SOUTHWEST FISHERIES SCIENCE CENTER

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APRIL 1993

PROGRESS IN ROCKFISH RECRUITMENT STUDIES

By

Staff of the Tiburon Laboratory

Edited by Stephen Ralston

ADMINISTRATIVE REPORT T-93-01

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3150 Paradise Drive
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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 ninth 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 1992 to March 1993 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).

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 cod-end 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. in the south (see Fig. 1 in Adams 1992). As part of the survey design, the study area is subdivided into seven geographical strata, with five to six standard stations located within each.

During the past year one pelagic juvenile survey cruise was conducted (DSJ-9206). This cruise spanned a 37-d 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 (e.g., Lenarz *et al.* 1991). Supplemental CTD data were also gathered during the day along tracklines that criss-crossed the entire study area (see also Schwing *et al.* 1990;

Table 1.--Summary of midwater trawl surveys conducted by the Groundfish Analysis Investigation for pelagic YOY rockfishes (Sebastes spp.) off the central California coast (1983-91).

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, "	26
	3	02 June	-- 17 June, "	32

Schwing and Ralston 1991; Johnson *et al.* 1992). Following the cruise, the identity of rockfish specimens was confirmed in the laboratory (Table 2), standard lengths 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.

Identification of Larval and Juvenile Rockfishes

To more accurately compile results of the pelagic juvenile surveys, larval and juvenile identifications of rockfish species previously undescribed (or not fully described) were undertaken. Fish were identified using meristic characters, pigment patterns, geographic location, head spination, time of year, and otolith structure. Over the last year, specimens of S. emphaeus, S. goodei, S. hopkinsi, S. saxicola, and members of the subgenus Sebastomus were studied. Representatives of many of the identified species were archived as reference material.

Table 2.--Species composition of pelagic juvenile rockfish taken during DSJ-9206.

Scientific Name	Common Name	N	%
Sebastes auriculatus	brown rockfish	8	0.150
Sebastes diploproa	splitnose rockfish	21	0.383
Sebastes entomelas	widow rockfish	1	0.018
Sebastes flavidus	yellowtail rockfish	18	0.322
Sebastes goodei	chilipepper	110	1.968
Sebastes hopkinsi	squarespot rockfish	211	3.782
Sebastes jordani	shortbelly rockfish	4,978	89.172
Sebastes levis	cowcod	5	0.090
Sebastes mystinus	blue rockfish	9	0.161
Sebastes paucispinis	bocaccio	6	0.114
Sebastes pinniger	canary rockfish	1	0.025
Sebastes rastrelliger	grass rockfish	8	0.143
Sebastes saxicola	stripetail rockfish	10	0.179
Sebastes semicinctus	half-banded rockfish	4	0.067
Sebastomus subgenus*	--	42	0.752
copper rockfish complex†	--	139	2.495
Unidentified Sebastes	--	10	0.179
Total:		5,581	100%

* see text

† i.e., Sebastes caurinus, S. carnatus, and S. chrysomelas

Pigmentation patterns for previously undescribed stages were identified for S. chlorostictus, S. constellatus, S. rosaceus, S. ensifer, S. goodei, S. hopkinsi, S. rosenblatti, S. saxicola, and S. helvomaculatus. Most of the identified patterns were from juvenile stages, where meristic counts were the primary means of identification. Some larval stages were identified, however, especially for S. goodei, S. hopkinsi, and S. saxicola. These were differentiated by creating a pigment series, identifying the larger individuals using meristic characters, and progressively identifying smaller individuals using pigment patterns and meristic counts (when available). Otolith characters were also used to further corroborate these identifications.

Work on distinguishing species in the difficult Sebastomus subgenus showed promising, but varied, results. Based on a combination of meristic counts (including gill rakers) and pigment patterns, we tentatively identified six species from this group (S. chlorostictus, S. constellatus, S. ensifer, S. helvomaculatus, S. rosaceus, and S. rosenblatti). It is noteworthy that two of these are rare along the central California coast as adults (i.e., S. rosenblatti and S. ensifer) and their appearance in our catches may have been due to the El Niño event that occurred during the first half of 1992.

Identifications were also confirmed for several specimens of S. emphaeus taken during our 1991 cruise. This is the first confirmed occurrence of this species in our collections and it may have been transported to the study area by strong southward flowing currents that year, as noted by the unusually cold water found off the coast. (K. Sakuma and T. Laidig)

Size Selectivity of Midwater Trawl

The primary objective of the midwater trawl survey is to obtain annual indices of pelagic juvenile rockfish abundance. Owing to the small size of fish captured in some years (Fig. 1), abundance indices may be biased by the selective properties of the trawl net. In particular, there was concern that the trawl, which is equipped with a 1.27 cm stretched mesh liner, did not adequately sample the small fish present in 1983, 1986, and 1992.

The selectivity of the trawl was studied during the 1992 May-June survey. A liner with 0.635 cm mesh was constructed to capture relatively small fish. Three nights were spent trawling in areas of high juvenile rockfish abundance. Each liner was used for half the night. The trawl began at the same position and was trawled in the same direction. A total of 20 trawls were made, ten with each liner. About 90% of the rockfish captured were shortbelly rockfish (S. jordani) and only this species was used for analysis. Eleven of the samples were too large to be fully sorted and subsamples were taken. Specimens were measured to the nearest 0.1 mm standard length (SL).

As expected, the 0.635 cm mesh liner caught more small fish at each station than did the 1.27 cm mesh liner (Fig. 2). These data indicate that the 1.27 cm mesh is reasonably efficient in capturing rockfish as small as 20 mm SL. Interestingly, the 0.635 cm liner did not catch as many of the larger fish. Several times the fine mesh liner clogged with euphausiids, which may have increased the avoidance of the larger fish.

Additional analysis included plotting the ratio of the numbers of juveniles caught at size from each liner. With equal effort this ratio should start at zero for the smaller sizes and attain a value of one at the size that both nets are sampling with equal efficiency. As seen in Figure 3, the ratio starts out small, increases to one in the 17-18 mm SL range, but then continues higher, confirming that the smaller mesh does not efficiently sample large fish. Still, the experiment was designed to assess the degree to which the large mesh liner undersampled small fish. Assuming the small mesh efficiently samples up to 18 mm FL, we tentatively conclude that at that size the large mesh is efficiently capturing juvenile rockfish.

Because pelagic juvenile shortbelly rockfish are relatively terete in shape, a cutoff of 25 mm SL provides a conservative size at which to truncate the midwater trawl data. Below that size we question the accuracy of our sampling procedures. Most

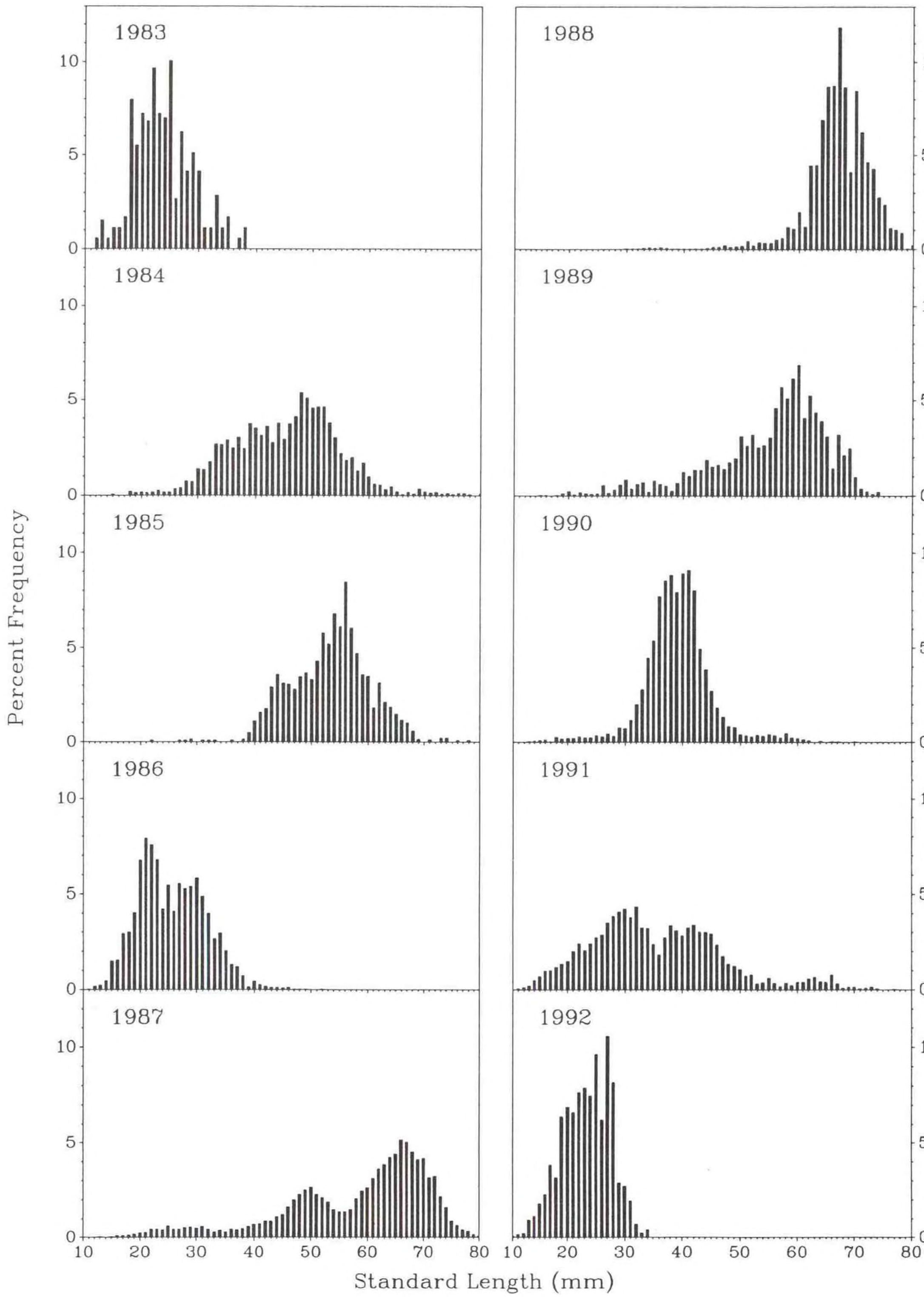

Figure 1. Length-frequency distributions of pelagic juvenile rockfish (1983-92). May-June samples and Table 3 species only.

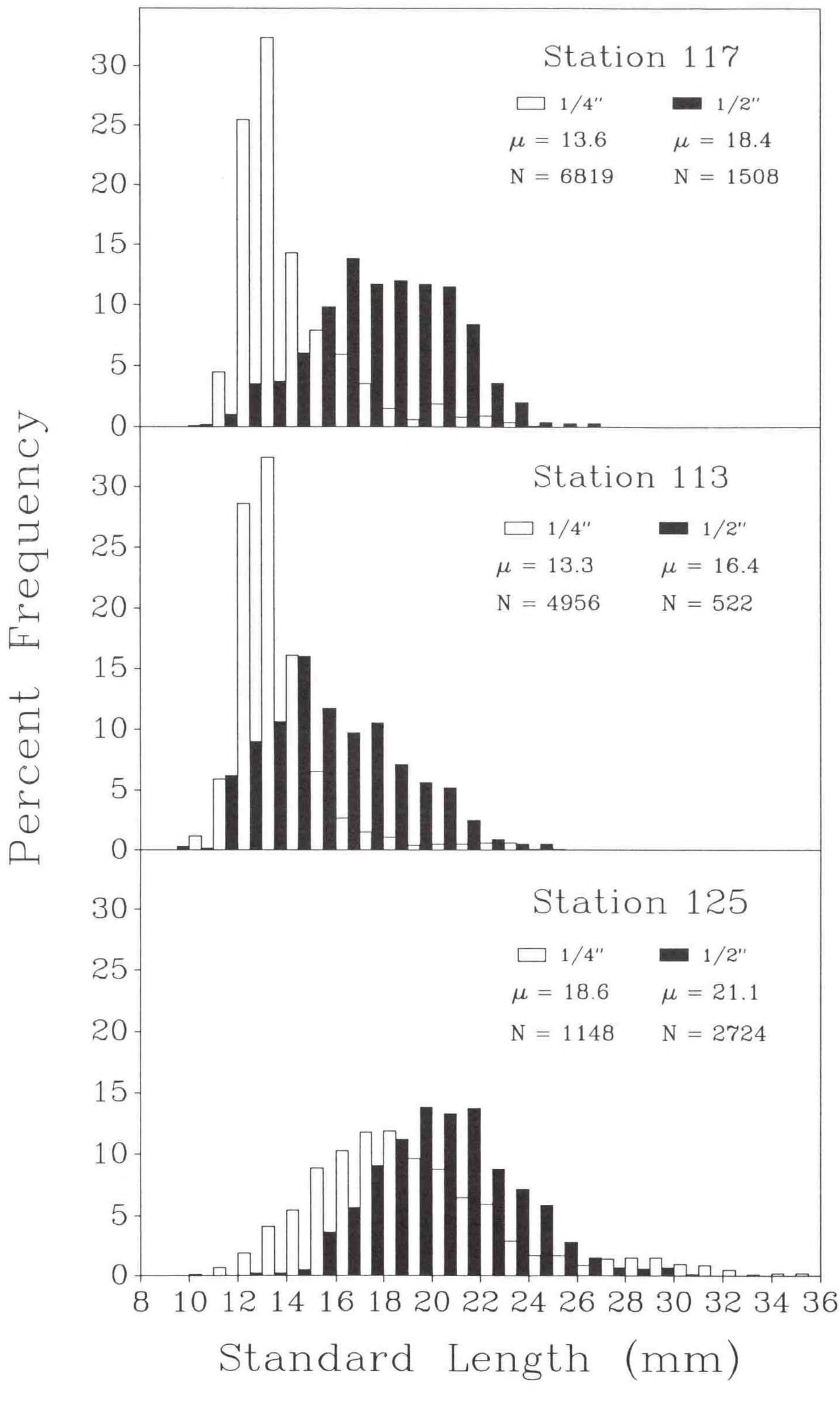

Figure 2. Size distributions of <u>Sebastes jordani</u> taken in trawls of two different mesh sizes.

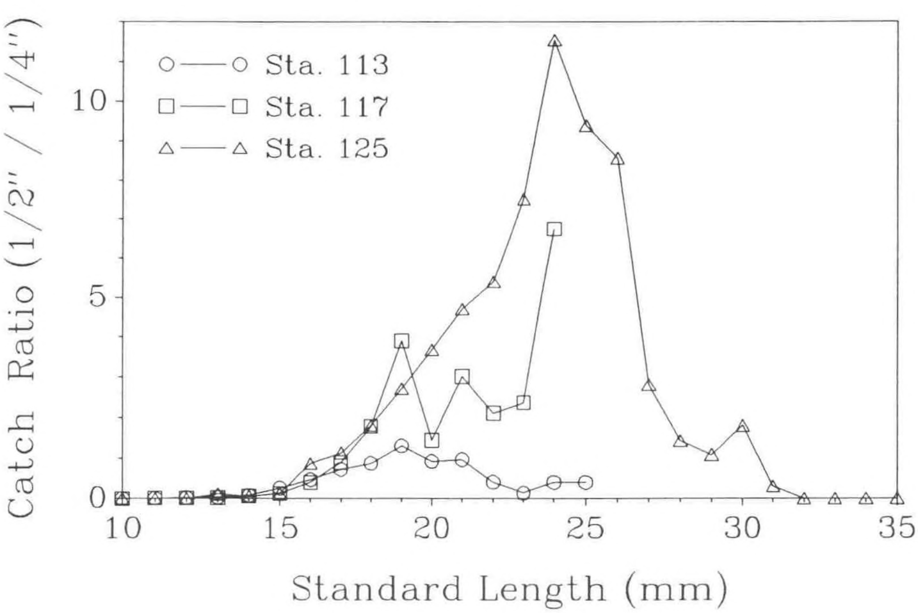

Figure 3. Ratio of Sebastes jordani catches by length interval taken in trawls of two different mesh sizes.

of the other rockfish species are more robust and are likely to be even more vulnerable to capture. It was fortuitous that the study was conducted during 1992 when small fish were abundant, although further investigations are planned. (D. Woodbury)

Estimation of Abundance

During the last year a major modification was made to the manner in which abundance indices are calculated. As noted in the previous report (Adams 1992), interannual differences in the size structure of pelagic juveniles captured by the trawl are marked (Fig. 1). Consequently, abundance indices were further adjusted to account for variable length composition above the size at which the net samples efficiently.

Following truncation of the data at 25 mm SL, additional adjustments were performed in a two-step process. First, fish ages were estimated from length measurements using inverse growth curves developed for each of the 15 primary species of rockfish sampled during the 10 year period from 1983-92, amounting to 150 species-year combinations. Specifically, the predicted age of species "s" in year "y" at standard length "l" is $\hat{\tau}_{syl} = \alpha_{sy} + \beta_{sy} l$, where the α_{sy} and β_{sy} were estimated by least-squares regressions in the 39 cases where direct age data were available from enumerations 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.

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.,

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

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 are 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}. This latter figure was based on estimates of mortality rate for larval shortbelly rockfish (S. jordani; unpublished data), settled juvenile blue rockfish (S. mystinus; Adams and Howard, In review), pelagic juvenile cod and northern anchovy (Bradford 1992), and Pacific whiting (Hollowed 1992). The N_l^* were then summed over all lengths that occurred within each haul, yielding a haul-specific catch of each rockfish species sampled, corrected for variation in 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 and J. Bence)

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		
Cruise	Sweep	Index	SE	Lower	Upper	Back 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
			Sebastes crameri (darkblotched rockfish)			
8401	1	-2.08	0.16	-2.47	-1.68	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
9105	1	-2.23	0.07	-2.42	-2.05	0.01
9105	2	-2.06	0.14	-2.37	-1.74	0.03
9105	3	-2.24	0.06	-2.41	-2.07	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
			Sebastes entomelas (widow rockfish)			
8301	1	-2.20	0.10	-2.49	-1.91	0.01
8401	1	-0.45	0.60	-2.18	1.27	0.66
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	-1.83	0.23	-2.39	-1.28	0.06
9005	2	-1.79	0.18	-2.21	-1.37	0.07
9005	3	-2.12	0.10	-2.35	-1.89	0.02
9105	1	-2.20	0.07	-2.37	-2.03	0.01
9105	2	-1.26	0.26	-1.81	-0.71	0.19
9105	3	0.78	0.39	-0.07	1.62	2.25
			Sebastes flavidus (yellowtail rockfish)			
8301	1	-2.12	0.12	-2.46	-1.78	0.02
8401	1	-0.63	0.53	-2.04	0.77	0.51
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	-2.03	0.13	-2.32	-1.73	0.03
9005	2	-1.74	0.22	-2.45	-1.02	0.08
9005	3	-2.08	0.13	-2.37	-1.79	0.03

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	-1.91	0.17	-2.27	-1.56	0.05
9105	2	-1.00	0.27	-1.56	-0.44	0.28
9105	3	0.19	0.32	-0.48	0.86	1.17
9206	3	-2.24	0.06	-2.41	-2.06	0.01
		Sebastes goodei (chilipepper)				
8401	1	-0.48	0.44	-1.63	0.67	0.58
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
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	-2.12	0.10	-2.35	-1.89	0.02
9105	2	-1.55	0.21	-2.01	-1.09	0.12
9105	3	-0.89	0.28	-1.48	-0.30	0.33
9206	3	-1.77	0.17	-2.14	-1.39	0.07
		Sebastes hopkinsi (squarespot rockfish)				
8401	1	-1.14	0.44	-2.19	-0.09	0.25
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
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

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

Cruise	Sweep	Index	SE	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Back Transform
8904	3	-2.06	0.10	-2.33	-1.79	0.03
9003	1	-2.27	0.03	-2.35	-2.20	0.00
9005	1	-1.87	0.24	-2.49	-1.25	0.06
9005	3	-2.22	0.08	-2.44	-2.01	0.01
9105	2	-2.18	0.09	-2.45	-1.90	0.01
9105	3	-1.36	0.18	-1.76	-0.97	0.16
9206	3	-1.71	0.19	-2.12	-1.31	0.08
		<u>Sebastes</u> <u>jordani</u> (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	-1.56	0.05
9005	1	-0.16	0.40	-1.03	0.72	0.83
9005	2	-0.79	0.31	-1.43	-0.15	0.38
9005	3	-1.88	0.19	-2.31	-1.46	0.05
9105	1	-1.55	0.23	-2.05	-1.05	0.12
9105	2	-0.72	0.26	-1.27	-0.16	0.41
9105	3	1.54	0.34	0.83	2.24	4.82
9206	3	-0.64	0.36	-1.54	0.25	0.46
		<u>Sebastes</u> <u>levis</u> (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

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	1	-2.22	0.09	-2.44	-1.99	0.01
8904	2	-2.21	0.10	-2.47	-1.94	0.01
		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
9005	1	-2.21	0.07	-2.36	-2.05	0.01
9005	2	-2.16	0.11	-2.51	-1.81	0.02
9105	1	-2.21	0.09	-2.51	-1.91	0.01
9105	2	-2.16	0.10	-2.42	-1.90	0.02
9105	3	-1.41	0.24	-1.92	-0.90	0.15
		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
		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

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	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	-1.56	0.24	-2.08	-1.04	0.12
9005	2	-2.07	0.16	-2.49	-1.66	0.03
9105	1	-1.84	0.14	-2.16	-1.52	0.06
9105	2	-1.56	0.20	-2.00	-1.12	0.11
9105	3	-1.12	0.30	-1.74	-0.49	0.24
		Sebastes pinniger (canary rockfish)				
8401	1	-0.60	0.52	-2.03	0.84	0.53
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
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	-1.83	0.02
9005	2	-2.15	0.11	-2.43	-1.86	0.02
9005	3	-2.24	0.07	-2.52	-1.95	0.01
9105	1	-1.67	0.16	-2.01	-1.34	0.09
9105	2	-0.41	0.27	-0.99	0.16	0.59
9105	3	0.34	0.27	-0.23	0.90	1.35

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
			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
			Sebastes saxicola (stripetail rockfish)			
8401	1	-1.42	0.34	-2.47	-0.37	0.16
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
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	-2.16	0.00
9005	1	-1.83	0.17	-2.20	-1.45	0.06
9005	2	-2.25	0.05	-2.39	-2.11	0.01
9105	1	-2.05	0.10	-2.27	-1.82	0.03
9105	2	-1.15	0.22	-1.61	-0.68	0.23
9105	3	-1.38	0.21	-1.82	-0.93	0.16
9206	3	-2.24	0.07	-2.42	-2.05	0.01
			Sebastes wilsoni (pygmy rockfish)			
8401	1	-2.08	0.17	-3.09	-1.06	0.03
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	-2.10	0.01
8904	3	-2.19	0.08	-2.39	-1.99	0.01
9005	1	-2.04	0.09	-2.23	-1.84	0.03

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
9005	2	-2.26	0.04	-2.37	-2.15	0.00
9105	1	-2.13	0.10	-2.37	-1.88	0.02
9105	2	-1.70	0.17	-2.06	-1.34	0.08
9105	3	-1.81	0.14	-2.11	-1.52	0.06
			PCA "entomelas" group			
8301	1	-2.11	0.13	-2.48	-1.73	0.02
8401	1	0.36	0.69	-1.47	2.19	1.71
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	-2.20	0.00
9005	1	-0.96	0.33	-1.67	-0.26	0.30
9005	2	-0.87	0.32	-1.59	-0.16	0.34
9005	3	-1.77	0.16	-2.12	-1.42	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	2.39	5.60
9206	3	-1.68	0.19	-2.10	-1.27	0.09
			PCA "jordani" group			
8301	1	-1.64	0.36	-2.49	-0.79	0.11
8401	1	2.04	0.70	-0.09	4.17	9.75
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

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	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	-1.73	0.18	-2.14	-1.33	0.08
9005	1	0.58	0.35	-0.21	1.36	1.79
9005	2	-0.55	0.33	-1.25	0.15	0.51
9005	3	-1.82	0.20	-2.26	-1.38	0.07
9105	1	-0.70	0.25	-1.23	-0.18	0.41
9105	2	1.00	0.27	0.45	1.55	2.71
9105	3	2.24	0.31	1.61	2.87	9.78
9206	3	-0.44	0.37	-1.34	0.45	0.59
			Total Sebastes spp.			
8301	1	-1.57	0.36	-2.42	-0.71	0.12
8401	1	2.43	0.74	0.13	4.73	14.85
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	9.02
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	-1.72	0.18	-2.13	-1.32	0.08
9005	1	0.88	0.33	0.15	1.62	2.46
9005	2	0.04	0.35	-0.68	0.77	1.01
9005	3	-1.36	0.23	-1.85	-0.86	0.16
9105	1	-0.32	0.28	-0.92	0.27	0.65
9105	2	1.50	0.30	0.87	2.13	4.59
9105	3	3.00	0.29	2.40	3.61	20.90
9206	3	-0.38	0.38	-1.28	0.52	0.64

Seasonal and Annual Trends in the Abundance of Pelagic Juveniles

Since 1986 the midwater trawl survey has been replicated anywhere from 3-4 times per year. In every year since, there have been three sweeps conducted during the May-June cruise. In addition, in 1987, 1988, and 1990 a single sweep was completed in April (Table 1). Results presented in Figure 4 show that the availability of pelagic juvenile rockfish typically peaks during late May and early June. However, it is noteworthy that in both 1991 and 1992 (the last two years of the survey) the abundance of pelagic juveniles was at its maximum during the third sweep of the May-June cruise. In fact, no Sebastes larger than 25 mm SL were taken at any of the standard trawl stations during the first two sweeps of DSJ-9206.

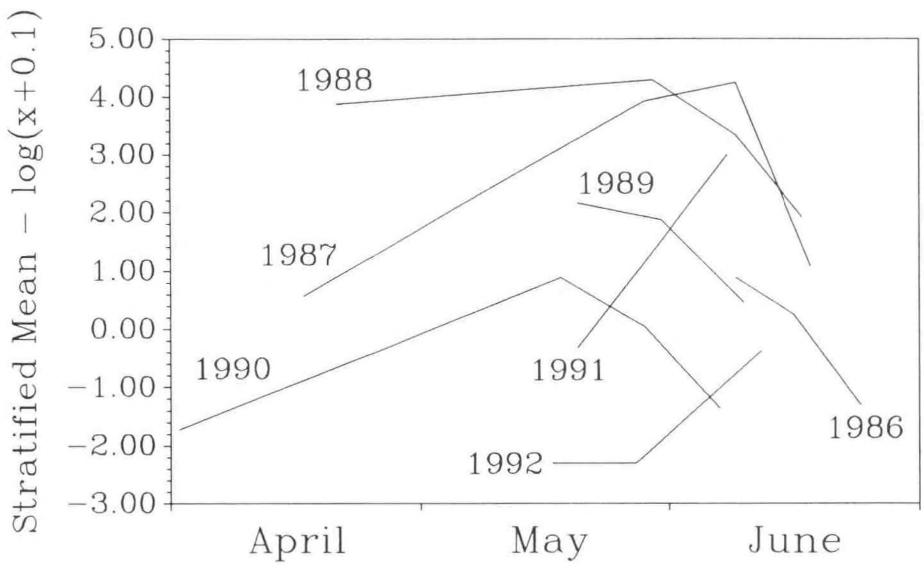

Figure 4. Seasonal abundance patterns of "Total Sebastes spp." in midwater trawl catches.

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 in 1992 abundances of the 15 most commonly sampled Sebastes spp. were at very low levels (Fig. 5). As has been the case since the inception of these surveys, catches of S. jordani 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 (10 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 1992 according to: $Z_{sy} = (I_{sy}-\mu_s)/\sigma_s$. Standard scores were calculated for the 10 most abundant species

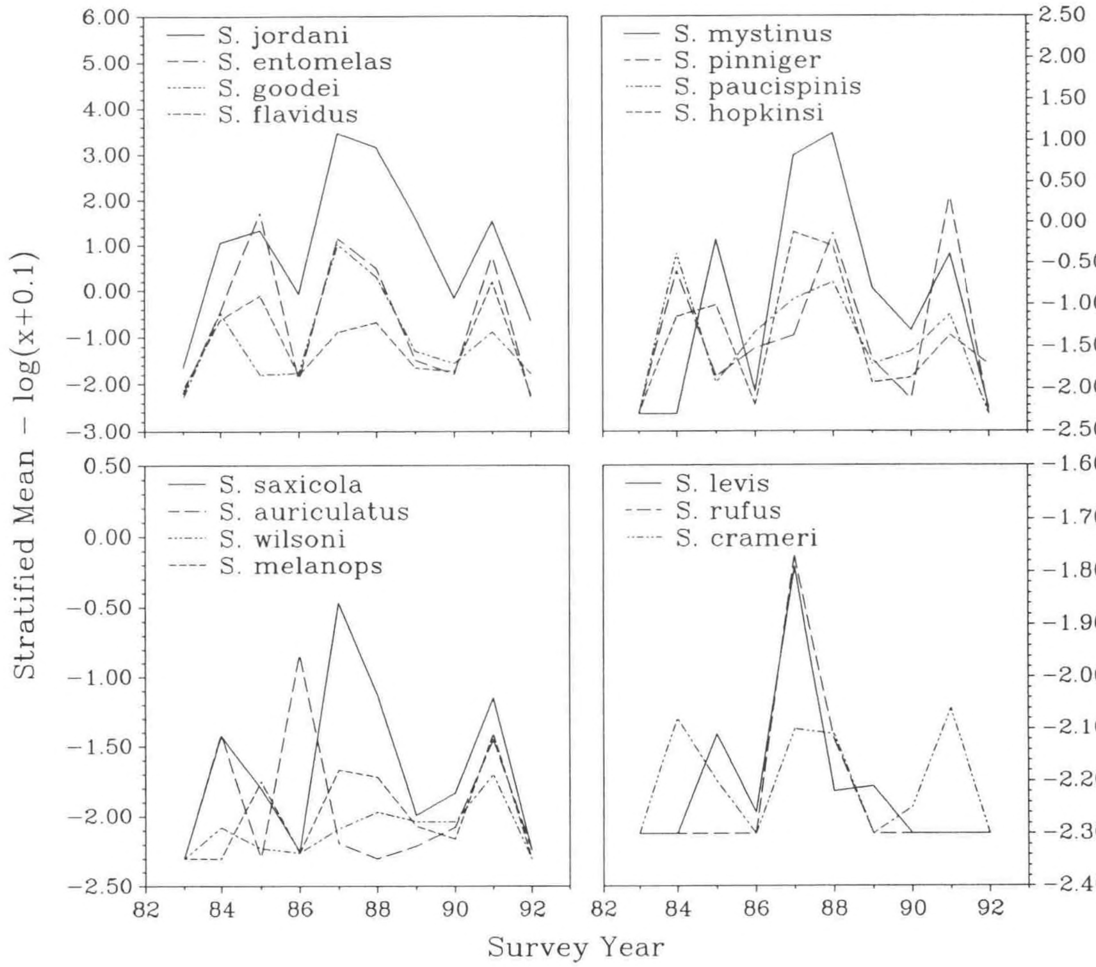

Figure 5. Annual (1983-92) estimates of pelagic juvenile relative abundance for species of Sebastes taken by midwater trawl.

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. 5) and four are uncommon (S. wilsoni, S. levis, S. rufus, and S. crameri). Results are plotted against survey year in Figure 6. A comparison of these data with the identical but unadjusted statistics presented last year (Fig. 3; Adams 1992) reveals substantially the same interannual trends in abundance. This is due to the fact that in years where fish are abundant they are also large and vice versa (see Figs. 1 & 5). Thus, the effect of the length composition adjustments is to accentuate differences already apparent in the time series.

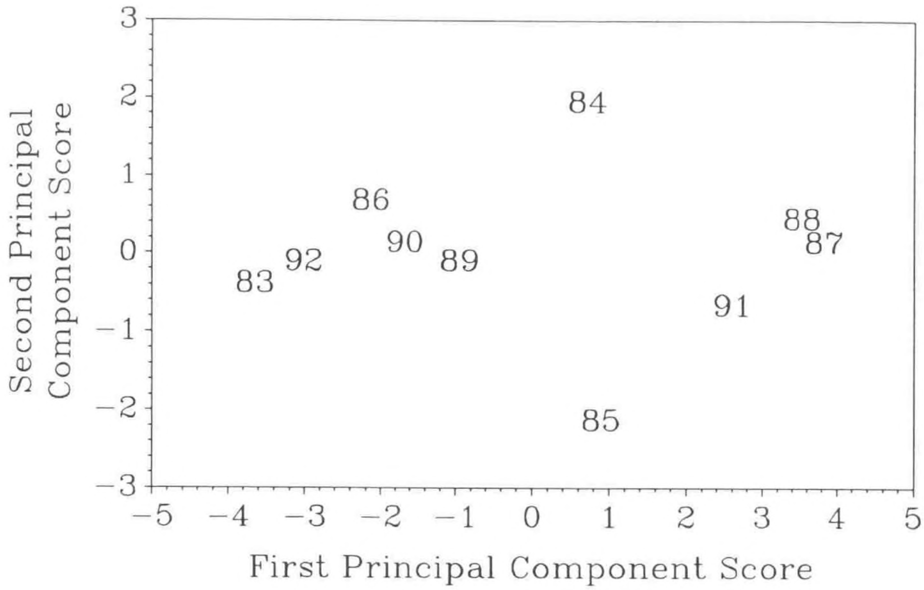

Figure 7. Yearly scores of pelagic YOY abundance plotted on the first two principal components.

1992). It is possible that the wide separation of the data along the second component axis for 1984 and 1985 is due to inadequate sampling replication (see Fig. 5). (S. Ralston)

Spatial Distribution of Aged Larval Shortbelly Rockfish

Since 1991 the Groundfish Analysis Investigation has been engaged in a pilot study to evaluate the egg production method as a fishery-independent means of assessing the spawning biomass of shortbelly rockfish (*Sebastes jordani*) inhabiting waters off the central California coast. While the primary goal of the project has been to develop a stock assessment tool, new information on rockfish recruitment is coming to light as a result of this work.

Specimens for the study were collected aboard the *David Starr Jordan* using a 505 µm mesh bongo net during February 6-19, 1991. Stations were located between Cypress Point and Point Reyes, with a tighter grid spacing near Pioneer and Ascension Canyons; these two areas often harbor large numbers of adult shortbelly rockfish. Field collection methods followed those developed by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) except that tows were made no deeper than 141 m, which is shallower than the 212 m maximum depth sampled on CalCOFI cruises. Over 17,000 *S. jordani* were collected, of which over 2,000 were aged. The number of fish captured ranged from 0 to > 2,000 per station. The catch of larval shortbelly rockfish was subsampled and a maximum of 50 fish were aged from each station.

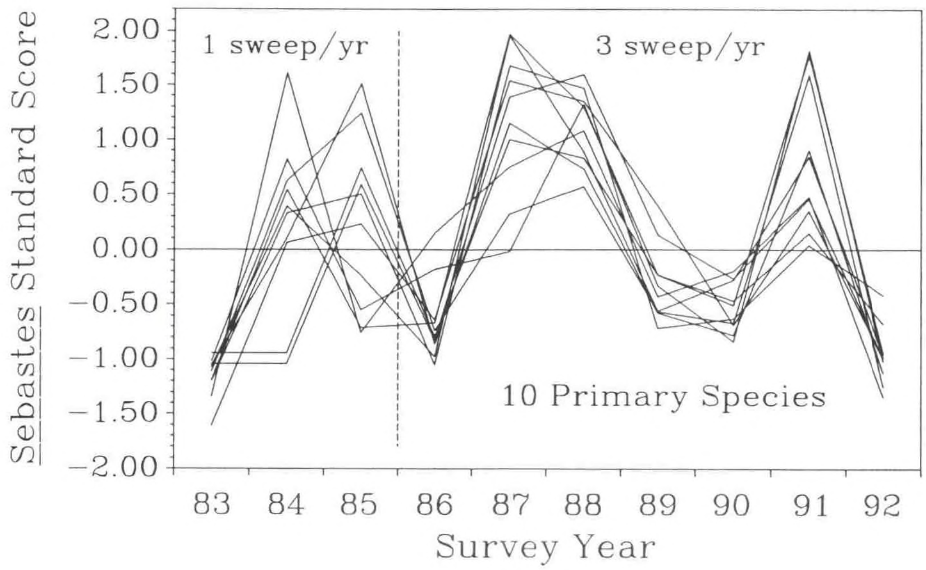

Figure 6. Normalized relative abundance trends for each of the 10 most commonly caught species of pelagic juvenile rockfish.

Note that for the principal subset of 10 species, 1983 (a strong El Niño year) had very low levels of abundance, as did 1986, which was a mild El Niño year. Conversely, 1987 and 1988 were very good years for virtually all of these species. As predicted in last year's recruitment report (Adams 1992), after correcting for differences in length structure, 1989 produced catches marginally better than 1990. 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. 5).

Results from the past year (1992) indicate it was one of the lowest years of pelagic juvenile rockfish abundance on record and it too has been characterized as an El Niño. It would seem, from the data collected thus far, that the reproductive success of these winter-spawning Sebastes spp. is poor during El Niño years.

There is extensive covariation in pelagic juvenile abundance patterns among the 10 species of rockfish plotted in the figure. For example, of the 90 possible pairwise combinations among the 10 species, the correlation coefficients between recruitment time series are positive in all cases. Likewise, principal components analysis of these data (species as variables, years as cases) revealed that the first principal component accounted for 73% of the variation among all 10 species-specific time series (λ_1 = 7.34) and the second component accounted for an additional 11% (λ_2 = 1.08). When annual scores on the first two principal components are plotted (Fig. 7), 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

Movements of larvae were tracked by mapping the distribution of different age cohorts. Examination of the average age at each station revealed a locus of young fish along the upper edge of the continental slope between Half Moon Bay and Santa Cruz; age generally increased with distance from this region (Fig. 8).

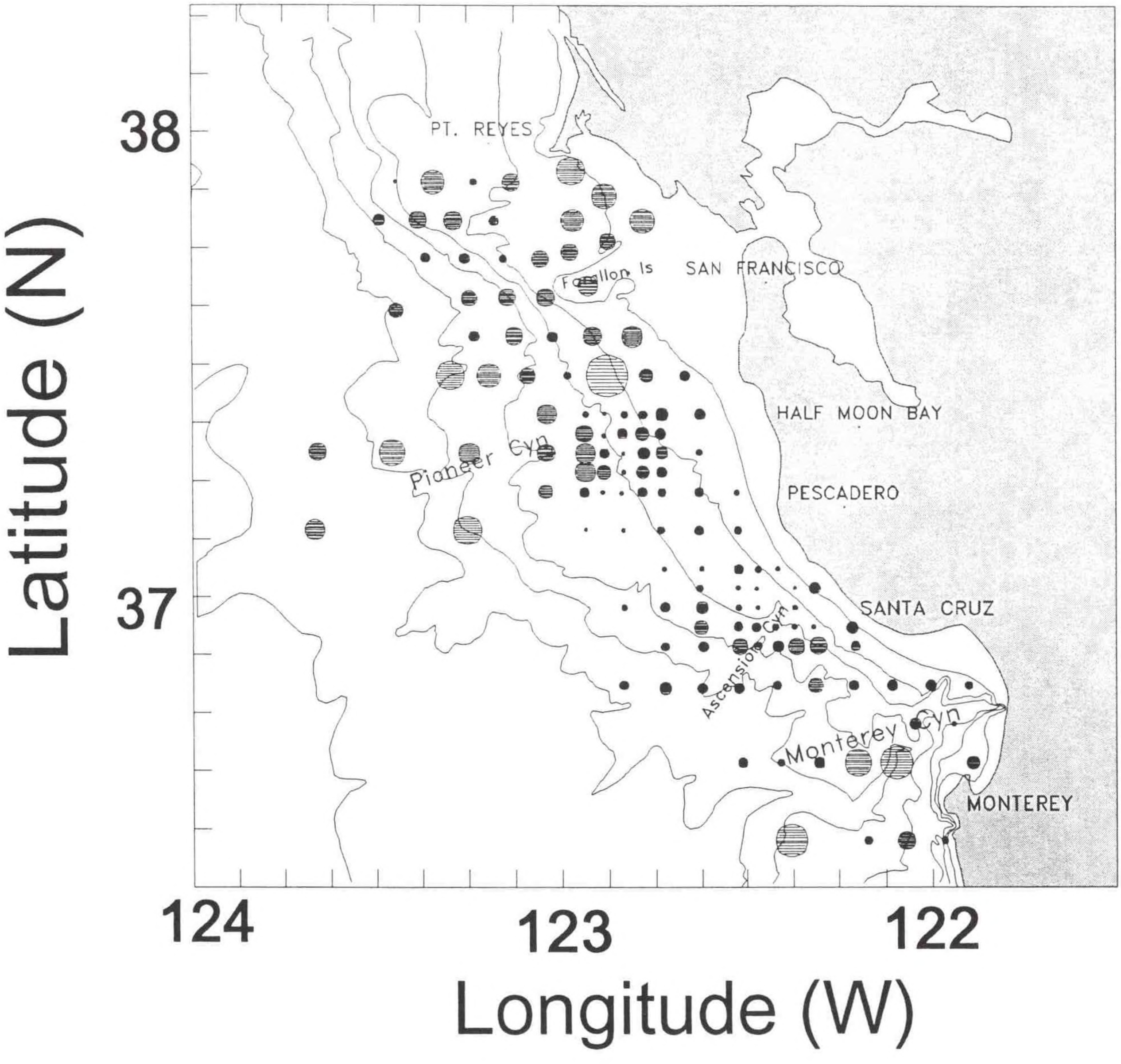

Figure 8. Locations of sampling stations relative to topographic features. Bottom contours from shallow to deep are 55, 90, 180, 900, 1800, 2750, and 3600 m. Station symbol sizes are proportional to the mean age of larvae collected at the station.

To further describe larval movement, stations were grouped into seven depth categories and the mean fish age from each category was plotted (Fig. 9). The youngest fish were found in water 120 to 300 m deep while the oldest fish were in less than

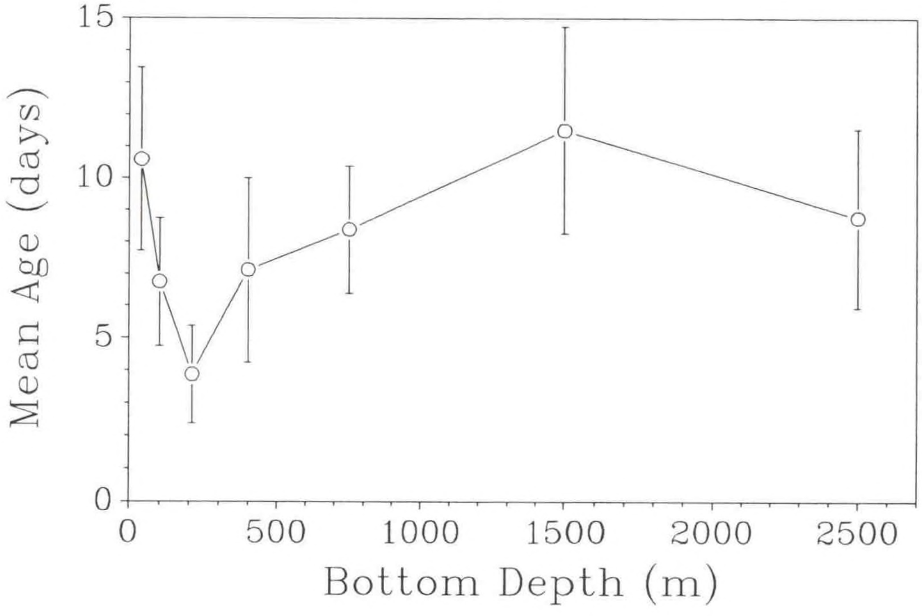

Figure 9. Average age (± standard error) of shortbelly rockfish at each of seven depth categories.

80 m (Gulf of the Farallons) or over 1,000 m (off the continental shelf). To examine latitudinal patterns the study area was subdivided into thirds and a two-factor ANOVA was performed on latitude and depth. This analysis showed effects of both depth and latitude ($p < 0.05$), with an insignificant depth by latitude interaction. Statistically younger fish were found in the middle latitude in the 120-300 m depth category.

Another method for visualizing larval movement is to map the distributional centroids of different age classes (Kendall and Picquelle 1990). Distributional centroids show the mean location of different age classes weighted by the number of larvae and the area represented by each station (closely spaced stations were assigned smaller areal weighting factors). Centroids were calculated for six age classes and plotted on a base map of the study area (Fig. 10). The map illustrates the general movement of fish offshore and in a northerly direction as they developed. It also suggests that some larvae remain in the area where they were extruded for nearly a month.

These observations confirm earlier observations, based on work with juvenile and adult _S. jordani_, that the area between Cypress Point and Point Reyes is a center of spawning activity and that submarine canyons along the continental shelf break are particularly important nursery areas.

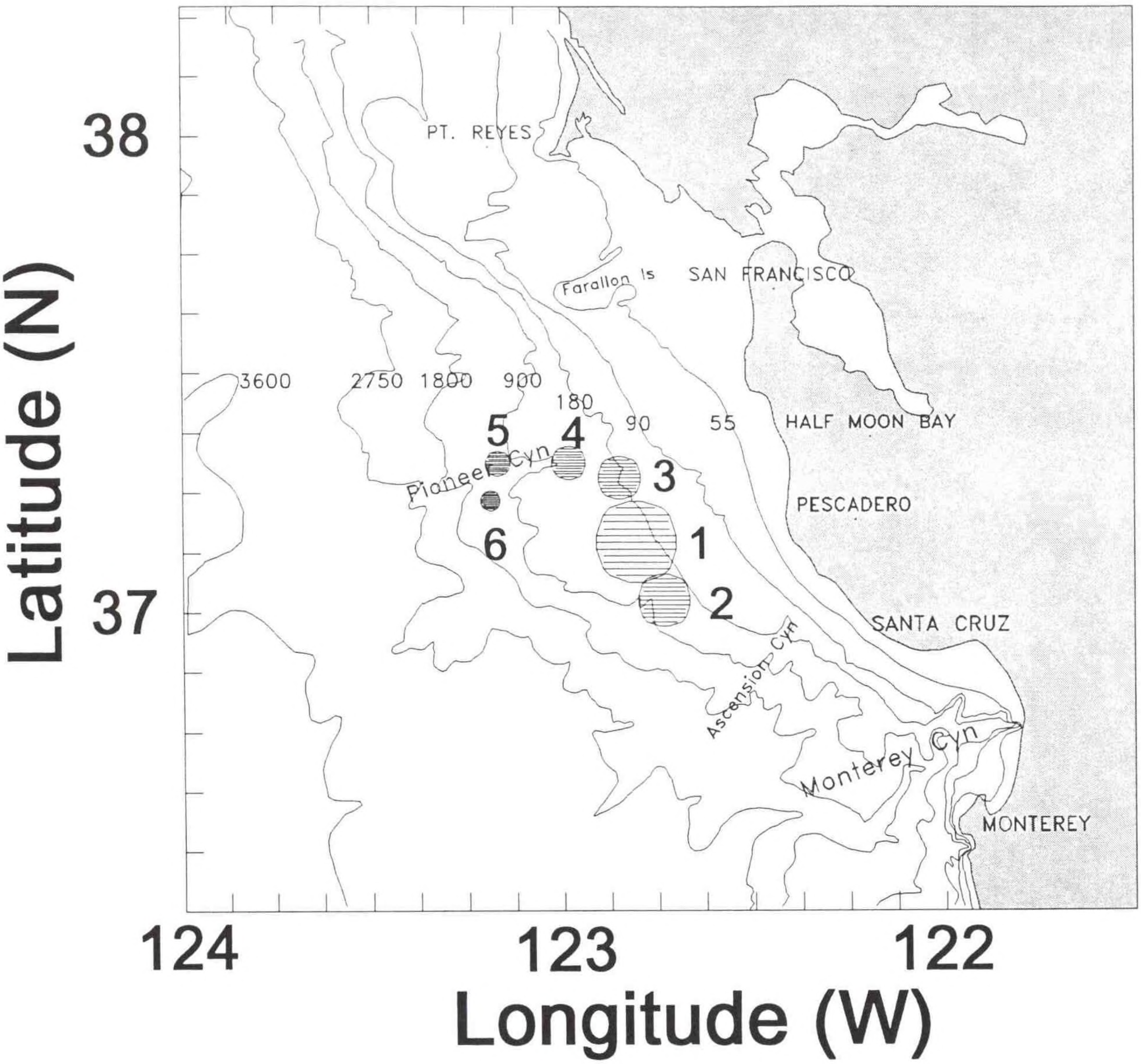

Figure 10. Distributional centroids depicting the mean locations of age (d) classes: 1=0-1, 2=2-5, 3=6-10, 4=11-15, 5=16-20, 6=21+. Symbol sizes are proportional to the number of fish in each age class.

Most of the larvae observed were too small to be capable of swimming significant horizontal distances and are subject to the vagaries of local oceanographic phenomena. The primary movement of larvae is away from the spawning locus in all directions. Spring upwelling currents are an obvious mechanism that could be responsible for directed movement of larvae into deeper water. Additionally, eddies which can trap and transport fish larvae have been shown to persist in the study area (Schwing *et al.* 1991). (D. Roberts)

Progress in Estimating Year-Class Strength from the Composition of Predator Diet

The relative abundance of juvenile rockfishes in the pelagic environment from May to July has been assessed each year since 1980 based on their occurrence in the diet of the king salmon (Oncorhynchus tshawytscha). This year, for only the second time since the assessments began, no pelagic juvenile rockfish were found among the gut contents of this predator (Table 4).

Table 4.--Mean number of young-of-the-year juvenile rockfishes (Sebastes spp.) in the stomachs of king salmon from the Gulf of the Farallones, 1980-92 (N = the number of salmon in collections that contained juvenile rockfishes).

Year	N	All Species	S. jordani	S. entomelas
1980	144	0.88	0.35	-
1981	406	2.98	1.11	-
1982	374	2.20	0.79	-
1983	-	-	-	-
1984	456	1.26	0.43	0.01
1985	506	2.64	0.86	0.07
1986	141	0.75	0.10	0.02
1987	883	2.71	1.72	0.06
1988	993	4.07	2.28	0.03
1989	517	5.97	4.47	0.01
1990	153	0.31	0.23	0.01
1991	637	0.93	0.14	0.11
1992	-	-	-	-

It is significant that the one other time this occurred (1983) was the year of the last major El Niño. This last year was also similar to 1983 in that the salmon were relatively small, concentrated near shore, and had been feeding on anchovies. These findings were complicated, however, by a management restriction on the area offshore that could be fished for salmon. We do not believe this a problem, however, because the salmon were inshore during the entire sampling period, with no evidence that any of them entered the offshore closed area. A similar inshore distribution was observed during the 1983 El Niño when there was no closure. (P. Adams and Kelly Silberberg)

STUDIES OF POST-PELAGIC JUVENILES

Progress in Visual Assessment of Juvenile Rockfishes in Near-Shore Habitats

The rockfish recruits monitored in near-shore habitats on the Mendocino and Sonoma coasts continued to be dominated by two species, the yellowtail rockfish (Sebastes flavidus) and the blue rockfish (S. mystinus), but at both sites the 1992 assessments noted exceptionally few recruits (Tables 5 and 6). There were fewer at the Mendocino location this year than during any other year since assessments began there in 1983, during an earlier El Niño. Similarly, the 1992 counts at the Sonoma sites, along with the similarly low 1990 counts there, indicated these to be the two weakest recruitment years since assessments began there in 1984. (E. Hobson, D. Howard, and J. Chess)

COMPARISON OF ANNUAL ESTIMATES OF YEAR-CLASS STRENGTH

Results given in Tables 3 and 6 present estimates of year-class strength for species of rockfish from 1984-92. These data afford the opportunity to compare and contrast recruitment indices that are based on different sampling strategies (midwater trawl versus diver counts) and different life history stages (pelagic versus settled YOY juvenile). Note that the trawl data are compared with the diver data set from Sonoma County, which is situated nearer to the midwater trawl survey area (Monterey-Marin Counties) than is Mendocino County.

Over the period 1984-92, annual abundance estimates of YOY juvenile rockfish from these two methods are in good agreement for S. flavidus and S. mystinus (Fig. 11). S. melanops, however, does not conform as closely. This is probably due to: (1) its overall scarcity in both data sets, (2) difficulty in identifying this species during the early pelagic juvenile stage (see Adams 1992), (3) its occurrence in settled juvenile habitats that are not well sampled during diver surveys (i.e., shallow water), and (4) its more northerly distribution.

These data suggest that trawl and diver assessments of YOY juvenile abundance track natural variability in the reproductive success of Sebastes spp. and serve to confirm and validate these census techniques. (S. Ralston and D. Howard)

Table 5.--Mean number (standard error in parenthesis) of young-of-the-year juveniles counted/minute off the Mendocino coast during August and September. n=number of one minute assesements.

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
S. flavidus	0.00 (0.00)	6.58 (2.29)	115.60 (21.26)	6.01 (1.50)	102.66 (11.08)	59.47 (10.23)	1.29 (0.35)	1.93 (0.90)	8.14 (3.04)	0.09 (0.05)
S. mystinus	0.27 (0.09)	1.49 (0.30)	70.56 (15.32)	7.83 (1.88)	181.04 (26.19)	75.89 (10.18)	6.08 (0.94)	0.76 (0.17)	0.64 (0.16)	0.26 (0.06)
S. melanops	0.41 (0.14)	0.31 (0.08)	4.34 (1.54)	9.52 (2.08)	7.58 (1.24)	5.94 (1.35)	3.14 (0.59)	0.84 (0.29)	1.22 (0.30)	0.01 (0.01)
Total	0.68 (0.19)	8.38 (2.33)	190.50 (29.82)	23.35 (3.91)	291.67 (33.99)	141.29 (16.88)	10.49 (1.44)	3.53 (1.05)	10.00 (3.05)	0.36 (0.09)

Table 6.--Mean number (standard error in parenthesis) of young-of-the-year juveniles counted/minute off the Sonoma coast during August and September. n=number of one minute assessments.

Species	1984 n=57	1985 n=50	1986 n=103	1987 n=112	1988 n=62	1989 n=186	1990 n=100	1991 n=79	1992 n=40
S. *flavidus*	4.39 (1.48)	135.17 (26.00)	6.73 (2.29)	89.39 (18.42)	39.92 (7.94)	1.54 (0.42)	0.12 (0.05)	38.33 (6.40)	0.49 (0.29)
S. mystinus	4.89 (1.29)	117.63 (19.50)	15.27 (3.81)	328.05 (52.15)	175.06 (16.76)	7.19 (0.93)	0.66 (0.12)	13.58 (1.82)	1.01 (0.25)
S. melanops	1.63 (0.52)	4.40 (1.17)	3.00 (1.31)	4.48 (1.70)	6.40 (1.95)	1.66 (0.39)	1.03 (0.42)	1.92 (5.18)	0.00 (0.00)
Total	10.91 (2.12)	257.20 (35.38)	24.97 (5.17)	421.92 (66.72)	221.38 (22.55)	10.39 (1.34)	1.81 (0.48)	57.09 (7.73)	1.50 (0.40)

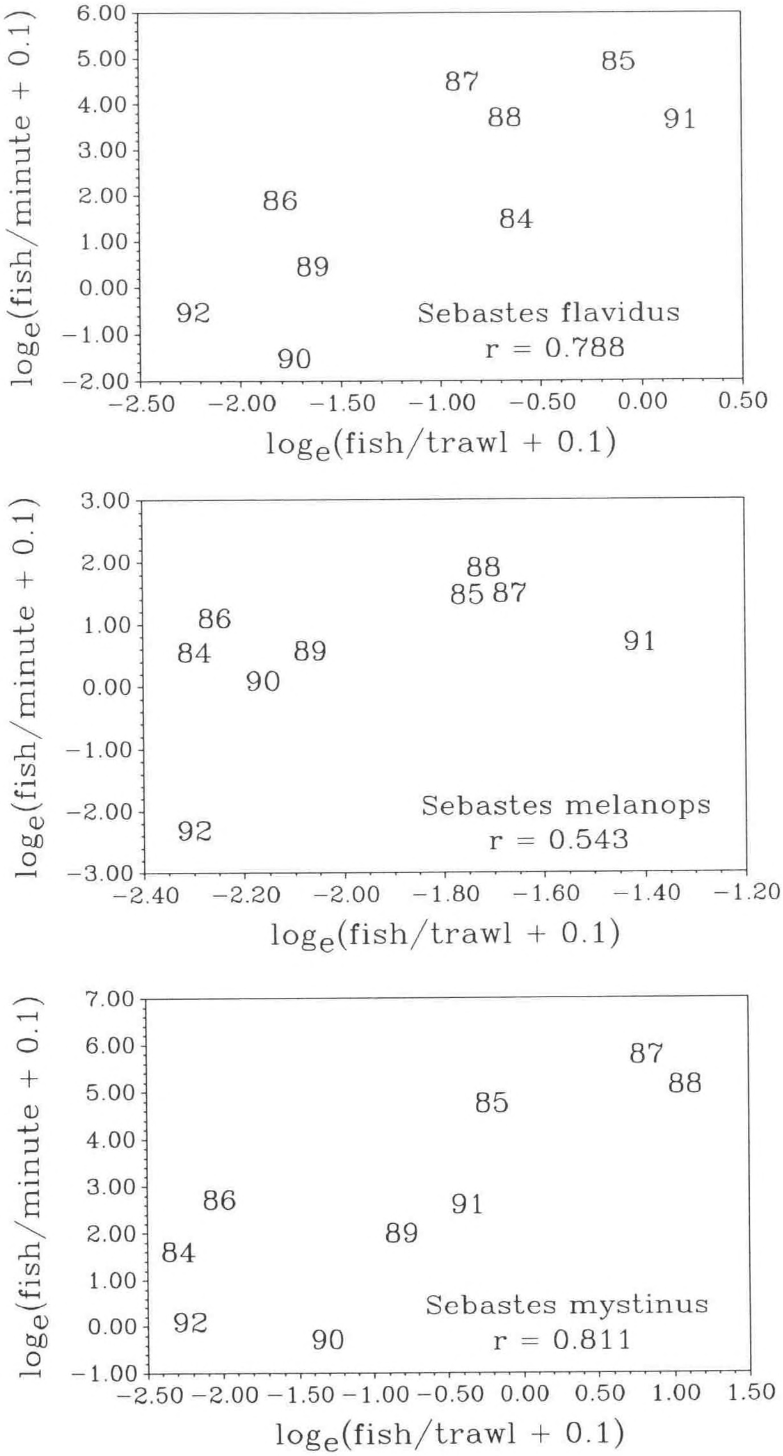

Figure 11. Comparison of annual estimates (1984-92) of rockfish year-class strength based upon midwater trawl catch rates (abscissa) and the numbers of recently settled YOY encountered during SCUBA surveys along the Sonoma coast (ordinate).

STUDIES OF ADULTS

Progress in Studies of Adult Sebastes mystinus

The 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 the adults has been studied since November 1987. Results through February 1992, presented in last year's Recruitment Report (Adams 1992), showed that the physical condition of adult females during the January-February spawning season is strongly influenced by feeding conditions during the previous summer and fall. There also were indications, up to that time, that recruitment to the nearshore habitats during the following spring-summer is influenced as well. However, this last relationship failed to hold during the 1992 recruitment season. Despite reasonably good feeding conditions during the summer-fall of 1991, followed by reasonably good physical condition of spawning females during the December 1991-February 1992 spawning season, the 1992 year-class proved to be among the weakest we have measured. This result is consistent with our opinion that other factors are involved in determining relative success of recruitment.

Based on occurrences of empty guts and relative gut fullness, one would conclude that feeding conditions during summer-fall of 1992 were the poorest of the past five years (Fig. 12). In terms of diet quality, however, 1992 was superior to both 1989 and 1990 when plant materials dominated among the gut contents. Although plant materials are important foods of the blue rockfish, nourishment comes from only a small portion of the ingested material. Despite the lower volume of materials ingested during 1992, the proportion of quality foods was much higher that year. The "other" category in the 1992 column in Figure 12 consisted mainly of crustacea.

Our measurements of physical condition (Fig. 13) have been defined in previous reports. The visceral fat ranking is a subjective visual assessment on a relative scale (1-5), whereas the liver condition and soma condition (with soma defined as body less viscera and gonads) are represented by Fulton's Condition Factor ($K=weight/length^3$). We were unable to measure these quantities during late fall and winter of 1992, however, as unusually severe weather prevented us from collecting specimens. Our evaluation, therefore, comes from an incomplete record based on specimens collected earlier (Fig. 13). This somewhat tentative assessment suggests a state of physical condition intermediate between the two poor years and the two somewhat better years. (E. Hobson, J. Chess, and D. Howard)

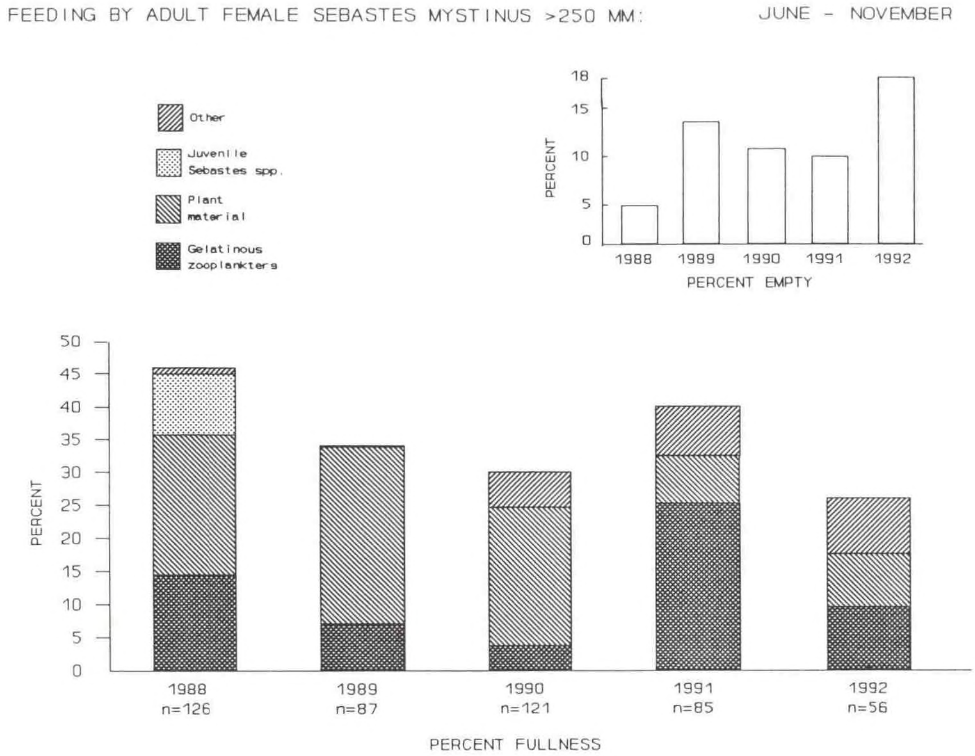

Figure 12. Feeding by adult female S. mystinus (June-November).

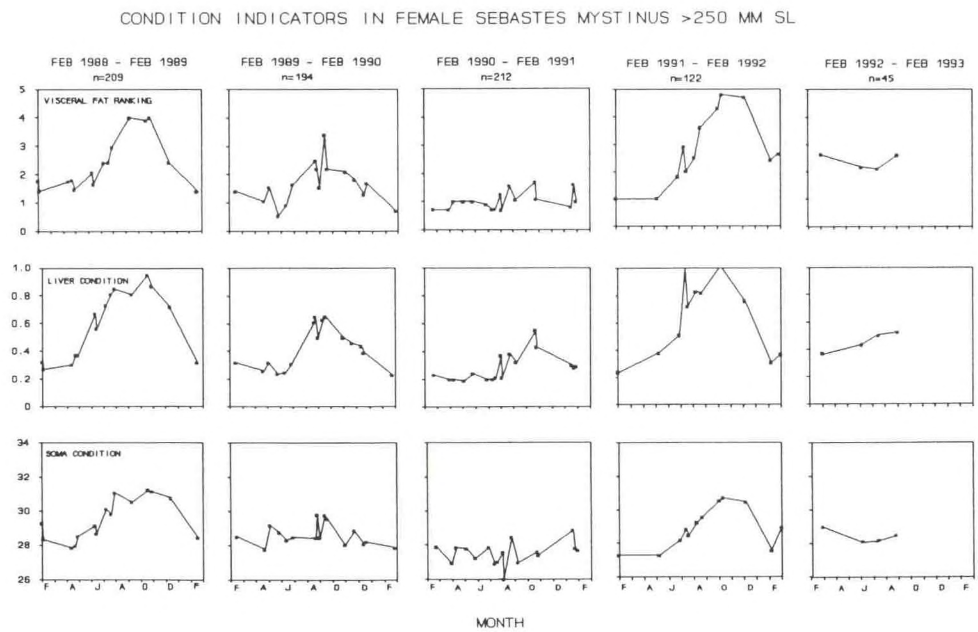

Figure 13. Condition indices in female S. mystinus > 250 mm SL.

Progress in Studies of Adult Sebastes flavidus

Many related factors, including physiologic condition, nutritional state, disease, and parasites, affect survival, growth, and reproduction in rockfishes. Their influence can be observed interannually, seasonally, among populations and species, and between life stages. During the 1992-93 research season, seven continuous years of study on yellowtail rockfish from Cordell Bank, California, were completed. Previous recruitment reports have presented findings of these studies. This report presents additional results from these long-term studies in the areas of maternal-embryonic nutrition and juvenile YOY abundance, geographic differences in reproductive effort, and the rates of embryonic and larval development during gestation.

Nutritional Aspects of Reproduction: The Relationship Between Maternal-Embryonic Nutritional Dynamics and Juvenile Abundance

The abundance of larval and juvenile fish during the first few months of life in the environment is influenced by many factors. These factors may be categorized as maternal (originating within the female during development) and environmental (all physical and biological forces experienced after birth). The results of processes in both categories determine the survival of the year-class. It is reasonable to assume that newly-released larvae are more likely to survive the critical period of the first days to months in the environment, when they are most vulnerable to food scarcity and predation, if they are healthy and contain substantial energy stores. Further, the relative physiologic status of newly released larvae is a function of maternally supplied resources. This premise has been presented often in the published literature, yet has been tested or investigated little. This line of reasoning forms the basis of our investigation into the relationship between maternal nutritional dynamics associated with reproductive development and measures of juvenile abundance.

Previous reports have documented the nutritional dynamics (MacFarlane *et al.* 1993) and energy balance (Adams 1992) of reproduction in yellowtail rockfish (Sebastes flavidus) from Cordell Bank. In summary, nutritional stores in females, gained during the summer upwelling season, are mobilized to ovarian development during the late fall and winter. The energy and mass balances of oocyte and embryonic development indicated that yellowtail rockfish are situated near the lecithotrophic end of the viviparous continuum, but may have matrotrophic supplementation of structural lipids and proteins.

To study the relationship between maternal nutritional dynamics and juvenile abundance, variables associated with nutrient input to intraovarian embryos and estimates of juvenile yellowtail abundance were evaluated. Female yellowtail data are from seven annual reproductive cycles between 1985/86 and 1991/92. These data were organized into two subsets to discern the importance of the disparate feeding and ovarian development periods: the summer feeding period and during late vitellogenesis and gestation in the winter. Juvenile abundance estimates were from (1) trawl surveys during May and June in the Gulf of the Farallones by Groundfish Analysis (Adams 1992; Ralston, pers. comm.) and (2) visual observations on the Sonoma and Mendocino coasts during August and September by Groundfish Communities (Adams 1992; Chess, pers. comm.).

Maternal variables which may be related to embryonic physiologic status correspond to measures of maternal energy storage (e.g., mesenteric fat index [MFI], liver mass [LSI], liver lipid concentration), concentrations of nutrients in maternal serum during reproductive development (lipids, protein, calcium [indicator of vitellogenin]), and accumulation of energetic and structural components in the ovaries during later stages of oocyte maturation and gestation. A selection of potentially significant maternal nutrition variables is presented in Table 7. Mean values of maternal energy storage and circulatory system transport, indicators of reproductive development, and ovarian

Table 7.--Mean values of female yellowtail rockfish (Sebastes flavidus) data used to assess relationship between reproductive nutritional dynamics and juvenile abundance.

			Year of Parturition				
	1986	1987	1988	1989	1990	1991	1992
Summer feeding							
MFI	0.91	0.75	1.25	1.86	0.62	0.19	0.65
LSI	2.16	2.32	2.45	2.72	2.11	1.80	2.29
Liver [Lipid] (mg/g)	--	--	262	447	359	283	--
Srm Triglyceride (mg/dl)	504	446	363	545	411	327	224
Srm Phospholipid (mg/dl)	687	731	686	883	737	632	585
Serum Protein (g/dl)	4.7	4.6	4.6	5.1	5.1	4.3	4.4
Serum Calcium (mg/dl)	16.1	15.4	15.3	15.6	16.1	14.2	13.4
N	33	60	65	18	38	79	41
Gestation							
GSI	10.0	9.1	9.0	--	8.7	10.1	11.9
Fecundity (x 10^3)	540	552	350	--	476	480	539
Ovary [Lipid] (mg/g)	--	--	66	--	130	131	132
Ovary [Protein] (mg/g)	--	--	198	--	177	166	159
Srm Triglyceride (mg/dl)	457	533	295	--	336	360	407
Srm Phospholipid (mg/dl)	614	744	602	--	524	734	650
Serum Calcium (mg/dl)	19.4	20.9	18.7	--	16.5	18.7	16.0
N	24	15	13	--	28	21	19

accumulation of organic components were variable among the seven years studied. Correlation analysis, however, revealed very little relationship to estimates of juvenile yellowtail rockfish abundance. Of 45 maternal variables assessed against juvenile abundance estimates from the Gulf of the Farallones, Sonoma, and Mendocino, only a few approached statistical significance ($\alpha = 0.05$). Perhaps the best relationships were found between serum

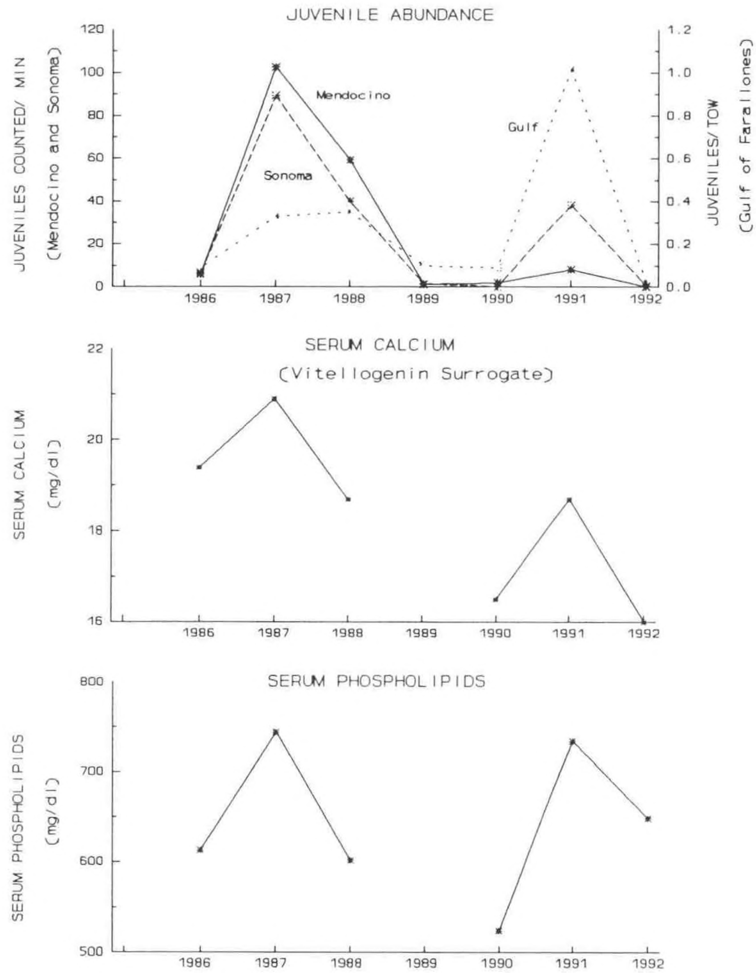

Figure 14. Mean estimates of juvenile yellowtail rockfish abundance, and serum concentrations of calcium (vitellogenin indicator) and phospholipids in gestating yellowtail rockfish. No data for maternal rockfish during 1989.

concentrations of phospholipids or calcium (vitellogenin) in gestating females and juvenile abundance in August and September on the Sonoma coast (Fig. 14). Pearson correlation coefficients and levels of significance between abundance estimates and serum phospholipids or calcium in pregnant females are:

	Phospholipids		Calcium	
Abundance estimate	r	P	r	P
Gulf of the Farallones	0.61	0.07	0.30	0.56
Mendocino	0.45	0.11	0.74	0.09
Sonoma	0.72	0.06	0.81	0.05

These correlations are not particularly strong, but are based on fairly small sample sizes (six years) and relate assessments separated temporally and spatially. Maternal values reflect physiological conditions in females from Cordell Bank in January to March, whereas the abundance estimates were made in May-June (Gulf of the Farallones) and August-September (Sonoma and Mendocino). Given the wide time span, number of years, and the disparate nature of the data, it is surprising that the correlations are as strong as they are. Further, it is interesting that phospholipids and the vitellogenin surrogate, Ca^{++}, the two variables with the best correlations to abundance estimates, are also the ones shown to remain elevated in maternal serum during gestation (relative to male serum and other nutrients in female serum during the same time interval) (Whipple 1991; MacFarlane *et al.* 1993). Matrotrophic input of serum phospholipids to embryos was shown in laboratory studies and, protein with molecular weight similar to vitellogenin from other teleosts, was also detected in pregnant females (MacFarlane, unpubl. data).

Taken together, these results may suggest that the extent of matrotrophy in a particular year may relate to the survivability of yellowtail rockfish early life stages. We believe, however, the variables of greatest potential significance to the physiologic energy status and health of progeny are protein and lipid distributions in gestating ovaries. At present, too little data are analyzed to evaluate their associations with juvenile abundance. Lipid and protein assessments (total, class analyses, image analysis of embryos) are to be performed on ovaries stored from the previous reproductive cycles and in future years.

Our research to date indicates that the Cordell Bank yellowtail rockfish population is adapted physiologically to compensate for variation in the temporal abundance of food. The population appears to have the capacity to supply energetic and structural components to embryos at any time during the annual cycle once oogonia initiate yolk accumulation. This mechanism provides an increased probability for maintaining high energy status of larvae at parturition, thus improving the likelihood of survival (MacFarlane *et al.* 1993).

The results of this study also indicate that environmental conditions during early life stages, and not parental factors, exert a dominating influence on the survival and year-class strength of yellowtail rockfish. (B. MacFarlane)

Comparison of Fecundity in Yellowtail Rockfish from California and Washington

The distribution of the commercially important yellowtail rockfish ranges from Alaska to southern California, but it is most abundant and commercially important from Oregon to British Columbia, Canada. In the early phases of our research on yellowtail rockfish, we examined fish from throughout its range and we found that more southern populations differed from northern populations in many life history traits. Generally, California yellowtail rockfish were older in average age, slower in growth, more heavily impacted by diseases and parasites, had less abundant mesenteric fat stores, and exhibited longer reproductive life spans than fish in coastal Washington waters.

Since measures of reproductive effort are critical to fishery science and management, we conducted a multi-year study to compare fecundities of Washington yellowtail rockfish with those of California fish. The Washington population is heavily impacted by commercial fishing and is now separately managed due to a decade of declining abundance. The California population, in contrast, is mostly a recreationally-fished population that has experienced low fishing pressure. From reproductive years 1988/89 to 1990/91, we collected and examined 308 adult female yellowtail rockfish from central Washington and compared their gravimetrically determined fecundities with those measured in 407 California fish taken from 1985/86 through 1991/92.

For geographic comparisons, data were pooled for all the years within each location, assuming that the observed patterns represented the natural variation occurring within each population. In earlier studies of temporal comparisons, we found that fecundity was asymptotically related to body length, somatic wet weight, and especially age. Thus, we divided fish into young (≤ 14 year) and old (≥ 15 year) categories for our analyses of geographic differences. As illustrated in Table 8 and Figure 15, Washington fish clearly were younger, larger, and generally more fecund than California fish. Data from all fish showed that while Washington fish averaged 11.9 years of age and 40.8 cm SL, California fish were 15.4 years and 36.3 cm SL.

Table 8.--Comparison of age (yr), somatic weight (g), standard length (cm), absolute fecundity (x 1000), and relative fecundity (no. eggs/g somatic wt.) of yellowtail rockfish from California (N = 407) and Washington (N = 308).

Variable	California		Washington	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Age	15.4	7.3	11.9	2.7
Somatic Weight	1,207	352	1,689	367
Standard Length	36.3	3.8	40.8	3.2
Absolute Fecundity	523.2	252.2	904.7	364.3
Relative Fecundity	416.1	121.7	496.7	146.2

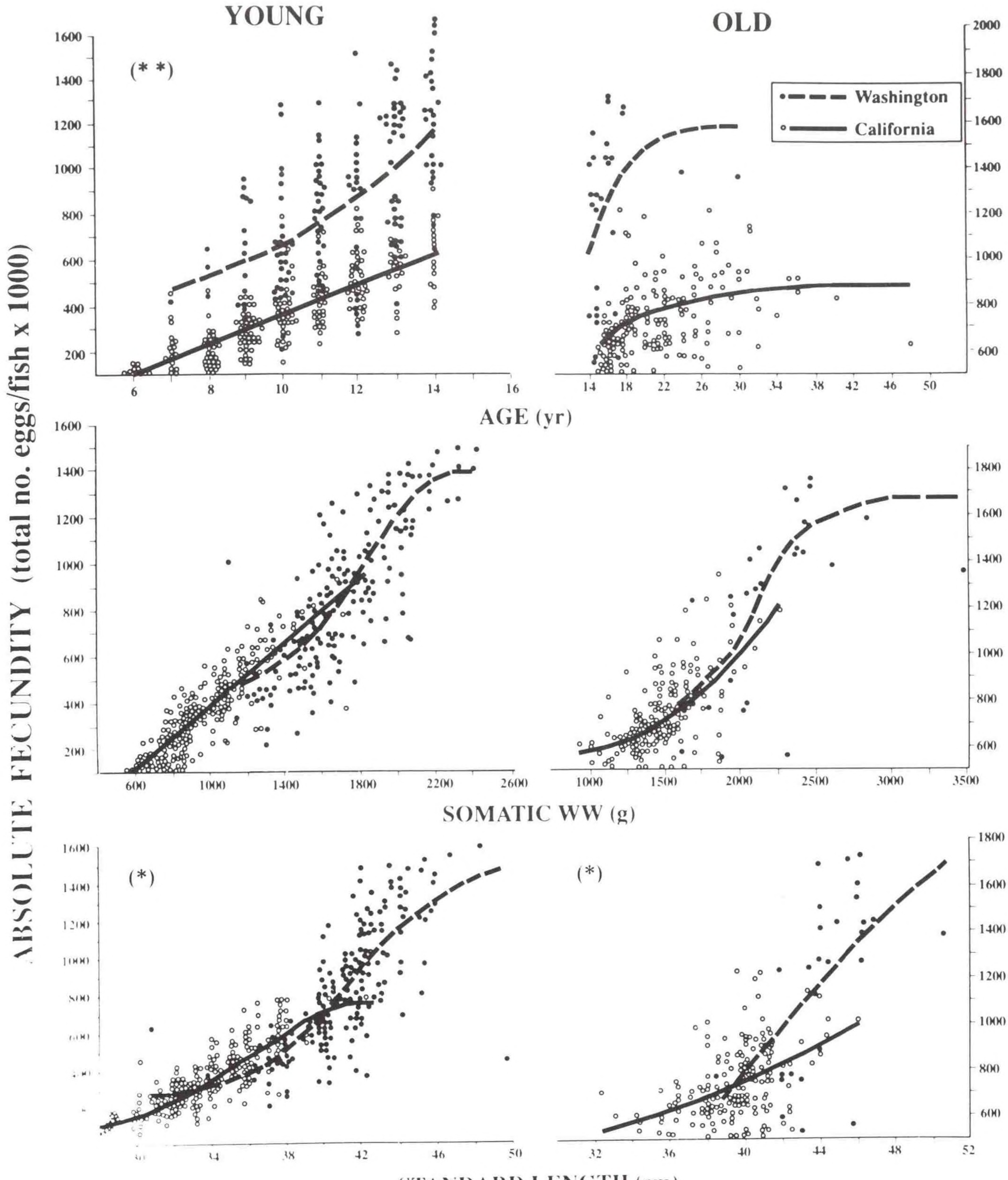

Figure 15. Absolute fecundities of young (≤ 14 yr) and old (≥ 15 yr) yellowtail rockfish from Washington (solid circles and hatched lines) and California (open circles and solid lines). Lines represent best-fit curves of respective data from the two locations. (** = P < 0.01; * = P < 0.05).

The mean absolute fecundity of Washington rockfish was 905,000 eggs/female versus 523,000 for California. Relative fecundities also showed Washington fish to be more productive (i.e., 416.1 versus 496.7 eggs/fish). Northern fish also were less variable in fecundity (coefficients of variation, 40.3% versus 48.2% for absolute fecundity).

Rate-specific patterns, when analyzed by analyses of covariance, indicated that young yellowtail rockfish displayed the most prominent geographic differences. The age-specific fecundities of Washington fish differed most from those of California fish ($P < 0.01$), while length-specific fecundities differed at the $P < 0.05$ level. Weight-specific fecundities were not significantly different. Older fish, in contrast, displayed much greater variability, less discernible patterns, and were significantly different ($P < 0.05$) only in length-specific fecundities.

These research findings have several implications for understanding differences in the reproductive life histories among different populations of rockfishes. First, age plays an important role in how fish respond to environmental conditions and how they allocate energetic resources to growth, maintenance, and reproduction. Second, there is some indication that senescence may occur in the reproductive output of these long-lived species. Lastly, younger yellowtail rockfish from the center of their distribution are more productive in absolute numbers of eggs and on a length-specific basis than their counterparts from the southern edge of their distribution. (M. Eldridge)

Rates of Development of Embryos and Larvae During Gestation in Yellowtail Rockfish

Sebastes species, including the yellowtail rockfish, share a unique reproductive life history in that their annual reproductive cycle includes internal fertilization, sperm storage, ovarian incubation of embryos and larvae, and varying degrees of viviparity. One of the problems facing researchers who attempt to estimate rockfish spawning biomass using the larval production technique is the lack of information on the time course required for embryonic and larval development, which is needed to estimate parturition dates. During the reproductive seasons (December-March) of 1990/91-1992/93 we conducted laboratory experiments on gestating yellowtail rockfish at the University of California Bodega Marine Laboratory, to determine these developmental rates.

Twenty-two previously inseminated adult yellowtail rockfish were collected by hook-and-line at the Cordell Bank seamount (~37 km from the coast) and transported live to 2,000 ℓ lab tanks. Fish were maintained at ambient water temperatures (10.3-14.1° C) and photoperiods. During this last year, a single female was maintained at a constant 10° C during gestation to determine the effect of low temperature on developmental rates. Oocytes were subsampled weekly by catheterization of anesthetized fish until fertilization was observed. After fertilization, developing embryos and larvae were subsampled at 1-4 day intervals until parturition. Staging was done with light microscopy of live specimens.

The sequence and time course of development for embryos and larvae displayed the following pattern:

Developmental Stage	Days Post-Fertilization
Newly fertilized oocyte	0
Germ disc formation	|
Early cell cleavage	↓
Morula	3
Blastula	|
Epiboly	↓
Gastrula	5
Embryonic shield	↓
Headfold formation	7
Optic vesicle	|
Somite formation	↓
Optic cups/Auditory vesicle	11
Otolith formation	↓
Retina pigmentation	18
Blood circulation;mouth & anus open	21
Yolk depletion	↓
Hatching	23
Yolk and oil globule depletion	↓
Parturition	29

The durations of significant developmental periods were estimated to cover the following time spans (d):

Developmental Period	Mean	S.D.	Range
Fertilization to hatching	22.7	1.2	21-24
Hatching to parturition	6.2	1.8	4-10
Fertilization to parturition	28.9	2.4	27-33

The effects of lower (i.e., 10° C) temperature on developmental rate were not apparent until later in embryonic development. The sequence and rate of morphological development appeared similar to those at warm temperatures until approximately the stage of retinal pigmentation (17 versus 18 days post fertilization). By hatching time, the cold-incubated embryos hatched two days later than the warm-incubated embryos (i.e., 25 versus 23 days fertilization to hatching). Further, this two-day delay was carried over to the time of parturition (31 versus 29 days). Based on these observations, it appears that developmental rates are influenced by water temperature during incubation and should be considered when precise and accurate estimates of parturition dates are needed. (M. Eldridge)

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