SOUTHWEST FISHERIES SCIENCE CENTER

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JUNE 1995

PROGRESS IN ROCKFISH RECRUITMENT STUDIES

Edited by

Peter B. Adams

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Staff of the Tiburon Laboratory

Edited by Peter B. Adams

Southwest Fisheries Science Center
National Marine Fisheries Service
3150 Paradise Drive
Tiburon, California 94920

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INTRODUCTION

Rockfish (*Sebastes* spp.) make up a major portion of landings from the west coast groundfish fishery (37,363 mt in 1991 or 45% of total groundfish landings exclusive of Pacific whiting). In this fishery, variability in year-class strength is a major source of uncertainty in management. This is the eleventh annual report on studies conducted at the NMFS Tiburon Laboratory to measure this variation and to understand its source. This report covers the period from March 1994 to March 1995 and is the combined result of efforts from the Laboratory's three research Investigations: Groundfish Analysis, Groundfish Communities, and Groundfish Physiological Ecology. Research is summarized by life history stage: pelagic young-of-the-year (YOY) juvenile, benthic YOY juvenile, and adult. Objectives, methods, and previous results have been presented in earlier reports from this series (Lenarz and Moreland, 1985; Hobson et al., 1986; Larson, 1987; Whipple, 1988; Hobson, 1989; Ralston, 1990; Whipple, 1991; Adams, 1992; Ralston, 1993; Eldridge, 1994).

STUDIES OF PELAGIC JUVENILES

The juveniles of *Sebastes* spp. school in the coastal pelagic environment for their first several months following parturition, and during this period are sampled by midwater trawl and from gut contents of predators.

Progress in Midwater Trawl Assessments

Since 1983 the Groundfish Analysis Investigation has fielded annual sea surveys designed to estimate the relative abundance of pelagic YOY juvenile rockfish (Table 1). This series of cruises has been conducted aboard the National Oceanic and Atmospheric Administration (NOAA) research vessel *David Starr Jordan* between March and June, a time when pelagic stage YOY of most commercial species are sampled most readily. These surveys use a standard 26 x 26 m modified Cobb midwater trawl, with a codend liner of 1.27 cm stretched mesh. Spatially replicated "sweeps" of a series of standard stations are conducted in the study area between Pt. Reyes to the north and Cypress Pt. to the south (Fig. 1). As part of the survey design, the study area is subdivided into seven geographical strata (DN, SN, GF, DS, SS, MO, & MI), with 5-6 standard stations located within each stratum.

During the past year, one pelagic juvenile survey cruise was conducted (DSJ-9406). This cruise spanned a 35-day period during May-June and resulted in three consecutive sweeps through the study area. At each station, a 15-minute nighttime trawl sample was taken at standard depth (30 m where possible, 10 m at shallow stations) and a CTD cast was made. In addition, at some stations standard trawls were made at 10-, 30-, and 100-m depth to provide information concerning the vertical distribution of pelagic YOY rockfishes. Supplemental CTD data were also gathered during the day along tracklines that crisscrossed the entire study area.

Table 1. Summary of midwater trawl surveys conducted by the Groundfish Analysis Investigation for pelagic YOY rockfishes (*Sebastes* spp.) off the central California coast (1983-94).

Cruise	Sweep	Begin End	Number of Standard Hauls
DSJ-8301	1	08 June -- 24 June, 1983	21
DSJ-8401	1	12 June -- 27 June, 1984	25
DSJ-8505	1	05 June -- 30 June, 1985	30
DSJ-8608	1	03 June -- 11 June, 1986	34
	2	11 June -- 18 June,	28
	3	20 June -- 25 June,	28
DSJ-8703	1	10 April -- 22 April, 1987	35
DSJ-8705	1	23 May -- 01 June,	35
	2	02 June -- 12 June,	36
	3	12 June -- 21 June,	35
DSJ-8804	1	16 April -- 22 April, 1988	29
DSJ-8806	1	22 May -- 02 June,	35
	2	02 June -- 11 June,	37
	3	11 June -- 18 June,	33
DSJ-8904	1	14 May -- 24 May, 1989	33
	2	24 May -- 04 June,	34
	3	04 June -- 13 June,	33
DSJ-9003	1	28 March -- 06 April, 1990	38
DSJ-9005	1	13 May -- 22 May,	34
	2	22 May -- 01 June,	33
	3	01 June -- 10 June,	32
DSJ-9105	1	14 May -- 24 May, 1991	35
	2	24 May -- 03 June,	52
	3	03 June -- 10 June,	34
DSJ-9206	1	11 May -- 19 May, 1992	31
	2	19 May -- 31 May,	25
	3	02 June -- 17 June,	32
DSJ-9307	1	13 May -- 21 May, 1993	32
	2	21 May -- 01 June,	35
	3	03 June -- 13 June,	33
DSJ-9406	1	19 May -- 25 May, 1994	30
	2	26 May -- 05 June,	33
	3	11 June -- 22 June,	33

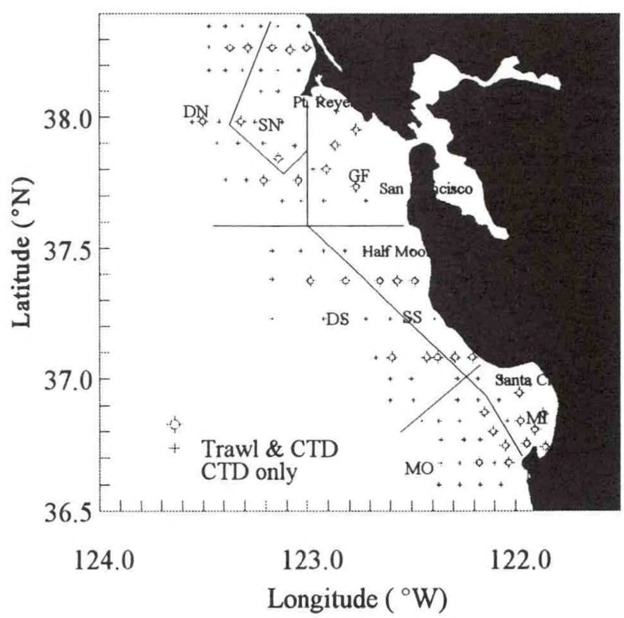

Figure 1. Map of the pelagic juvenile rockfish midwater trawl study area.

Following the cruise, the identity of rockfish specimens was confirmed in the laboratory (Table 2), standard lengths were measured, and a subsample of otoliths collected. As in previous years, the data were then compiled, edited, and added to the midwater trawl data base.

Descriptions of Larval and Pelagic Juvenile Rockfish

Developmental series of YOY *S. goodei* and *S. saxicola* collected off central California were recently described and illustrated by Laboratory staff (Figs. 2 and 3). Pigment patterns were described from pre-extrusion larvae through the pelagic juvenile stage. Whenever possible, meristic characters, including dorsal, anal, and pectoral fin ray counts and the number of gill rakers on the first gill arch were enumerated. Morphometric data and the development of head spines were also noted on selected specimens. Likewise, otolith characteristics (primarily the radius to the extrusion check) were recorded on selected larval *S. goodei* and *S. saxicola*. For comparison, otolith characteristics were noted on other species of *Sebastes* commonly found in

Table 2. Species composition of pelagic juvenile rockfish taken by midwater trawl during DSJ-9406 (includes nonstandard stations).

Scientific Name	N	Percentage
Sebastes jordani	1,919	85.251
caurinus-carnatus-chrysomelas complex	86	3.820
Unidentified YOY *Sebastes* juvenile	73	3.243
Sebastes entomelas	29	1.288
Sebastes auriculatus	24	1.066
Sebastes goodei	24	1.066
Sebastes zacentrus	17	0.755
Sebastes saxicolia	13	0.578
Sebastes mystinus	12	0.533
Sebastes paucispinis	12	0.533
Sebastes flavidus	8	0.355
Sebastes hopkinsi	5	0.222
Sebastes wilsoni	5	0.222
Sebastes maliger	4	0.178
Sebastes melanops	3	0.133
Sebastes pinniger	3	0.133
Sebastes rastrelliger	3	0.133
Sebastes semicinctus	3	0.133
Sebastomus subgenus	2	0.089
melanops-flavidus complex	2	0.089
Sebastes crameri	1	0.044
Sebastes diploproa	1	0.044
Sebastes proriger	1	0.044
Sebastes serranoides	1	0.044

the region that had pigment patterns similar to, but slightly different from, those of *S. goodei* and *S. saxicola*. Ages were obtained from *S. goodei* and *S. saxicola* otoliths.

Pigment patterns, meristic characters, and otolith characteristics readily distinguished *S. goodei* and *S. saxicola* from other *Sebastes* spp. In general, early larvae of *S. goodei* could be readily identified by their lack of pigment on the lower jaw, the cleithral region, and the caudal/hypural area, and the presence of pigment on the cranium and the outer blade of the pectoral fin (Figs. 2B-2D). Early larvae of *S. saxicola* were distinguished by their intense dorsal, lateral, and ventral midline pigment and the absence of pigment on all fins and the axillary

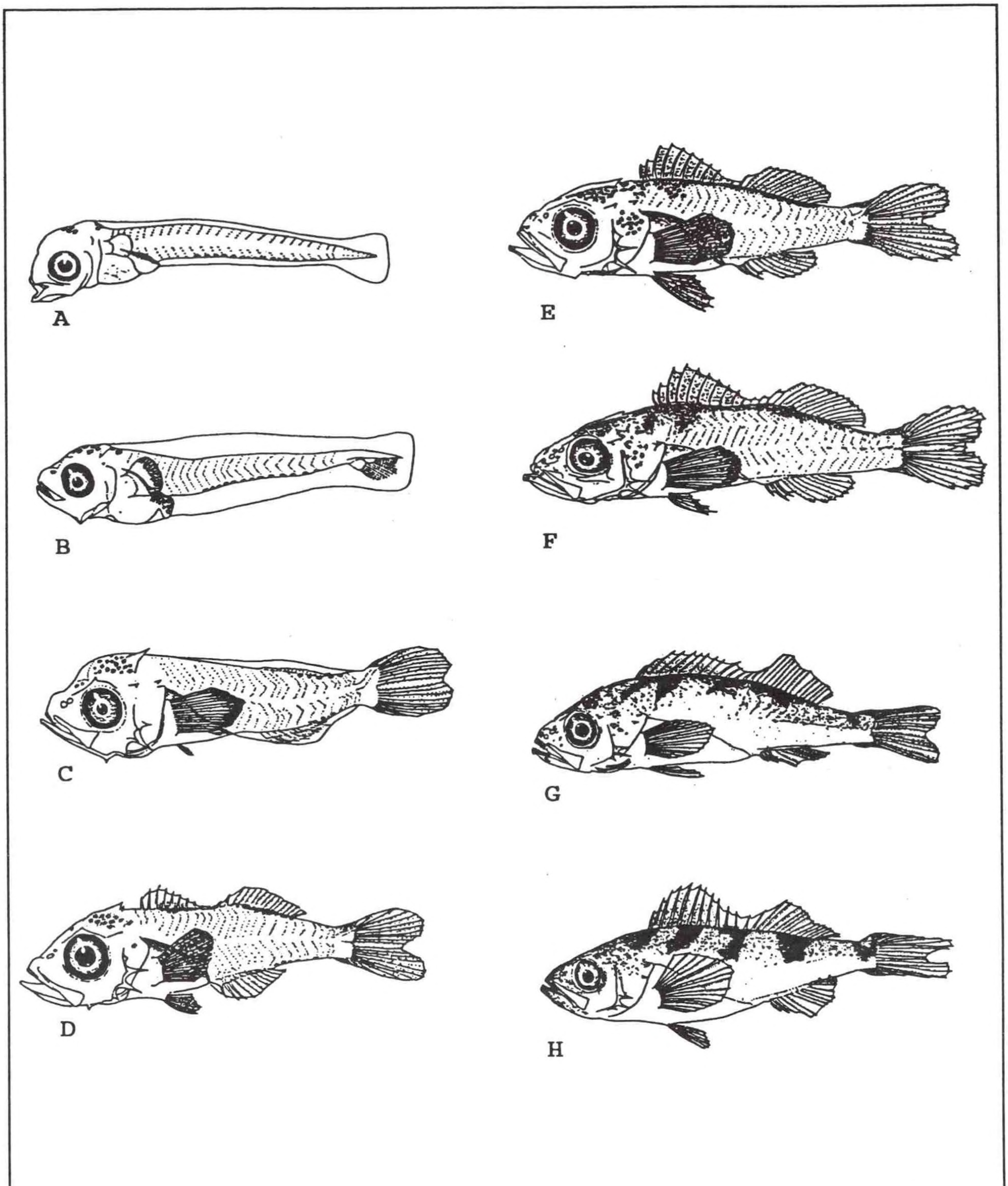

Figure 2. Developmental series of *Sebastes goodei*: (A) 5.5-mm pre-extrusion larvae; (B) 6.1-mm larvae; (C) 8.5-mm larvae; (D) 11.1-mm larvae; (E) 16.5-mm larvae; (F) 26.5-mm pelagic juvenile; (G) 35.9-mm pelagic juvenile; and (H) 55.5-mm pelagic juvenile. Illustrations by R. DeFelice, T. Laidig, and K. Sakuma.

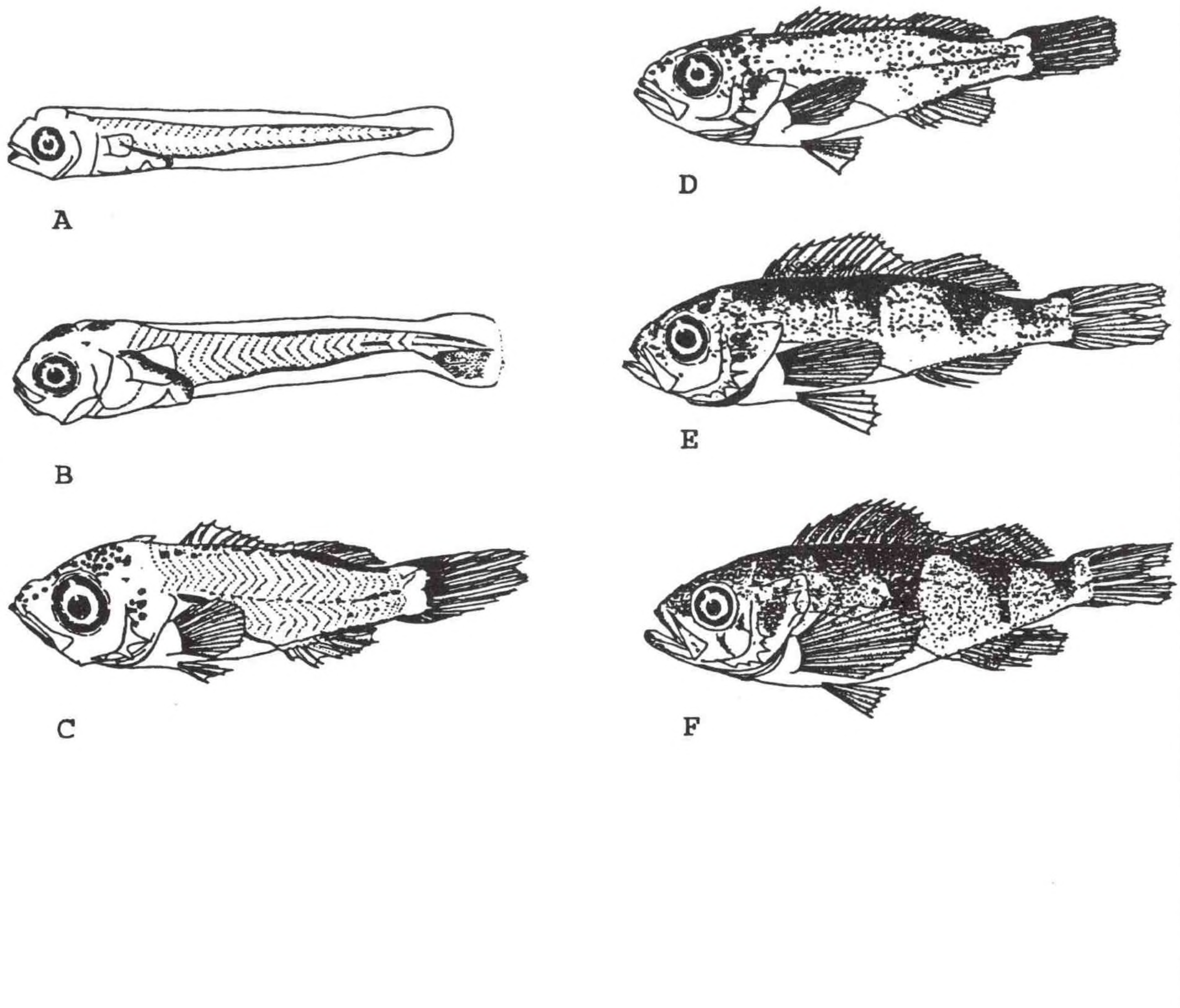

Figure 3. Developmental series of *Sebastes saxicola*: (A) 4.7-mm pre-extrusion larvae; (B) 6.0-mm larvae; (C) 9.9-mm larvae; (D) 17.8-mm larvae; (E) 25.9-mm pelagic juvenile; and (F) 38.2-mm pelagic juvenile. Illustrations by T. Laidig and K. Sakuma.

region (Figs. 3B and 3C). Juvenile *S. goodei* and *S. saxicola* were readily identified by their distinctive barred patterns (Figs. 2F-2H, 3E-3F). Otolith characteristics were useful in confirming identifications of larvae with incomplete meristic characters. Both *S. goodei* and *S. saxicola* had extrusion check radii that were largely distinctive from other *Sebastes* spp. (Figs. 4 and 5).

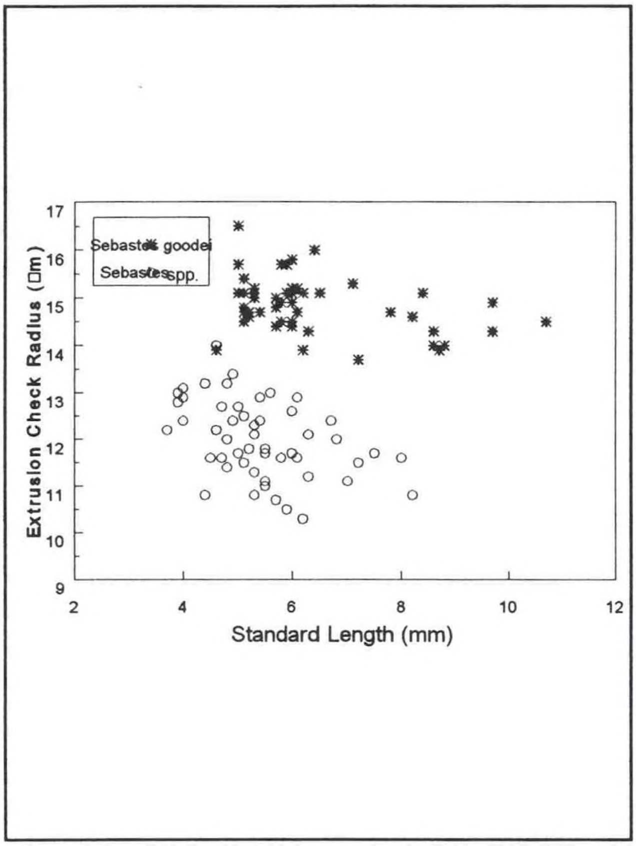

Figure 4. Comparison extrusion check radius between *Sebastes goodei* and other *Sebastes* spp.

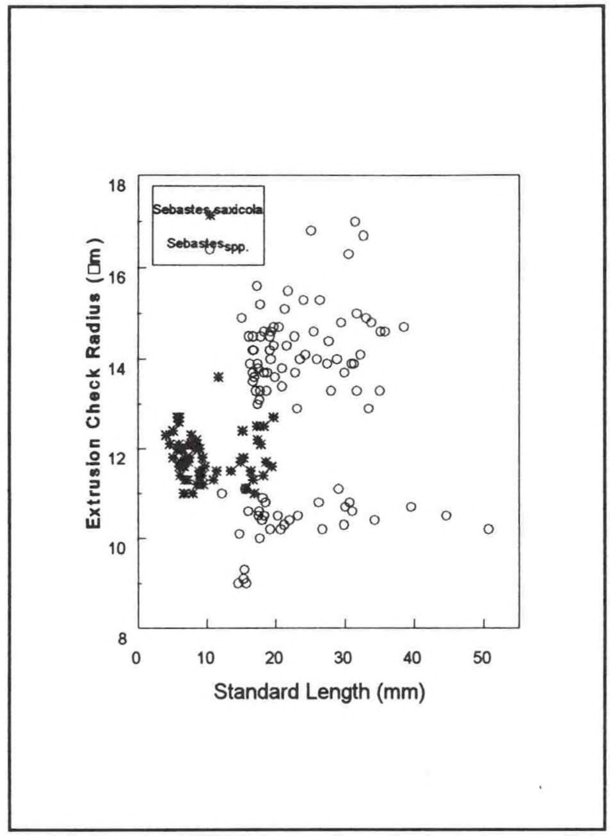

Figure 5. Comparison extrusion check radius between *Sebastes saxicola* and other *Sebastes* spp.

Larval growth rates of *S. goodei* and *S. saxicola* calculated from the otolith age data (Figs. 6 and 7) were slower than those previously reported for pelagic juveniles (Woodbury and Ralston, 1991). A similar trend of slow growth during the larval stage and accelerated growth during the juvenile stage was observed for *S. jordani* by Laidig et al. (1991). (K. Sakuma and T. Laidig)

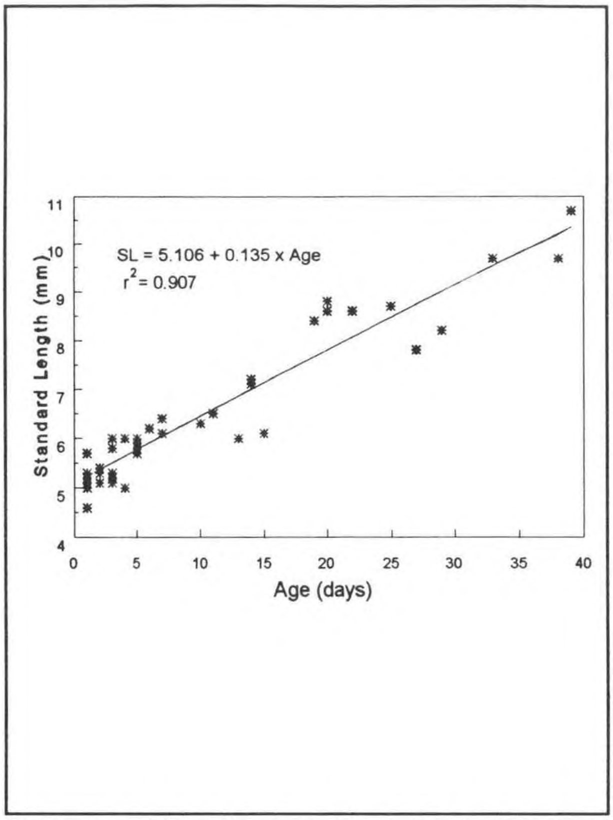

Figure 6. Growth curve for larval *Sebastes goodei*. The solid line represents the predicted values of the model (linear regression).

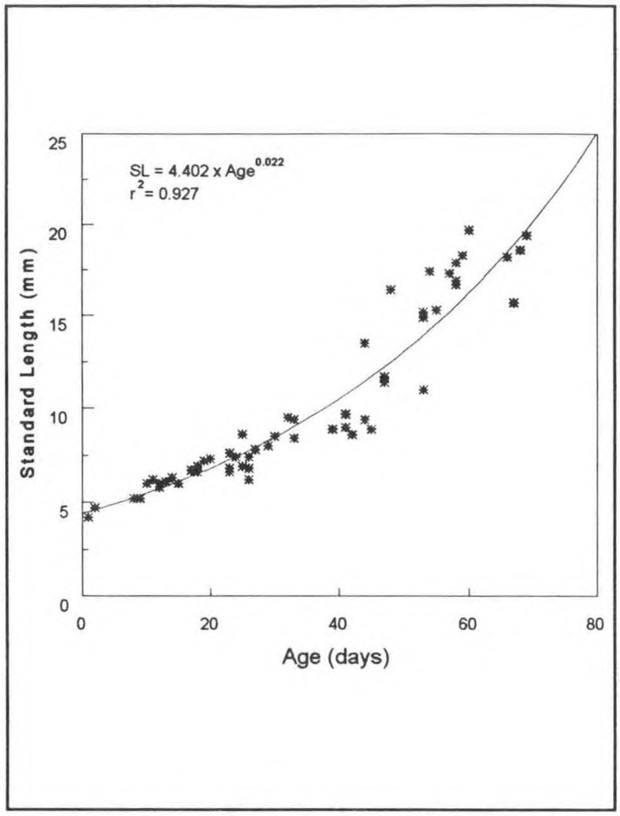

Figure 7. Growth curve for larval *Sebastes saxicola*. The solid line represents the predicted values of the model (power curve).

Estimation of Abundance

As described previously (Ralston, 1993), pelagic juvenile rockfish abundance indices are adjusted to account for among year differences in size structure (Fig. 8). After truncating the data to only include fish greater than or equal to 25 mm SL (the smallest size of fully vulnerable fish), additional adjustments were performed in a two-step process. First, fish ages were predicted from length measurements using inverse growth curves estimated for each of the 15 primary species of rockfish sampled during the 12-year period from 1983-94, amounting to 180 species-year combinations. Specifically, the predicted age of species "s" in year "y" at standard length "l" is $\hat{t}_{syl} = \alpha_{sy} + \beta_{sy} l$, where the α_{sy} and β_{sy} were estimated by least-squares regressions in the 48 situations where direct age data were available from counts of daily increments (e.g., Woodbury and Ralston, 1991). If otolith data were unavailable in a particular year, the growth parameters were estimated from analyses of covariance of the otolith data, assuming a common slope (days/mm) and either (1) the mean of interannual intercepts (within species) or, (2) the mean of within-year interspecific intercepts for those species where no otolith data were available at all.

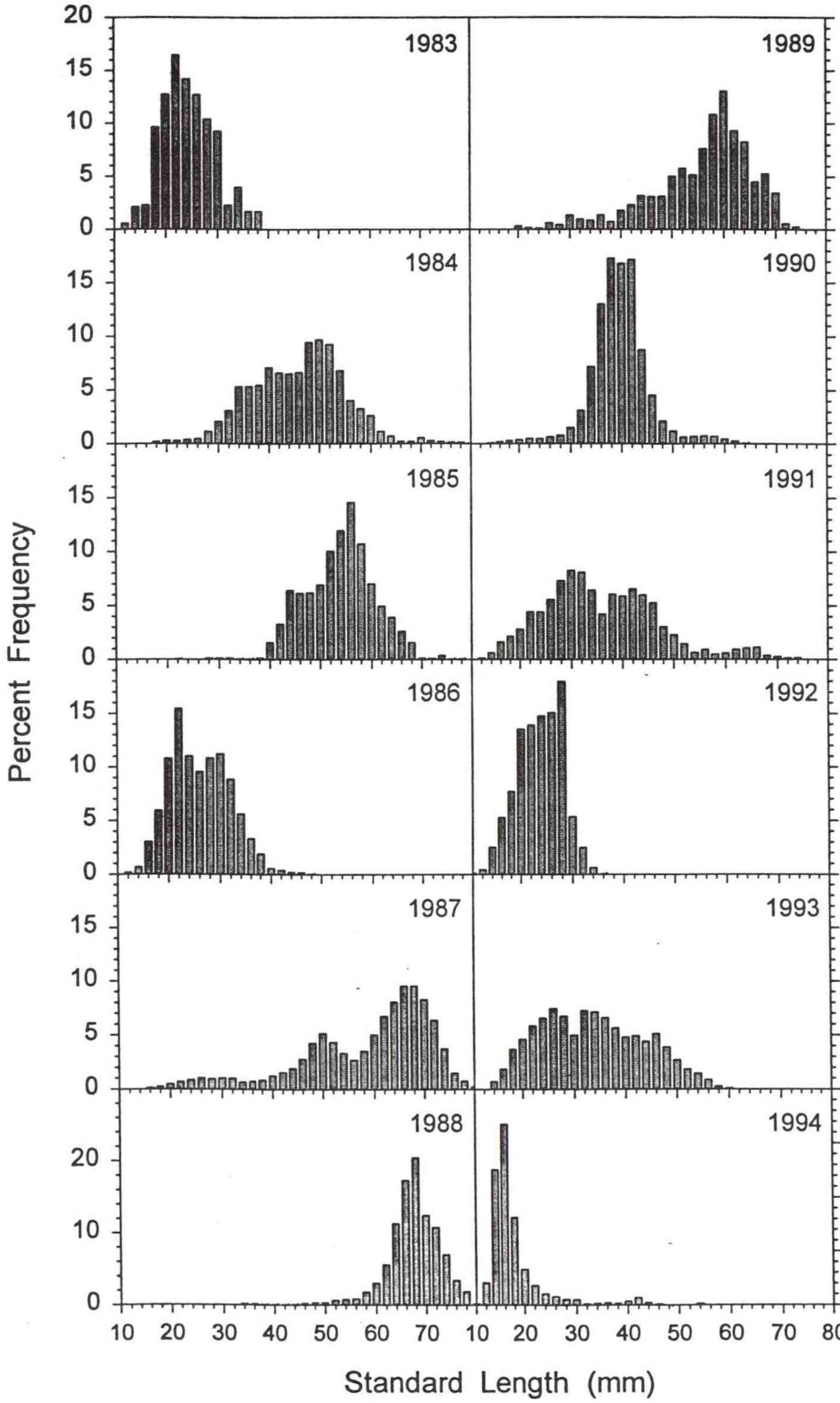

Figure 8. Length-frequency distributions of pelagic juvenile rockfish (1983-94). May-June samples and Table 3 species only.

For each haul conducted and each species sampled (subscripts not included), abundances of fish of different ages were then adjusted to a common age using an exponential model with a constant mortality rate (Z), i.e.,

$$N_l^* = N_l \exp[-Z(\tau^* - \hat{\tau}_{syl})]$$

where N_l^* is the adjusted number of individuals of length "l", N_l is the unadjusted number, and τ^* is the common age to which abundances were adjusted. In all calculations, τ^* was set equal to 100 days, which is representative of the midrange of pelagic juvenile rockfish ages (Woodbury and Ralston, 1991), and Z was fixed at 0.04 d^{-1} (see Eldridge, 1994). The N_l^* were then summed over all lengths that occurred within each haul, yielding a haul-specific catch of each rockfish species sampled, adjusted for variable length structure.

As in years past, final calculation of abundance statistics from our midwater trawl surveys is based upon simple logarithmic transformation of the data, i.e., $y_{jk} = \log_e[x_{jk} + 0.1]$, where x_{jk} is the length-adjusted catch taken in haul j = 1 to N_k located in stratum k = 1 to 7. We estimate the stratum means and variances according to

$$\bar{y}_k = \frac{1}{N_k} \sum_{j=1}^{N_k} y_{jk}$$

$$s_k^2 = \frac{1}{N_k - 1} \sum_{j=1}^{N_k} (y_{jk} - \bar{y}_k)^2 \quad .$$

The equally weighted stratified mean ($\bar{y}_{str}$) is then used as a sweep-specific index of abundance. This statistic and its squared standard error are defined as

$$\bar{y}_{str} = \frac{1}{7} \sum_{k=1}^{7} \bar{y}_k$$

$$s_{\bar{y}_{str}}^2 = \frac{1}{7} \sum_{k=1}^{7} \frac{s_k^2}{N_k} \quad .$$

We report all indices, their standard errors and 95% confidence intervals, and back-transformations of the indices in Table 3. Note that abundance statistics have been developed for each of the fifteen most commonly caught rockfish species taken during each sweep completed since 1983. Shown also are indices for the total catch of juvenile rockfish and indices for two sets of species that tend to fluctuate in synchrony, i.e., the *Sebastes entomelas* PCA group and the *S. jordani* PCA group (Hobson, 1989; Ralston, 1990). (S. Ralston)

Table 3. Annual sweep-specific indices of abundance for 15 of the most common species of YOY *Sebastes* collected. Species/sweep combinations wherein a species was not collected at sizes > 25 mm SL at any of the standard stations are not listed. Shown are the adjusted index (on $\log_e$ scale), its standard error (SE), a 95% confidence interval for the estimate, and a back-transformation of the index that has been corrected for first order bias.

				95% Confidence Bounds		Back
Cruise	Sweep	Index	SE	Lower	Upper	Transform
			Sebastes auriculatus (brown rockfish)			
8401	1	-1.41	0.20	-1.86	-0.96	0.15
8608	1	-0.83	0.19	-1.24	-0.41	0.35
8608	2	-1.37	0.23	-1.86	-0.88	0.16
8608	3	-2.00	0.13	-2.31	-1.69	0.04
8703	1	-2.08	0.12	-2.35	-1.81	0.03
8705	1	-2.19	0.08	-2.38	-2.01	0.01
8705	2	-2.23	0.07	-2.43	-2.03	0.01
8804	1	-1.93	0.13	-2.23	-1.62	0.05
8904	1	-2.21	0.06	-2.37	-2.05	0.01
9005	1	-2.08	0.11	-2.33	-1.84	0.03
9005	2	-2.21	0.07	-2.38	-2.04	0.01
9105	1	-1.89	0.11	-2.15	-1.63	0.05
9105	2	-1.53	0.19	-1.99	-1.07	0.12
9105	3	-1.45	0.28	-2.11	-0.80	0.14
9206	3	-2.24	0.07	-2.42	-2.05	0.01
9307	1	-1.87	0.11	-2.09	-1.64	0.06
9307	2	-0.79	0.30	-1.42	-0.15	0.38
9307	3	-0.74	0.24	-1.29	-0.19	0.39
9406	2	-2.16	0.07	-2.31	-2.01	0.02
9406	3	-2.14	0.09	-2.36	-1.93	0.02
			Sebastes crameri (darkblotched rockfish)			
8401	1	-2.09	0.15	-2.46	-1.72	0.03
8505	1	-2.20	0.11	-2.49	-1.90	0.01
8703	1	-2.16	0.10	-2.40	-1.91	0.02
8705	1	-2.10	0.13	-2.41	-1.80	0.02
8705	2	-2.25	0.06	-2.40	-2.09	0.01
8804	1	-1.91	0.12	-2.19	-1.62	0.05
8806	1	-2.11	0.14	-2.43	-1.79	0.02
8806	2	-2.23	0.07	-2.42	-2.04	0.01
9005	1	-2.25	0.05	-2.40	-2.10	0.01

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
9105	1	-2.23	0.07	-2.41	-2.05	0.01
9105	2	-2.07	0.13	-2.37	-1.76	0.03
9105	3	-2.24	0.06	-2.41	-2.08	0.01
9307	1	-2.03	0.11	-2.28	-1.79	0.03
9307	2	-2.23	0.07	-2.41	-2.05	0.01
		Sebastes entomelas (widow rockfish)				
8301	1	-2.20	0.11	-2.49	-1.91	0.01
8401	1	-0.44	0.60	-2.18	1.29	0.67
8505	1	1.71	0.58	0.22	3.19	6.43
8608	1	-1.92	0.17	-2.28	-1.55	0.05
8608	2	-2.13	0.12	-2.41	-1.86	0.02
8703	1	-1.92	0.15	-2.26	-1.58	0.05
8705	1	0.34	0.36	-0.41	1.09	1.40
8705	2	1.15	0.36	0.40	1.89	3.27
8705	3	-1.72	0.22	-2.21	-1.23	0.08
8804	1	-1.32	0.31	-2.28	-0.36	0.18
8806	1	-0.26	0.34	-0.97	0.45	0.72
8806	2	0.50	0.29	-0.11	1.11	1.62
8806	3	-1.77	0.21	-2.25	-1.29	0.07
8904	1	-2.22	0.08	-2.44	-2.01	0.01
8904	2	-1.49	0.24	-2.06	-0.92	0.13
8904	3	-2.14	0.12	-2.42	-1.85	0.02
9005	1	-1.81	0.24	-2.38	-1.24	0.07
9005	2	-1.75	0.19	-2.21	-1.30	0.08
9005	3	-2.11	0.11	-2.36	-1.86	0.02
9105	1	-2.20	0.07	-2.37	-2.03	0.01
9105	2	-1.25	0.26	-1.81	-0.70	0.20
9105	3	0.79	0.40	-0.05	1.64	2.29
9307	1	-1.57	0.17	-1.94	-1.21	0.11
9307	2	-0.85	0.30	-1.48	-0.23	0.35
9307	3	-1.43	0.29	-2.07	-0.78	0.15
9406	1	-1.84	0.15	-2.21	-1.47	0.06
9406	2	-2.07	0.13	-2.37	-1.76	0.03
9406	3	-2.23	0.08	-2.44	-2.02	0.01

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	Upper	Back Transform
			Sebastes flavidus (yellowtail rockfish)			
8301	1	-2.12	0.12	-2.46	-1.79	0.02
8401	1	-0.64	0.53	-2.04	0.76	0.50
8505	1	-0.11	0.34	-0.81	0.59	0.85
8608	1	-1.93	0.15	-2.28	-1.57	0.05
8608	2	-1.81	0.15	-2.16	-1.45	0.07
8608	3	-2.13	0.13	-2.53	-1.74	0.02
8705	1	-1.64	0.25	-2.16	-1.13	0.10
8705	2	-0.89	0.27	-1.46	-0.33	0.33
8705	3	-1.55	0.25	-2.08	-1.03	0.12
8804	1	-2.12	0.13	-2.43	-1.81	0.02
8806	1	-0.68	0.32	-1.35	-0.01	0.43
8806	2	-1.32	0.25	-1.85	-0.79	0.18
8904	1	-2.06	0.13	-2.38	-1.74	0.03
8904	2	-1.68	0.19	-2.09	-1.27	0.09
8904	3	-1.65	0.22	-2.13	-1.18	0.10
9005	1	-2.04	0.13	-2.32	-1.76	0.03
9005	2	-1.76	0.21	-2.46	-1.06	0.08
9005	3	-2.10	0.12	-2.37	-1.82	0.02
9105	1	-1.92	0.16	-2.27	-1.56	0.05
9105	2	-1.01	0.26	-1.56	-0.45	0.28
9105	3	0.18	0.32	-0.49	0.85	1.15
9206	3	-2.20	0.10	-2.48	-1.93	0.01
9307	1	-1.92	0.17	-2.27	-1.56	0.05
9307	2	-1.61	0.22	-2.08	-1.14	0.10
9307	3	-1.42	0.29	-2.08	-0.76	0.15
9406	1	-2.18	0.09	-2.41	-1.95	0.01
9406	2	-2.12	0.18	-2.91	-1.32	0.02
9406	3	-2.18	0.08	-2.38	-1.99	0.01
			Sebastes goodei (chilipepper)			
8401	1	-0.50	0.44	-1.63	0.63	0.57
8505	1	-1.80	0.13	-2.07	-1.52	0.07
8608	1	-1.76	0.14	-2.06	-1.46	0.07
8608	2	-1.93	0.15	-2.25	-1.61	0.05

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
8608	3	-2.11	0.10	-2.35	-1.88	0.02
8703	1	-0.49	0.30	-1.13	0.15	0.54
8705	1	1.02	0.35	0.29	1.75	2.84
8705	2	-0.35	0.38	-1.16	0.45	0.66
8705	3	-1.25	0.25	-1.82	-0.68	0.20
8804	1	2.65	0.41	1.75	3.55	15.26
8806	1	0.31	0.48	-0.69	1.31	1.43
8806	2	-1.48	0.33	-2.20	-0.76	0.14
8806	3	-1.91	0.28	-2.57	-1.25	0.05
8904	1	-1.30	0.31	-1.97	-0.62	0.19
8904	2	-2.17	0.09	-2.39	-1.95	0.01
9003	1	-2.04	0.12	-2.32	-1.76	0.03
9005	1	-1.55	0.25	-2.07	-1.02	0.12
9005	2	-1.80	0.19	-2.22	-1.39	0.07
9105	1	-2.14	0.10	-2.35	-1.92	0.02
9105	2	-1.57	0.21	-2.02	-1.13	0.11
9105	3	-0.92	0.27	-1.50	-0.34	0.31
9206	3	-1.85	0.14	-2.18	-1.52	0.06
9307	1	0.53	0.27	-0.03	1.10	1.67
9307	2	0.28	0.30	-0.35	0.91	1.29
9307	3	-1.32	0.30	-1.99	-0.65	0.18
9406	1	-2.26	0.04	-2.38	-2.14	0.00
9406	3	-2.24	0.06	-2.40	-2.09	0.01
			Sebastes hopkinsi (squarespot rockfish)			
8401	1	-1.19	0.42	-2.19	-0.20	0.23
8505	1	-1.01	0.31	-1.66	-0.37	0.28
8608	1	-2.19	0.08	-2.38	-2.00	0.01
8608	2	-2.24	0.06	-2.42	-2.06	0.01
8703	1	-2.04	0.13	-2.33	-1.76	0.03
8705	1	-0.12	0.25	-0.66	0.42	0.81
8705	2	-0.69	0.34	-1.40	0.02	0.43
8705	3	-2.23	0.08	-2.44	-2.02	0.01
8804	1	-0.42	0.37	-1.21	0.36	0.60
8806	1	-0.29	0.38	-1.08	0.51	0.71
8806	2	-0.85	0.25	-1.36	-0.34	0.34

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
8806	3	-2.22	0.08	-2.45	-1.98	0.01
8904	1	-1.93	0.18	-2.34	-1.53	0.05
8904	2	-2.15	0.11	-2.40	-1.89	0.02
8904	3	-2.06	0.10	-2.33	-1.80	0.03
9003	1	-2.27	0.03	-2.35	-2.19	0.00
9005	1	-1.86	0.25	-2.49	-1.23	0.06
9005	3	-2.22	0.08	-2.44	-2.00	0.01
9105	2	-2.18	0.09	-2.45	-1.91	0.01
9105	3	-1.39	0.18	-1.79	-1.00	0.15
9206	3	-1.79	0.17	-2.15	-1.43	0.07
9307	1	-1.85	0.13	-2.12	-1.57	0.06
9307	2	-1.82	0.13	-2.11	-1.54	0.06
9307	3	-2.24	0.04	-2.35	-2.13	0.01
9406	3	-2.27	0.04	-2.37	-2.17	0.00
		Sebastes jordani (shortbelly rockfish)				
8301	1	-1.64	0.36	-2.49	-0.79	0.11
8401	1	1.06	0.71	-0.78	2.90	3.61
8505	1	1.33	0.50	0.24	2.42	4.19
8608	1	-0.07	0.33	-0.77	0.63	0.89
8608	2	-0.35	0.33	-1.05	0.35	0.64
8608	3	-1.65	0.23	-2.17	-1.14	0.10
8703	1	-0.94	0.28	-1.53	-0.35	0.31
8705	1	2.14	0.42	1.25	3.03	9.17
8705	2	3.46	0.47	2.47	4.46	35.66
8705	3	0.14	0.40	-0.70	0.98	1.14
8804	1	2.30	0.52	0.94	3.65	11.29
8806	1	3.16	0.52	2.04	4.27	26.83
8806	2	2.29	0.42	1.39	3.18	10.64
8806	3	1.60	0.52	0.50	2.69	5.53
8904	1	1.61	0.33	0.93	2.29	5.19
8904	2	1.25	0.38	0.46	2.03	3.64
8904	3	-0.07	0.40	-0.91	0.77	0.91
9003	1	-1.91	0.15	-2.25	-1.57	0.05
9005	1	-0.16	0.40	-1.03	0.71	0.83
9005	2	-0.79	0.31	-1.43	-0.14	0.38

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes.*

				95% Confidence Bounds		
Cruise	Sweep	Index	SE	Lower	Upper	Back Transform
9005	3	-1.88	0.19	-2.31	-1.45	0.06
9105	1	-1.54	0.24	-2.05	-1.03	0.12
9105	2	-0.71	0.26	-1.26	-0.15	0.41
9105	3	1.55	0.34	0.84	2.25	4.87
9206	3	-0.71	0.35	-1.57	0.15	0.43
9307	1	0.22	0.23	-0.27	0.71	1.18
9307	2	0.58	0.37	-0.20	1.36	1.82
9307	3	-0.65	0.38	-1.64	0.34	0.46
9406	1	-1.85	0.18	-2.23	-1.46	0.06
9406	2	-1.92	0.23	-2.62	-1.22	0.05
9406	3	-2.12	0.09	-2.32	-1.92	0.02
			Sebastes levis (cowcod)			
8505	1	-2.11	0.14	-2.45	-1.76	0.02
8608	1	-2.26	0.04	-2.38	-2.15	0.00
8703	1	-2.11	0.14	-2.44	-1.78	0.02
8705	1	-1.79	0.18	-2.19	-1.39	0.07
8705	2	-2.21	0.09	-2.47	-1.95	0.01
8705	3	-2.05	0.12	-2.32	-1.78	0.03
8804	1	-1.53	0.23	-2.02	-1.03	0.12
8806	1	-2.22	0.09	-2.44	-1.99	0.01
8904	2	-2.21	0.10	-2.47	-1.94	0.01
9307	1	-2.21	0.06	-2.37	-2.04	0.01
9307	2	-2.14	0.11	-2.40	-1.89	0.02
			Sebastes melanops (black rockfish)			
8505	1	-1.75	0.26	-2.40	-1.09	0.08
8608	1	-2.26	0.05	-2.39	-2.12	0.00
8705	1	-1.96	0.14	-2.26	-1.65	0.04
8705	2	-1.67	0.20	-2.10	-1.23	0.09
8705	3	-2.18	0.09	-2.41	-1.94	0.01
8806	1	-2.08	0.12	-2.37	-1.80	0.03
8806	2	-1.72	0.20	-2.14	-1.30	0.08
8904	2	-2.07	0.12	-2.36	-1.78	0.03
8904	3	-2.16	0.14	-2.76	-1.57	0.02

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	Upper	Back Transform
9005	1	-2.20	0.07	-2.37	-2.04	0.01
9005	2	-2.16	0.11	-2.52	-1.79	0.02
9105	1	-2.21	0.09	-2.49	-1.93	0.01
9105	2	-2.17	0.09	-2.41	-1.92	0.02
9105	3	-1.45	0.23	-1.94	-0.96	0.14
9307	1	-2.22	0.05	-2.36	-2.08	0.01
9307	2	-2.23	0.05	-2.35	-2.11	0.01
9307	3	-2.13	0.14	-2.60	-1.66	0.02
9406	1	-2.16	0.10	-2.41	-1.92	0.02
			Sebastes mystinus (blue rockfish)			
8505	1	-0.21	0.31	-0.86	0.45	0.75
8608	1	-2.03	0.15	-2.37	-1.69	0.03
8703	1	-1.95	0.17	-2.34	-1.56	0.04
8705	1	0.82	0.38	0.03	1.60	2.33
8705	2	-0.02	0.42	-0.90	0.87	0.97
8804	1	0.12	0.34	-0.62	0.86	1.09
8806	1	1.08	0.35	0.35	1.80	3.03
8806	2	0.50	0.26	-0.05	1.05	1.60
8806	3	-2.13	0.12	-2.42	-1.84	0.02
8904	1	-1.11	0.31	-1.77	-0.44	0.25
8904	2	-0.81	0.31	-1.48	-0.13	0.37
8904	3	-1.89	0.20	-2.32	-1.45	0.05
9005	1	-1.31	0.28	-1.89	-0.73	0.18
9005	2	-1.51	0.27	-2.09	-0.94	0.13
9005	3	-2.25	0.05	-2.40	-2.10	0.01
9105	1	-1.99	0.19	-2.41	-1.56	0.04
9105	2	-0.85	0.25	-1.39	-0.31	0.34
9105	3	-0.38	0.35	-1.11	0.36	0.63
9206	3	-2.23	0.07	-2.43	-2.02	0.01
9307	1	-1.59	0.22	-2.05	-1.14	0.11
9307	2	-1.36	0.28	-1.96	-0.76	0.17
9406	1	-2.03	0.19	-2.50	-1.56	0.03
9406	2	-2.10	0.14	-2.42	-1.78	0.02
9406	3	-2.22	0.08	-2.43	-2.02	0.01

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

				95% Confidence Bounds		
Cruise	Sweep	Index	SE	Lower	Upper	Back Transform
			Sebastes paucispinis (bocaccio)			
8401	1	-0.38	0.45	-2.00	1.23	0.66
8505	1	-1.93	0.09	-2.14	-1.71	0.05
8608	1	-1.33	0.25	-1.89	-0.78	0.17
8608	2	-1.70	0.16	-2.04	-1.35	0.09
8608	3	-2.20	0.10	-2.49	-1.91	0.01
8703	1	-1.85	0.17	-2.26	-1.43	0.06
8705	1	-1.07	0.33	-1.76	-0.38	0.26
8705	2	-0.94	0.31	-1.59	-0.29	0.31
8705	3	-1.82	0.19	-2.23	-1.41	0.06
8804	1	-0.31	0.25	-0.84	0.22	0.65
8806	1	-0.73	0.31	-1.37	-0.09	0.41
8806	2	-1.44	0.30	-2.09	-0.79	0.15
8806	3	-2.12	0.19	-2.63	-1.60	0.02
8904	1	-1.71	0.22	-2.17	-1.24	0.09
8904	2	-1.80	0.22	-2.31	-1.30	0.07
9005	1	-1.53	0.24	-2.06	-1.01	0.12
9005	2	-2.06	0.17	-2.51	-1.62	0.03
9105	1	-1.85	0.14	-2.16	-1.54	0.06
9105	2	-1.58	0.20	-2.01	-1.15	0.11
9105	3	-1.15	0.29	-1.76	-0.53	0.23
9307	1	-1.74	0.18	-2.12	-1.35	0.08
9307	2	-1.97	0.17	-2.38	-1.56	0.04
9307	3	-2.24	0.06	-2.42	-2.06	0.01
9406	1	-2.17	0.13	-3.83	-0.51	0.01
			Sebastes pinniger (canary rockfish)			
8401	1	-0.68	0.50	-2.05	0.70	0.47
8505	1	-1.86	0.14	-2.20	-1.51	0.06
8608	1	-1.52	0.13	-1.82	-1.22	0.12
8608	2	-2.04	0.12	-2.32	-1.77	0.03
8608	3	-2.23	0.07	-2.54	-1.93	0.01
8703	1	-1.95	0.16	-2.29	-1.61	0.04
8705	1	-1.81	0.15	-2.14	-1.49	0.07
8705	2	-1.37	0.16	-1.72	-1.02	0.16

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	Upper	Back Transform
8705	3	-1.88	0.17	-2.26	-1.51	0.05
8804	1	-1.95	0.15	-2.31	-1.59	0.04
8806	1	-0.13	0.27	-0.69	0.44	0.81
8806	2	-1.44	0.22	-1.93	-0.95	0.14
8806	3	-2.10	0.13	-2.45	-1.75	0.02
8904	1	-1.78	0.16	-2.18	-1.39	0.07
8904	2	-1.66	0.15	-1.99	-1.33	0.09
8904	3	-2.09	0.08	-2.28	-1.89	0.02
9005	1	-2.13	0.11	-2.44	-1.81	0.02
9005	2	-2.14	0.11	-2.44	-1.84	0.02
9005	3	-2.23	0.07	-2.53	-1.93	0.01
9105	1	-1.72	0.15	-2.03	-1.42	0.08
9105	2	-0.52	0.26	-1.07	0.02	0.51
9105	3	0.20	0.26	-0.34	0.75	1.17
9307	1	-2.17	0.08	-2.34	-2.00	0.01
9307	2	-2.17	0.07	-2.34	-2.01	0.01
9307	3	-2.26	0.04	-2.38	-2.14	0.00
9406	1	-2.22	0.06	-2.36	-2.08	0.01
			Sebastes rufus (bank rockfish)			
8705	1	-1.77	0.19	-2.18	-1.37	0.07
8705	2	-1.89	0.18	-2.27	-1.50	0.05
8705	3	-2.23	0.07	-2.41	-2.06	0.01
8804	1	-1.62	0.28	-2.30	-0.93	0.11
8806	2	-2.12	0.11	-2.41	-1.83	0.02
9307	2	-1.94	0.14	-2.26	-1.62	0.05
			Sebastes saxicola (stripetail rockfish)			
8401	1	-1.48	0.31	-2.34	-0.61	0.14
8505	1	-1.80	0.17	-2.18	-1.42	0.07
8608	1	-2.25	0.06	-2.40	-2.09	0.01
8703	1	-1.44	0.17	-1.79	-1.09	0.14
8705	1	-0.47	0.24	-0.97	0.03	0.54
8705	2	-1.76	0.16	-2.09	-1.43	0.07
8705	3	-2.24	0.06	-2.40	-2.08	0.01

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
8804	1	-0.07	0.27	-0.66	0.53	0.87
8806	1	-1.12	0.25	-1.64	-0.59	0.24
8806	2	-1.95	0.13	-2.23	-1.68	0.04
8904	1	-1.99	0.13	-2.28	-1.70	0.04
9003	1	-2.26	0.04	-2.37	-2.15	0.00
9005	1	-1.81	0.18	-2.20	-1.42	0.07
9005	2	-2.25	0.05	-2.40	-2.11	0.01
9105	1	-2.07	0.09	-2.27	-1.86	0.03
9105	2	-1.21	0.21	-1.66	-0.77	0.20
9105	3	-1.43	0.20	-1.86	-1.01	0.14
9206	3	-2.25	0.06	-2.40	-2.09	0.01
9307	1	-1.03	0.22	-1.50	-0.57	0.26
9307	2	-0.51	0.28	-1.10	0.07	0.52
9406	1	-2.04	0.11	-2.28	-1.80	0.03
9406	2	-2.17	0.08	-2.36	-1.98	0.01
			Sebastes wilsoni (pygmy rockfish)			
8401	1	-2.09	0.16	-3.03	-1.15	0.02
8505	1	-2.23	0.07	-2.43	-2.03	0.01
8608	1	-2.26	0.04	-2.38	-2.14	0.00
8703	1	-1.84	0.14	-2.16	-1.52	0.06
8705	1	-2.17	0.10	-2.40	-1.93	0.02
8705	2	-2.09	0.13	-2.37	-1.81	0.02
8804	1	-0.42	0.35	-1.51	0.66	0.60
8806	1	-1.97	0.14	-2.27	-1.67	0.04
8806	2	-2.25	0.05	-2.38	-2.12	0.01
8806	3	-2.24	0.06	-2.41	-2.08	0.01
8904	1	-2.04	0.12	-2.33	-1.76	0.03
8904	2	-2.25	0.05	-2.40	-2.11	0.01
8904	3	-2.19	0.08	-2.39	-1.99	0.01
9005	1	-2.02	0.10	-2.23	-1.82	0.03
9005	2	-2.26	0.04	-2.37	-2.14	0.00
9105	1	-2.14	0.10	-2.37	-1.92	0.02
9105	2	-1.75	0.16	-2.08	-1.41	0.08
9105	3	-1.85	0.13	-2.12	-1.58	0.06
9307	1	-2.22	0.06	-2.35	-2.09	0.01

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	Upper	Back Transform
9406	1	-2.26	0.04	-2.38	-2.15	0.00
9406	2	-2.24	0.05	-2.34	-2.13	0.01
		PCA "*entomelas*" Group				
8301	1	-2.11	0.13	-2.48	-1.74	0.02
8401	1	0.33	0.68	-1.50	2.16	1.66
8505	1	2.31	0.57	0.92	3.70	11.79
8608	1	-1.46	0.25	-1.98	-0.95	0.14
8608	2	-1.62	0.18	-2.03	-1.22	0.10
8608	3	-2.13	0.13	-2.53	-1.74	0.02
8703	1	-1.64	0.22	-2.11	-1.17	0.10
8705	1	2.22	0.29	1.60	2.84	9.47
8705	2	2.12	0.35	1.38	2.87	8.80
8705	3	-1.10	0.28	-1.70	-0.50	0.25
8804	1	1.05	0.41	0.17	1.93	3.01
8806	1	2.16	0.35	1.44	2.88	9.13
8806	2	1.56	0.33	0.86	2.25	4.91
8806	3	-1.57	0.25	-2.11	-1.04	0.11
8904	1	-0.75	0.32	-1.43	-0.07	0.40
8904	2	-0.08	0.32	-0.79	0.64	0.87
8904	3	-1.03	0.29	-1.65	-0.42	0.27
9003	1	-2.27	0.03	-2.35	-2.19	0.00
9005	1	-0.95	0.33	-1.66	-0.24	0.31
9005	2	-0.87	0.31	-1.58	-0.17	0.34
9005	3	-1.76	0.16	-2.12	-1.41	0.07
9105	1	-1.69	0.23	-2.19	-1.20	0.09
9105	2	0.05	0.34	-0.66	0.76	1.02
9105	3	1.68	0.34	0.97	2.40	5.60
9206	3	-1.72	0.18	-2.11	-1.34	0.08
9307	1	-0.75	0.22	-1.21	-0.28	0.39
9307	2	0.26	0.30	-0.37	0.89	1.26
9307	3	-1.07	0.34	-1.83	-0.30	0.27
9406	1	-1.61	0.22	-2.10	-1.12	0.10
9406	2	-1.83	0.25	-2.45	-1.22	0.06
9406	3	-1.99	0.12	-2.27	-1.72	0.04

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
			PCA "*jordani*" Group			
8301	1	-1.64	0.36	-2.49	-0.79	0.11
8401	1	2.03	0.70	-0.08	4.14	9.56
8505	1	1.45	0.49	0.36	2.53	4.70
8608	1	0.71	0.29	0.08	1.33	2.01
8608	2	0.04	0.34	-0.69	0.77	1.00
8608	3	-1.41	0.26	-1.98	-0.85	0.15
8703	1	0.29	0.31	-0.35	0.94	1.31
8705	1	3.47	0.28	2.87	4.07	33.28
8705	2	3.93	0.39	3.10	4.75	54.64
8705	3	0.66	0.39	-0.16	1.47	1.98
8804	1	3.67	0.42	2.50	4.83	42.55
8806	1	3.80	0.44	2.85	4.75	49.12
8806	2	2.58	0.41	1.73	3.43	14.24
8806	3	1.67	0.52	0.57	2.78	6.01
8904	1	1.96	0.32	1.29	2.64	7.39
8904	2	1.30	0.38	0.52	2.09	3.85
8904	3	0.10	0.39	-0.73	0.93	1.09
9003	1	-1.74	0.18	-2.14	-1.34	0.08
9005	1	0.60	0.35	-0.18	1.39	1.84
9005	2	-0.55	0.34	-1.25	0.16	0.51
9005	3	-1.81	0.20	-2.26	-1.37	0.07
9105	1	-0.73	0.25	-1.25	-0.22	0.40
9105	2	0.92	0.26	0.38	1.47	2.51
9105	3	2.20	0.30	1.57	2.83	9.36
9206	3	-0.54	0.36	-1.40	0.32	0.52
9307	1	1.37	0.21	0.92	1.82	3.94
9307	2	2.01	0.35	1.28	2.74	7.83
9307	3	0.44	0.40	-0.57	1.44	1.57
9406	1	-1.50	0.25	-2.05	-0.94	0.13
9406	2	-1.69	0.24	-2.37	-1.01	0.09
9406	3	-1.95	0.13	-2.24	-1.67	0.04

Table 3 (cont.). Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of *Sebastes*.

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
			Total *Sebastes* spp.			
8301	1	-1.57	0.36	-2.42	-0.71	0.12
8401	1	2.40	0.74	0.12	4.69	14.45
8505	1	3.06	0.57	1.75	4.37	24.88
8608	1	0.88	0.29	0.26	1.50	2.41
8608	2	0.26	0.33	-0.43	0.95	1.27
8608	3	-1.30	0.29	-1.92	-0.68	0.18
8703	1	0.57	0.29	-0.04	1.17	1.74
8705	1	3.93	0.26	3.35	4.51	52.70
8705	2	4.25	0.39	3.42	5.08	75.80
8705	3	1.07	0.38	0.27	1.87	3.04
8804	1	3.88	0.40	2.82	4.95	52.68
8806	1	4.29	0.38	3.48	5.11	78.63
8806	2	3.34	0.34	2.63	4.05	29.88
8806	3	1.91	0.50	0.86	2.97	7.59
8904	1	2.16	0.32	1.49	2.83	9.01
8904	2	1.87	0.34	1.16	2.59	6.79
8904	3	0.45	0.41	-0.43	1.33	1.61
9003	1	-1.73	0.18	-2.13	-1.32	0.08
9005	1	0.91	0.33	0.18	1.65	2.53
9005	2	0.06	0.35	-0.67	0.78	1.02
9005	3	-1.35	0.23	-1.85	-0.85	0.17
9105	1	-0.35	0.28	-0.94	0.24	0.63
9105	2	1.45	0.30	0.83	2.08	4.37
9105	3	2.98	0.29	2.37	3.58	20.36
9206	3	-0.48	0.36	-1.35	0.38	0.56
9307	1	1.59	0.21	1.14	2.05	4.93
9307	2	2.34	0.31	1.69	2.99	10.82
9307	3	0.69	0.44	-0.36	1.75	2.11
9406	1	-1.01	0.30	-1.66	-0.37	0.28
9406	2	-1.40	0.30	-2.15	-0.66	0.16
9406	3	-1.69	0.17	-2.04	-1.34	0.09

Annual Trends in the Abundance of Pelagic Juveniles

As in past years, the maximum value of the stratified mean index, taken from sweeps conducted during the May-June cruise, was used as an annual estimate of the relative abundance of pelagic juvenile rockfish. Results show that abundances of the 15 most commonly sampled *Sebastes* spp. were very low in 1994 (Fig. 9). Catch rates and size structure during DSJ-9406 were generally quite similar to the 1992 El Niño year. As has been the case since the inception of these surveys, catches of *S. jordani* greatly outnumbered those of other species (Table 2).

To better compare and contrast the annual abundance indices (I_{sy}) of the various species (s) in each year (y), the long-term (12 yr) means (μ_s) and standard deviations (σ_s) were calculated. From these, species-specific standard scores were derived for each year from 1983 to 1994 according to: $Z_{sy} = (I_{sy}-\mu_s)/\sigma_s$. Standard scores were calculated for the ten most abundant species occurring in our trawl samples (i.e., *S. jordani*, *S. entomelas*, *S. goodei*, *S. flavidus*, *S. mystinus*, *S. melanops*, *S. paucispinis*, *S. pinniger*, *S. hopkinsi*, and *S. saxicola*). Of the five species excluded, one (*S. auriculatus*) correlates poorly with the trends of other species (see Fig. 9) and four are uncommon (*S. wilsoni*, *S. levis*, *S. rufus*, and *S. crameri*). Results are plotted against survey year in Figure 10.

Note that for this primary subset of ten species, El Niño years (1983, 1992, and to some degree 1986) result in very much reduced levels of abundance. Conversely, 1987 and 1988 were very strong years for virtually all of these species. Data from 1991 suggest high levels of abundance, although they were especially high for northerly distributed species such as *S. entomelas*, *S. flavidus*, *S. melanops*, and *S. pinniger* (Fig. 9). Data collected during this most recent year (DSJ-9406) indicate extremely poor catches, with all ten species well below their long-term means.

There is extensive covariation in pelagic juvenile abundance patterns among the ten species of rockfish plotted in the figure, particularly after 1986 when multiple sweeps were conducted each year. For example, of the 45 possible pairwise combinations among the species, the correlation coefficients between recruitment time series are positive in all cases ($\hat{\rho}$ = 0.36-0.94). Likewise, principal components analysis of these data (species as variables, years as cases) revealed that the first component accounted for 71% of the variation among the ten species-specific time series and the second component accounted for an additional 11%. When annual scores on the first two principal components are plotted (Fig. 11), the strength of the 1987, 1988, and 1991 year-classes is revealed, as is the weakness of year-classes associated with El Niño conditions (1983, 1986, and 1992). The fall, winter, and spring of 1993-1994 had significant El Niño conditions, and levels of pelagic juvenile rockfish abundance were extremely low.

The separation of overall rockfish reproductive success along the first principal component axis illustrates the strong positive covariation among these ten *Sebastes* spp. In particular, first principal component weights (i.e., eigenvector values) for the ten species only

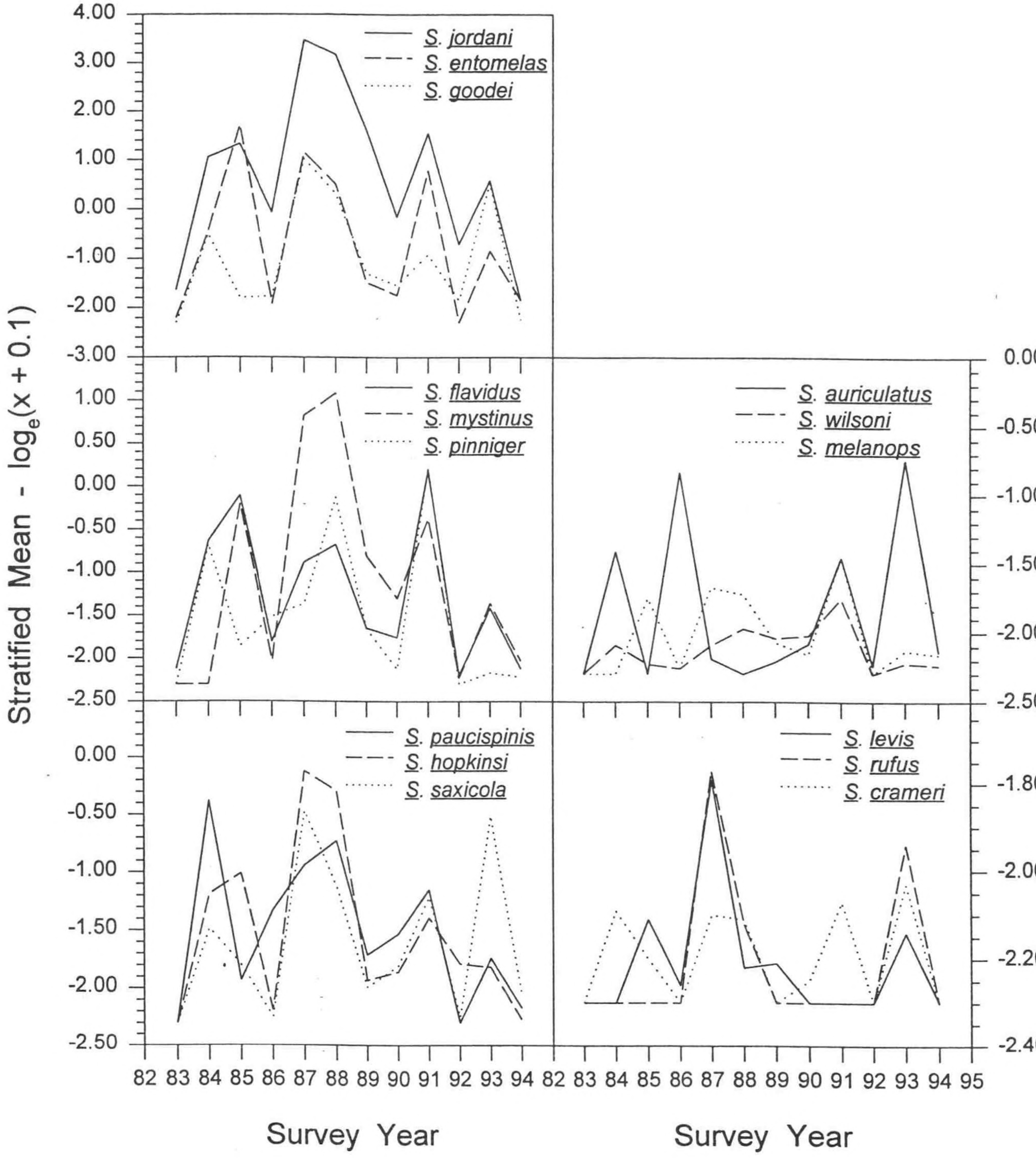

Figure 9. Annual (1983-94) estimates of pelagic juvenile relative abundance for species of *Sebastes* taken by midwater trawl.

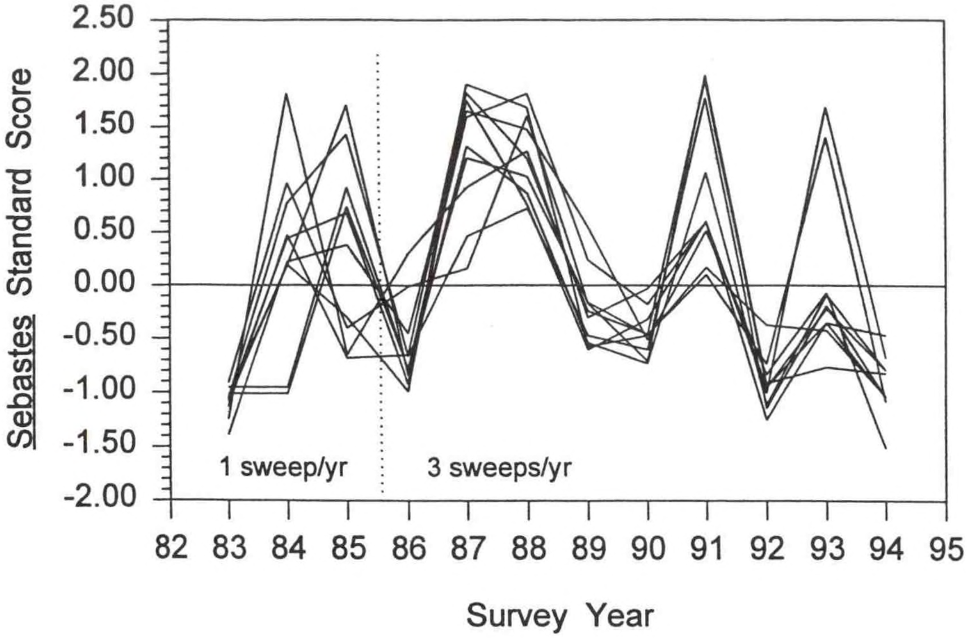

Figure 10. Normalized relative abundance trends for each of the ten most commonly caught species of pelagic juvenile rockfish.

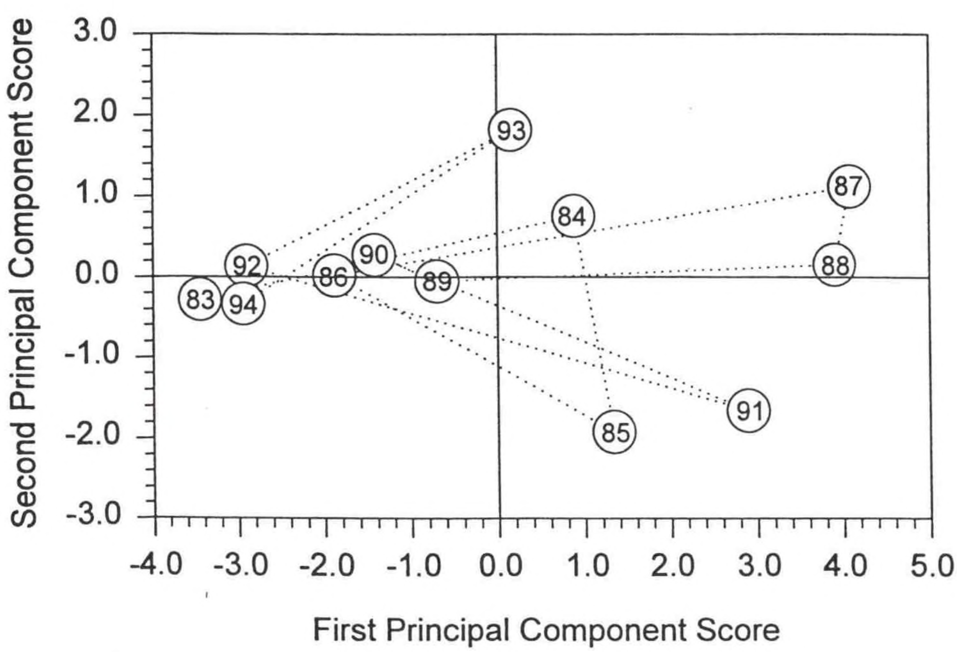

Figure 11. Yearly scores of pelagic YOY abundance plotted on the first two principal components.

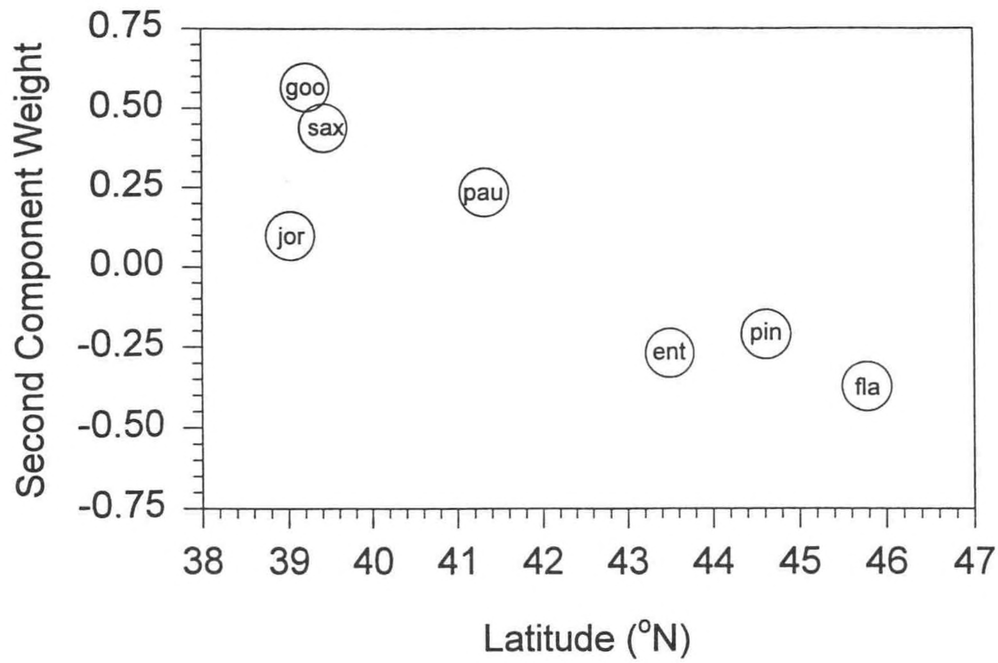

Figure 12. Interspecific differences in the second component eigenvector weight in relationship to geographic distribution.

ranged from +0.28 (*S. paucicpinis*) to +0.35 (*S. jordani*). In contrast, there are clear differences in annual species abundance patterns along the second principal component axis. For this axis, eigenvector values ranged from -0.39 (*S. melanops*) to +0.57 (*S. goodei*). Species-specific patterns along this axis are apparently linked to geographic distributions (Fig. 12). In this figure, the second component eigenvector multiplier (i.e., species weight) is plotted against an average measure of latitudinal distribution. This latter figure is calculated as the mean latitude of catch-weighted trawl landings from samples taken during the Alaska Fisheries Science Center's triennial surveys. These results indicate that the 1985 and 1991 year-classes are distinct along the second component axis (Fig. 11) due to strong representation of northerly distributed species in the those years (e.g., *S. pinniger, S. melanops*, and *S. flavidus*). Conversely, 1993 was characterized by the relative dominance of southerly distributed species, including especially *S. goodei* and *S. saxicola*. (S. Ralston)

Seasonality of Chilipepper Rockfish Parturition

Back-calculated birthdate distributions of YOY rockfish, which survive to the pelagic juvenile stage, indicate substantial interannual differences in location, with distributions centered from January to April (Fig. 13). To determine if this shifting is due to variability in the time of spawning, a study of parturition in chilipepper rockfish (*S. goodei*) was initiated. This species was selected due to its major commercial importance. During the 1990-92 parturition seasons (November-April), ovaries from adult female fish were collected at several northern and central California commercial ports and the gonads were examined for maturity state. Ovaries were classified into one of six stages that ranged from early vitellogenesis to spent condition.

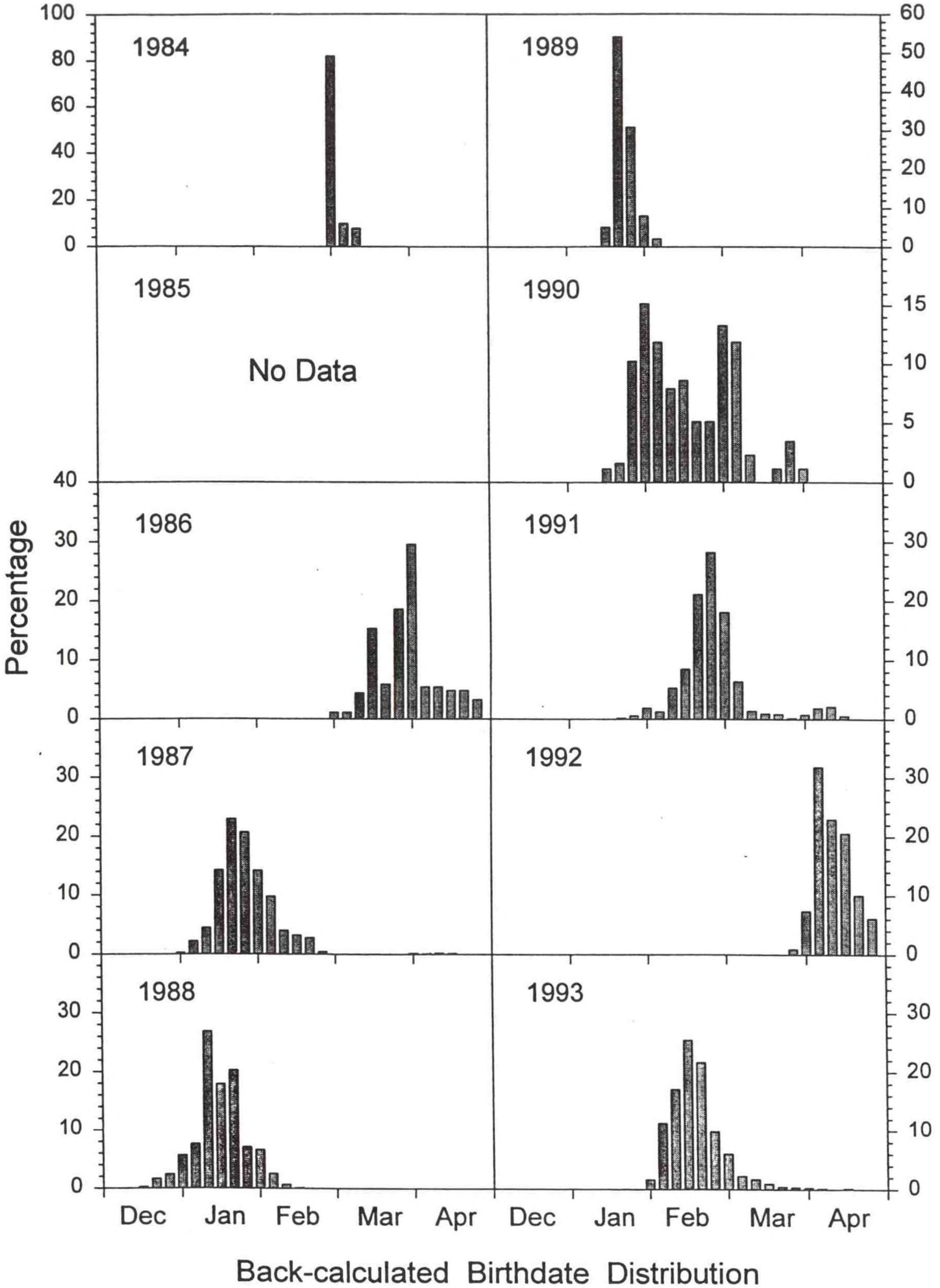

Figure 13. Back-calculated birthdate distributions of YOY pelagic juvenile chilipepper rockfish (1984-93).

A plot of percent frequency of spent gonads against the month of collection (Fig. 14) reveals relatively synchronous timing of parturition in comparison with the back-calculated birthdate distributions of YOY pelagic juveniles collected in the same three years (Fig 13). Parturition in 1990 appeared to be slightly earlier than in the other two years, although a similar percent of population released their young from January-March each year.

In summary, interannual differences in the time of spawning exist that are on the order of a week or two, whereas several month differences occur in the means of back-calculated birthdate distributions of surviving YOY pelagic juveniles. These findings indicate that the observed differences in back-calculated birthdates are likely due to interannual variability in seasonal survival rates of larval rockfish. (D. Woodbury)

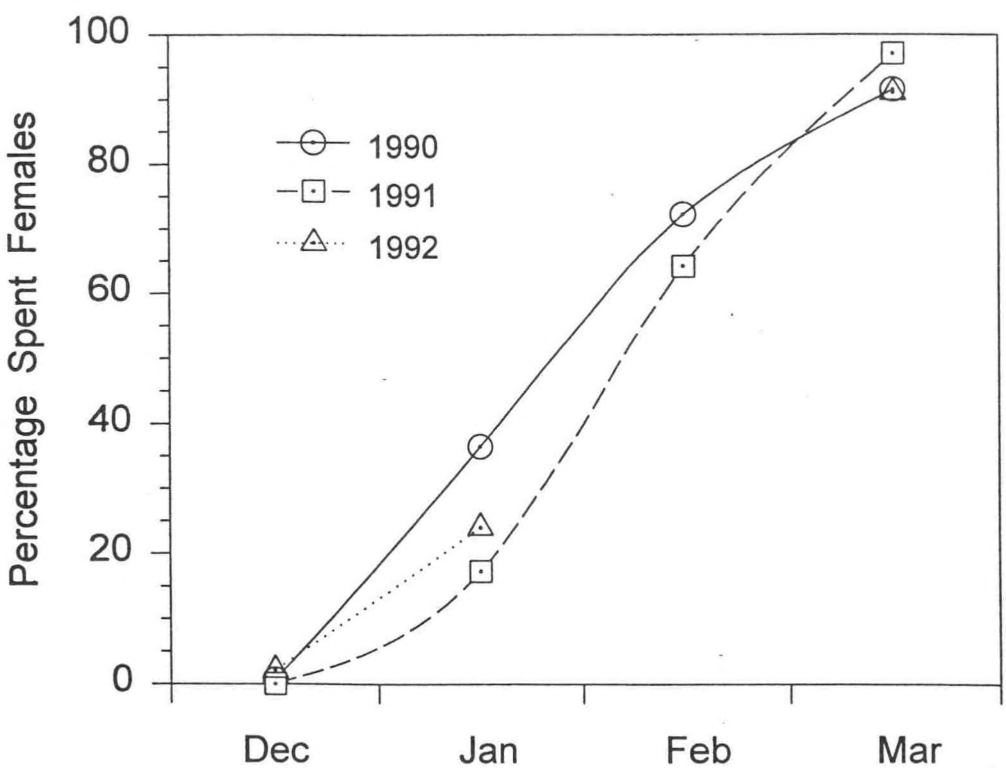

Figure 14. Seasonal incidence of spent ovaries in adult female chilipepper rockfish sampled in the commercial catch along the northern and central California coast (1990-92).

Progress in Studies of Physiological Condition of Juvenile Shortbelly Rockfish

In 1993, a study was initiated to determine variation of physiological condition in shortbelly rockfish (*Sebastes jordani*) early life stages. Nutritional status is an important indicator of physiological condition and survival potential during periods of low food availability. Measures of physiological condition, such as size, feeding, and lipid concentrations, along with abundance, distribution, and environmental data, may improve understanding of variation in recruitment and year-class strength.

Our main objectives are to determine if physiological condition of larval shortbelly rockfish varies on temporal and spatial bases along with the effects of seasonal and annual environmental conditions. Early larval stages and associated environmental data were collected in 1993 and 1994 from Bodega, Pioneer, and Ascension Canyons. Each canyon area was divided into three longitudinal sections covering the canyon axis. Sections were determined by the distance from shore with the midshore section representing the central spawning area around the 100-fathom line. Nearshore locations were 5-10 miles, midshore 10-20 miles, and offshore > 20 miles from the coast.

A number of measures were used to assess the condition of larvae, focusing on total lipid and lipid class composition. For lipid determinations, larvae were pooled to reach a biomass necessary for analysis. Composites of preflexion larvae ranged from 25 to 35 individuals and of postflexion larvae from 5 to 10 individuals were pooled. Standard length, oil globule diameter (in preflexion stages), and feeding rank were also measured on individual larvae. Lipid analyses involved quantification and fractionation of total lipid to determine concentrations and ratios of neutral lipids (generally regarded as energy-yielding [E], triacylglycerols (TAG), and esters] and polar lipids (considered as primarily structural [S], phospholipids, and cholesterol). The concentrations of energy-yielding lipids and the ratio of neutral to polar lipids (E/S) indicate energetic or physiological status. Another ratio, triacylglycerol (the main source of fuel) to cholesterol (cell membrane constituent) (TAG/CHOL) reflects nutritional status on a short-term basis, because TAG is readily utilized whereas cholesterol levels remain relatively stable. The best estimate of condition results from a synthesis of data from a combination of lipid measures, as well as other physiological variables. For example, larvae with higher levels of all lipid classes and total lipid have a better chance of survival than ones with high E/S ratios and low lipid concentrations because all lipids, including cholesterol and phospholipids, can be metabolized during periods of low food abundance.

Initial data analyses of condition factors among nearshore, midshore, and offshore locations for postflexion stages in 1993 indicate larvae from offshore appeared to be in a better nutritional state compared to larvae in nearshore or midshore locations (Table 4). Larvae offshore were significantly larger and had greater TAG, E/S, TAG/CHOL and were feeding more. Better nutritional status offshore may be explained by favorable feeding conditions although feeding rank may reflect recent conditions only.

Table 4. Means and standard errors (in parentheses) for condition factors of postfexion shortbelly rockfish larvae. Analyses are among means by distance from shore for larvae collected in the Bodega Canyon area during 1993 and 1994. Statistical significance ($P < 0.05$) determined within year. Lipid values are concentrations in mg/g and *n* is the number of composites.

	1993			1994		
FACTOR	NEAR	MID	OFF	NEAR	MID	OFF
n	2	7	8	8	10	9
LENGTH (mm)	8.33	7.89 (0.26)	9.00 * (1.98)	8.98 (0.38)	9.67 (0.34)	8.69 (0.36)
FEEDING (rank)	2.241	1.83 (0.27)	3.20 * (0.19)	2.33 (0.30)	2.21 (0.27)	3.10 † † (0.28)
TOT LIPID	16.84	19.93 (0.80)	18.09 (0.75)	22.25 (0.84)	22.94 (0.75)	20.94 (0.79)
ESTER	0.27	0.42 (0.16)	0.32 (0.32)	0.22 (0.11)	0.23 (0.10)	0.44 (0.10)
TAG	0.71	0.98 (0.17)	2.09 * (0.15)	2.17 (0.25)	2.97 † (0.23)	1.86 (0.24)
NEFA	0.42	0.63 (0.06)	0.33 (0.05)	0.53 (0.10)	0.56 (0.09)	0.86 * (0.10)
CHOL	3.21	2.54 (0.20)	2.54 (0.17)	4.08 (0.21)	4.06 (0.19)	3.90 (0.20)
POLAR	12.24	5.51 ** (0.77)	12.82 (0.67)	15.25 (0.82)	15.12 (0.73)	13.89 (0.77)
E/S	0.07	0.08 (0.02)	0.16 * (0.01)	0.12 (0.02)	0.17 (0.02)	0.14 (0.02)
TAG/CHOL	0.23	0.38 (0.09)	0.75 * (0.30)	0.53 (0.10)	0.74 † (0.26)	0.48 (0.08)

* significantly > than near and midshore
** significantly > than inshore
† significantly > than off and nearshore
† † significantly > than midshore

A difference in condition among nearshore, midshore, and offshore sections in 1994 was not as evident as in 1993 (Table 4). In 1994, postflexion larvae were similar in size, but had significantly greater TAG and TAG/CHOL in the midshore locations. It seems larvae in the midshore section had more energetic lipids readily available than in nearshore and offshore sites.

An interannual comparison between 1993 and 1994 postflexion larvae from the Bodega Canyon area showed 1994 larvae were in better nutritional condition (Table 5). In 1994, larvae contained significantly more total lipid, TAG, nonesterified fatty acids (NEFA), cholesterol, and polar lipids than in 1993 for similar sized larvae. The combination of both higher total lipid and individual component levels provides a long-term measure of better condition, whereby more lipids are available to survive periods of low food abundance. These results seem to relate to abundance data collected by the Groundfish Analysis Investigation. They found greater numbers of juveniles in the Bodega Canyon area in 1994 (May/June cruise) compared to 1993. Possibly, better nutritional condition during pelagic larval stages contributed to greater juvenile survival in 1994 in the Bodega Canyon area.

Further data analyses, including more developmental stages, southern canyon areas (Pioneer and Ascension), and years may reveal additional patterns of variation in physiological condition. The ultimate plan is to relate the effects of environmental variation to physiological condition on seasonal and annual bases to achieve a better understanding of fluctuations in recruitment. (E. Norton)

Table 5. Means and standard errors (in parentheses) for condition factors of postflexion shortbelly rockfish larvae. Analyses are comparisons of means between 1993 and 1994 for larvae from the Bodega Canyon area. Lipid values are concentrations in mg/g and *n* represents the number of composites.

FACTOR	1993	1994
n	17	27
LENGTH (mm)	8.71 (0.36)	9.14 (0.22)
FEEDING (rank)	2.55 (0.26)	2.54 (0.17)
TOT LIPID	18.69 (0.55)	22.07 (0.46) *
ESTER	0.38 (0.09)	0.30 (0.06)
TAG	1.46 (0.18)	2.36 (0.16) *
NEFA	0.45 (0.06)	0.65 (0.06) *
CHOL	2.77 (0.14)	4.01 (0.11) *
POLAR	13.60 (0.61)	14.74 (0.44) **
E/S	0.12 (0.01)	0.15 (0.01)
TAG/CHOL	0.55 (0.07)	0.59 (0.04)

* (P<0.05)
** (P<0.10)

Progress in Estimating Year-class Strength from Composition of Predator Diet

The relative abundance of pelagic juvenile rockfishes in the diet of king salmon (*Oncorhynchus tshawytscha*) during May to June has been monitored since 1980 as a measure of future year-class strength. In 1994, no juvenile rockfish were found in the king salmon stomach sample collections, placing 1994 in the same category with 1983 and 1992 as the only years when no rockfish were found (Table 6). All three of these years (1983, 1992, and 1994) were years with significant El Niño conditions. As in other El Niño years, salmon catches were low, individual size was small, and the salmon were concentrated nearshore.

Table 6. Mean number of first year juvenile rockfishes (Genus *Sebastes*) in the stomach contents of king salmon (*Oncorhynchus tshawytscha*) from the Gulf of the Farallones, 1983-1993 (N = the total number of stomachs from collections which contained rockfish and N_r = the number of stomachs that individually contained rockfish).

Year	N	N_r	All Species	*S. jordani*	*S. entomelas*
1980	144	34	0.88	0.35	-
1981	406	266	2.98	1.11	-
1982	374	186	2.20	0.79	-
1983	-	-	-	-	-
1984	456	133	1.26	0.43	0.01
1985	506	169	2.64	0.86	0.07
1986	141	33	0.75	0.10	0.02
1987	883	392	2.71	1.72	0.06
1988	993	453	4.07	2.28	0.03
1989	517	287	5.97	4.47	0.01
1990	153	15	0.31	0.23	0.01
1991	637	210	0.93	0.14	0.11
1992	-	-	-	-	-
1993	457	127	2.56	2.09	-
1994	-	-	-	-	-

In 1994, king salmon caught off Eureka were sampled for stomach contents through a contract with Humbolt State University. The sampling was not completed due to an emergency closure of the fishery on June 7. Only one stomach collection contained rockfish and that was made on June 5, two days before the season closed. Numbers of juvenile rockfish were quite high, averaging 5.00 rockfish/salmon. The commonest species was widow rockfish

(*S. entomelas*), averaging 2.86 rockfish/salmon, and the next most common was blue rockfish (*S. mystinus)*, 0.71 rockfish/salmon. In 1995, we hope to expand our sampling out of the central California area, where species composition is dominated by shortbelly rockfish (*S. jordani*). (P. Adams and K. Silberberg)

Progress in Comparison of Assessments from Different Methods

Comparison of annual indices of total numbers of juvenile rockfish from midwater trawl assessments and from predator diet show a high level of agreement (Fig. 15). Correlations between the annual Total *Sebastes* trawl index for the highest sweep in Table 3 and the natural log transformed predator diet mean number for All Species in Table 6 were very high ($r = 0.90$, $P > 0.001$). Both the midwater trawl and the predator diet indices are dominated by shortbelly rockfish, annually ranging from 50 to 80%. A similar level of agreement was found between midwater trawl and diver count indices (see **Studies of Post-Pelagic Juveniles**) for blue rockfish, *S. mystinus*, and yellowtail rockfish (Ralston and Howard, in prep.).

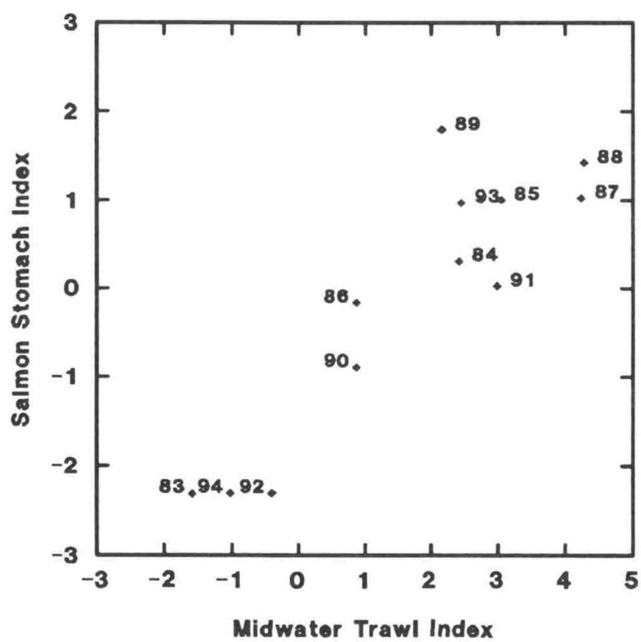

Figure 15. Comparison of total rockfish midwater trawl index and the natural log of the salmon stomach index by year.

STUDIES OF POST-PELAGIC JUVENILES

Progress in Visual Assessment of Juvenile Rockfishes in Nearshore Habitats

Two species, *Sebastes mystinus* and *S. flavidus*, continued to dominate among rockfish recruits monitored at nearshore sites on the Mendocino and Sonoma coasts of northern California. Counts by D. H. Howard indicated that 1994 was a poor recruitment year for both species (Table 7). The number of *S. flavidus* recruits at the Mendocino sites was the lowest since the El Niño year of 1983, when there were none. And only once since 1983 were there fewer *S. mystinus*--the El Niño year of 1992. *Sebastes flavidus* did only slightly better on the Sonoma coast, but still experienced one of its weakest recruitment years there. There were noticeably more *S. mystinus* recruits in the Sonoma habitats, but its numbers nevertheless were low compared to most previous years. The relative strength of recruitment by these two species during 1994, therefore, is consistent with what has been observed during El Niño conditions. (E. Hobson, D. Howard, J. Chess)

Table 7. Numbers of recruits counted nearshore during August and September 1983-1994. Values are mean number (standard error in parentheses) counted per minute. n = number of 1-min counts.

MENDOCINO

Species	1983 n=36	1984 n=57	1985 n=50	1986 n=103	1987 n=112	1988 n=62	1989 n=181	1990 n=99	1991 n=80	1992 n=120	1993 n=90	1994 n=120
S. flavidus	0.00	6.58	115.60	6.01	102.66	59.47	1.29	1.93	8.14	0.09	0.24	0.03
	(0.00)	(2.29)	(21.26)	(1.50)	(11.08)	(10.23)	(0.35)	(0.90)	(3.04)	(0.05)	(0.14)	(0.01)
S. mystinus	0.27	1.49	70.56	7.83	181.04	75.89	6.08	0.76	0.64	0.26	6.21	0.59
	(0.09)	(0.30)	(15.32)	(1.88)	(26.19)	(10.18)	(0.94)	(0.17)	(0.16)	(0.06)	(1.40)	(0.16)

SONOMA

Species	1983 no data	1984 n=57	1985 n=50	1986 n=60	1987 n=56	1988 n=62	1989 n=186	1990 n=100	1991 n=79	1992 n=40	1993 n=100	1994 n=80
S. flavidus		4.39	135.17	6.73	89.39	39.92	1.54	0.12	38.33	0.49	1.14	0.28
		(1.48)	(26.00)	(2.29)	(18.42)	(7.94)	(0.42)	(0.05)	(6.40)	(0.29)	(0.78)	(0.11)
S. mystinus		4.89	117.63	15.27	328.05	175.06	7.19	0.66	13.58	1.01	2.96	2.15
		(1.29)	(19.50)	(3.81)	(52.15)	(16.76)	(0.93)	(0.12)	(1.82)	(0.25)	(0.87)	(0.43)

STUDIES OF ADULTS

Progress in Studies of Adult Blue Rockfish

Effects of Feeding Conditions on Physical Condition and Recruitment Success

The possibility that recruitment of the blue rockfish is influenced by feeding conditions experienced by adult *S. mystinus* has been studied since November 1987. Each year since then, including the one just past, it has been apparent that physical condition of the adult females during the months before parturition (when young are developing) was relatable to feeding success during the previous summer-fall. A comparison of relative feeding success during the past seven years, based on relative gut fullness and incidence of empty guts (Fig. 16), shows that 1994 ranks among the top three with 1988 and 1991. When quality of diet is considered, however, the 1994 condition is weakened by the high proportion of plant materials in the diet. Although these are important foods (particularly the sorri of *Nereocystis*), most of the material contributing to the volume is undigestible. Despite this, however, 1994 remains among the top three years for feeding, particularly considering the low incidence of empty guts.

The object of this study has been to relate physical condition of the adult female to feeding conditions during the previous summer and fall, and to the success of recruitment during the following summer. As noted in previous numbers of this series, there have been apparent connections most years but not during 1992. Recruitment was exceptionally weak that year even though the reproducing females had been in relatively good shape (Figure 17), possibly because the early pelagic juveniles had been adversely affected by the strong El Niño conditions that prevailed during the period after parturition. A similar effect was apparent last year. The 1994 Recruitment Report had predicted that, based on feeding and condition factors alone, the upcoming recruitment that year would be "on the low side of moderate." That it turned out to be even weaker than that can be attributed to the mild El Niño conditions that existed through the winter of 1993-94. This would suggest that the present year's substantially increased El Niño conditions may overwhelm any positive influence on 1995 recruitment that might otherwise have resulted from females being in relatively good condition during the spawning season just past (Figure 17). (E. Hobson, J. Chess, D. Howard)

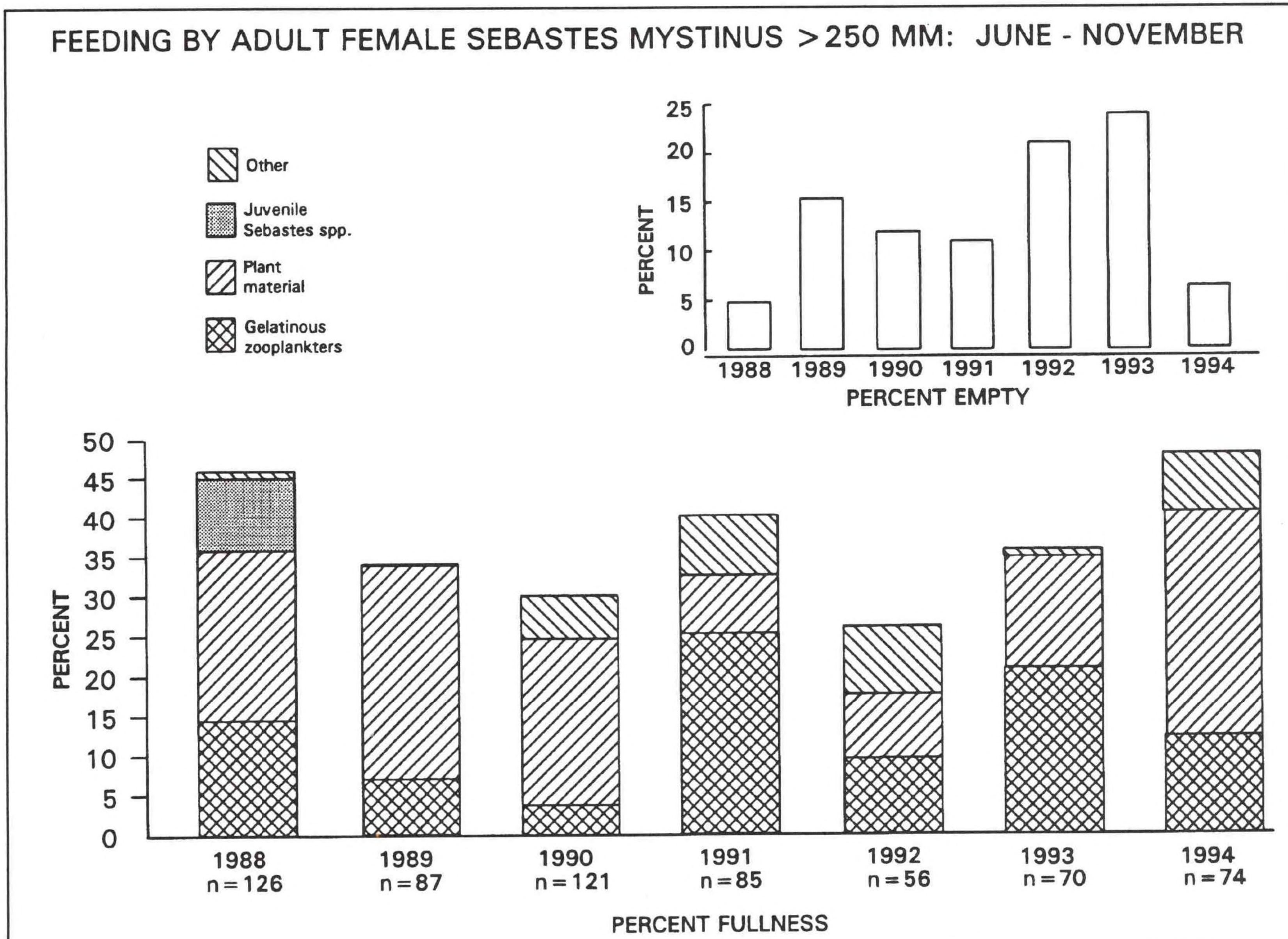

Figure 16.. Feeding by adult blue rockfish, *S. mystinus*, (June-November).

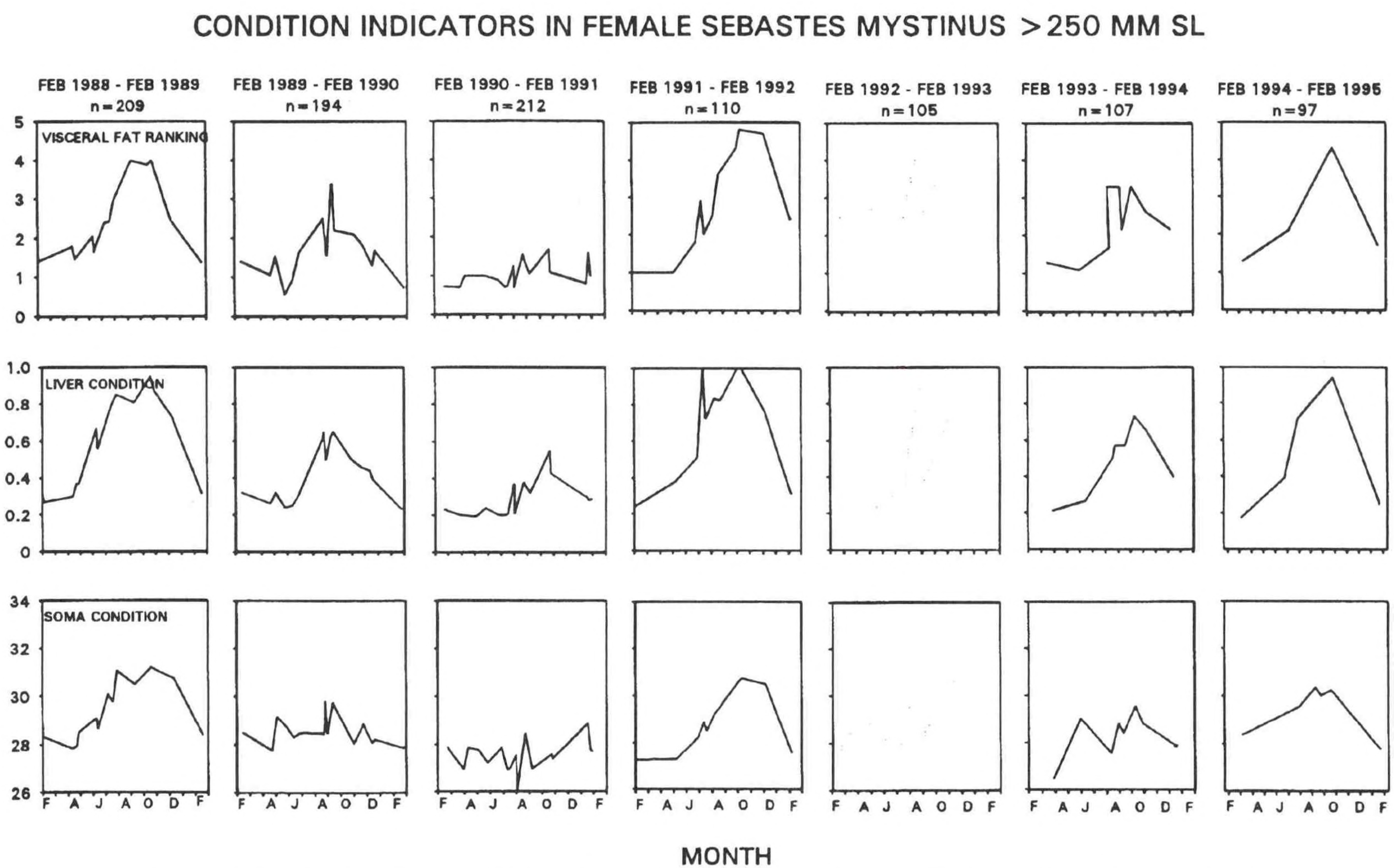

Figure 17. Condition indices in female blue rockfish, *S. mystinus*, > 250 mm SL.

Progress in Studies of Adult Yellowtail Rockfish

Long-term Studies of Fecundity of Yellowtail Rockfish

Persistence of rockfish stocks depends on high adaptive capacities, successful reproduction, and recruitment. Knowledge of variability of reproductive effort helps characterize different stocks, provides essential information for the estimation of stock biomass by the larval production method, and it helps identify the effects of environmental influences such as those associated with El Niño. Field studies begun in 1985 showed that yellowtail rockfish from northern California were smaller in weight and length and older than fish off central Washington. Despite their younger ages, Washington fish were more fecund, both in total eggs per female and in the number of eggs per unit body weight. Over seven consecutive years, interannual differences were found in fecundities of fish younger than 15 years. Older fish from California and all fish from Washington appeared not to be effected by factors that varied temporally. Since the completion of that study, we have continued to monitor the fecundities and physiological conditions of California yellowtail rockfish. Reproductive effort and conditions of fish during the 1993/1994 season did not significantly (ANOVA, $P > 0.05$) differ from previous years (Table 8), although last year's samples were younger in age and smaller in size with lower average fecundities. (M. Eldridge and B. Jarvis)

Table 8. Ages (years), somatic wet weights(g), standard lengths(cm), and absolute fecundities (thousands of eggs per female) of yellowtail rockfish from Cordell Bank, California, during the collective reproductive years 1985-1992 and the 1993/1994 season.

Year	Age Mean	Age SD	Somatic WW Mean	Somatic WW SD	Std. Length Mean	Std. Length SD	Abs. Fecundity Mean	Abs. Fecundity SD
1985/ 1992	15.4	7.3	1,207	352	36.3	3.8	523.2	252.2
1993/ 1994	14.1	6.7	1,069	298	34.8	3.8	440.2	189.2

Progress in Studies of Adult Shortbelly Rockfish

Fecundities of Shortbelly Rockfish

The shortbelly rockfish is the only groundfish species along the Pacific coast that is classified as underutilized with an above average stock level status. Studies which began in 1990 have provided the opportunity to collect information on the basic life history of unfished groundfish stocks. The studies were conducted in three submarine canyon areas off central

California; Bodega Canyon, Pioneer Canyon, and Ascension Canyon. Summary data showed that fish did vary in age and size among the four years, though not significantly (Table 9). Fish averaged six years of age, had mean lengths of 20.0 cm and weighed 136.8 g. Unlike patterns found in longer-lived *Sebastes* species, such as yellowtail rockfish, fecundities did not decline with advancing age or size (Figure 18). Fecundities, however, were highly variable, especially in the older, larger fish. There is some preliminary evidence that a small proportion of the adult population (< 5%) shortbelly rockfish are multiple or indeterminate spawners. More detailed examination of specimens are underway to establish the extent of this strategy. (M. Eldridge and B. Jarvis)

Table 9. Ages, total wet weights, standard lengths, and absolute fecundities of shortbelly rockfish collected from central California during reproductive years 1990/1991 through 1993/1994. * = ages to be determined

Year	n	Age		Total WW		Std. Length		Abs. Fec.	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1990/ 1991	372	6.1	4.1	125.1	78.4	19.3	4.0	10,148	8,513
1991/ 1992	52	5.7	2.8	161.8	51.0	21.2	2.3	30,905	14,003
1992/ 1993	78	5.8	3.7	127.9	66.2	20.0	3.9	12,421	7,308
1993/ 1994	282	*	*	145.8	61.2	20.5	2.8	18,616	10,184
All	784	6.0	4.5	136.8	70.0	20.0	3.5	15,621	11,796

Nutritional Dynamics of Embryonic Development in Shortbelly Rockfish (Sebastes jordani)

Previous research with yellowtail rockfish (*Sebastes flavidus*) showed that the dynamics of lipid and protein metabolism in ovaries during embryogenesis varied from year to year and related to differences in maternal and environmental factors. For example, during five annual reproductive cycles, 1988 - 1992, ovarian lipid concentration was significantly correlated to relative fecundity (number of eggs/weight somatic tissue; $r^2 = 0.826$, $P < 0.05$) and estimates of upwelling intensity ($r^2 = 0.748$, $P < 0.05$) . These results supported the hypothesis that nutritional status during embryonic development is a function of environmental conditions and it effects reproductive output of rockfish along the California coast. We have extended our study

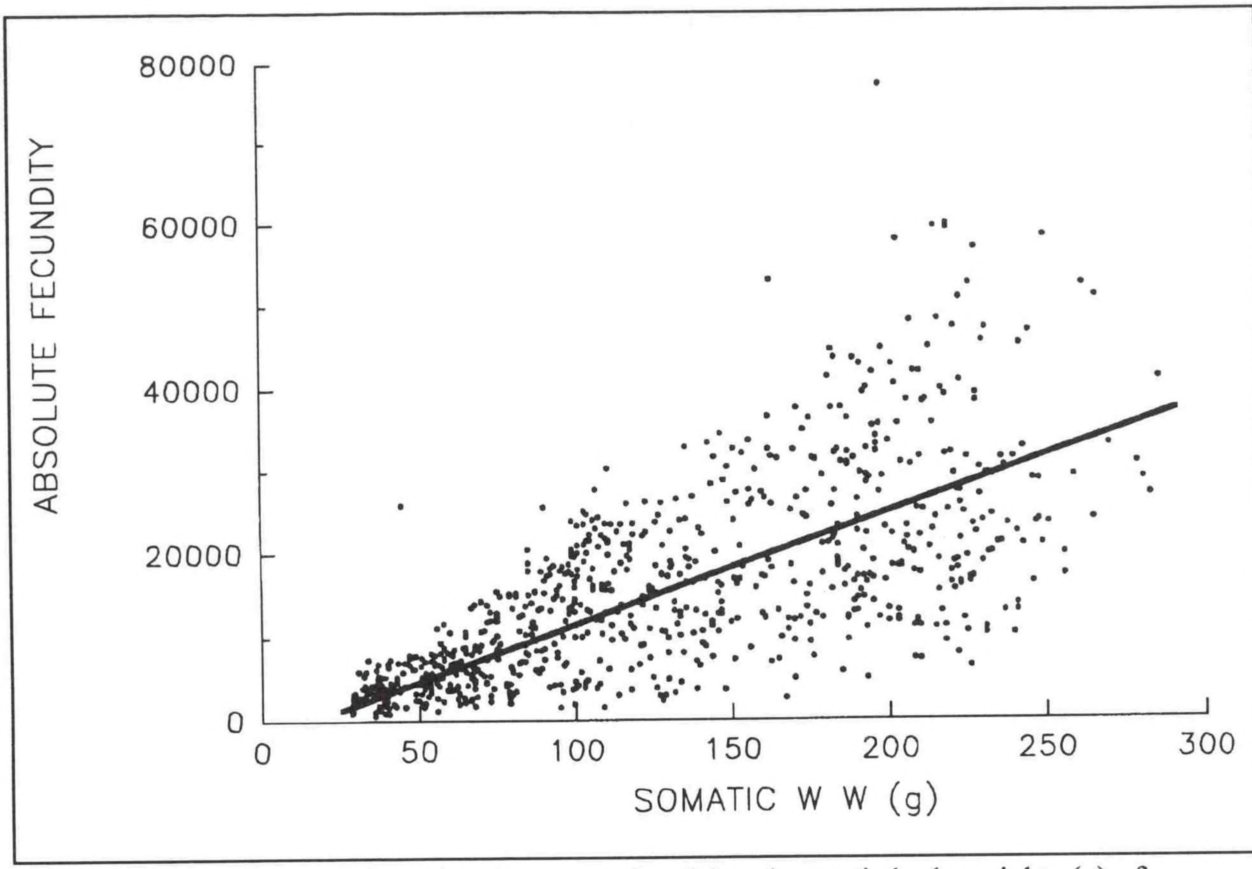

Figure 18. Absolute fecundities (total eggs per female) and somatic body weights (g) of shortbelly rockfish sampled during reproductive years 1990-1994.

of this linkage to another rockfish species, the shortbelly rockfish. The ability to identify and collect large numbers of pelagic larvae provides the unique opportunity to evaluate the contribution of ovarian nutritional dynamics to growth, condition, and survival during the early pelagic larval period when mortality is highest. The relative lack of abundance and difficulty in identifying other rockfish larvae, including yellowtail rockfish, greatly diminished the ability to relate the importance of ovarian nourishment to larval survival.

In 1994, changes in ovary lipid and protein content during embryogenesis were measured in three populations of shortbelly rockfish to determine whether the nutritional status of larvae at parturition varied by population. Gravid shortbelly rockfish were collected from populations at three submarine canyons: Ascension, Pioneer, and Bodega. Ovaries were excised from females in stages of development ranging from late vitellogenesis through fully formed, hatched larvae. Tissue samples were analyzed for protein and lipid content. The concentrations of total protein, total lipid, and the lipid classes wax/sterol esters, triacylglycerols (TAG), nonesterified fatty acids (NEFA), cholesterol (Chol), and polar lipids (PL) in ovaries were analyzed by ANOVA and linear regression to determine the effects of location and embryo maturation stage.

Two-way ANOVA found that embryo maturation stage and location of the population were highly significant in contributing to the variation of all lipid and protein variables, except NEFA (Table 9). NEFA were infrequently found in embryos and at very low concentrations (0.15±0.04 mg/g). Although maturation stage accounted for the greatest variability in lipids and protein, location was also a significant main effect, particularly for lipid variables. The interaction of location and maturation stage was statistically significant for total protein, total lipid, TAG, Chol, and PL, suggesting that changes in concentrations of these variables during embryo development varied significantly among the populations.

Protein and lipids declined from late vitellogenesis (Stage 1) through embryo maturation to hatched larvae (Stage 33) (Fig. 19). This pattern is typical of lecithotrophic livebearers. The decrease in total protein and lipid was much greater than that found in yellowtail rockfish embryos which are supplemented matrotrophically during gestation.

Table 10. ANOVA summary of location and stage of embryonic development on embryonic lipid and protein concentrations. N = 182. Fish were obtained from three locations (Ascension, Pioneer, and Bodega Canyons) and embryos were categorized according to maturation stage (1 = late vitellogenesis; 2 through 33 = two-celled stage to hatched larva).

Variable	*F*	Model *P*	*r*	Effects (P > F) *Location*	*Mat. Stage*	*Location x Mat. Stg*
Total Protein	26.14	0.0001	0.9194	0.01	0.0001	0.05
Total Lipid	26.97	0.0001	0.9136	0.0001	0.0001	0.01
Esters	9.36	0.0001	0.7859	0.05	0.0001	NS
Triacylglycerols	20.89	0.0001	0.8912	0.001	0.0001	0.05
Nonesterified Fatty Acids	0.41	0.9998	0.1379	NS	NS	NS
Cholesterol	17.87	0.0001	0.8751	0.0001	0.0001	0.05
Polar Lipids	30.28	0.0001	0.9224	0.0001	0.0001	0.01

As yolk and oil nutrient stores were depleted, the decline of TAG, esters, PL, and protein indicated utilization as energy for embryo tissue synthesis. Surprisingly, polar lipids, which are largely phospholipids, were also depleted. Since they are the precursors of membranes, and embryo development requires extensive proliferation of membranes, it may be expected that polar lipid levels would remain unchanged, reflecting translocation from yolk to body, or increase as phospholipids are synthesized *de novo* within the ovary. The use of phospholipids for energy-requiring processes in fish eggs and larvae has been noted in other species as well, however.

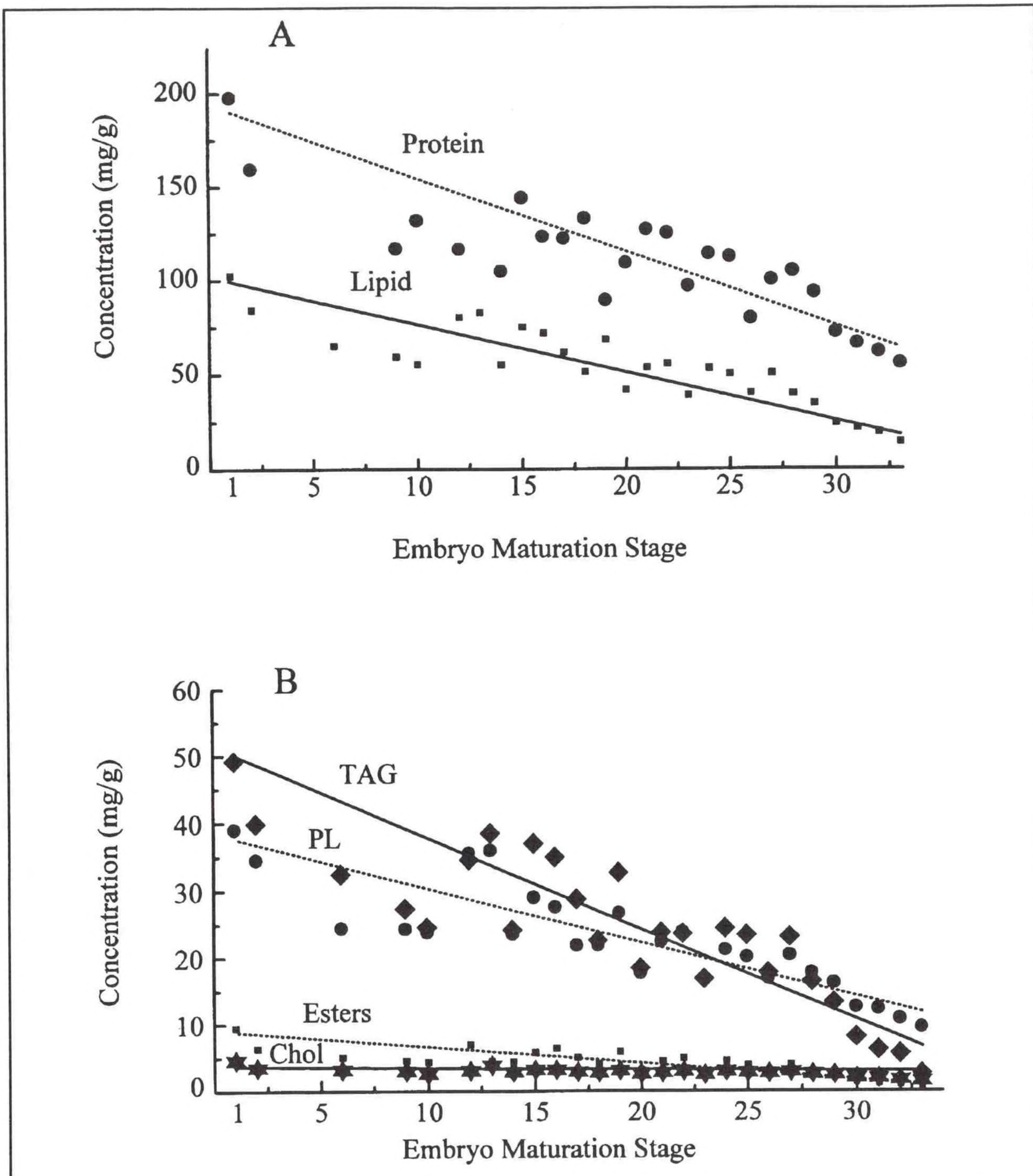

Figure 19. (A) Total protein and total lipid concentrations, and (B) lipid class concentrations in embryos of shortbelly rockfish during ovarian development in 1994. Concentrations determined by embryo maturation stage, where Stage 1 is prefertilized, and Stage 2 through Stage 33 are progressive developmental stages from two-celled embryo to hatched larva. Symbols represent means; lines are least squares regressions. Symbols: (A) ● Protein, ■ Lipid; (B) ◆ TAG, ● PL, ■ Esters, ✱ Chol.

The general pattern of decreases in protein and lipid components during embryonic development (Fig. 19) was evident in each canyon's population. Linear regressions of lipid and protein variables by embryo maturation stage for each canyon's population were all highly significant ($P < 0.0001$) and produced estimated slopes and intercepts significantly different from zero ($P < 0.0001$). Consistent with the results of the ANOVA, slopes and intercepts of variables among the populations varied. Using these regression equations, it was possible to estimate the nutritional composition of larvae at parturition for each population. Thus, a comparison among canyon populations of the nutritional status of larvae can be made.

Based on these analyses, in 1994, the larvae released at Ascension Canyon appeared to have the greatest content of protein and all lipid classes (Table 10) and, therefore, the highest potential for survival during the first days in the environment until appropriate food becomes available to further sustain their growth and development. The year-class born at Bodega Canyon would seem to be somewhat better prepared to grow and survive until feeding begins than the larvae from the Pioneer Canyon population. This is particularly apparent from the TAG concentrations. Triacylglycerols are the primary energy source for metabolism.

Annual comparisons of nutritional dynamics of embryo development among shortbelly rockfish populations are envisioned for 1994 through at least 1996. Embryo data will be related to annual environmental data and to estimates of pelagic larval condition and abundance to elucidate the relative influences of physiological "fitness" at birth and environmental factors, such as upwelling intensity and duration, temperature, etc., to abundance. (B. MacFarlane)

Image Analysis of Shortbelly Rockfish Oocytes and Embryos

An image analysis system was used for descriptive measurements of shortbelly rockfish oocyte and embryonic components (tissue, yolk, oil globule, and total area) through the sequence of developmental stages. An understanding of the sequestering, mobilization, and utilization of yolk and oil (lipid) components during embryonic development may more clearly define embryonic condition, viability, and factors promoting recruitment. Anabolic contributions of yolk and oil as structural and energetic resources are understood at the biochemical level, but the actual rates of yolk and oil utilization through embryonic development have not been determined, and may vary among reproductive seasons and populations . This study was initiated to explore the use of image analysis as a tool for rapid assessment of oocyte and embryonic condition.

Adult female shortbelly rockfish were collected from three separate locations (Bodega, Ascension, and Pioneer canyons) during the 1994 reproductive season, and were assumed to represent distinct reproductive populations. Oocytes and embryos in sequential stages of development were sub-sampled from ovaries and preserved in 10% buffered formalin for latter analyses. An image analysis system with an Optimas software program (Bioscan, Edmonds, Washington) was used to measure and record oocyte, yolk, and oil globule diameters in addition

Table 11. Estimates of lipid and protein concentrations of larvae at parturition from populations at three submarine canyons off central California coast. Values are for final embryo maturation stage, hatched larvae (Stage 33) from linear regressions of variable by embryo maturation stage for populations from each canyon. All estimates are mg/g fresh weight.

Variable	*Ascension Canyon*	*Pioneer Canyon*	*Bodega Canyon*
Total Protein	90.0	62.8	63.1
Total Lipid	40.5	19.9	29.8
Esters	2.8	1.1	1.9
Triacylglycerols	18.2	5.8	11.0
Cholesterol	2.3	1.6	2.2
Polar Lipids	17.3	10.9	14.6

to areas of embryonic tissue. Mean areas and volumes of the various components for each developmental stage sampled were then calculated from these measurements.

Initial analysis of mean areas for yolk, oil, tissue, and total area are shown in Figure 20 . A general trend where yolk and oil decline concurrently with increases in total and tissue area is clearly demonstrated as embryonic development progresses. It is interesting to note a slight increase in yolk at the earliest stages of development. This may suggest that yolk continues to be sequestered after ovulation and fertilization. If additional sampling and analysis continue to demonstrate this trend, it would further support evidence of matrotrophic viviparity in this genus. Currently, studies are underway to determine if there are differences among populations from the three locations sampled. Samples from the 1995 reproductive season are similarly being analyzed and may reveal variations from the 1994 reproductive year.

The initial results of the image analysis data is in close agreement with other studies where more conventional methods of biochemical analyses are performed. To that extent, image analysis appears to be a useful tool for rapidly assessing oocyte and embryo development. Also, beyond quantifying changes in embryo components, image analysis offers the advantage of determining the extent of normal organ development. Another benefit is the capability of obtaining data from fresh or preserved images and immediately deriving useful information. The elimination of sample preparation is highly desirable. (M. Bowers)

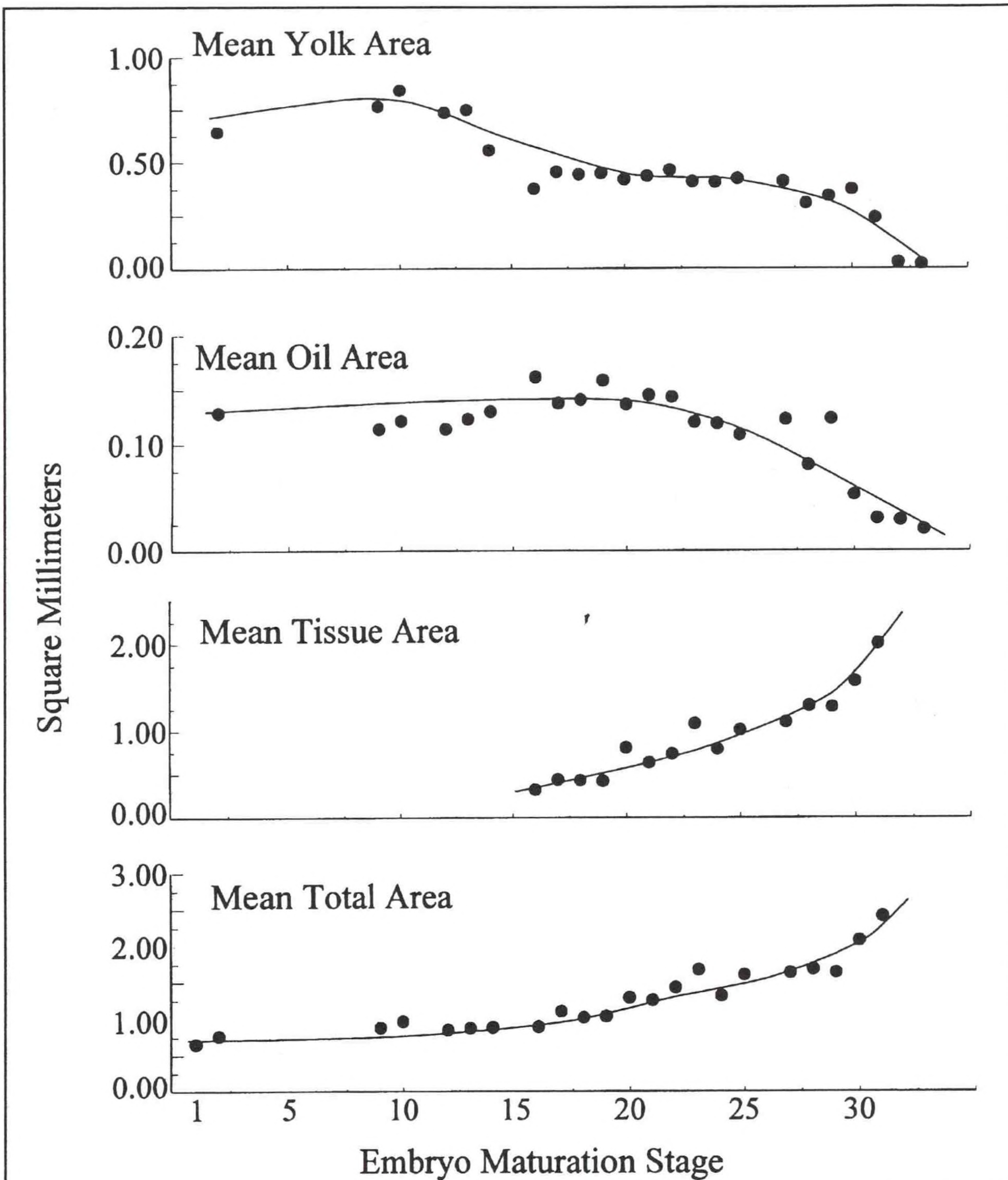

Figure 20. Changes in yolk, oil, embryonic tissue, and total areas of shortbelly rockfish embryos from late vitellogenesis (Stage 1) through embryogenesis to hatched larvae (Stage 33). Points are mean areas, in mm^2, for each embryo maturation stage. Measurements were made on at least 10 embryos/ovary from each female (N = 184). Curves representing estimated patterns of change were constructed by eye.

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