in only a small minority of other *Sebastes* spp. (Table 6). The extrusion check radius of the other *Sebastes* spp. otoliths with "strong" patterns ranged from 11.6 to 12.4 µ, which was much smaller than the extrusion check radius range of 13.7 to 16.5 µ observed for *S. goodei*.

An exponential model provided a good fit for SL versus total otolith radius with no discernible pattern in the residuals (r^2=0.933)(Fig. 3), whereas a linear model was used to regress SL on age (r^2=0.909)(Fig. 4). The slope of the linear regression indicated a growth rate of 0.135 mm·day^{-1} (Fig. 4). The model's estimate of size at age 0 was 5.1 mm, which closely approximates the observed sizes of pre-extrusion (5.0 to 5.8 mm NL) and recently extruded
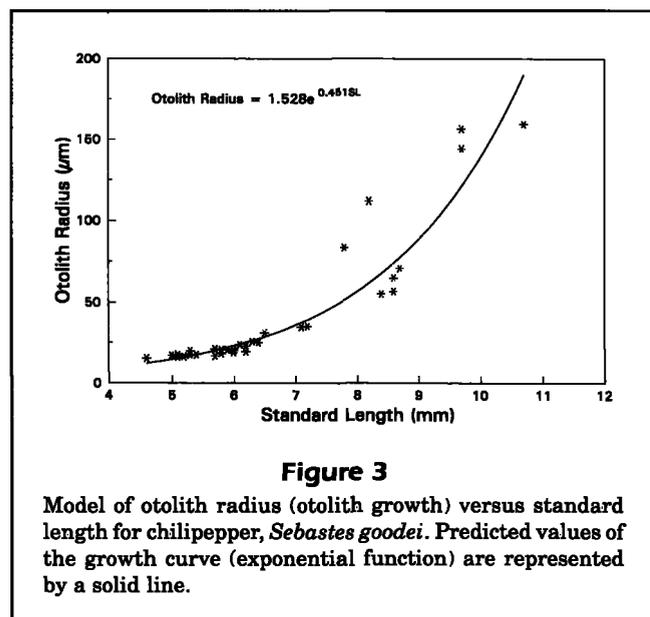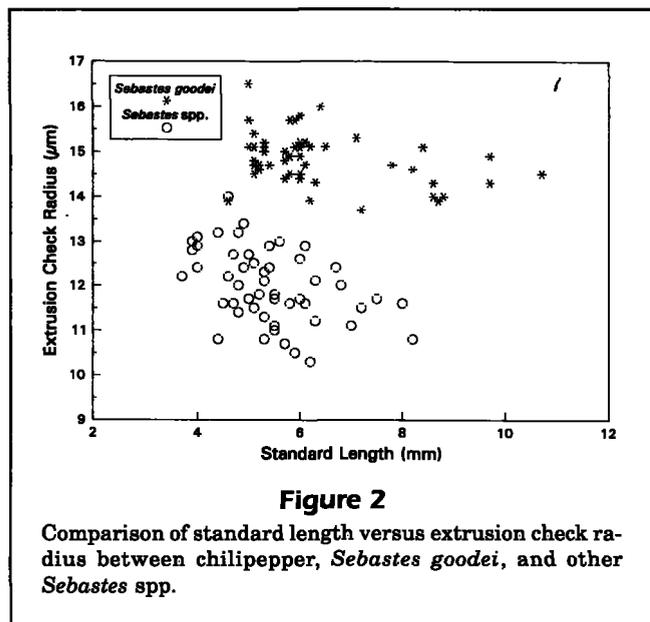
Table 4

Frequency of occurrence of supraocular spines in chili-pepper, *Sebastes goodei*.

Supraocular spine	Frequency of occurrence	Percent occurrence
Neither side	119	88.0
One side	14	10.4
Both sides	1	0.7

Table 5

Proportions of chilipepper, *Sebastes goodei*, with melanophores present at various pigment loci averaged over 2.0-mm size bins (range of +/– 1.0 mm). SL = standard length in mm. FLEX = flexion stage where "0" indicates preflexion, "1" indicates undergoing flexion, and "2" indicates that flexion is complete. n = number of specimens examined. Definitions of pigment loci are as follows: LJ = anterior tip of the lower jaw; EYE = posterioventral edge of the eye orbit; HEAD = cranial surface (including nape pigment); FACE = dorsal surface anterior to the eyes; OPER = operculum; CHK = radiating cheek bars; DORS = dorsal body surface; VENT = ventral body surface; MID = along the lateral midline; HYP = hypural region; DFIN = spinous dorsal fin; AFIN = anal fin; PEC = blade of the pectoral fin; PEL = pelvic fin; B1 = first (most anterior) body bar; B2 = second body bar; B3 = third body bar; B4 = fourth body bar; and B5 = fifth body bar (on peduncle).

SL	FLEX	n	LJ	EYE	HEAD	FACE	OPER	CHK	DORS	VENT	MID	HYP	DFIN	AFIN	PEC	PEL	B1	B2	B3	B4	B5
4	0	11	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1	54	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
8	2	21	0.0	0.0	1.0	0.4	0.0	0.0	0.4	1.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.0
10	2	16	0.0	0.0	1.0	0.9	0.0	0.0	0.6	1.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0
12	2	15	0.3	0.0	1.0	0.9	1.0	0.0	1.0	1.0	0.2	0.3	0.9	0.0	1.0	1.0	0.3	0.0	0.0	0.0	0.0
14	2	8	0.6	0.0	1.0	1.0	1.0	0.0	1.0	1.0	0.4	0.3	1.0	0.0	1.0	1.0	0.6	0.3	0.0	0.0	0.0
16	2	2	0.5	0.0	1.0	1.0	1.0	0.0	1.0	1.0	0.5	1.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
18	2	2	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	0.5	1.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
20	2	5	0.6	0.6	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
22	2	13	0.6	0.9	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
24	2	5	0.8	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
26	2	6	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.2
28	2	8	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.5	0.3	0.5
30	2	6	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.8	0.8	1.0	1.0	1.0	0.7	0.7
32	2	6	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.8	1.0	1.0	1.0	1.0	0.8	1.0
34	2	6	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.8	0.8	1.0	1.0	1.0	0.7	1.0
36	2	6	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.7	0.8	1.0	1.0	1.0	1.0	1.0
38	2	7	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.4	0.6	1.0	1.0	1.0	1.0	1.0
40	2	3	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
42	2	3	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
44	2	7	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
46	2	13	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
48	2	9	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
50	2	11	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
52	2	16	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.3	0.0	1.0	1.0	1.0	1.0	1.0
54	2	5	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.4	0.0	1.0	1.0	1.0	1.0	1.0
56	2	2	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.5	0.0	1.0	1.0	1.0	1.0	1.0
58	2	2	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.5	0.5	1.0	1.0	1.0	1.0	1.0

Figure 2

Comparison of standard length versus extrusion check radius between chilipepper, *Sebastes goodei*, and other *Sebastes* spp.

Otolith Radius $= 1.528e^{0.451SL}$

Figure 3

Model of otolith radius (otolith growth) versus standard length for chilipepper, *Sebastes goodei*. Predicted values of the growth curve (exponential function) are represented by a solid line.

(4.5 to 5.7 mm NL) larvae. In comparison to the other *Sebastes* spp., *S. goodei* was significantly larger at any given age (ANCOVA, df=1, 99, $P=0.0001$)(Fig. 4).

Discussion

The ability to identify larval and juvenile *S. goodei* can potentially lead to future studies on the spatial and temporal extent of spawning and the estimation of larval production biomass for this species based on larvae and juveniles collected in standard plankton studies (Moser and Butler, 1987; Ralston et al.[3]). Preflexion *S. goodei* larvae can be distinguished from other *Sebastes* spp. off central California by the presence of pigment on the cranium and nape (evident even in pre-extrusion larvae), and by the absence of pigment on the dorsal midline surface, the tip of the lower jaw, the caudal area, and the cleithral region (Fig. 1, A and B). In general, extrusion and pre-extrusion larvae of other *Sebastes* spp. that have been described in the literature either lack pigment on the cranium and the nape and/or possess pigment on at least one of the other areas described above (Morris, 1956; Moser et al., 1977; Moser and Ahlstrom, 1978; Moser and Butler, 1981, 1987; Stahl-Johnson, 1985; Kendall and Lenarz, 1987; Matarese et al., 1989; Wold, 1991; Moreno, 1993; Laroche[2]), Based on a cluster analysis by Wold (1991) and existing descriptions of early larvae (Westrheim, 1975; Moser et al., 1977; Stahl-Johnson, 1985; Moser and Butler, 1987; Matarese et al., 1989; Wold, 1991; Moreno, 1993; Laroche[2]), other *Sebastes* spp. commonly found in the study region with larval pigment patterns similar to *S. goodei* include *S. entomelas*, *S. flavidus*, *S. melanops*, *S. mystinus*, *S. pinniger*, *S. ruberrimus*, and members of the subgenus *Sebastomus*, which includes *S. chlorostictus*, *S. constellatus*, *S. helvomaculatus*, and *S. rosaceus*. Otolith analysis showed that other *Sebastes* spp. with similar pigmentation had otolith characters significantly different from those of *S. goodei* (Fig. 2; Table 6) indicating that *S. goodei* could be accurately identified solely on the basis of pigment patterns described in this study (Fig. 1, A and B). It should be noted that pigment on the cleithral region has not always been documented, because it may be partially obscured by the operculum in some specimens and, therefore, overlooked. To avoid identification problems, the operculum should be lifted to reveal the pigment on the cleithral region.

Juvenile *S. goodei* can be distinguished from other *Sebastes* spp. off central California by their distinctive barred pigment pattern (Fig. 1, G and H)(Matarese et al., 1989; Moreland and Reilly, 1991; Laroche[2]). The forward projecting pattern of the first three body bars readily distinguishes *S. goodei* from other barred *Sebastes* spp., such as *S. saxicola* and *S. caurinus*, in which the body bars do not project forward (Matarese et al., 1989; Laroche[2]). Meristic characters can also be used to distinguish *S. goodei* from these other barred *Sebastes* spp. because the modal anal-fin-ray count in *S. goodei* is 8, whereas the modal counts for *S. saxicola* and *S. caurinus* are 7 and 6 respectively (Chen, 1986; Matarese et al., 1989; Moreland and Reilly, 1991). Although the majority of *S. goodei* did not possess supraocular spines,

Figure 4

Comparison of age at length for chilipepper, *Sebastes goodei*, and other *Sebastes* spp. The solid line represents the predicted values of the growth curve (linear regression) for larval *Sebastes goodei* alone.

Table 6

Frequency of occurrence of the pre-extrusion optical pattern in chilipepper, *Sebastes goodei*, otoliths and its occurrence in the otoliths of other *Sebastes* spp. with similar larval pigment patterns.

Species	Optical pattern	Frequency of occurrence	Percent occurrence
S. goodei	Strong	38	76.0
	Weak	10	20.0
	Absent	2	4.0
Other *Sebastes* spp.	Strong	4	7.7
	Weak	14	26.9
	Absent	34	65.4

this characteristic is variable (Table 4). Such variability has been reported in other species, including *S. entomelas, S. flavidus, S. melanops,* and *S. mystinus* (Laroche and Richardson, 1981), and should be taken into account when using this characteristic in the identification process.

The identification of *S. goodei* larvae, initially based on pigment patterns, can be confirmed by using otolith characters, given the distinctive optical pattern and the relatively large extrusion check radius (Fig. 2; Table 6). The mean extrusion check radius of 14.84 μ (SD=0.577) in larvae from this study is similar to the mean extrusion check radius of 15.15 μ (SD=0.89) in pelagic juveniles reported by Laidig and Ralston (1995). Although the use of otoliths is more labor intensive than the use of pigment patterns or meristic characters, otoliths can provide relatively accurate identifications when pigment patterns and meristic characters yield dubious results or when pigment patterns and meristic characters are compromised (e.g. in identification of specimens from stomach contents). Studies have shown that otolith characters can be used to separate both species (Hecht and Appelbaum, 1982; Victor, 1987; Gago, 1993;) and stocks (Messieh, 1972; McKern et al., 1974; Rybock et al., 1975). Laidig and Ralston (1995) have found distinctive otolith characters in *S. auriculatus, S. flavidus, S. goodei, S. jordani, S. mystinus,* and *S. paucispinis.* Therefore, the use of otolith characters may be very useful in the identification of other species.

It appears that *S. goodei* grows slower during the larval stage (Fig. 4) than during the juvenile stage (Woodbury and Ralston, 1991). The growth rate of

0.135 mm·day^{-1} for larvae during the first 40 days in this study (Fig. 4) is relatively slow in comparison with the 0.399 to 0.555 mm·day^{-1} growth rates reported by Woodbury and Ralston (1991) for *S. goodei* juveniles 35 to 170 days old. Laidig et al. (1991) observed a similar trend of slow growth during the larval stage and accelerated growth during the juvenile stage in *S. jordani.* During the first 20 days of life, *S. jordani* had a growth rate of approximately 0.165 mm·day^{-1}, whereas at 35 to 165 days, the growth rate was 0.53 mm·day^{-1}. Laidig et al. (1991) also indicated that owing to notochord flexion, early larval growth in *S. jordani* was slightly sigmoidal rather than linear. Growth for *S. goodei* probably follows a similar pattern, but because of the small sample size in this study, such a pattern could not accurately be discerned.

Acknowledgments

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