# SOUTHWEST FISHERIES SCIENCE CENTER

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# PROGRESS IN ROCKFISH RECRUITMENT STUDIES

By

Staff of the Tiburon Laboratory
Edited by Jeannette Whipple

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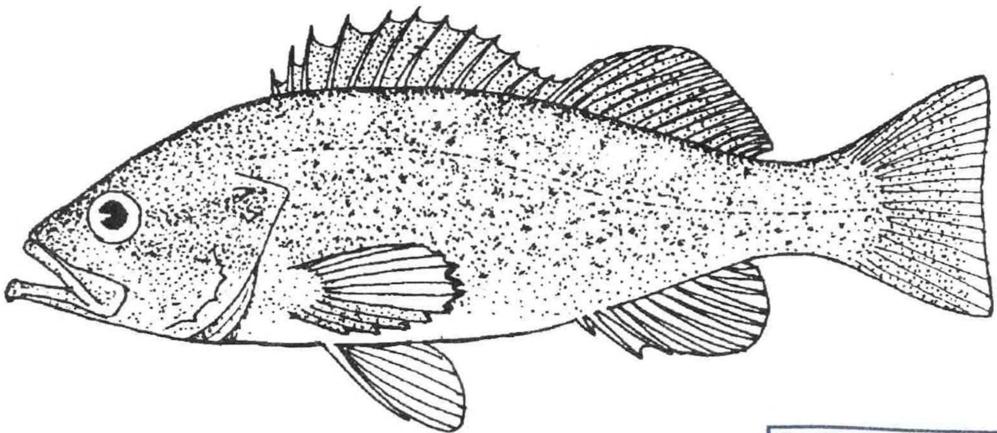



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## INTRODUCTION

Rockfishes (Sebastes sp.) make up a major portion of the groundfish fishery. As in other fisheries, year-classes vary in abundance resulting in problems for management. Understanding the causes of variation in recruitment presents a challenge to fishery scientists. The NMFS Tiburon Laboratory has been engaged in research designed to measure such variation early in the life cycle of rockfishes, and to determine some of its causes. Originally, research investigations used several approaches that focused on different methods and on different ontogenetic stages: the Groundfish Analysis Investigation studying pelagic juveniles; the Groundfish Communities, post-pelagic juveniles; and the Groundfish Physiological Ecology, adults. Subsequently, the coordinated effort of these investigations has resulted in considerable overlap among programs, with expansion to study of additional stages and techniques. The coordination of these approaches is expected to elucidate the mechanisms of recruitment in rockfishes and to improve predictions of recruitment to the fishery.

## STUDIES OF PELAGIC JUVENILES

The juveniles of Sebastes spp. school in the coastal pelagic environment for several months following parturition (larval extrusion). During this time they are sampled by midwater trawl and from the gut-contents of predators.

### Progress in Midwater Trawl Assessments

Since 1983 the Groundfish Analysis Investigation has fielded annual surveys designed to estimate the relative abundance of pelagic young-of-the-year (YOY) juvenile rockfish (Table 1). All cruises have 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 9.53 mm (3/8") 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 Ralston 1990). As part of the survey design the study area is subdivided into seven geographical strata, with 5-6 standard stations located within each.

Two pelagic juvenile survey cruises were conducted during the preceding year (DSJ-9003 and DSJ-9005). The first cruise spanned a 10 day period in March-April and resulted in one sweep through the study area. The second cruise was substantially

**Table** 1.--Summary of midwater trawl surveys conducted by the Groundfish Analysis Investigation for pelagic YOY rockfishes (Sebastes spp.) off the central California coast (1983-90).

| Cruise | Sweep | Dates | Number of Standard Trawls |
|---|---|---|---|
| 8301 | 1 | June 8 -- June 23, 1983 | 20 |
| 8401 | 1 | June 12 -- June 27, 1984 | 24 |
| 8505 | 1 | June 5 -- June 30, 1985 | 28 |
| 8608 | 1 | June 3 -- June 11, 1986 | 33 |
| 8608 | 2 | June 11 -- June 18, 1986 | 28 |
| 8608 | 3 | June 20 -- June 25, 1986 | 28 |
| 8703 | 1 | April 10 -- April 20, 1987 | 33 |
| 8705 | 1 | May 23 -- June 1, 1987 | 32 |
| 8705 | 2 | June 2 -- June 11, 1987 | 34 |
| 8705 | 3 | June 12 -- June 21, 1987 | 33 |
| 8804 | 1 | April 16 -- April 22, 1988 | 27 |
| 8806 | 1 | May 22 -- May 31, 1988 | 33 |
| 8806 | 2 | June 2 -- June 10, 1988 | 34 |
| 8806 | 3 | June 11 -- June 18, 1988 | 31 |
| 8904 | 1 | May 14 -- May 21, 1989 | 31 |
| 8904 | 2 | May 24 -- June 3, 1989 | 32 |
| 8904 | 3 | June 4 -- June 13, 1989 | 31 |
| 9003 | 1 | March 29 -- April 6, 1990 | 38 |
| 9005 | 1 | May 13 -- May 22, 1990 | 34 |
| 9005 | 2 | May 22 -- May 30, 1990 | 33 |
| 9005 | 3 | June 1 -- June 10, 1990 | 32 |

longer (30 d) and comprised three sweeps. 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. At certain stations standard trawls were made at 10, 30, and 100 m depth to provide information concerning the vertical distribution of pelagic YOY rockfishes (see Hobson 1989; Lenarz et al. MS). Supplemental CTD data were also gathered during the day along tracklines that criss-crossed the entire study area (see Schwing et al. 1990; Schwing and Ralston 1991). As in previous years, data from both cruises were compiled, edited, and added to the midwater trawl data base.

Improvements in Data Base Management

A separate report was prepared (Reilly and Bence 1990) documenting the structure and management of the task's midwater trawl data. These data are now available as both a SAS data base and as dBase III files. Last year a new system for editing our midwater trawl data was developed. Cruise data from the recruitment surveys are first entered into dBase III files; a set of nine SAS programs was written to import the data, perform edits, and check for logical errors (see Ralston 1990). The use of these programs greatly reduced the time required to prepare the 1990 cruise data for use. More recently, additional SAS macros have been developed during this past year to create a permanent SAS library from the dBase files. This extra step in processing was taken because virtually all data analyses are now conducted within the SAS system and because many potential users outside the Tiburon Laboratory also rely on this software. The structure of these files was slightly altered and expanded from their dBase III counterparts to simplify and facilitate data manipulations needed for future analytical work. (J. Bence and C. Reilly)

Depth Distributions of Pelagic Juveniles

During this past year a detailed analysis of the depth distributions of pelagic juvenile YOY rockfish was completed (Lenarz et al. MS). This work was based on examining all stations sampled from 1983-90 where synoptic midwater trawling was conducted at several depths (i.e., 10, 30, and 100 m).

The results of this analysis show (Fig. 1) that the average depth of most rockfish species was close to the average expected if fish densities were equally distributed at the three sampled depths (represented by the vertical dashed line in the figure). There were notable exceptions, however.

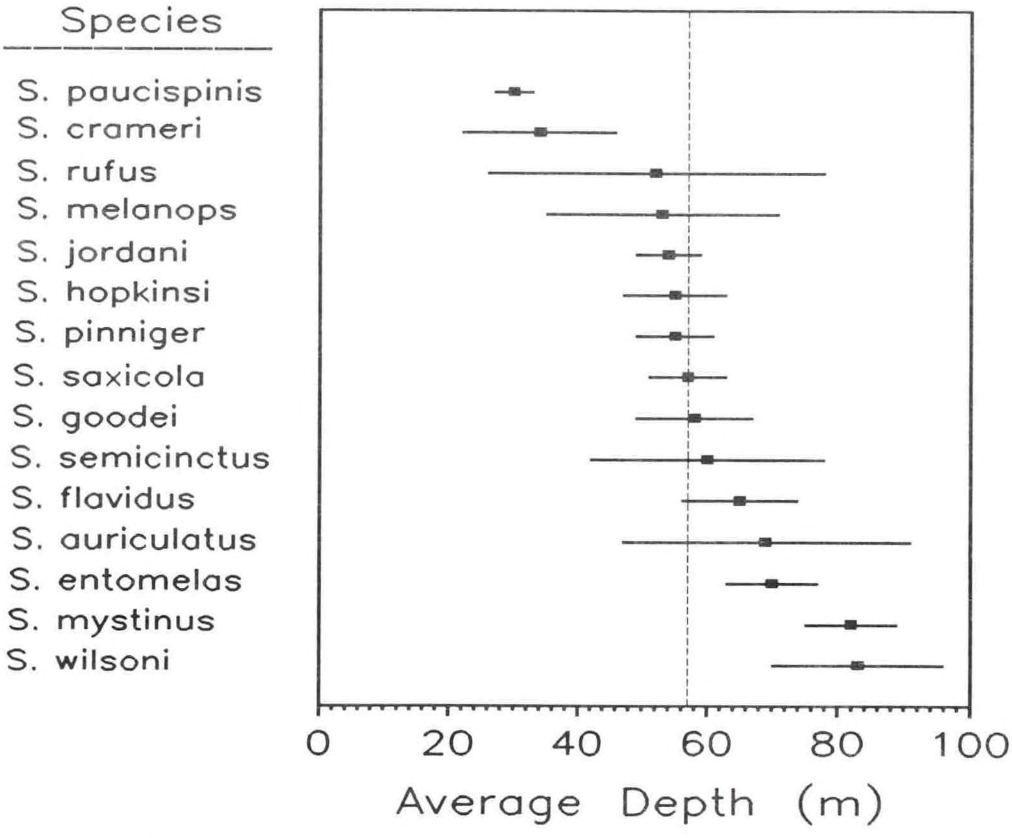


**Figure 1.** Depth distributions of pelagic juvenile rockfishes taken by midwater trawl. Solid squares represent the mean depth of capture, which are bracketed by ±1 standard error.

Bocaccio, for example, were much more abundant in shallow tows and densities of canary and halfbanded rockfish were reduced in shallow hauls relative to the mid-depth area. At 100 m, yellowtail, widow, blue, and pygmy rockfish appear to have been more abundant than at the shallower depths.

Some data are available to show that these average depths may change as the season progresses. Comparisons of average depth of capture for S. mystinus, S. jordani, S. entomelas, and S. goodei, taken in March-April with samples obtained during the May-June time period indicate an increase in average depth over time. This does not appear to be a size effect, wherein small fish sampled early in the season reside in shallow water while large fish are found deeper. On the contrary, during May and June the smallest size classes are actually found at the greatest depths. Seasonal and size related movements into deeper water are consistent with the hypothesis that fish avoid the surface layer during the peak of the upwelling season (June), a time when offshore Ekman transport is strongest. (W. Lenarz, R. Larson, and S. Ralston)

## Estimates of Year-Class Strength

In this year's report we estimate the mean and variance of pelagic juvenile catch rates within each geographical stratum, based on a simple arithmetic average of $y = \log_e[x+0.1]$ transformed data, where x is the number of juvenile rockfish, of a particular type, caught in a given tow. The stratified average, $\Sigma_j\ (1/k)\ y._j$, over k strata was then calculated. This is the same method used in years prior to 1990, except that the added constant is now 0.1 instead of 1. We report these indices, their standard errors, and their 95% confidence intervals in Table 2, for each of the 15 most commonly caught rockfish species for each sweep completed since 1983. Shown also are indices of total juvenile rockfish, and two subgroups of species that tend to fluctuate in synchrony (i.e., PCA entomelas group and PCA jordani group [see Hobson 1989]). We also report back-transformed indices of abundance, equal to $\exp(\text{index} + s^2/2) - 0.1$, which is corrected for first order bias. We approximate confidence intervals under the assumption of normality; i.e. index $\pm\ t^{\alpha/2}{}_v\ s$, where v is the degrees of freedom, and $\alpha=0.05$ to obtain 95% confidence intervals. Here, $s = 1/k \sqrt{(\ \Sigma_i\ s_i^2\ )}$, where the $s_i^2$ are the usual squared standard errors of the individual stratum means. Since the true variance among (transformed) observations within strata may well vary among strata, we use an extension of Welch's approximate method to determine the correct degrees of freedom associated with s (e.g., Ames and Webster 1991):

$$v = (\ \Sigma_i\ \lambda_i\ )^2\ /\ \Sigma_i\ \{\lambda_i^2\ /\ (n_i - 1)\},$$

where $\lambda_i = (1/k)^2\ s_i^2$.

We have now discarded an index based upon the Δ-distribution that we introduced last year. In applying that index we assumed that within each stratum observations followed a Δ-distribution, and the mean and standard error for each stratum were estimated by iterative solution of the maximum likelihood equations given by Pennington (1983, 1986). The mean and its standard error over all strata was then calculated using the procedures described above. The Δ-distribution assumes that there is a finite probability of obtaining a zero catch, and that positive tows follow a lognormal distribution. This distribution has some appeal because zero counts are common in our data and the remaining observations are clearly skewed, as expected of a lognormal distribution. Pennington (1983) showed that if observations are drawn from a Δ-distribution, the proposed estimator is the most efficient. However, we discarded the index for several reasons.

First, by combining a number of separate tests (each based on the number of non-zero observations within a stratum-sweep) we were able to reject the null hypothesis that our positive tow data are lognormally distributed. Second, by simulation, we found that for certain departures from the Δ-distribution, the estimator assuming this distribution was inefficient (relative to estimates based on a simple arithmetic average). Myers and Pepin (1990) have demonstrated that estimators based on the Δ-distribution can be both inefficient and biased, even when deviations from the assumed distribution are so slight as to be essentially undetectable. Third, we were at first over-optimistic regarding gains in efficiency based on the large sample result reported by Pennington (1983). Smith (1988) gives methods for calculating efficiency exactly, and for our survey (with relatively small samples within strata) gains in efficiency (relative to a simple arithmetic average) are slight, even if the Δ-distribution were to correctly describe the data. A fourth reason was that, in certain circumstances, the estimator elicited an odd property, wherein the mean estimated for total rockfish was less than that estimated for the dominant species (shortbelly rockfish).

We expect to explore the distribution of our catch numbers further and to evaluate different ways of estimating an index of year class strength. As is common in trawl studies, rare but large catches have a major influence on estimated indices, and alternative approaches weight these large catches differently. Likewise, we are exploring the relationship between abundance estimates derived from the 1983-85 period, when only one sweep of the study area was conducted, with more recent data, when three sweeps are completed. We believe that data from these early years is subject to increased error due to mismatches between the timing of the survey cruise and the availability of the pelagic juveniles. (J. Bence and S. Ralston)

**Table** 2.--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 any of the standard stations are not listed. Shown are the index (on $\log_e$ scale), its standard error (SE), a 95% confidence interval for the estimate, and a back-transformation of the index, corrected for first order bias.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| S. auriculatus | 8401 | 1 | -1.19 | 0.27 | -1.88 | -0.49 | 0.22 |
| S. auriculatus | 8608 | 1 | -0.07 | 0.29 | -0.71 | 0.57 | 0.87 |
| S. auriculatus | 8608 | 2 | -0.40 | 0.32 | -1.08 | 0.27 | 0.61 |
| S. auriculatus | 8608 | 3 | -1.66 | 0.23 | -2.17 | -1.15 | 0.09 |
| S. auriculatus | 8703 | 1 | -1.46 | 0.23 | -1.94 | -0.98 | 0.14 |
| S. auriculatus | 8705 | 1 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| S. auriculatus | 8705 | 2 | -2.01 | 0.15 | -2.32 | -1.70 | 0.04 |
| S. auriculatus | 8705 | 3 | -2.10 | 0.11 | -2.35 | -1.85 | 0.02 |
| S. auriculatus | 8804 | 1 | -1.38 | 0.28 | -2.07 | -0.69 | 0.16 |
| S. auriculatus | 8904 | 1 | -2.15 | 0.10 | -2.41 | -1.88 | 0.02 |
| S. auriculatus | 9003 | 1 | -1.89 | 0.17 | -2.28 | -1.50 | 0.05 |
| S. auriculatus | 9005 | 1 | -1.84 | 0.16 | -2.19 | -1.50 | 0.06 |
| S. auriculatus | 9005 | 2 | -1.86 | 0.24 | -2.48 | -1.23 | 0.06 |
| S. crameri | 8401 | 1 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| S. crameri | 8703 | 1 | -2.03 | 0.16 | -2.37 | -1.69 | 0.03 |
| S. crameri | 8705 | 1 | -2.06 | 0.14 | -2.37 | -1.75 | 0.03 |
| S. crameri | 8705 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. crameri | 8804 | 1 | -2.01 | 0.08 | -2.22 | -1.80 | 0.03 |
| S. crameri | 8806 | 1 | -2.11 | 0.14 | -2.48 | -1.75 | 0.02 |
| S. crameri | 9005 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. entomelas | 8301 | 1 | -2.18 | 0.12 | -2.52 | -1.84 | 0.01 |
| S. entomelas | 8401 | 1 | -0.69 | 0.53 | -2.21 | 0.82 | 0.47 |
| S. entomelas | 8505 | 1 | 0.05 | 0.30 | -0.61 | 0.71 | 1.00 |
| S. entomelas | 8608 | 1 | -1.90 | 0.17 | -2.28 | -1.53 | 0.05 |
| S. entomelas | 8608 | 2 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| S. entomelas | 8703 | 1 | -1.81 | 0.17 | -2.21 | -1.42 | 0.07 |
| S. entomelas | 8705 | 1 | -0.01 | 0.35 | -0.75 | 0.73 | 0.95 |
| S. entomelas | 8705 | 2 | 0.62 | 0.32 | -0.04 | 1.28 | 1.86 |
| S. entomelas | 8705 | 3 | -1.81 | 0.19 | -2.24 | -1.38 | 0.07 |
| S. entomelas | 8804 | 1 | -1.36 | 0.25 | -2.04 | -0.67 | 0.17 |
| S. entomelas | 8806 | 1 | -0.48 | 0.29 | -1.10 | 0.14 | 0.55 |
| S. entomelas | 8806 | 2 | -0.13 | 0.24 | -0.65 | 0.38 | 0.80 |
| S. entomelas | 8806 | 3 | -1.85 | 0.17 | -2.25 | -1.45 | 0.06 |
| S. entomelas | 8904 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. entomelas | 8904 | 2 | -1.72 | 0.19 | -2.16 | -1.29 | 0.08 |
| S. entomelas | 8904 | 3 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| S. entomelas | 9005 | 1 | -1.75 | 0.27 | -2.38 | -1.12 | 0.08 |
| S. entomelas | 9005 | 2 | -1.44 | 0.25 | -1.99 | -0.90 | 0.14 |
| S. entomelas | 9005 | 3 | -2.08 | 0.12 | -2.36 | -1.80 | 0.03 |

**Table** 2 (cont.).--Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of Sebastes.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| S. flavidus | 8301 | 1 | -2.08 | 0.14 | -2.48 | -1.68 | 0.03 |
| S. flavidus | 8401 | 1 | -0.74 | 0.51 | -2.11 | 0.64 | 0.45 |
| S. flavidus | 8505 | 1 | -0.96 | 0.27 | -1.54 | -0.38 | 0.30 |
| S. flavidus | 8608 | 1 | -1.97 | 0.13 | -2.29 | -1.65 | 0.04 |
| S. flavidus | 8608 | 2 | -1.69 | 0.16 | -2.04 | -1.34 | 0.09 |
| S. flavidus | 8608 | 3 | -2.03 | 0.17 | -2.47 | -1.59 | 0.03 |
| S. flavidus | 8705 | 1 | -1.78 | 0.21 | -2.22 | -1.33 | 0.07 |
| S. flavidus | 8705 | 2 | -1.02 | 0.26 | -1.55 | -0.48 | 0.27 |
| S. flavidus | 8705 | 3 | -1.58 | 0.24 | -2.09 | -1.07 | 0.11 |
| S. flavidus | 8804 | 1 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| S. flavidus | 8806 | 1 | -0.86 | 0.29 | -1.47 | -0.26 | 0.34 |
| S. flavidus | 8806 | 2 | -1.41 | 0.24 | -1.91 | -0.92 | 0.15 |
| S. flavidus | 8904 | 1 | -2.06 | 0.13 | -2.37 | -1.76 | 0.03 |
| S. flavidus | 8904 | 2 | -1.62 | 0.20 | -2.06 | -1.19 | 0.10 |
| S. flavidus | 8904 | 3 | -1.62 | 0.22 | -2.09 | -1.14 | 0.10 |
| S. flavidus | 9003 | 1 | -2.17 | 0.13 | -2.59 | -1.75 | 0.02 |
| S. flavidus | 9005 | 1 | -1.98 | 0.15 | -2.32 | -1.64 | 0.04 |
| S. flavidus | 9005 | 2 | -1.67 | 0.23 | -2.34 | -1.01 | 0.09 |
| S. flavidus | 9005 | 3 | -2.15 | 0.11 | -2.40 | -1.89 | 0.02 |
| S. goodei | 8401 | 1 | -0.73 | 0.42 | -1.78 | 0.32 | 0.43 |
| S. goodei | 8608 | 1 | -1.40 | 0.21 | -1.86 | -0.95 | 0.15 |
| S. goodei | 8608 | 2 | -1.60 | 0.21 | -2.06 | -1.14 | 0.11 |
| S. goodei | 8608 | 3 | -2.03 | 0.15 | -2.38 | -1.68 | 0.03 |
| S. goodei | 8703 | 1 | -0.17 | 0.35 | -0.91 | 0.56 | 0.79 |
| S. goodei | 8705 | 1 | 0.55 | 0.28 | -0.05 | 1.14 | 1.70 |
| S. goodei | 8705 | 2 | -0.91 | 0.32 | -1.60 | -0.21 | 0.33 |
| S. goodei | 8705 | 3 | -1.52 | 0.22 | -2.01 | -1.03 | 0.12 |
| S. goodei | 8804 | 1 | 2.53 | 0.55 | 0.58 | 4.49 | 14.58 |
| S. goodei | 8806 | 1 | 0.03 | 0.41 | -0.83 | 0.88 | 1.01 |
| S. goodei | 8806 | 2 | -1.65 | 0.29 | -2.34 | -0.96 | 0.10 |
| S. goodei | 8806 | 3 | -1.98 | 0.25 | -2.63 | -1.32 | 0.04 |
| S. goodei | 8904 | 1 | -1.44 | 0.26 | -2.01 | -0.87 | 0.14 |
| S. goodei | 8904 | 2 | -2.17 | 0.08 | -2.40 | -1.93 | 0.02 |
| S. goodei | 9003 | 1 | -1.36 | 0.26 | -1.92 | -0.80 | 0.16 |
| S. goodei | 9005 | 1 | -1.33 | 0.29 | -1.94 | -0.72 | 0.18 |
| S. goodei | 9005 | 2 | -1.78 | 0.19 | -2.20 | -1.37 | 0.07 |
| S. hopkinsi | 8401 | 1 | -1.34 | 0.34 | -2.22 | -0.45 | 0.18 |
| S. hopkinsi | 8505 | 1 | -1.71 | 0.25 | -2.25 | -1.17 | 0.09 |
| S. hopkinsi | 8608 | 1 | -2.15 | 0.11 | -2.40 | -1.89 | 0.02 |
| S. hopkinsi | 8608 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. hopkinsi | 8703 | 1 | -1.98 | 0.15 | -2.32 | -1.64 | 0.04 |
| S. hopkinsi | 8705 | 1 | -0.29 | 0.25 | -0.84 | 0.26 | 0.67 |
| S. hopkinsi | 8705 | 2 | -1.03 | 0.28 | -1.62 | -0.44 | 0.27 |
| S. hopkinsi | 8705 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. hopkinsi | 8804 | 1 | -0.77 | 0.32 | -1.49 | -0.05 | 0.39 |

**Table** 2 (cont.).--Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of <u>Sebastes</u>.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| S. hopkinsi | 8806 | 1 | -0.62 | 0.35 | -1.36 | 0.13 | 0.47 |
| S. hopkinsi | 8806 | 2 | -1.15 | 0.22 | -1.61 | -0.68 | 0.22 |
| S. hopkinsi | 8806 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. hopkinsi | 8904 | 1 | -2.08 | 0.13 | -2.37 | -1.79 | 0.03 |
| S. hopkinsi | 8904 | 2 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| S. hopkinsi | 8904 | 3 | -2.10 | 0.08 | -2.33 | -1.86 | 0.02 |
| S. hopkinsi | 9003 | 1 | -2.17 | 0.09 | -2.39 | -1.96 | 0.01 |
| S. hopkinsi | 9005 | 1 | -1.81 | 0.27 | -2.47 | -1.15 | 0.07 |
| S. hopkinsi | 9005 | 3 | -2.15 | 0.10 | -2.41 | -1.88 | 0.02 |
| S. jordani | 8301 | 1 | -1.55 | 0.43 | -2.92 | -0.18 | 0.13 |
| S. jordani | 8401 | 1 | 1.23 | 0.76 | -0.82 | 3.29 | 4.47 |
| S. jordani | 8505 | 1 | -0.06 | 0.41 | -1.00 | 0.88 | 0.92 |
| S. jordani | 8608 | 1 | 1.02 | 0.45 | 0.07 | 1.96 | 2.96 |
| S. jordani | 8608 | 2 | 0.97 | 0.40 | 0.05 | 1.90 | 2.76 |
| S. jordani | 8608 | 3 | -1.09 | 0.37 | -1.92 | -0.26 | 0.26 |
| S. jordani | 8703 | 1 | -0.61 | 0.34 | -1.34 | 0.12 | 0.48 |
| S. jordani | 8705 | 1 | 1.84 | 0.37 | 1.02 | 2.66 | 6.62 |
| S. jordani | 8705 | 2 | 2.88 | 0.44 | 1.97 | 3.80 | 19.62 |
| S. jordani | 8705 | 3 | 0.31 | 0.43 | -0.61 | 1.24 | 1.40 |
| S. jordani | 8804 | 1 | 2.31 | 0.57 | 0.82 | 3.81 | 11.78 |
| S. jordani | 8806 | 1 | 2.35 | 0.51 | 1.24 | 3.45 | 11.83 |
| S. jordani | 8806 | 2 | 1.19 | 0.38 | 0.37 | 2.02 | 3.45 |
| S. jordani | 8806 | 3 | 0.73 | 0.43 | -0.19 | 1.64 | 2.17 |
| S. jordani | 8904 | 1 | 1.05 | 0.30 | 0.42 | 1.68 | 2.89 |
| S. jordani | 8904 | 2 | 0.52 | 0.31 | -0.13 | 1.18 | 1.67 |
| S. jordani | 8904 | 3 | -0.36 | 0.28 | -0.95 | 0.24 | 0.63 |
| S. jordani | 9003 | 1 | -0.81 | 0.28 | -1.40 | -0.23 | 0.36 |
| S. jordani | 9005 | 1 | 0.18 | 0.43 | -0.75 | 1.12 | 1.22 |
| S. jordani | 9005 | 2 | -0.40 | 0.34 | -1.11 | 0.31 | 0.61 |
| S. jordani | 9005 | 3 | -1.66 | 0.25 | -2.35 | -0.96 | 0.10 |
| S. levis | 8505 | 1 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| S. levis | 8608 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. levis | 8703 | 1 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| S. levis | 8705 | 1 | -1.91 | 0.16 | -2.26 | -1.55 | 0.05 |
| S. levis | 8705 | 3 | -1.97 | 0.16 | -2.33 | -1.61 | 0.04 |
| S. levis | 8804 | 1 | -1.44 | 0.21 | -1.89 | -0.99 | 0.14 |
| S. levis | 8806 | 1 | -2.25 | 0.06 | -2.39 | -2.10 | 0.01 |
| S. levis | 8904 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. levis | 9003 | 1 | -2.17 | 0.13 | -2.59 | -1.75 | 0.02 |
| S. melanops | 8505 | 1 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| S. melanops | 8608 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. melanops | 8705 | 1 | -2.01 | 0.13 | -2.31 | -1.71 | 0.04 |
| S. melanops | 8705 | 2 | -1.76 | 0.19 | -2.15 | -1.36 | 0.08 |
| S. melanops | 8705 | 3 | -2.08 | 0.13 | -2.37 | -1.79 | 0.03 |
| S. melanops | 8806 | 1 | -2.08 | 0.12 | -2.37 | -1.79 | 0.03 |

**Table** 2 (cont.).--Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of _Sebastes_.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| _S. melanops_ | 8806 | 2 | -1.81 | 0.17 | -2.19 | -1.43 | 0.07 |
| _S. melanops_ | 8904 | 2 | -2.04 | 0.13 | -2.38 | -1.70 | 0.03 |
| _S. melanops_ | 8904 | 3 | -2.19 | 0.11 | -2.68 | -1.70 | 0.01 |
| _S. melanops_ | 9005 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| _S. melanops_ | 9005 | 2 | -2.10 | 0.14 | -2.50 | -1.71 | 0.02 |
| _S. mystinus_ | 8505 | 1 | -1.34 | 0.20 | -1.80 | -0.88 | 0.17 |
| _S. mystinus_ | 8608 | 1 | -2.08 | 0.12 | -2.36 | -1.80 | 0.03 |
| _S. mystinus_ | 8703 | 1 | -1.97 | 0.16 | -2.32 | -1.62 | 0.04 |
| _S. mystinus_ | 8705 | 1 | 0.03 | 0.31 | -0.62 | 0.67 | 0.98 |
| _S. mystinus_ | 8705 | 2 | -0.66 | 0.30 | -1.28 | -0.04 | 0.44 |
| _S. mystinus_ | 8804 | 1 | -0.36 | 0.27 | -0.96 | 0.23 | 0.62 |
| _S. mystinus_ | 8806 | 1 | 0.23 | 0.30 | -0.40 | 0.85 | 1.21 |
| _S. mystinus_ | 8806 | 2 | -0.23 | 0.22 | -0.69 | 0.23 | 0.72 |
| _S. mystinus_ | 8806 | 3 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| _S. mystinus_ | 8904 | 1 | -1.45 | 0.24 | -1.96 | -0.93 | 0.14 |
| _S. mystinus_ | 8904 | 2 | -1.08 | 0.27 | -1.66 | -0.50 | 0.25 |
| _S. mystinus_ | 8904 | 3 | -1.96 | 0.16 | -2.33 | -1.60 | 0.04 |
| _S. mystinus_ | 9003 | 1 | -2.25 | 0.05 | -2.37 | -2.13 | 0.01 |
| _S. mystinus_ | 9005 | 1 | -1.46 | 0.24 | -1.97 | -0.95 | 0.14 |
| _S. mystinus_ | 9005 | 2 | -1.67 | 0.21 | -2.13 | -1.21 | 0.09 |
| _S. mystinus_ | 9005 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| _S. paucispinis_ | 8401 | 1 | -0.55 | 0.41 | -1.93 | 0.83 | 0.53 |
| _S. paucispinis_ | 8608 | 1 | -0.98 | 0.26 | -1.55 | -0.41 | 0.29 |
| _S. paucispinis_ | 8608 | 2 | -1.06 | 0.23 | -1.56 | -0.57 | 0.26 |
| _S. paucispinis_ | 8608 | 3 | -1.99 | 0.19 | -2.44 | -1.54 | 0.04 |
| _S. paucispinis_ | 8703 | 1 | -1.80 | 0.19 | -2.23 | -1.37 | 0.07 |
| _S. paucispinis_ | 8705 | 1 | -1.21 | 0.27 | -1.78 | -0.64 | 0.21 |
| _S. paucispinis_ | 8705 | 2 | -1.12 | 0.27 | -1.68 | -0.56 | 0.24 |
| _S. paucispinis_ | 8705 | 3 | -1.48 | 0.26 | -2.05 | -0.91 | 0.14 |
| _S. paucispinis_ | 8804 | 1 | -0.65 | 0.20 | -1.07 | -0.22 | 0.43 |
| _S. paucispinis_ | 8806 | 1 | -0.96 | 0.24 | -1.46 | -0.45 | 0.30 |
| _S. paucispinis_ | 8806 | 2 | -1.91 | 0.16 | -2.27 | -1.54 | 0.05 |
| _S. paucispinis_ | 8806 | 3 | -2.20 | 0.10 | -2.48 | -1.93 | 0.01 |
| _S. paucispinis_ | 8904 | 1 | -1.83 | 0.19 | -2.26 | -1.41 | 0.06 |
| _S. paucispinis_ | 8904 | 2 | -1.81 | 0.22 | -2.30 | -1.33 | 0.07 |
| _S. paucispinis_ | 9003 | 1 | -2.25 | 0.05 | -2.37 | -2.13 | 0.01 |
| _S. paucispinis_ | 9005 | 1 | -1.50 | 0.26 | -2.06 | -0.94 | 0.13 |
| _S. paucispinis_ | 9005 | 2 | -2.02 | 0.20 | -2.54 | -1.49 | 0.04 |
| _S. pinniger_ | 8401 | 1 | -0.55 | 0.54 | -2.01 | 0.92 | 0.57 |
| _S. pinniger_ | 8505 | 1 | -2.08 | 0.16 | -2.49 | -1.68 | 0.03 |
| _S. pinniger_ | 8608 | 1 | -1.26 | 0.19 | -1.69 | -0.84 | 0.19 |
| _S. pinniger_ | 8608 | 2 | -1.84 | 0.18 | -2.22 | -1.45 | 0.06 |
| _S. pinniger_ | 8608 | 3 | -2.17 | 0.13 | -2.74 | -1.60 | 0.02 |
| _S. pinniger_ | 8703 | 1 | -1.71 | 0.23 | -2.21 | -1.22 | 0.09 |
| _S. pinniger_ | 8705 | 1 | -1.67 | 0.19 | -2.07 | -1.27 | 0.09 |

**Table** 2 (cont.).--Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of Sebastes.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| S. pinniger | 8705 | 2 | -1.06 | 0.22 | -1.53 | -0.59 | 0.25 |
| S. pinniger | 8705 | 3 | -1.63 | 0.23 | -2.14 | -1.12 | 0.10 |
| S. pinniger | 8804 | 1 | -1.33 | 0.34 | -2.26 | -0.39 | 0.18 |
| S. pinniger | 8806 | 1 | -0.03 | 0.28 | -0.64 | 0.57 | 0.91 |
| S. pinniger | 8806 | 2 | -1.29 | 0.24 | -1.81 | -0.76 | 0.18 |
| S. pinniger | 8806 | 3 | -2.03 | 0.16 | -2.43 | -1.64 | 0.03 |
| S. pinniger | 8904 | 1 | -1.70 | 0.19 | -2.13 | -1.28 | 0.09 |
| S. pinniger | 8904 | 2 | -1.58 | 0.18 | -1.98 | -1.18 | 0.11 |
| S. pinniger | 8904 | 3 | -1.84 | 0.12 | -2.13 | -1.56 | 0.06 |
| S. pinniger | 9003 | 1 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| S. pinniger | 9005 | 1 | -2.01 | 0.17 | -2.43 | -1.60 | 0.04 |
| S. pinniger | 9005 | 2 | -1.58 | 0.24 | -2.14 | -1.03 | 0.11 |
| S. pinniger | 9005 | 3 | -2.06 | 0.18 | -3.38 | -0.74 | 0.03 |
| S. rufus | 8705 | 1 | -1.89 | 0.15 | -2.23 | -1.55 | 0.05 |
| S. rufus | 8705 | 2 | -1.92 | 0.16 | -2.27 | -1.58 | 0.05 |
| S. rufus | 8705 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. rufus | 8804 | 1 | -1.57 | 0.33 | -2.52 | -0.61 | 0.12 |
| S. rufus | 8806 | 2 | -2.16 | 0.09 | -2.39 | -1.92 | 0.02 |
| S. saxicola | 8401 | 1 | -1.51 | 0.28 | -2.34 | -0.68 | 0.13 |
| S. saxicola | 8505 | 1 | -2.13 | 0.13 | -2.45 | -1.80 | 0.02 |
| S. saxicola | 8608 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| S. saxicola | 8703 | 1 | -0.90 | 0.22 | -1.38 | -0.43 | 0.32 |
| S. saxicola | 8705 | 1 | -0.43 | 0.25 | -0.96 | 0.10 | 0.57 |
| S. saxicola | 8705 | 2 | -1.76 | 0.17 | -2.13 | -1.39 | 0.08 |
| S. saxicola | 8705 | 3 | -2.22 | 0.09 | -2.46 | -1.97 | 0.01 |
| S. saxicola | 8804 | 1 | 0.07 | 0.30 | -0.57 | 0.72 | 1.02 |
| S. saxicola | 8806 | 1 | -1.00 | 0.26 | -1.54 | -0.45 | 0.28 |
| S. saxicola | 8806 | 2 | -1.89 | 0.15 | -2.21 | -1.57 | 0.05 |
| S. saxicola | 8904 | 1 | -1.92 | 0.16 | -2.27 | -1.57 | 0.05 |
| S. saxicola | 9003 | 1 | -1.43 | 0.22 | -1.92 | -0.95 | 0.14 |
| S. saxicola | 9005 | 1 | -1.54 | 0.24 | -2.04 | -1.04 | 0.12 |
| S. saxicola | 9005 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. wilsoni | 8401 | 1 | -2.13 | 0.17 | -4.31 | 0.04 | 0.02 |
| S. wilsoni | 8608 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| S. wilsoni | 8703 | 1 | -1.69 | 0.19 | -2.10 | -1.27 | 0.09 |
| S. wilsoni | 8705 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. wilsoni | 8705 | 2 | -1.95 | 0.17 | -2.32 | -1.58 | 0.04 |
| S. wilsoni | 8705 | 3 | -2.22 | 0.09 | -2.46 | -1.97 | 0.01 |
| S. wilsoni | 8804 | 1 | -0.25 | 0.42 | -1.45 | 0.95 | 0.75 |
| S. wilsoni | 8806 | 1 | -1.90 | 0.16 | -2.26 | -1.55 | 0.05 |
| S. wilsoni | 8806 | 2 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| S. wilsoni | 8806 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. wilsoni | 8904 | 1 | -1.99 | 0.16 | -2.40 | -1.58 | 0.04 |
| S. wilsoni | 8904 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| S. wilsoni | 8904 | 3 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |

**Table** 2 (cont.).--Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of _Sebastes_.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| _S. wilsoni_ | 9005 | 1 | -1.96 | 0.13 | -2.24 | -1.68 | 0.04 |
| _S. wilsoni_ | 9005 | 2 | -2.14 | 0.12 | -2.42 | -1.85 | 0.02 |
| PCA _ent_. group | 8301 | 1 | -2.07 | 0.16 | -2.50 | -1.63 | 0.03 |
| PCA _ent_. group | 8401 | 1 | 0.06 | 0.62 | -1.63 | 1.75 | 1.18 |
| PCA _ent_. group | 8505 | 1 | 0.57 | 0.30 | -0.10 | 1.24 | 1.74 |
| PCA _ent_. group | 8608 | 1 | -1.48 | 0.24 | -1.98 | -0.97 | 0.13 |
| PCA _ent_. group | 8608 | 2 | -1.54 | 0.17 | -1.92 | -1.15 | 0.12 |
| PCA _ent_. group | 8608 | 3 | -2.03 | 0.17 | -2.47 | -1.59 | 0.03 |
| PCA _ent_. group | 8703 | 1 | -1.54 | 0.24 | -2.05 | -1.04 | 0.12 |
| PCA _ent_. group | 8705 | 1 | 1.56 | 0.27 | 0.93 | 2.18 | 4.82 |
| PCA _ent_. group | 8705 | 2 | 1.45 | 0.30 | 0.82 | 2.08 | 4.35 |
| PCA _ent_. group | 8705 | 3 | -1.19 | 0.26 | -1.75 | -0.63 | 0.21 |
| PCA _ent_. group | 8804 | 1 | 0.50 | 0.35 | -0.28 | 1.27 | 1.65 |
| PCA _ent_. group | 8806 | 1 | 1.44 | 0.31 | 0.80 | 2.08 | 4.32 |
| PCA _ent_. group | 8806 | 2 | 0.83 | 0.29 | 0.22 | 1.44 | 2.30 |
| PCA _ent_. group | 8806 | 3 | -1.68 | 0.21 | -2.14 | -1.23 | 0.09 |
| PCA _ent_. group | 8904 | 1 | -1.10 | 0.26 | -1.65 | -0.55 | 0.24 |
| PCA _ent_. group | 8904 | 2 | -0.44 | 0.28 | -1.06 | 0.17 | 0.57 |
| PCA _ent_. group | 8904 | 3 | -1.10 | 0.27 | -1.66 | -0.54 | 0.24 |
| PCA _ent_. group | 9003 | 1 | -2.04 | 0.16 | -2.43 | -1.64 | 0.03 |
| PCA _ent_. group | 9005 | 1 | -1.00 | 0.33 | -1.73 | -0.28 | 0.29 |
| PCA _ent_. group | 9005 | 2 | -0.72 | 0.32 | -1.43 | 0.00 | 0.41 |
| PCA _ent_. group | 9005 | 3 | -1.70 | 0.16 | -2.06 | -1.34 | 0.09 |
| PCA _jord_. group | 8301 | 1 | -1.55 | 0.43 | -2.92 | -0.18 | 0.13 |
| PCA _jord_. group | 8401 | 1 | 1.90 | 0.73 | -0.36 | 4.17 | 8.67 |
| PCA _jord_. group | 8505 | 1 | 0.09 | 0.40 | -0.83 | 1.02 | 1.09 |
| PCA _jord_. group | 8608 | 1 | 1.79 | 0.40 | 0.93 | 2.64 | 6.35 |
| PCA _jord_. group | 8608 | 2 | 1.52 | 0.40 | 0.59 | 2.45 | 4.85 |
| PCA _jord_. group | 8608 | 3 | -0.68 | 0.41 | -1.57 | 0.21 | 0.45 |
| PCA _jord_. group | 8703 | 1 | 1.08 | 0.31 | 0.43 | 1.73 | 2.99 |
| PCA _jord_. group | 8705 | 1 | 2.98 | 0.28 | 2.35 | 3.61 | 20.29 |
| PCA _jord_. group | 8705 | 2 | 3.26 | 0.37 | 2.47 | 4.05 | 27.77 |
| PCA _jord_. group | 8705 | 3 | 0.84 | 0.40 | -0.03 | 1.70 | 2.40 |
| PCA _jord_. group | 8804 | 1 | 3.66 | 0.46 | 2.45 | 4.87 | 43.13 |
| PCA _jord_. group | 8806 | 1 | 3.12 | 0.42 | 2.21 | 4.04 | 24.79 |
| PCA _jord_. group | 8806 | 2 | 1.60 | 0.35 | 0.86 | 2.34 | 5.16 |
| PCA _jord_. group | 8806 | 3 | 0.86 | 0.44 | -0.06 | 1.79 | 2.52 |
| PCA _jord_. group | 8904 | 1 | 1.46 | 0.30 | 0.84 | 2.08 | 4.41 |
| PCA _jord_. group | 8904 | 2 | 0.65 | 0.32 | -0.01 | 1.31 | 1.91 |
| PCA _jord_. group | 8904 | 3 | 0.06 | 0.28 | -0.54 | 0.65 | 1.00 |
| PCA _jord_. group | 9003 | 1 | 0.17 | 0.30 | -0.45 | 0.79 | 1.14 |
| PCA _jord_. group | 9005 | 1 | 1.22 | 0.35 | 0.42 | 2.02 | 3.50 |
| PCA _jord_. group | 9005 | 2 | 0.05 | 0.38 | -0.74 | 0.85 | 1.04 |
| PCA _jord_. group | 9005 | 3 | -1.54 | 0.29 | -2.45 | -0.63 | 0.12 |

**Table 2** (cont.).--Annual sweep-specific indices of abundance for each of the 15 most commonly collected species of Sebastes.

| Species | Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|---|
| Total Sebastes | 8301 | 1 | -1.12 | 0.48 | -2.44 | 0.20 | 0.27 |
| Total Sebastes | 8401 | 1 | 2.16 | 0.75 | -0.23 | 4.55 | 11.31 |
| Total Sebastes | 8505 | 1 | 1.34 | 0.30 | 0.68 | 2.01 | 3.90 |
| Total Sebastes | 8608 | 1 | 1.87 | 0.40 | 1.02 | 2.72 | 6.90 |
| Total Sebastes | 8608 | 2 | 1.75 | 0.35 | 1.00 | 2.49 | 5.98 |
| Total Sebastes | 8608 | 3 | -0.61 | 0.42 | -1.52 | 0.30 | 0.49 |
| Total Sebastes | 8703 | 1 | 1.35 | 0.29 | 0.74 | 1.96 | 3.94 |
| Total Sebastes | 8705 | 1 | 3.35 | 0.27 | 2.70 | 3.99 | 29.40 |
| Total Sebastes | 8705 | 2 | 3.55 | 0.36 | 2.77 | 4.33 | 37.02 |
| Total Sebastes | 8705 | 3 | 1.21 | 0.40 | 0.35 | 2.07 | 3.54 |
| Total Sebastes | 8804 | 1 | 3.84 | 0.44 | 2.70 | 4.99 | 51.40 |
| Total Sebastes | 8806 | 1 | 3.50 | 0.38 | 2.67 | 4.33 | 35.52 |
| Total Sebastes | 8806 | 2 | 2.30 | 0.30 | 1.67 | 2.93 | 10.33 |
| Total Sebastes | 8806 | 3 | 1.06 | 0.42 | 0.18 | 1.95 | 3.06 |
| Total Sebastes | 8904 | 1 | 1.64 | 0.30 | 1.02 | 2.26 | 5.29 |
| Total Sebastes | 8904 | 2 | 1.22 | 0.28 | 0.63 | 1.81 | 3.42 |
| Total Sebastes | 8904 | 3 | 0.38 | 0.32 | -0.30 | 1.06 | 1.43 |
| Total Sebastes | 9003 | 1 | 0.31 | 0.31 | -0.33 | 0.94 | 1.33 |
| Total Sebastes | 9005 | 1 | 1.50 | 0.31 | 0.79 | 2.22 | 4.62 |
| Total Sebastes | 9005 | 2 | 0.85 | 0.35 | 0.12 | 1.59 | 2.39 |
| Total Sebastes | 9005 | 3 | -1.04 | 0.32 | -1.90 | -0.18 | 0.27 |

## Annual Trends in the Abundance of Pelagic Juveniles

As in years past, we use the maximum value of the $\log_e$ index (Table 2) across sweeps within May-June cruises as an annual estimate of the relative abundance of pelagic YOY rockfish. Results show (Fig. 2) that in 1990 the abundances of the 15 most commonly sampled Sebastes spp. were more or less comparable to 1989. In both years catch rates of juvenile rockfish were, depending on the species in question, moderate to poor. As has been the case since the inception of these surveys, catches of S. jordani (shortbelly rockfish) greatly outnumbered those of other species.

To better compare and contrast annual abundances indices (I) among species, the long-term (8 yr) means ($\mu_s$) and standard deviations ($\sigma_s$) were calculated for each of the s = 1 to 15 species. From these statistics, species-specific standard scores were calculated for each year y = 1983 to 1990 according to:

$$Z_{sy} = (I_{sy}-\mu_s)/\sigma_s$$

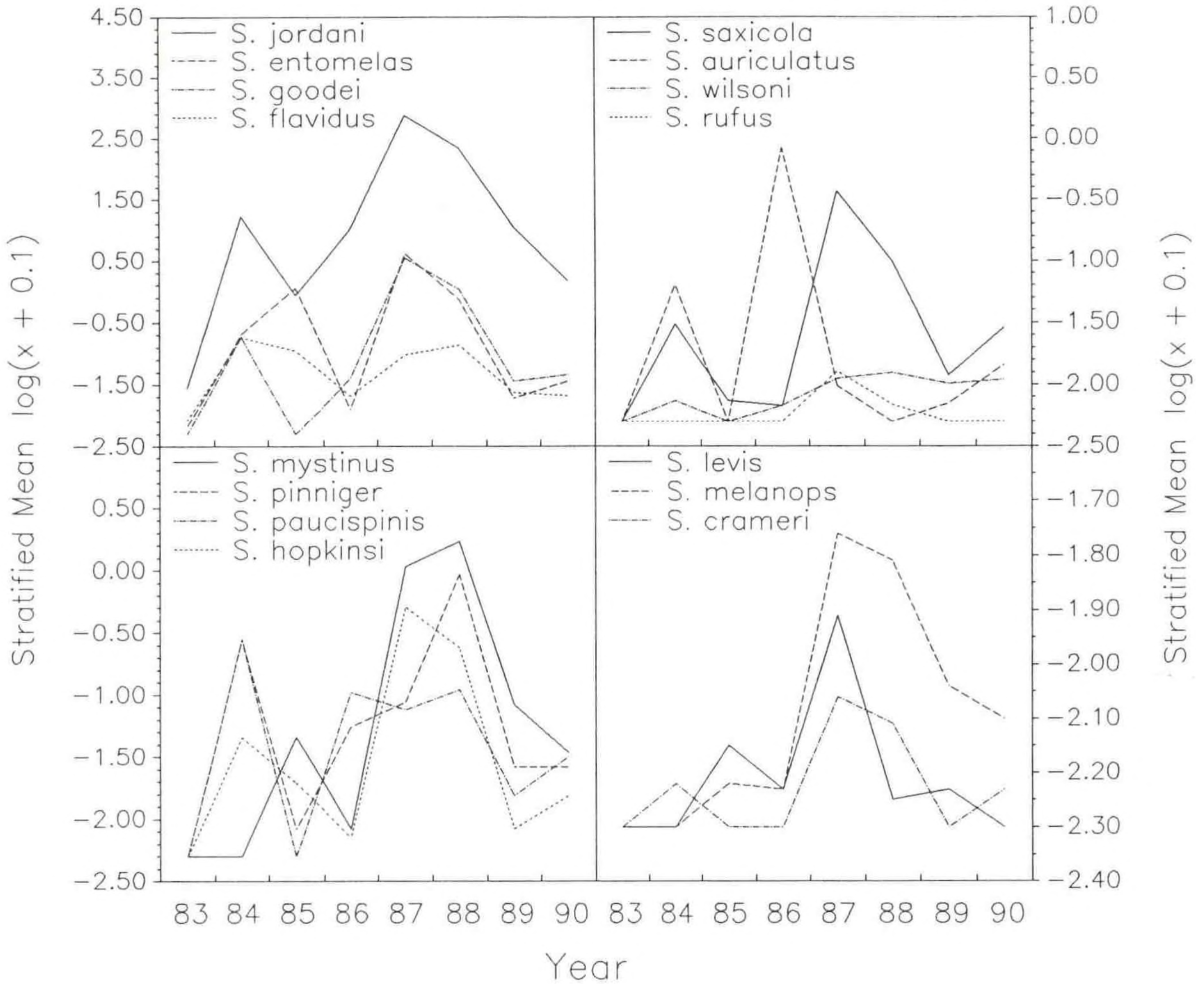


**Figure 2.** Annual (1983-90) estimates of pelagic juvenile relative abundance for 15 species of Sebastes taken by midwater trawl.

The distribution of standard scores within each year was then summarized using order statistics (i.e., the median, the first and third quartiles, and the first and ninth deciles). Results show (Fig. 3) the overall long-term trend in relative abundances of the 15 species of pelagic YOY Sebastes sampled in our surveys.

These data suggest that among these species there is a noticeable coherence in year class strength within the survey region. This finding is more clearly evident when individual standard scores are plotted (Fig. 4) for the 9 most abundant species in our trawl samples (i.e., S. jordani, S. entomelas, S. goodei, S. flavidus, S. mystinus, S. pinniger, S. paucispinis, S. hopkinsi, and S. saxicola). Of the six species excluded from this group, five are uncommon to rare (S. wilsoni, S. rufus, S. levis, S. melanops, and S. crameri) and one (S. auriculatus) tracks poorly with the other species (see Fig. 2). Note that for the primary group as a whole, 1983 (an El Niño year) was a very

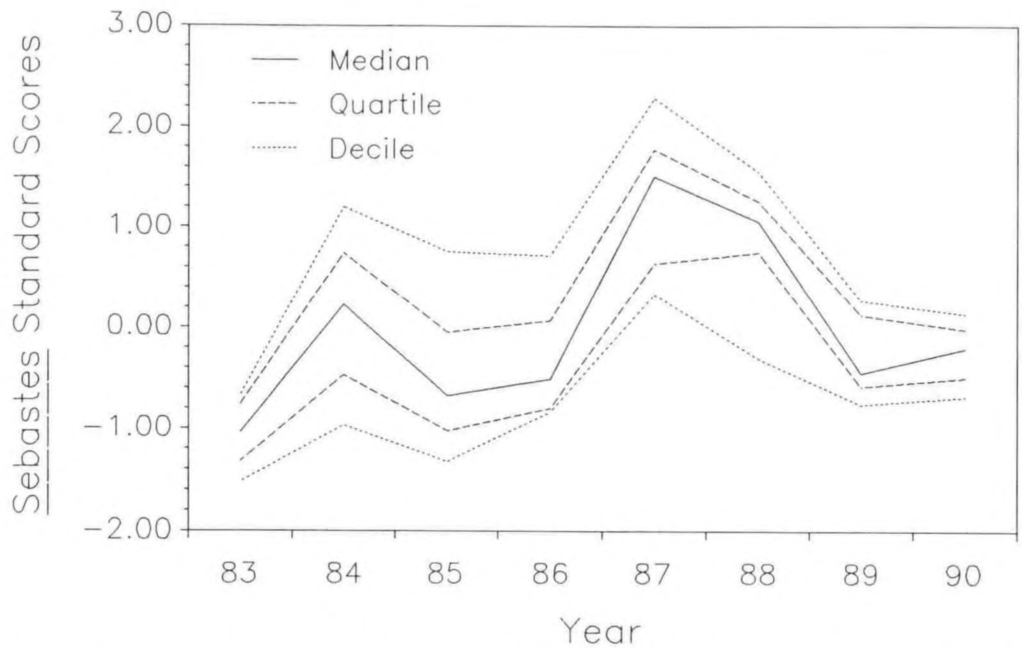


**Figure 3.** Yearly variation in the distribution of Sebastes spp. standard abundance scores (n = 15), relative to long-term means and variances.

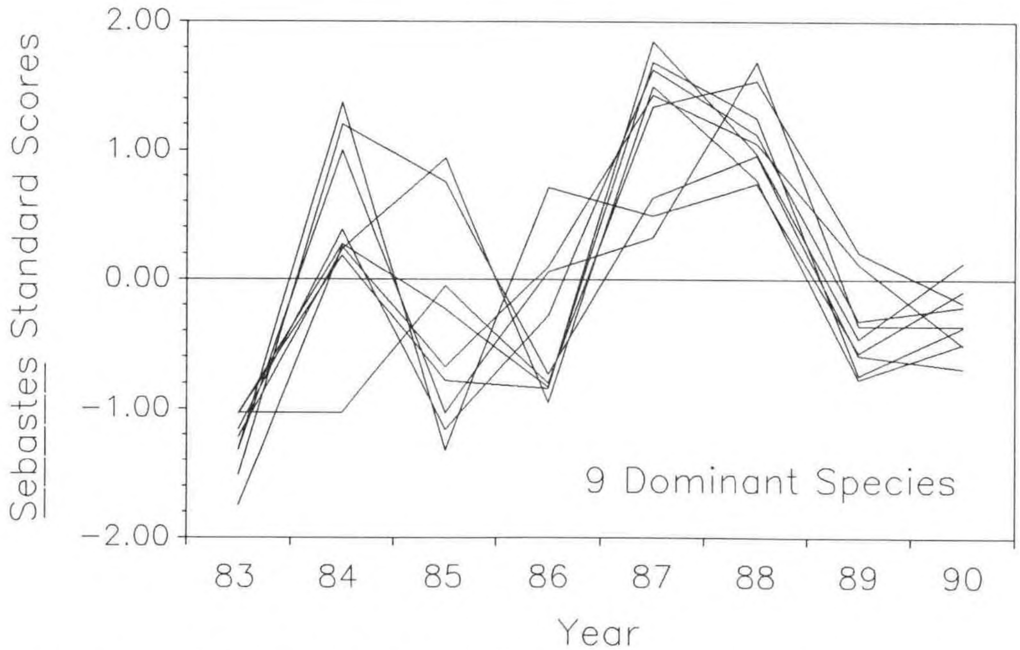


**Figure 4.** Normalized relative abundance trends for each of the 9 most commonly caught species of pelagic juvenile rockfish.

poor year. Likewise, 1987 and 1988 were very good years for all 9 species, and catches were consistently moderate to poor in 1989 and 1990.

Multispecies time series of relative abundance data are well suited to Principal Component Analysis (PCA; see Green 1978). This multivariate technique was used to describe patterns of covariation in year class strength among the nine rockfish species. For this purpose, annual indices of abundance (maximum across May-June sweeps of the stratified mean) were tabulated for the 9 primary species listed above. Ordination of the correlation matrix was first conducted using species as variables and years as cases. Following that, species were treated as cases and years as variables in a second analysis of the data.

In the first analysis, the dominant eigenvalue associated with the first principal component ($\lambda_1 = 6.58$) explained 73% of the variance in the nine most abundant species. Moreover, all the elements in the first eigenvector were positive in sign and ranged 0.271-0.374, reflecting the fact that all signs in the correlation matrix were positive. These results demonstrate the strong positive covariation in relative abundance of pelagic YOY among the nine species. In contrast, the second principal component ($\lambda_2 = 1.25$) explained less (14%) of the variance, and certain elements of the second eigenvector were negative in sign. In particular, those elements associated with S. entomelas, S. mystinus, S. hopkinsi, S. flavidus, and S. saxicola were negative. The remaining positive elements were for S. goodei, S. paucispinis, S. jordani, and S. pinniger. These results show that, although there is an overriding tendency for all nine species to vary in synchrony, superimposed on this is an independent inverse association between the two groups of species listed above. This topic will be returned to shortly.

The results of the first PCA are presented graphically in Fig. 5, where the second component score for each year is plotted against its score on the first principal component. Clearly evident along the first component axis is the contrast between good (1987 and 1988) and poor (1983) years. Among the years of moderate overall abundance (1984-86, 1989-90) a fair amount of separation occurs along the second component. Note that 1984-86, in particular, were years in which coherence was more weakly expressed (see also Fig. 4). For example, 1985 was a good year for S. entomelas and S. mystinus (Fig. 2); in that year both species had relatively large positive standard scores. In contrast, all other species had negative standard scores. Thus, the separation that occurs along the second principal component in Fig. 5 is due primarily to altered abundance relationships among species during the 1984-86 time period.

For the second PCA (years treated as variables and species as cases) the pattern was even more clearly defined ($\lambda_1 = 6.40$, 80% of the variance explained). In this case all years loaded similarly on the first principal component (elements of the first eigenvector ranged 0.26-0.39). A graphical presentation of the results (Fig. 6) shows that S. jordani numerically dominates our surveys, with a large positive score on the first component axis.

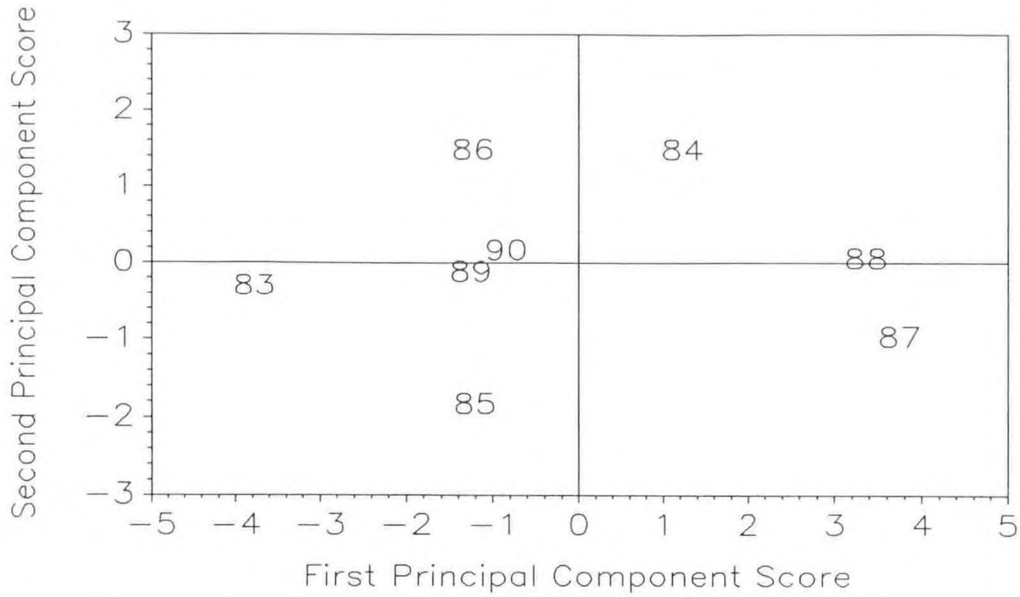


**Figure 5.** Annual variation in the abundance of 9 species of pelagic juvenile rockfish, as captured in the first two principal components.

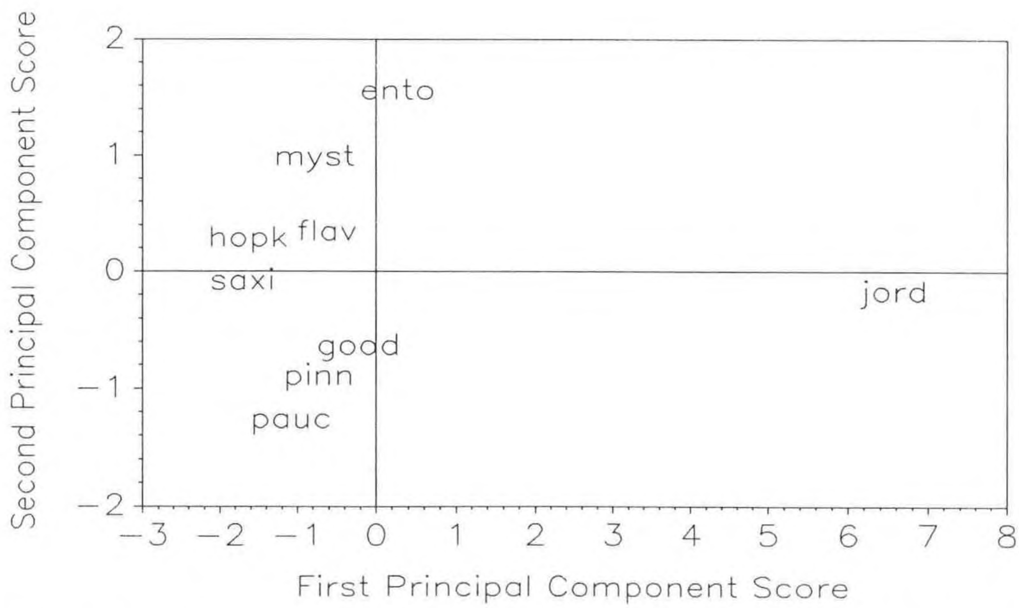


**Figure 6.** Species variation in abundance, as captured in the first two principal components, over 8 years of midwater trawl survey data . Note that species are identified by the first 4 letters of their specific name [see Table 2].

More interesting is the separation that occurs along the second principal component, which reflects differences among species in rank order abundance from year to year. For example, S. paucispinis and S. entomelas, which are situated at opposite ends of this axis, represent two species with relatively asynchronous time series of YOY abundance, vis-à-vis the remaining species (see Fig. 2).

There is some evidence that these abundance patterns are related to fluctuations in the physical environment. Ainley et al. (MS), for example, show a parabolic relationship between the annual incidence of pelagic juvenile YOY rockfish in the diet of the common murre (Uria aalge) at the Farallon Islands and an index (Bakun 1975; Mason and Bakun 1986) of coastal upwelling during January and February. We also have identified a tentative relationship between the abundance of pelagic YOY rockfish, as measured by annual scores along the first principal component axis (see Fig. 5), and the cumulative amount of positive upwelling through March (Fig. 7). Although the data are quite preliminary, and the correlation is largely due to the influence of one year (1983), there is evidence to support the view that upwelling early in the year can have a favorable influence on rockfish year class strength.

There is also a physical explanation for the separation of species along the second principal component, as illustrated in Fig. 6. Our work on the depth distributions of pelagic juvenile YOY rockfish revealed species-specific differences in the depth ranges occupied. In particular, S. mystinus and S. entomelas were found deeper than most other species and S. paucispinis was taken much shallower (Fig. 1). When abundance scores along the second component (Fig. 5) are plotted against the mean depth of capture a significant correlation results ($P < 0.01$, Fig. 8). These findings suggest that interspecific variation in YOY abundance patterns depends, to an appreciable degree, on species-specific depth distributions. For example, that both S. mystinus and S. entomelas were anomalously abundant in 1985, when other species were not, may have been due to their deep-dwelling habit. We intend to pursue this line of inquiry further by generating testable hypotheses that are based on interannual variations in shear within the water column. (S. Ralston)

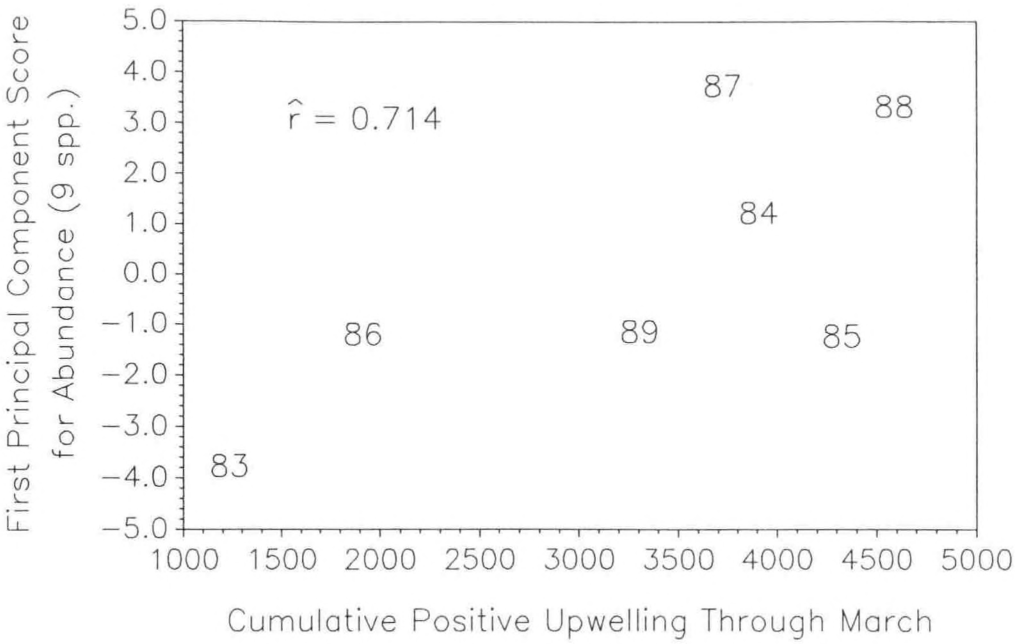


**Figure 7.** Relationship between the abundance of 9 species of pelagic juvenile rockfish and upwelling early in the year.

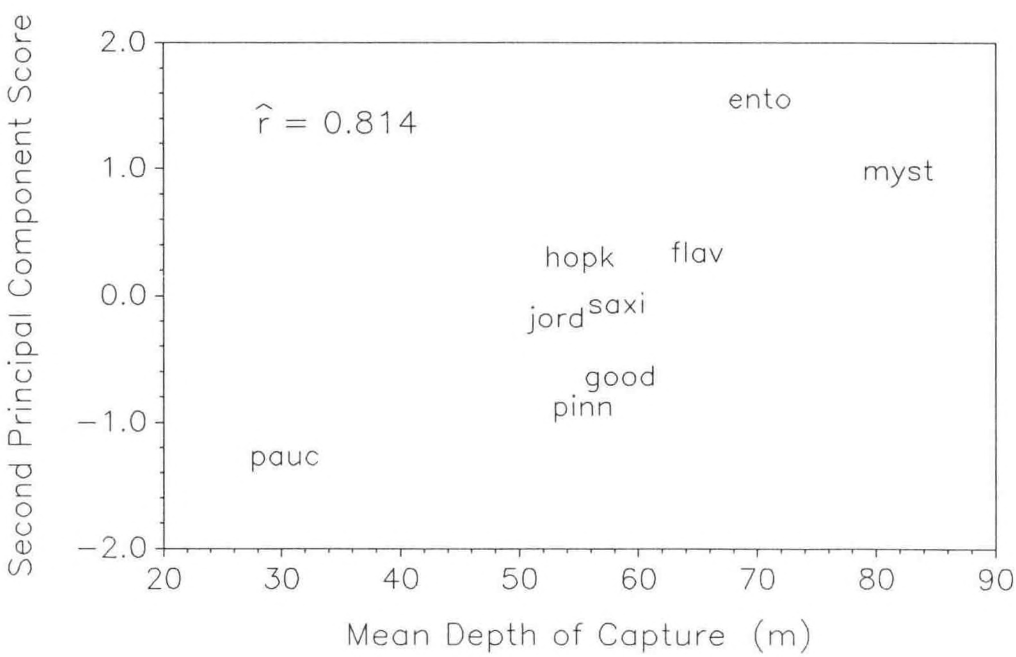


**Figure 8.** The relationship between second principal component score and depth of capture [see text for further discussion]. Species abbreviations as in Fig. 6.

Growth and Back-Calculated Birthdate Distributions

In past reports we have described our progress in aging pelagic YOY rockfish (larvae and juveniles) using daily otolith increments (e.g., Hobson 1989, Ralston 1990). A detailed growth model has now been developed for S. jordani (Laidig et al. MS) and interannual variation in the juvenile growth of five Sebastes species has been studied since 1983 (Woodbury and Ralston MS). In addition, the birthdate distributions of the juveniles that survive from parturition to the time of sampling have been back-calculated from date of capture and size information.

There is now firm evidence that interannual variations in these aspects of the biology of pelagic juvenile YOY rockfish are influenced strongly by water temperatures early in the life history. Cold years, as indicated by negative early February SST anomalies at the Farallon Islands shore station, are associated with reduced growth performance of S. jordani (Fig. 9). On the other hand, warm years, such as 1983, 1984, and 1987, result in more rapid growth. There is a similar effect of late February SST anomalies on the mean of back-calculated birthdate distributions (Fig. 10). In this instance, the mean birthdate of the S. jordani surviving until our May-June cruise, occurs early in the season during cold years and late in the season during warm years. We are presently evaluating whether these year to year fluctuations in the timing of successful reproduction are due to interannual variations in the timing of parturition or to within season variations in the mortality rates of larvae and juveniles. (S. Ralston and D. Woodbury).

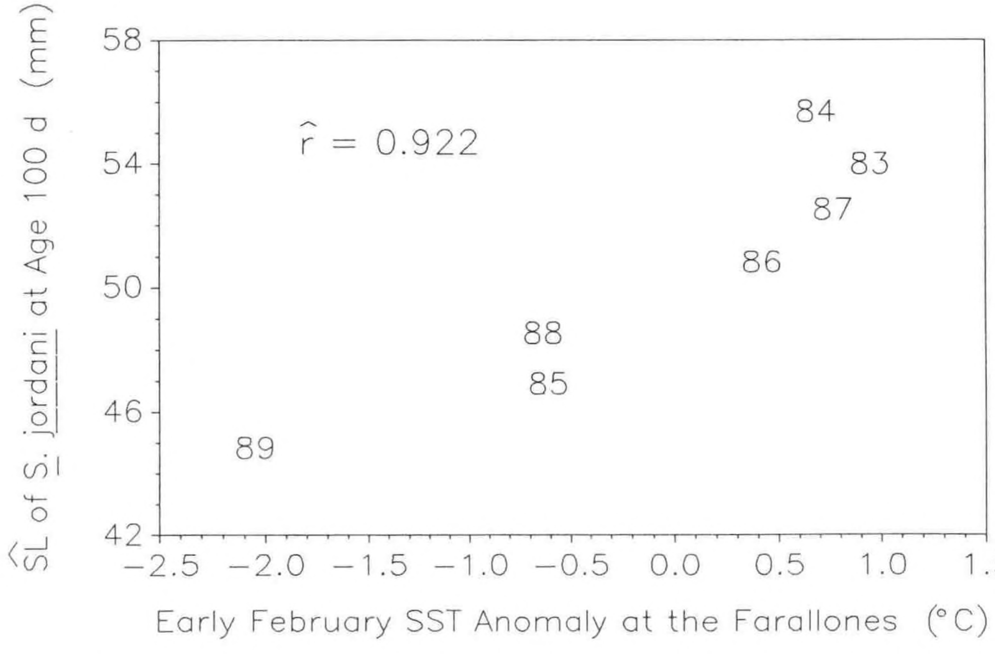


**Figure 9.** The effect of SST anomaly early in the year on the growth of juvenile Sebastes jordani.

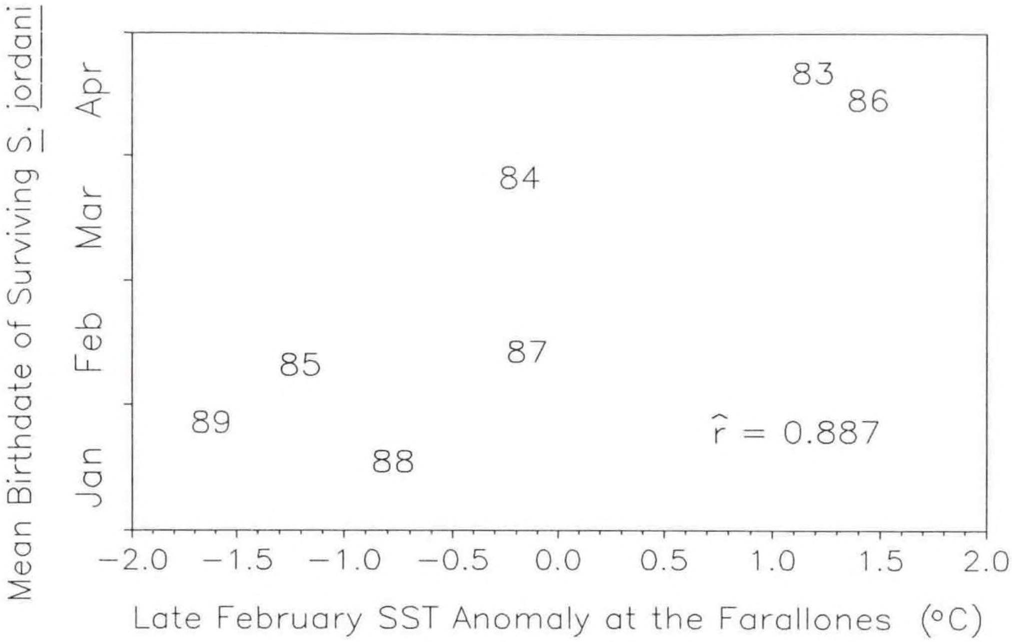


**Figure 10.** The effect of SST anomaly early in the year on the mean birthdate of the Sebastes jordani that survive until May-June, when sampled by midwater trawl.

## Evaluation of Plankton Samples

Since the midwater trawl surveys began in 1983, sampling procedures have included nightly surface tows using a one-meter plankton net with a 505 $\mu$m mesh cod-end. The contents were stored in a formaldehyde solution and returned to the lab to be keyed out. Identified species were then used as voucher specimens to aid in stomach analysis of prey items of juvenile rockfish (Reilly et al. MS). Since flow meters to measure water volume were not used, data from these plankton tows were never analyzed quantitatively. In contrast, bongo nets equipped with flow meters are a quantitative means of sampling plankton.

Recently a study was implemented to compare paired bongo and plankton net tows, which were taken during the 1990 cruises, to determine if the samples collected since 1983 with a plankton net can be used to estimate the abundance and distribution of prey items of juvenile rockfish. If so, we can include data from previous years to study historical levels of prey abundance and distribution.

During cruises DSJ-9003 and DSJ-9005 tows were made consecutively with a one-meter plankton net and a bongo net at the same location. Flow meters were attached to each of the nets to measure volume of water sampled. The one-meter net was towed obliquely with 51 meters of cable at a 50° angle for 30 seconds at depth. The bongo net was towed using CalCOFI procedures (i.e., with 300 meters of cable at an angle of 45° for 30 seconds at depth).

A total of five paired samples from the April cruise have been analyzed thus far. Preliminary results show that the most common species sampled are copepods, juvenile euphausiids (including larval stage furcillia and calyptopis), fish and invertebrate eggs, and crab zoea. Some paired hauls seem to be quite similar, both in terms of content and relative abundance for species. However, each pair of hauls is very different from other pairs. Identification and analysis of the data should be completed this fall. (A. McBride)

Distributional Patterns of YOY to the North

Since the last progress report we have become involved in a study of the seasonal and spatial distribution patterns of rockfish larvae and juveniles in the region north of our study area. Specimens of Sebastes spp. from a series of cooperative U.S.- U.S.S.R. ichthyoplankton surveys, conducted off the west coast of the United States, have been provided to the Groundfish Analysis Task for identification and enumeration (samples provided by A. W. Kendall, Jr., AFSC, Seattle). These surveys occurred once or twice a year from 1980-87; the samples were collected with bongo and neuston nets (both 505 $\mu$m mesh) from stations located 40° - 48° N latitude off the Washington, Oregon, and northern California coasts. Upon receipt, the larvae and juveniles had only been identified to the genus Sebastes. We will evaluate if our identification procedures and techniques, developed from local central California stocks, are more widely applicable to these more northern populations. A technical memorandum on this work is planned. (C. Reilly)

## Progress in Trophic Studies of Predators

Estimates of Recruitment Based on Occurrence in Predator Diet

Assessments of pelagic juvenile rockfishes in the gut contents of the king salmon, Oncorhynchus tshawytscha indicated there were fewer recruits during 1990 than during any year since 1983, when there was a particularly strong El Niño. This was evident in the numbers recovered from the gut contents (Table 3), and also in that they were present in the diet for a shorter period, 17 May to 15 June, than during any other year since 1983. Shortbelly rockfish were 92% of the juveniles identified and the only other species recovered were the yellowtail, S. flavidus and the widow rockfish, S. entomelas. (P. Adams and K. Silberberg)

**Table** 3.--Mean number of first year juvenile rockishes (Genus *Sebastes*) in the stomach contents of king salmon (*Oncorhynchus tshawytscha*) from the Gulf of the Farallones, 1983-1990 (N = the number of stomachs from collections which contained rockfish).

| 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 |

## STUDIES OF POST-PELAGIC JUVENILES

The post-pelagic juveniles of *Sebastes* spp. school in nearshore habitats for several months following the pelagic period of development. During this time their abundance is assessed in kelp bed communities by visual observations while diving.

### Progress in Visual Assessment of Juveniles in Nearshore Habitats

#### Estimates of Recruitment Based on **in situ** Assessments

Assessments of first-year juveniles during the months after they had settled in benthic habitats near shore indicated, as did assessments of the salmon diet, that there were fewer recruits during 1990 than during any year since 1983, when there was a particularly strong El Niño. This finding is based on annual assessments at permanent study sites off the Sonoma (since 1984) and Mendocino (since 1983) coasts. There, researchers of the Groundfish Communities Investigation have used SCUBA to monitor occurrences of the three species that dominate among first-year juveniles: the yellowtail rockfish, *Sebastes flavidus*; the blue rockfish, *S. mystinus*; and the black rockfish, *S. melanops* (Tables 4 & 5).

**Table 4**.-- Mean number (standard error in parentheses) of first year juveniles counted/minute off the Mendocino coast during August and September. n=number of one minute assessments.

| 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 |
|---|---|---|---|---|---|---|---|---|
| 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) |
| 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) |
| 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) |
| 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) |

**Table 5**.-- Mean number (standard error in parentheses) of first 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 |
|---|---|---|---|---|---|---|---|
| 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) |
| 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) |
| 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) |
| Total | 10.91 (2.12) | 257.20 (35.38) | 24.97 (5.17) | 442.48 (66.72) | 221.38 (22.55) | 10.39 (1.34) | 1.81 (0.48) |

The low numbers present do not permit comparing the Sonoma and Mendocino populations to the extent done in previous years, but certain differences between sites are noteworthy. While recruitment of S. mystinus was stronger at Sonoma than Mendocino during every year from 1984 to 1989, during 1990 the pattern reversed (Tables 4 & 5). The significance of this observation is questioned, however, by the scarcity of S. mystinus during 1990. In fact, the normally dominant S. mystinus was outnumbered during 1990 by S. melanops, which ordinarily is much fewer (Tables 4 & 5). S. flavidus, on the other hand, continued as in previous years being more numerous at Mendocino than at Sonoma, although like S. mystinus it experienced during 1990 a second straight year of exceptionally weak recruitment. (E. Hobson, D. Howard and J. Chess)

Mortality Rates Are Density-Related

Estimates of natural mortality in juvenile S. mystinus during their first nine months in near-shore habitats have become a part of the annual sampling program, but severe weather during late winter and early spring of 1991 prevented completing estimates for the 1990 year-class. Thus, for the second consecutive year weather has interfered with collecting data needed for these estimates and during both years the problem has been compounded by scarcity of recruits. Despite these frustrations, however, there has been significant progress in understanding how natural mortality affects the supply of recruits to the fishery.

It has been determined that natural mortality in first-year S. mystinus correlates positively with the numbers of recruits that enter the near-shore habitat. This can be demonstrated with data from four years, 1985 to 1988, at one site at Mendocino (Fig. 11) and is consistent with Lockwood's (1980) suggestion that natural mortality among juvenile plaice, Pleuronectes platessa, is density dependent. That density influences mortality has been evident in findings by the Groundfish Communities Investigation that certain predators, for example the kelp greenling, Hexagrammos decagrammus, feed heavily on juvenile S. mystinus and other juvenile rockfishes when they are abundant, but show no interest in them when they are scarce.

The density-related aspect of natural mortality in juvenile S. mystinus can be examined with a simple model based on the 1985-1988 data from Mendocino, referred to above. Recruitment during these four years was weakest in 1986 and strongest in 1987, with a 23-fold difference in numbers of recruits and a five-fold difference in mortality rates between the two years. The model compares these differences (Fig. 12), using the 1/23 ratio established by the counts as basis for the number of recruits representing each year, i. e. 1,000 in 1986 and 23,000 in 1987. The model then applies the daily natural mortality experienced by the recruits from late July to April each year, as calculated from results of the periodic counts: 0.001 in 1986, 0.005 in 1987. It is assumed that from April until age 15 years recruits of both years experience a daily mortality rate of 0.00069, which is based on an estimated annual adult mortality rate of 0.25 (Gotshall 1969). That an adult mortality rate can be assumed from this point is suggested in the similarity of the April ratio, 1/7, to the ratio of 1/6.5 between numbers of adults in smallest and largest year classes of the closely related widow rockfish, S. entomelas (Hightower and Lenarz 1989).

It would appear, therefore, that the effects of density on natural mortality occur mainly during the first year. Furthermore, the decline to a ratio of 1/7 from one of 1/23 just eight

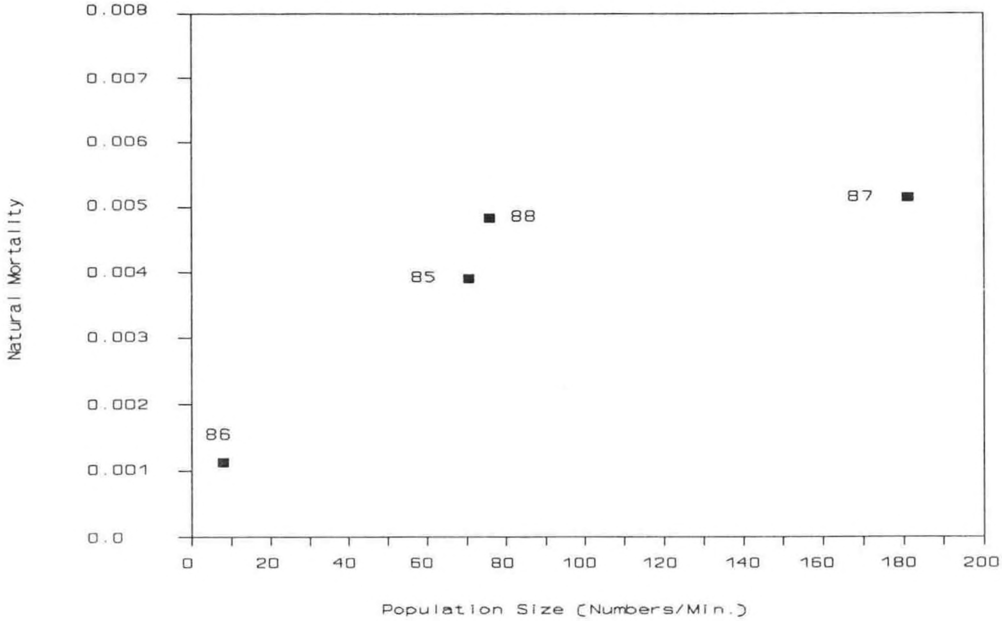


**Figure 11.** Average number of first-year juvenile <u>Sebastes mystinus</u> counted per minute plotted against natural mortality estimates (1985 to 1988) at site on Mendocino coast.

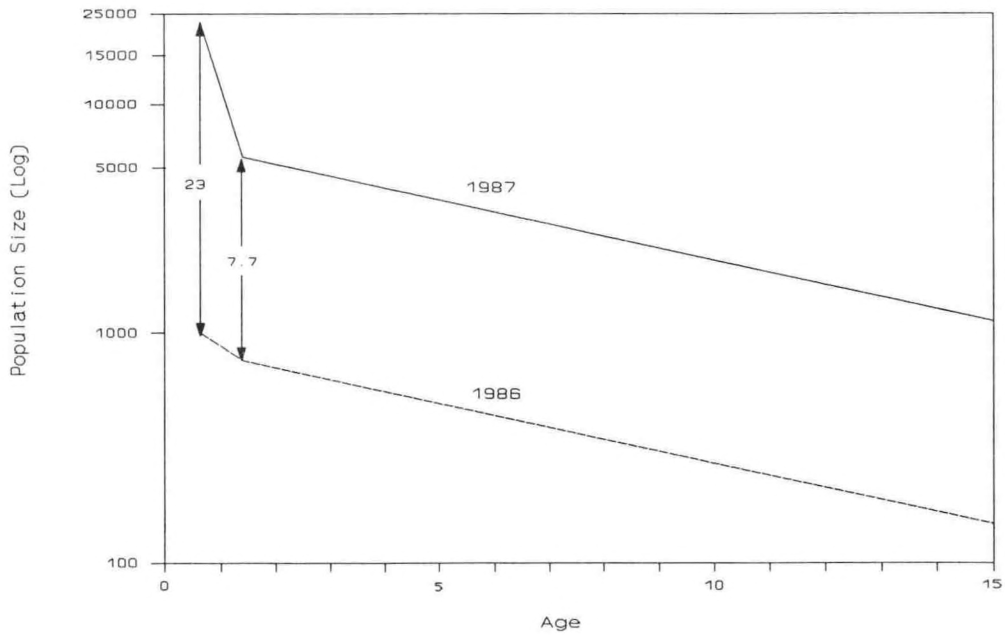


**Figure 12.** Model of effect of density-related mortality on first-year juvenile <u>Sebastes</u> <u>mystinus</u> based on 1986 and 1987 year classes at site on Mendocino coast.

months earlier demonstrates that density-related mortality among first-year <u>S</u>. <u>mystinus</u> acts as a buffer to reduce variation in size of year-class among adults. (P. Adams and D. Howard)

### Progress in Manual for Identification of Juvenile Rockfishes

The studies of recruitment in rockfishes at the Tiburon Laboratory share the need to identify juvenile specimens correctly. Often this is a difficult task because it involves very young fish that lack many of the characters ordinarily used to identify the species. Many juveniles are damaged also by digestion in the gut contents of predators. A number of investigators have worked to resolve the varied problems involved, and now their results are being brought together for publication as a Technical Memorandum.

Chapters include: 1) a meristic key by Sharon Moreland and Carol Reilly, 2) a computerized key for identifying specimens from gut contents by Peter Adams and Wayne Samiere, 3) identifications based on otolith microstructure, by Tom Laidig and Steve Ralston, 4) identifications based on the cleithrum (a bone in the pectoral girdle), by Kelly Silberberg, 5) identifications based on caudal bones, by Tom Laidig and Wayne Samiere, and 6) ways to distinguish the black rockfish, S. melanops, from the yellowtail rockfish, S. flavidus, using patterns of pigmentation. The methods to be described have been used by researchers at Tiburon for some time and have greatly improved their ability to identify specimens. For example, the proportion of juveniles identified in gut contents of predators has increased from 63% to over 95% over the time of the juvenile studies. (T. Laidig and P. Adams)

## STUDIES OF ADULTS

### Progress in Studies of Adult Sebastes mystinus

Adult S. mystinus occur in nearshore habitats, where they are sampled by divers.

Effects of Feeding Conditions on Physical Condition and Recruitment Success

The question of whether recruitment of S. mystinus is influenced by how well adults of that species feed has been under study by the Groundfish Communities Investigation since November of 1988. The possibility that this relation exists became apparent during the 1982-83 El Niño, when the exceptionally poor recruitment of 1983 (Table 4) followed a year when the adult fish had become emaciated from severe lack of food. Taking its lead from this observation, the present study evaluates feeding conditions and physical condition of adult females during the course of each year and then considers the results in relation to the number of recruits counted during the following year.

The study is in its early stages, with just three years covered to date, so it is too early to draw conclusions. Nevertheless, when the results summarized in Figures 13 and 14 are integrated and then related to the relative abundance of first-year juveniles (Tables 4 & 5), we have evidence not only that summer-fall feeding conditions affect physical condition, but also that subsequent recruitment may be influenced as well.

The evaluation of feeding conditions is based on study of gut contents and samples of the plankton (S. mystinus is a planktivore). The period June to November is considered critical, because this is when adults ordinarily feed best (Hobson and Chess 1988) and when they store energy used to produce the next year's recruits (parturition in this species occurs from December to February). The evaluation of physical condition is based on assessments of selected condition indicators: a visceral fat ranking represents subjective visual estimates of fat content on a relative scale, 0 to 5, whereas liver condition and soma condition (with soma defined here as body less viscera and gonads) are represented by Fulton's Condition Factor ($k = weight/length^3$).

Relative to other years, feeding conditions were subpar during all three years considered here. This is evident in the relative prominence of algae, an uncertain food source for this species (Fig. 13). In an earlier study, Hobson and Chess (1988) concluded that S. mystinus consumes more algae in the absence of preferred gelatinous zooplankters. Nevertheless, it is clear that feeding conditions were better during 1988 than during either 1989 or 1990 and it would seem significant that the condition indicators also were higher that year (Fig. 14). The occurrence of juvenile Sebastes spp. among the gut contents during 1989 reflects the relative strength of the 1988 year class (one of the stronger, see Tables 4 & 5). Like a number of other nearshore predators (see section on estimates of natural mortality, below), the planktivorous adult S. mystinus feed significantly on juvenile rockfishes only when these prey are particularly abundant.

Thus, the exceptionally poor recruitment by S. mystinus during 1990 may have been influenced by the poor feeding conditions and relatively low condition-indicators experienced by the adults of this species during 1989. If this is so, the outlook for the 1991 year class would seem bleak, because the feeding conditions and condition indicators experienced by adults during 1990 were even worse than they had been the year before.

Whether or not recruitment is influenced by feeding success and physical condition of adult females remains problematical, however. The response to relative feeding success evident in fat, liver and soma conditions identified above, has been far less evident in our assessments of stage and weight of female gonads. Consider, for example, how gonads developed each year from 1988 to 1991 in females of 260-280 mm SL (Fig. 15). Fish of similar size were selected because gonads develop earlier and to a larger relative size in larger fish.

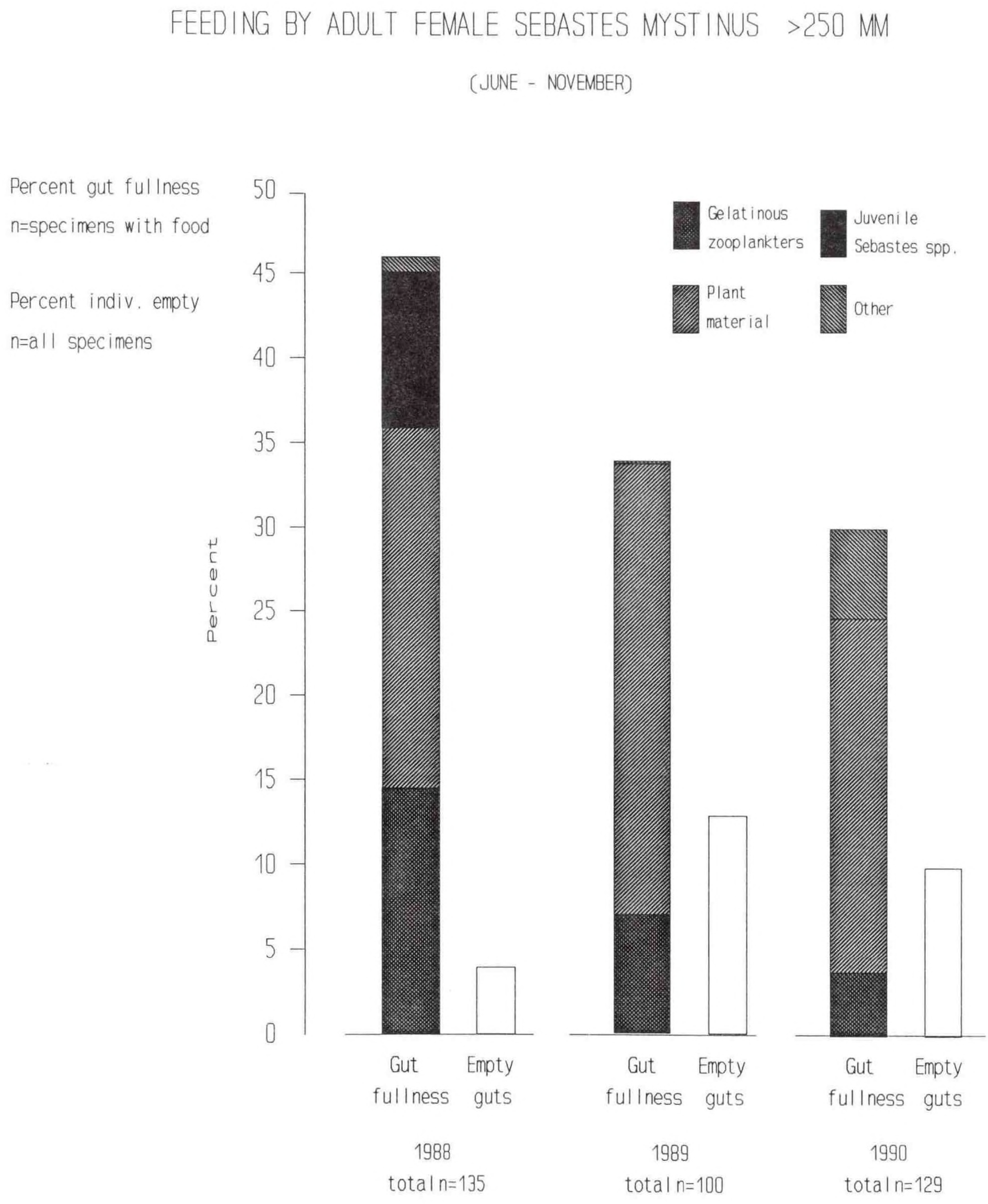


**Figure 13.** Feeding by adult female Sebastes mystinus.

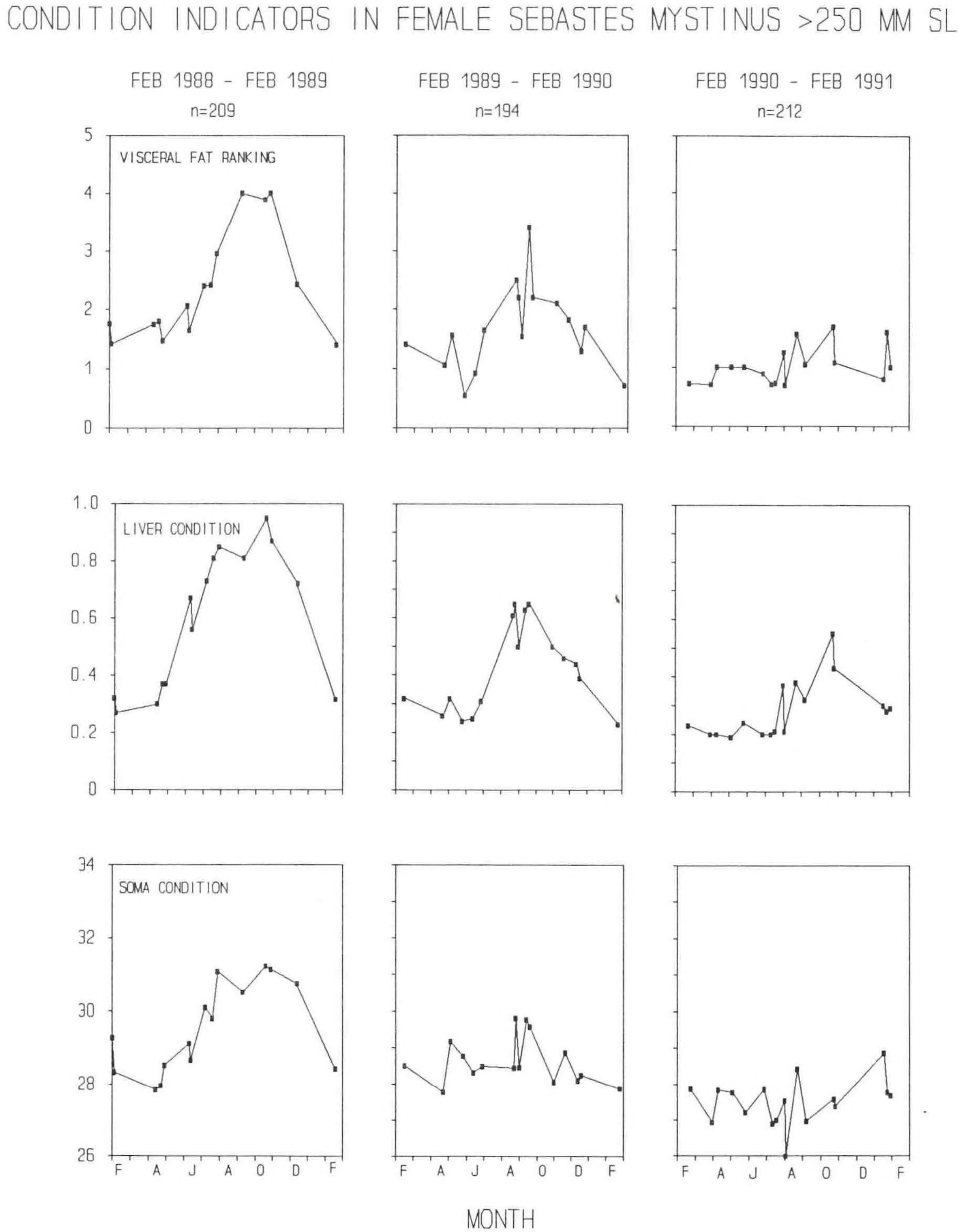


Figure 14. Condition indicators in female Sebastes mystinus.

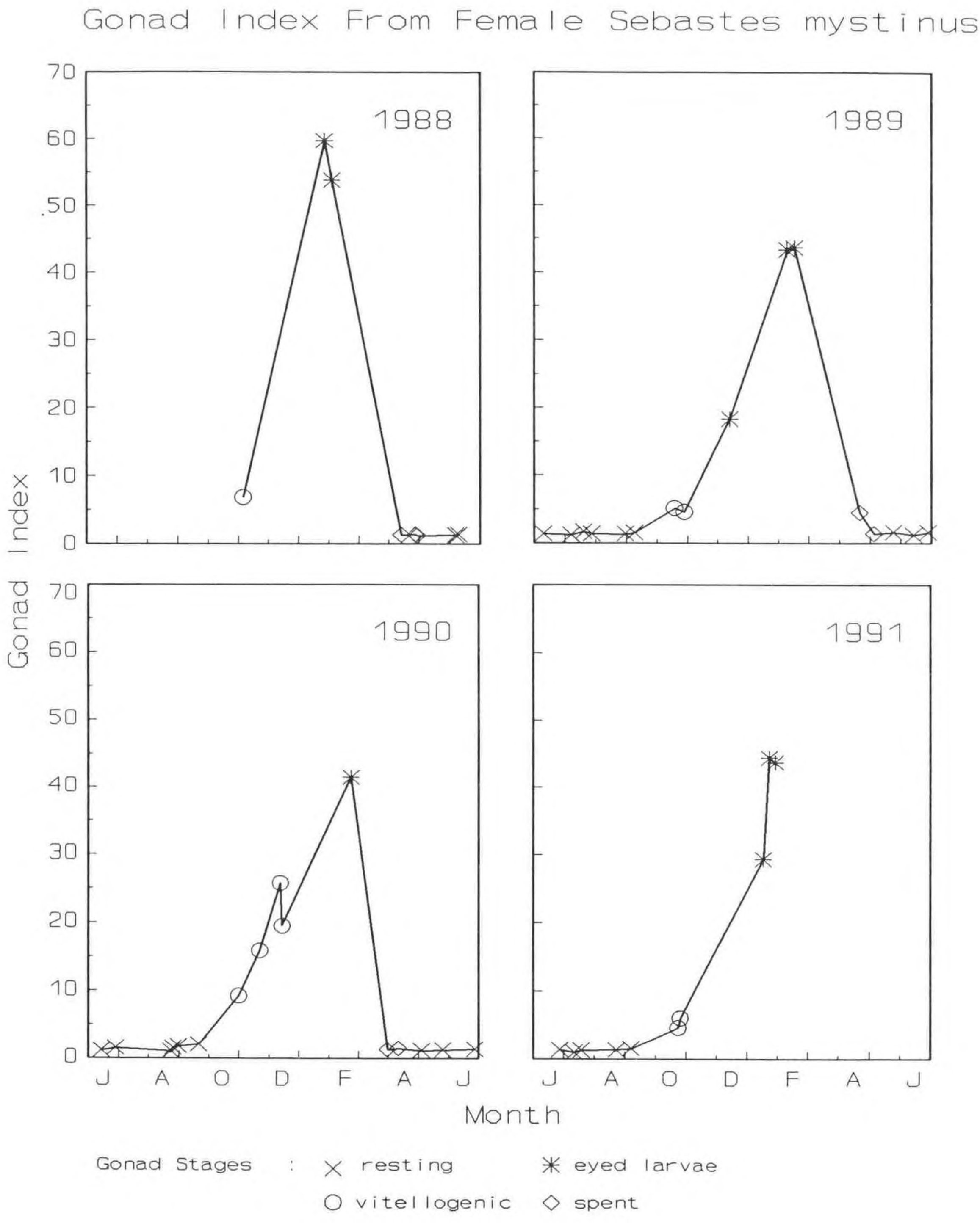


**Figure 15.** Gonad index from female Sebastes mystinus.

The comparison is based on an index calculated as gonad weight/standard length[3], where each point represents from 1 to 10 fish (x = 3.3) and maximum gonad development each year is at the eyed-larvae stage. Because sampling began in November of 1987, the data include females that would have been among those which produced the strong year-class of 1988. This would seem to offer a better opportunity than with the above to consider the possibility of an influence on recruitment, but the data show no obvious difference in gonad development among these years. The mean index values from females that would have produced the very strong 1988 year class (upper-left panel) were just 10 to 15 units above the others (and the range of variation within each sample tended to exceed this). Furthermore, the highest index value of all came from a female that would have contributed to the very weak 1990 year class. (That value (78) was so far from the others that it was excluded from this analysis.) Although this is a crude measure and the sample is limited, the results caution against a premature suggestion that feeding and physical condition affect recruitment. The small difference observed in gonad development between 1988 and the other years may be real and enough to have affected recruitment. On the other hand, it is also possible that despite poor feeding the females were able to channel sufficient energy to develop their gonads and that this in fact contributed to the relatively poor physical condition observed during those years. Either way, it is clear that there is need for additional study. (E. Hobson, J. Chess and D. Howard)

## Progress in Studies of Adult *Sebastes flavidus*

Adult yellowtail rockfish (*S. flavidus*) occur in deeper waters offshore and are sampled by hook-and-line in 25-100 fathoms of water at Cordell Bank (approx. 38° N latitude; 124° W longitude).

The Physiological Ecology group has been assessing the condition and reproduction of adult fish. The results will help determine how variation in reproductive performance affects variation in recruitment. Previous administrative reports presented the overall objectives, general methods, and initial results (e.g., Ralston [ed.] 1990). This report provides an update of results obtained during the last two spawning years (April 1989 through March 1991) and summarizes new information on food studies.

Monthly collection of adults was continued. After the first three years of monthly sampling, a less frequent monitoring schedule was instituted in the 1988-1989 spawning year and sampling was done for fewer months. Because of atypical oceanographic conditions over the last two years, we renewed sampling on a monthly basis in December 1989 in anticipation of a possible El Niño. In addition, spatial coverage of sampling was extended to more northern populations off Washington state and British Columbia, Canada.

The sampling period now covers six spawning years (1=1985-1986, 2=1986-1987, 3=1987-1988, 4=1988-1989, 5=1989-1990, 6=1990-1991). A spawning year is defined as beginning on April 1 of the first year and ending March 30 the following year. The first three years appeared fairly similar, with some variation in adults of year 1. The last two appear to represent years of poor adult condition (1989-1990 and 1990-1991).

Somatic Wet Weights and Condition

The original objective of this research was to determine the relationship of temporal variability (seasonal and interannual) in inherent and environmental variables to temporal variability in condition and reproduction of adult yellowtail rockfish.

Examinations of yellowtail rockfish from Cordell Bank were continued, including analyses at whole animal, organ, tissue, cellular and subcellular levels of biological organization. During the monthly synoptic sampling, we have examined a total of 861 fish through April of 1991, including 807 adults and 54 subadults. Adults of both sexes ranged from 6 to 45 years of age. There were 583 adult females and 224 adult males (females were selected in larger numbers for our studies). Results reported in this section are primarily for the female adult yellowtail rockfish). The annual means of condition variables obtained from recent covariance analyses of data for adult females are shown in Fig. 16. In covariance analyses, means were adjusted for the effect of age of female. We found from previous work that seasonal month to month differences were highly significant ($P<0.001$), so monthly comparisons were made.

Condition of fish was significantly poorer in the last part of the spawning year 1989-1990 and particularly in 1990-1991. Analyses showed that for the month of August 1990, for example, condition of females was significantly less than in previous years ($P<0.05$). The reduced condition in 1990-1991 was particularly noted in reduction of mesenteric fat of females during July 1990 when all spawning years are compared ($P<0.01$)(Fig. 17). (J. Whipple)

Interannual Variability in Growth

A von Bertalanffy growth equation (Ricker 1975) was used to relate length and age in yellowtail rockfish. Growth equations were fitted separately for each sex and years were compared using the Extra Sum of Squares Principle (Draper and Smith 1981, Ratkowsky 1983). Females showed a significant interannual variation ($P<0.05$)in growth in the 6 years of the study (Table 6).

The results show that fish during the 1986-1987 and 1987-1988 spawning years exhibited highest growth rates, while those from the 1985-1986, 1989-1990 and 1990-1991 spawning years exhibited the lowest. These results are in accord with mean condition factors observed during those years (Fig. 16, 17). (J. Whipple and D. Pearson)

**Table 6.**--The von Bertalanffy growth curve parameters for 6 yrs of study. Adult female yellowtail rockfish.

| Year[1] | $L^{\infty}$ (Cm) | K ($Years^{-1}$) | $t_1$ (Years) |
|---|---|---|---|
| 1 (1985-1986) | 54.13 | 0.07 | 34.58 |
| 2 (1986-1987) | 49.07 | 0.14 | 35.73 |
| 3 (1987-1988) | 49.48 | 0.16 | 33.10 |
| 5 (1989-1990) | 50.69 | 0.10 | 35.03 |
| 6 (1990-1991) | 49.70 | 0.09 | 35.34 |
| Total (1985-1991) | 50.89 | 0.10 | 35.17 |

[1]Year 4 (1988-1989 spawning year) omitted because of unrepresentative sampling months.

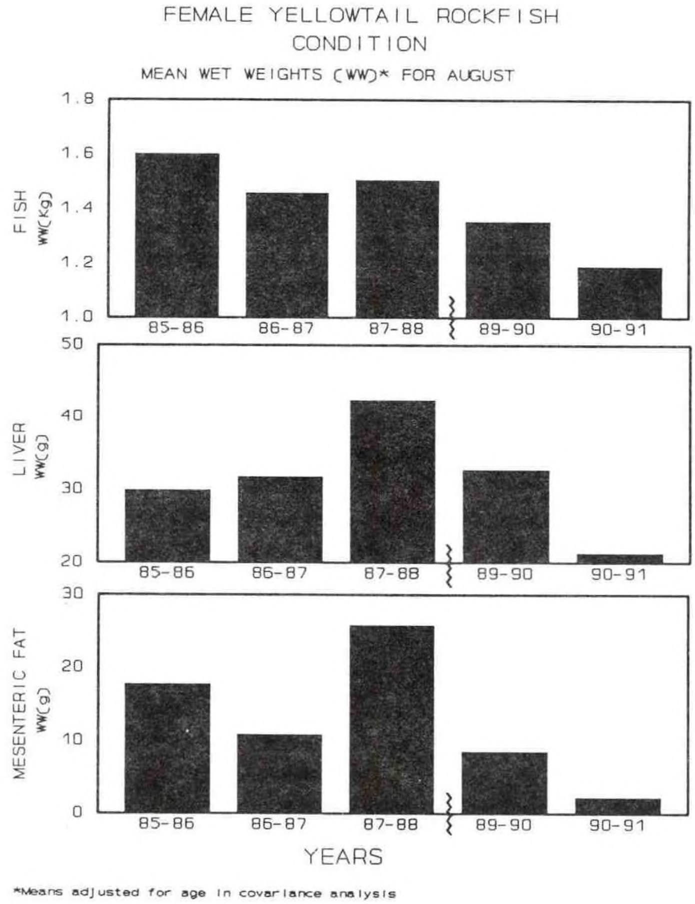


**Figure 16.** Condition of female S. flavidus, as indicated by mean weights of fish, liver and mesenteric fat. Means were adjusted for age in covariance analysis.

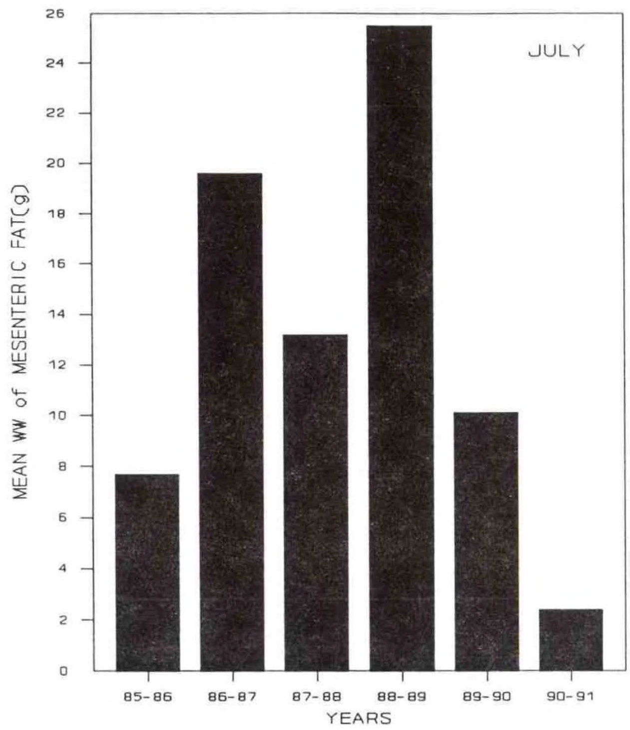


**Figure 17.** Mean weight of mesenteric fat of female S. flavidus in July for the six years of the study. Means adjusted for age-size of fish.

Disease; Chromatophoromas

As fish age, effects of a higher prevalence of parasites and chromatophoromas become apparent. The diseases and parasites found in yellowtail rockfish adults were described in previous reports.

A manuscript describing a cooperative study with the Histopathology Department, School of Veterinary Medicine, U. C. Davis, has been completed and is under outside review. The manuscript describes chromatophoromas in yellowtail rockfish and includes additional information on other species. The title of the manuscript is "Chromatophoromas and related hyperplastic lesions in Pacific Rockfish (Sebastes)" by M. S. Okihiro, J. A. Whipple, J. M. Groff and D. E. Hinton.

In summary, the manuscript describes chromatophoromas from Pacific rockfish (genus Sebastes) sampled from Cordell Bank, 37 kilometers off the coast of central California, for a period of six years (1985 to 1991). Hyperplastic and neoplastic cutaneous lesions, involving dermal chromatophores, were observed in five species; yellowtail rockfish (S. flavidus), bocaccio (S. paucispinus), olive rockfish (S. serranoides), widow rockfish (S. entomelas), and chilipepper rockfish (S. goodei). Yearly prevalences were initially low in S. flavidus, but increased more than 3-fold from 1985 (7.5%) to 1990 (25%). The mean prevalence in yellowtail rockfish for the 6 years of the study was approximately 13%. Prevalences in the other species are also given. The majority of lesions were black, but white, red, orange, yellow, and mixed color variants were also seen. Lesions were found in skin, fins, lips, gingiva, tongue, urogenital papilla, conjunctiva and cornea of the eye. Histologically, flat lesions were consistent with either melanophore (black), erythrophore (red), or xanthophore (yellow or orange) hyperplasia. Neoplastic lesions included melanophoromas, amelanotic melanophoromas, xanthophoromas, erythrophoromas, and mixed chromatophoromas. Electron microscopy did not reveal the presence of virus and etiology has not been determined.

The prevalence of chromatophoromas and other diseases was significantly higher in 1989-1990 and 1990-1991 ($P<0.01$), indicating increased stress in fish from Cordell Bank. Higher incidence of melanophoromas was found to relate to reduced condition in yellowtail rockfish as reported previously (Ralston [ed.] 1990). (J. Whipple)

Wet Weight of Gonads and Condition Indices

Condition, particularly the amount of fat in liver and mesenteries, was poorer in 1989-1990 and 1990-1991, and this appears to be reflected in lower weights of female gonads in August of those years and in lower effective fecundity of 1989-1990, particularly in older females (Figs. 18 & 19). Effective fecundity is the total number of eggs per fish minus the number of atretic eggs and/or abnormal eggs and embryos.

We have not determined yet what the relationship of lowered condition to reproduction was in 1990-1991. Based upon the some of the measurements taken to date, it would appear that there should be poorer reproduction. This is not certain, however, because in the fall and winter months yellowtail rockfish were able to feed heavily on an unseasonable occurrence of euphausiids and may have been able to recover in time to reproduce normally. Serum and gonad proteins and lipids during and just prior to gestation would suggest high nutrient (energy) input into eggs and embryos (see below). The above results are from the monthly synoptic sampling study. The following study, determining fecundity of a larger sample, generally supports the above results. (J. Whipple)

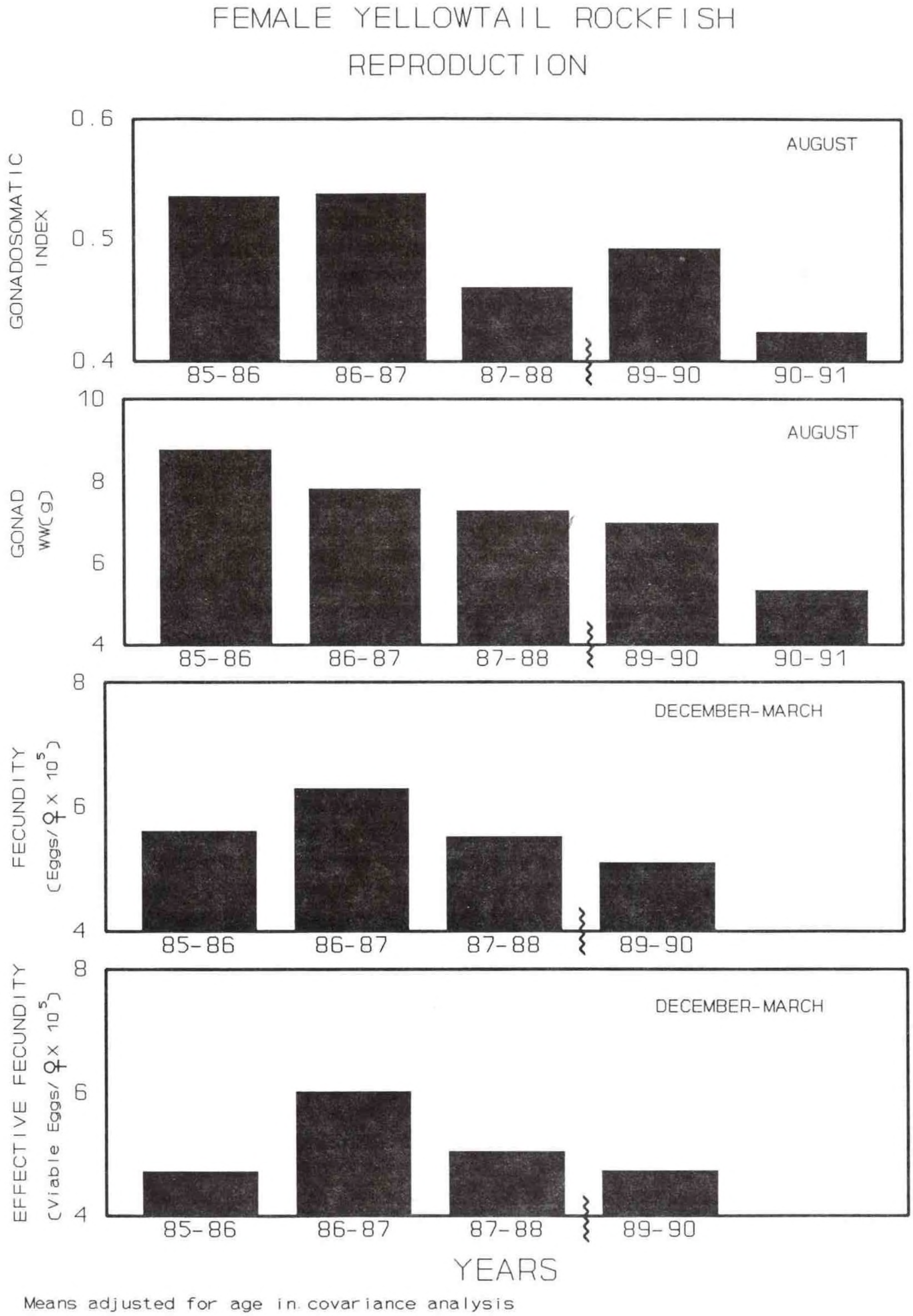


**Figure 18.** Reproduction of female S. flavidus, as indicated by GSI and weight of gonad in August; fecundity and effective fecundity during spawning months.

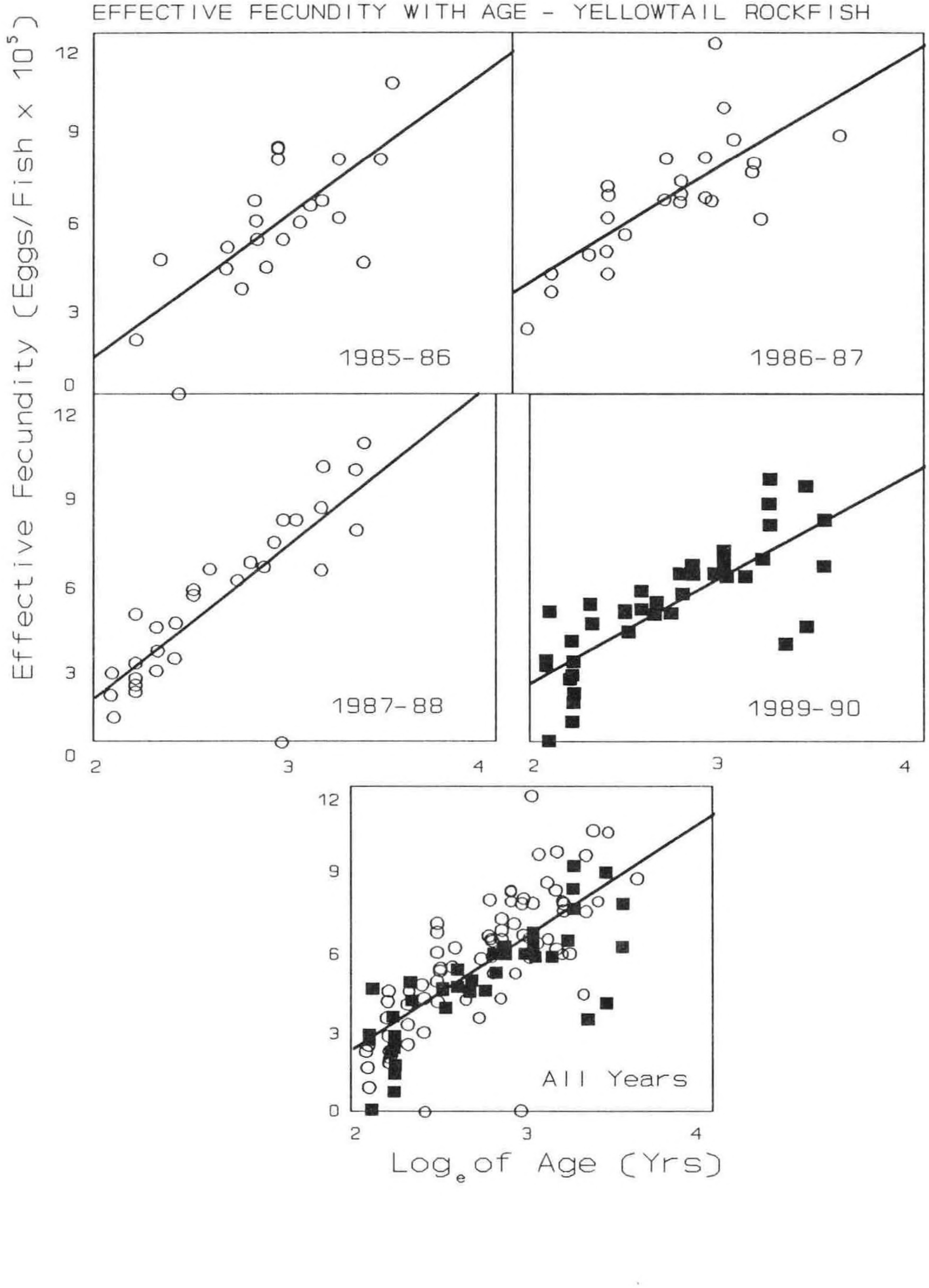


**Figure 19.** Effective fecundity of S. flavidus for 4 of the years of the study. Regression line for year 1989/1990 significantly (P<.05) lower than other years.

Fecundity Research

Fecundity plays an important role in population growth and maintenance and it serves as a specific measure of reproductive effort (Eldridge et al. 1991). During the last recruitment year a five year (1985-90) study of annual variation in yellowtail rockfish (S. flavidus) fecundity was completed. The general objective of this study was to determine the interannual variations in reproductive effort and to relate them to adult physiological conditions. The research design consisted of monthly collections of adult female yellowtail rockfish during peak reproductive months, ovarian subsampling for estimation of fecundity, and comprehensive whole body and organ examinations. A total of 346 adult female yellowtail rockfish were collected monthly by hook and line from November through March. Specimens in this study ranged from 5 to 48 years of age with a mean of 15.5 years. Mean sizes were 36.4 cm standard length (SL) (range 27.0-46.0 cm) and 1304 g total wet weight (range 552 - 2627 g).

Absolute fecundities (total eggs per fish) increased in a curvilinear fashion with age, somatic weight, and standard length (Fig. 20) with the highest correlation with somatic weight ($r=0.91$). The rates of increase in fecundity were also found to decline with age, most noticeably after 20 years of age. Annual comparisons of absolute fecundities showed significant differences (ANACOV $P<.01$) among years, especially in the age- and weight-specific fecundities. Analyses indicated that the reproductive efforts (monitored from April to the following March) were higher during 1988-1989 and lower during 1987-1988 and in older fish in 1989-1990.

Most of the annual variation was due to differences in reproductive efforts between older, larger fish (>20y) and younger, smaller fish (<19y) (Fig. 21). The 1987-1988 low production was due mainly to the lower effort of younger fish. The relatively high production of 1988-1989 was due to combined effort of both young and old fish. The 1989-1990 season apparently had opposite effects for members of the two age groups. Younger fish produced their highest mean absolute fecundity while older fish produced their lowest.

Relative fecundities (RF) (eggs/g of somatic tissue) showed a strong linear relationship to absolute fecundities (AF); ($RF = 180 + 0.000423\ AF$, $r=0.81$). Unlike absolute fecundities we found no significant differences among pooled age fish (ANACOV $p>0.05$;-Fig. 22). When fish were again separated into young (<19y) and old (>20y) age groups we found that older fish produced greater numbers of eggs per unit body weight and they also showed significant interannual variation in patterns similar to those of absolute fecundities (Figs. 20 & 21). We also observed that, as with absolute fecundities, the rate of egg production declined with advancing age and size (Fig. 22).

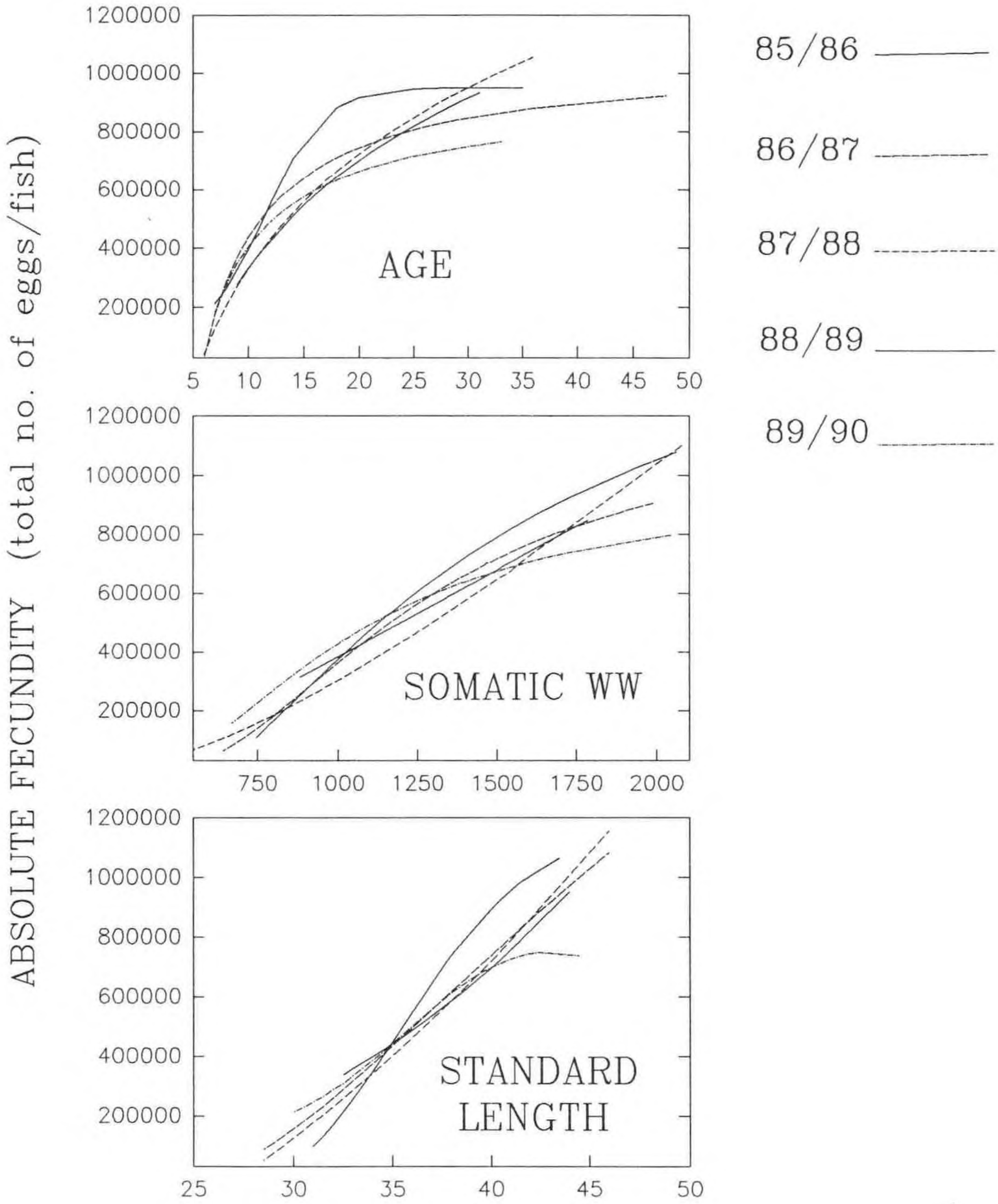


**Figure 20.** Best fit curves of absolute fecundities of S. flavidus from 1985-1990 according to age, somatic wet weight, and standard length.

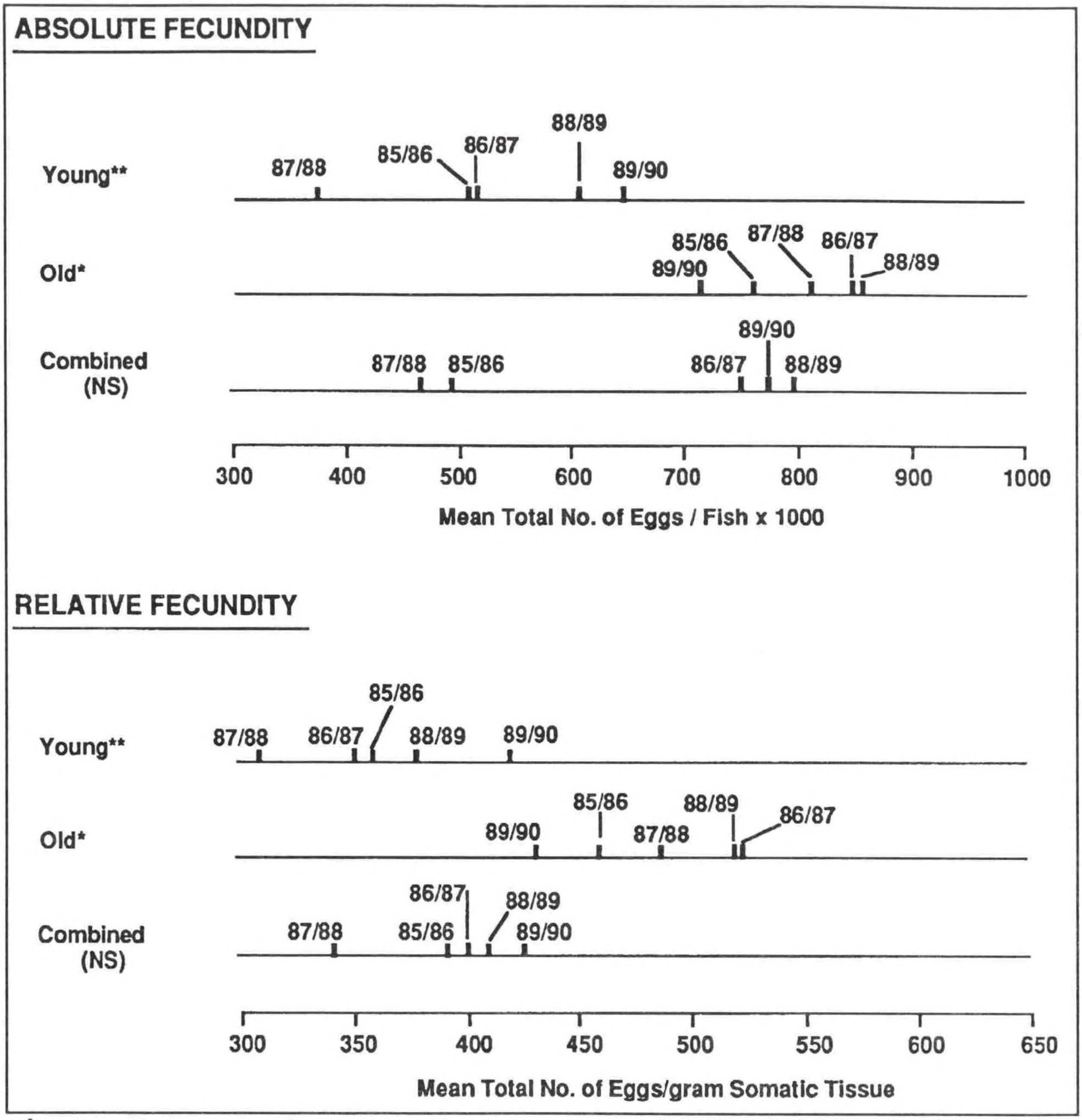


**Figure 21.** Annual means of absolute and relative fecundities for young (<19y) and old (>20y) and all ages of <u>S</u>. <u>flavidus</u> from 1985-1990.

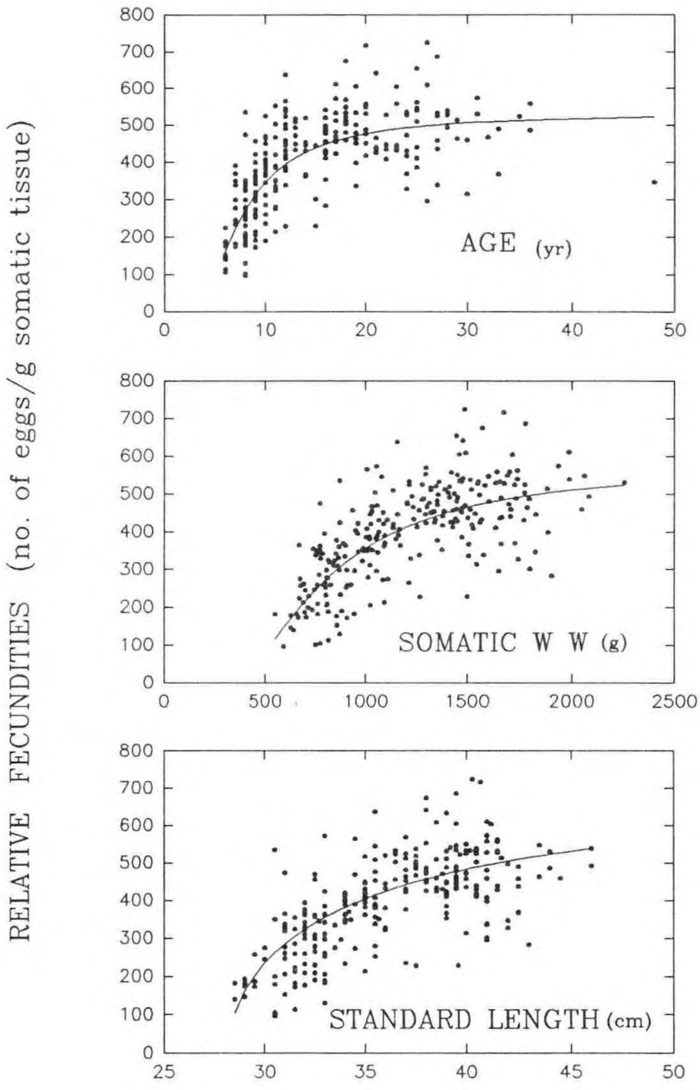


**Figure 22.** Relative fecundities of *Sebastes flavidus* according age, somatic wet weight, and standard length.

As observed in the first three years of this study, no significant difference (ANACOV P>0.05) was found over the five years between potential (unfertilized eggs) and realized (fertilized eggs) fecundities (Fig. 23) with high correlations in both types (real fecundity, r=0.83; potential fecundity, r=0.81).

Results of this research show that estimates of reproductive effort are most accurate when measured over a number of years and covering a range of specimen ages and sizes. Attention should be given to age-specific reproductive performances since fish of different ages apparently respond differently to varying annual environmental conditions.

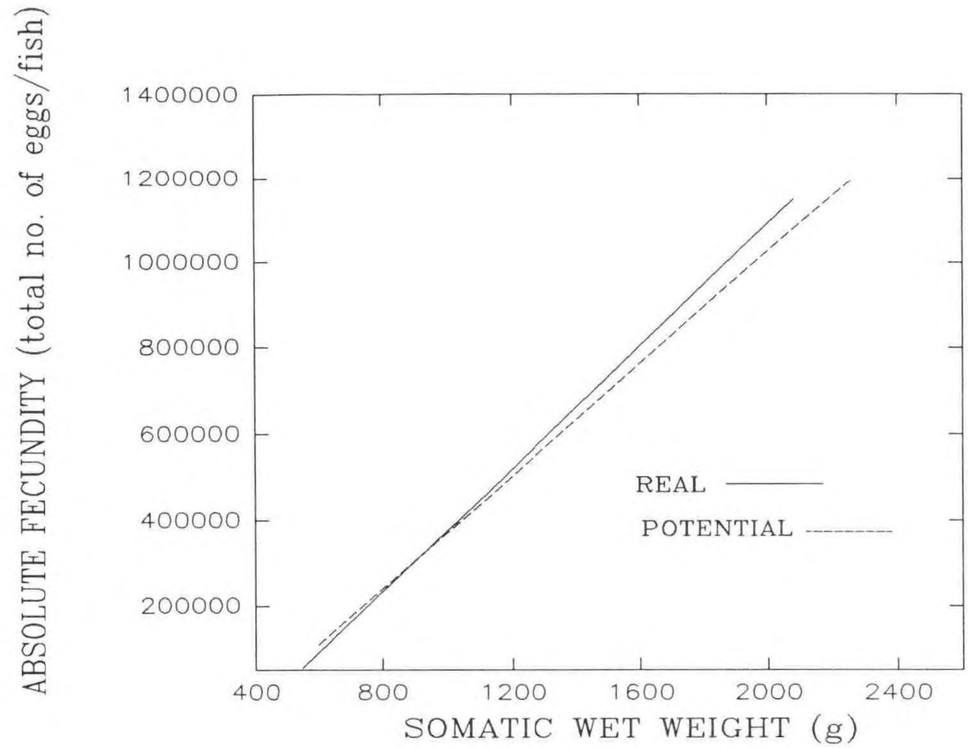


**Figure 23.** Linear regressions of real and potential absolute fecundities of *Sebastes flavidus* according to somatic wet weight.

## Gestation Study

One of the problems facing researchers who attempt to estimate spawning biomass of rockfishes by the larval production technique is the lack of information on the rate of gestation, that is, the time course required for embryonic and larval development leading to an estimate of parturition date. In December 1990, we conducted laboratory experiments that involved monitoring the rate of gestation in four yellowtail rockfish that had been transported from Cordell Bank, CA, maintained in 2000-L tanks, and sampled weekly by catheterization for 14 weeks. Three fish were captured with fertilized eggs already present. The developmental progression of their eggs were individually monitored for the duration of the remaining development until larval release. The remaining female entered the laboratory with unfertilized eggs. Within two weeks of collection, the eggs matured and fertilization took place. This particular fish was sampled from the day of fertilization until parturition.

The following (Table 7) outlines the general developmental sequence and rate for yellowtail rockfish embryos and larvae. We believe these rates may be advanced because the ambient tank water temperatures (11.0 - 11.5° C ) were warmer than those that occurred at Cordell Bank. In general the entire gestation period lasted from 28-31 days. This period consisted of embryonic incubation from fertilization to hatching at 22-25 days, and an internal larval incubation lasting 6-9 days. (M. Eldridge and B. Jarvis)

**Table** 7.--Development Features and time to development of eggs and embryos of S. flavidus.

| Day | Developmental Features |
|---|---|
| 0 | Eggs opaque; yolk becomes progressive transparent and granulated. |
| 1 | Fertilization; yolk and oil translucent, non-granulated; single oil globule; early formation of germ disc. |
| 2 | Well-developed blastodisc (morula to blastula). |
| 4 | Advanced gastrula; early appearance of embryonic body. |
| 10 | Embryo well formed; otic and optic vesicles developed; eyes with lens and no retinal pigmentation. |
| 19 | Embryos well pigmented; eyes 90 % pigmented; mouth open. |
| 22-25 | Hatched. |
| 26 | Larval yolksac contents approx. 1/2 consumed. |
| 28 | Yolk almost totally gone. |
| 28-31 | Parturition. |

## Lipid Dynamics in Relation to Reproductive Development in Females

Reproductive success, or the production of maximal numbers of healthy larvae, is influenced by several factors, including environmental conditions and the physiological, genetic, and nutritional states of the adult females. In fishes, especially marine species, lipids play a dominant role in the nutrition of the adult and the provision of energy and structural components for egg and embryo development. A previous report described the well-defined annual pattern of lipid accumulation, translocation, and deposition into the ovary of adult female yellowtail rockfish (S. flavidus), the model species used to investigate nutritional dynamics - reproduction interactions (Ralston [ed.] 1990).

Briefly, lipids are accumulated in the mesenteries and liver during the summer feeding period, and transferred via the circulatory system to the developing ovaries during the fall and winter months, the period of oocyte and embryonic development. Although the annual pattern is consistent among years, the concentrations of specific lipid compounds in various tissues varies considerably. The causes of this variability are uncertain, however, and the availability of appropriate forage is implicated. Lipid values in mesenteric depots, liver, and blood are related to the feeding intensity on euphausiids, whose abundance, in turn, seems to be a function of upwelling dynamics (i.e., intensity, duration, time of initiation, etc.).

Lipid concentrations in the ovaries during the period of oocyte and/or embryonic development have been related to the energetic state, and thus the health, of the eggs and larvae in some fish species. It is reasonable that reduced transport of specific lipids at critical phases of ovarian maturation, or decreased levels in the ovaries at critical phases of oocyte or embryonic development, may result in impaired development or reduced probability of survival.

Fishery managers benefit from valid estimates of year-class strength, which has an upper limit established by reproductive success. To determine the potential for using nutritional variables in a predictive model of reproductive success, lipids have been measured in serum, mesenteries, liver, and gonads of adult yellowtail rockfish since 1985. This progress report provides an update on lipid dynamics for the 1990-1991 reproductive year compared to previous cycles and an evaluation of the data according to the state of ovarian maturation for all specimens collected between April 1985 and September 1990. The latter analysis was intended to identify changes in total lipid concentration in specific tissues and lipid classes in serum at specific stages of oocyte and embryonic development (Bowers, MS in Press) to elucidate which components may contribute to reproductive success.

Similar to previous reproductive cycles, serum levels of triglycerides, cholesterol, and phospholipids started to increase from their annual minima in April. However, unlike previous years when serum lipids continued to increase through the summer, all lipid components declined to low concentrations in July 1990. That this was attributable to abbreviated feeding was revealed by the continuation of very low accumulation of fat in mesenteries, the primary storage tissue in this species.

Liver, which functions less as a depot and more as a processor and synthesizer of lipids in yellowtail rockfish, accumulated lipid to typical concentrations, although relative liver mass (LSI) was reduced from previous years. Starting in October, serum levels of all lipids increased greatly due to increased feeding, atypical for this time of year when food supply usually declines coincident with the end of the upwelling season. Inspection of the Upwelling Index values for 39°N, 125°W revealed that upwelling persisted through December and may have promoted the production of euphausiids which contributed to the greatly increased lipids in the serum. During the period of ovarian maturation (December 1990 through February 1991), lipid levels in all tissues except mesenteries had returned to concentrations representative of previous reproductive cycles (Table 8). Thus, despite rather poor energy accumulation during the usually heavy feeding interval of the summer, females were able to obtain at least adequate nutrition later in the year to promote oocyte and embryonic development.

**Table** 8.--Mean values of selected nutritional variables from female yellowtail rockfish with ovaries in yolk accumulation or later stages of maturation during annual reproductive cycles. Values represent means ± SE. N in parentheses.

| Variable | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 |
|---|---|---|---|---|---|---|
| LSI | 1.55±0.84 (32) | 1.92±0.14 (30) | 1.48±0.11 (23) | 2.41±0.13 (7) | 1.32±0.06 (38) | 1.42±0.08 (32) |
| MFI* | 0.90±0.09 (32) | 0.81±0.14 (29) | 0.63±0.09 (23) | 0.94±0.15 (7) | 0.17±0.04 (38) | 0.26±0.07 (32) |
| Serum $Ca^{++}$ (mg/dl) | 19.3±0.7 (31) | 21.9±1.0 (29) | 18.9±0.6 (23) | 19.0±0.7 (7) | 17.2±0.4 (38) | 19.1±0.5 (32) |
| Serum Triglycerides (mg/dl) | 472±40 (31) | 561±41 (29) | 393±47 (23) | 573±110 (7) | 376±32 (38) | 438±41 (32) |
| Serum Cholesterol (mg/dl) | 154±13 (31) | 234±10 (29) | 171±10 (23) | 232±32 (7) | 125±9 (38) | 207±18 (32) |
| Serum Phospholipids (mg/dl) | 659±30 (27) | 756±26 (30) | 617±22 (23) | 745±60 (7) | 576±27 (38) | 842±52 (11) |
| Liver Lipid (mg/g) | | | 195±17 (16) | 311±24 (7) | 192±12 (31) | 167±11 (29) |
| Gonad Lipid (mg/g) | | | 81±7 (16) | 134±3 (7) | 144±8 (32) | 139±6 (28) |
| Gonad Protein (mg/g) | | | 223±22 (16) | 217±8 (7) | 198±12 (37) | 179±10 (29) |

* Mesenteric Fat Index (MFI) = [mesenteric fat(g)/body fresh weight (g)] X 100

Analysis of lipid distributions in female tissues according to the stage of ovarian maturation reveals compartmental allocations required for energetic processes and organelle synthesis during oocyte and embryonic development.

Ovarian maturation in yellowtail rockfish has been organized into nine stages as follows:

| STAGE | DESCRIPTION |
|---|---|
| 1 | Recovery/developing |
| 2 | Early yolk accumulation |
| 3 | Late yolk accumulation |
| 4 | Migratory nucleus |
| 5 | Ovulation/fertilization |
| 6 | Early celled embryo |
| 7 | Embryonic body |
| 8 | Eyed larva |
| 9 | Spent |

Temporally, oocytes progress from oogonia through yolk (and lipid) accumulating stages from about July into January or February, when ovulation and fertilization occurs. Embryonic development from blastula stage through fully-formed functional larvae requires approximately 30 to 40 days, followed by parturition in February, March, and April.

As oocytes develop through sequential stages, the mass of the ovaries increases to approximately 14% of the body mass (Fig. 24). Simultaneously, energy in the form of lipids is transferred from mesenteric and hepatic stores to the maturing ovaries (Fig. 24). The maximum mobilization of lipid components occurs during Stages 2 and 3 of ovarian maturation (Fig. 25), and results in the decline of mesenteric lipids (almost entirely triglycerides) and liver lipid concentrations (Fig. 26) as oocyte and embryonic development advances.

There were no statistically significant differences in muscle lipid concentration among ovarian maturation stages, suggesting that muscle is not a major lipid storage site (Fig. 26). Serum calcium concentrations reflect the transfer of the yolk precursor,vitellogenin (female-specific glycolipophosphoprotein), from the liver to the ovaries and reveal enhanced protein (phosvitin) and lipid (lipovitellin) incorporation beginning during Stage 3 (Fig. 25). The concentration of lipid in ovaries during Stage 3 was significantly greater than earlier or later embryonic stages ($P<0.05$, Tukey's Range Test) (Fig. 26). Whereas vitellogenin transport continued at significantly elevated levels through the eyed larva stage ($P<0.05$), circulatory transfer of lipid compounds decreased during earlier developmental stages. The significant reductions in the transport of energetic lipids, triglycerides ($P<0.0001$) and non-esterified fatty acids (NEFA) ($P<0.0005$) occurred while ovarian maturation was in Stage 5 or Stage 4, respectively, or later.

These data would suggest that the flow of energy-bearing compounds is diminished during gestation, indicating a more lecithotrophic form of viviparity for this species. This contention becomes less certain when the structural lipids, cholesterol and phospholipids, are evaluated. Significantly diminished transport to the ovaries occurred following Stage 3, ($P<0.0001$);

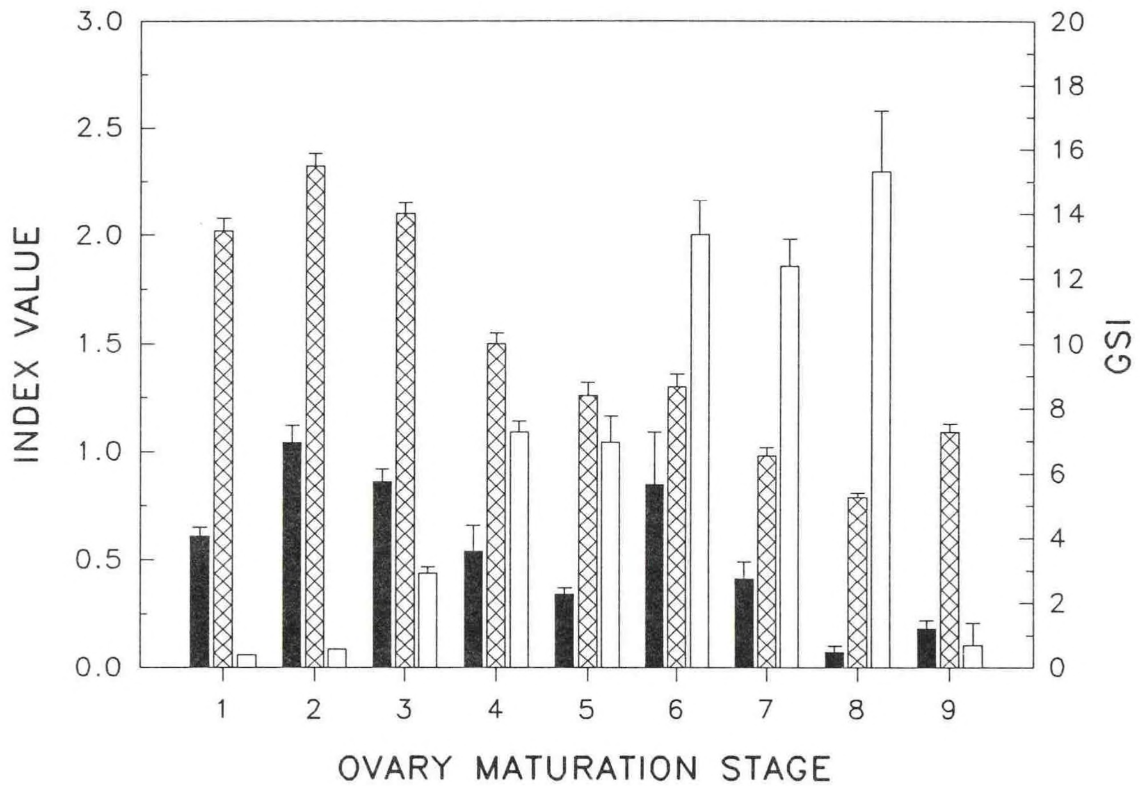


**Figure 24.** Index values (±SEM) of female yellowtail rockfish from Cordell Bank (April 1985 and September 1990), according to ovarian maturation stage. MFI, filled; LSI, cross-hatched; GSI, open bar.

however, there were increased concentrations in the maternal serum during Stages 6 and 7, when embryonic developmental stages are undergoing extensive synthesis of cell and organelle membranes. It is tempting to speculate that the increased transport of phospholipids and cholesterol, as well as vitellogenin (Fig. 25, serum calcium) during gestation, is utilized to provide the ovary with material for the developing embryos, which would amend the previously stated contention of lecithotropic viviparity to include a more matrotrophic aspect, particularly related to structural precursors.

The results of this analysis indicate that the predominant period of nutrient transport and incorporation into the ovaries occurs during the oocyte stages of yolk accumulation, similar to that of oviparous species, and as long as adequate quantities of lipids and proteins are available by the end of the endogenous

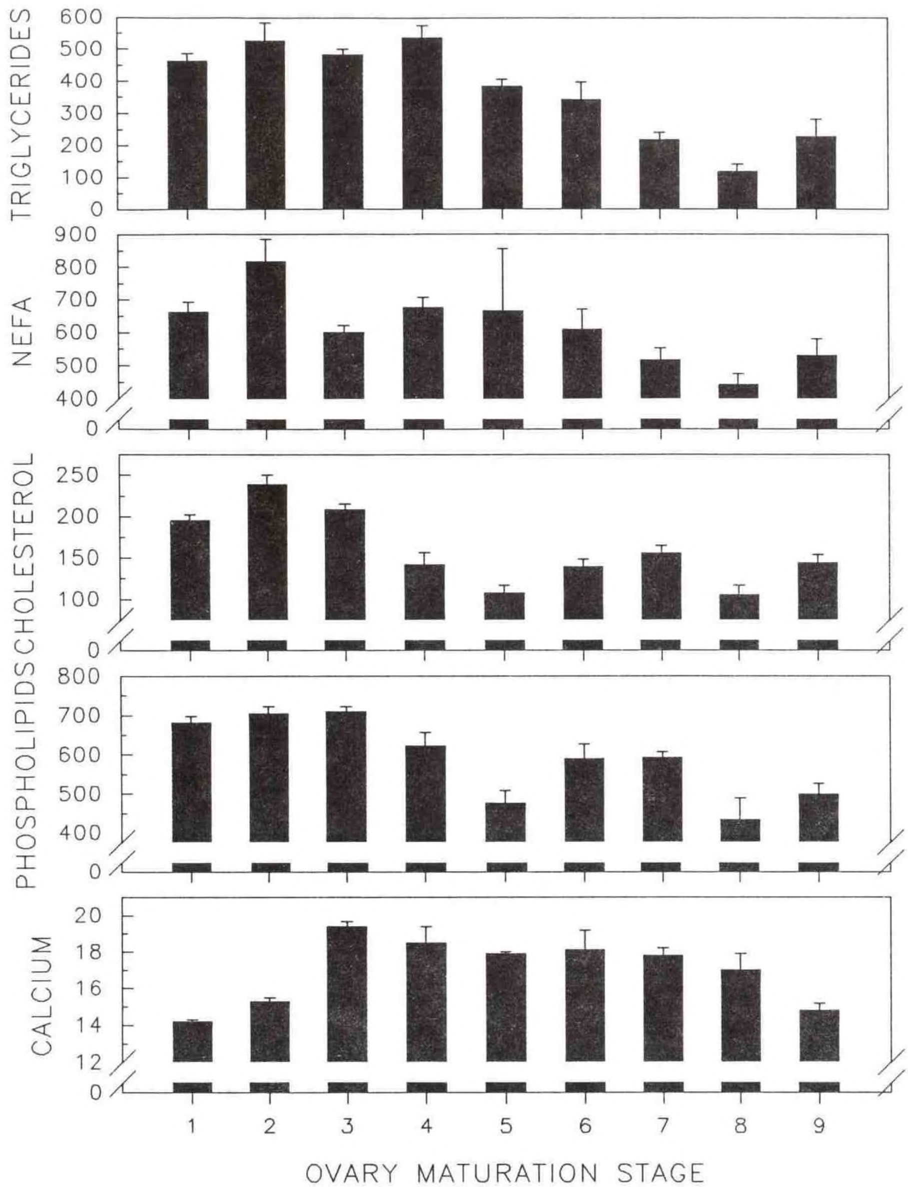


**Figure 25.** Mean concentrations (±SEM) of serum lipids and calcium (vitellogenin surrogate) in female yellowtail rockfish according to stage of ovarian maturation. Values are mg/dl, except nonesterified fatty acids (NEFA) which are $\mu$Eq/l.

vitellogenesis phase, successful reproduction can proceed. Moreover, the data suggest that yellowtail rockfish fall more towards the lecithotrophic end of the viviparity spectrum, which would be ecologically adaptive for species living in an ecosystem with unpredictable, but usually depleted, food supply during the time of greatest reproductive development (i.e., winter). Forage is typically in much greater abundance during the summer months when upwelling is in greatest force, and the greatest accumulation of energy reserves occurs. (B. MacFarlane, B. Norton, M. Bowers)

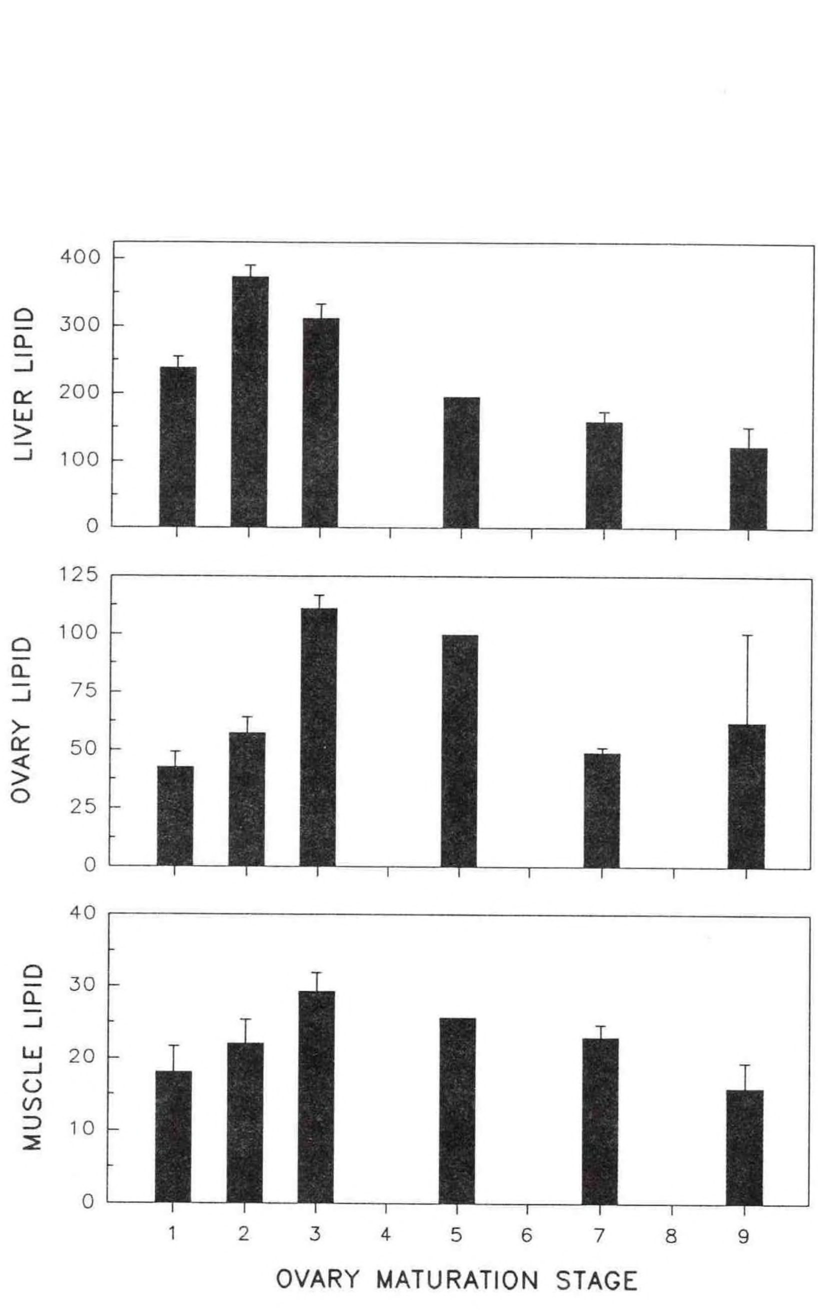


**Figure 26.** Mean concentrations (±SEM) of total lipids in tissues of female yellowtail rockfish according to stage of ovarian maturation during annual reproductive cycle. Values are mg/g fresh weight.

## Progress in Relating Adult Condition and Reproduction to Environmental Variability

An ultimate objective of this research is to relate variability (seasonal and interannual) in adult condition and reproduction to environmental variability so that we can improve predictions of juvenile abundance and recruitment.

Previously, descriptive statistics and factor analysis of selected data were done for all fish to determine the distributions and interrelationships of variables and some general results were reported last year (Ralston [ed.] 1990). Several reproductive variables measured for this spawning year (1990-1991) have not been analyzed, e.g., fecundity, atresia, egg weights and calorimetry. As soon as this year's reproductive effort is assessed, final analyses will be completed and a manuscript summarizing the interannual variability in yellowtail rockfish will be completed.

### Adult Food Studies

We have long hypothesized that food, particularly euphausiids, are important to survival of yellowtail rockfish. Body condition as exemplified by liver and mesenteric fat weights probably relates to the feeding success during different seasons and in different years. From August of 1989, additional studies were initiated to look at the type and quantity of food in stomachs of yellowtail rockfish. The mean scores for stomach fullness indicated that in 1988-1989 adult females were feeding more in that year, while in 1989-1990, stomachs were less often full. Stomach fullness scores in the last two years have been lower than in previous years, indicating poor feeding conditions. The types and abundance of food species were identified from stomachs of yellowtail rockfish (Table 9). Prey species identifications were confirmed by the Groundfish Communities Investigation (J. Chess, pers. comm).

**Table** 9.--List of taxa, frequency of occurrence (F.O.), mean number and mean wet weight of prey per stomach in Sebastes flavidus from August 1989 through February 1991. Data are for fish with food in stomachs.

| Prey Organism | F.O. (%) | Number Mean | Wet Weight (g) Mean |
|---|---|---|---|
| **Unidentified food** | 3.4 | N/A | 4.03 |
| **Euphausiacea** | 31.8 | | 3.14 |
| Euphausia pacifica | 25.8 | 46.0 | 2.06 |
| Thysanoessa gregaria | 2.3 | 5.6 | 0.21 |
| Thysanoessa spinifera | 13.8 | 41.7 | 1.86 |
| Euphausiacea (unidentified) | 8.9 | 50.4 | 2.32 |
| **Amphipoda** | | | |
| Hyperiidea unidentified | 2.0 | 1.6 | 0.03 |

**Table** 9.--List of taxa, frequency of occurrence (F.O.), mean number and mean wet weight of prey per stomach in Sebastes flavidus from August 1989 through February 1991. Data are for fish with food in stomachs.

| Prey Organism | F.O. | Number | Wet Weight (g) |
|---|---|---|---|
| | (%) | Mean | Mean |
| **Mollusca-Pteropoda** | | | |
| Limacina helcina | 5.4 | 43.5 | 0.63 |
| Corolla spectabilis | 2.3 | 1.1 | 2.03 |
| **Mollusca-Heteropoda** | | | |
| Carinaria japonica | 4.0 | 3.2 | 2.70 |
| **Mollusca-Cephalopoda** | | | |
| Loligo opalescens (Adults, juveniles, larvae) | 7.2 | 1.6 | 5.45 |
| Octopus sp. (juveniles) | 2.3 | 1.9 | 5.78 |
| **Miscellaneous Invertebrates** | | | |
| Schyphozoan medusae | 0.6 | 1.0 | 3.22 |
| Ctenophora<br>Beroe sp. | 3.2 | 19.0 | 3.66 |
| Polychaeta<br>Plothelmis tenuis<br>Tomopteris sp. | 2.6 | 3.2 | 0.09 |
| **Thaliacea** | | | |
| Doliolium sp. | 8.9 | 86.2 | 3.00 |
| Iasis zonaria | 0.6 | 10 | 1.64 |
| Salpa fusiformis | 12.9 | 28.4 | 21.28 |
| Thetys vagina | 0.3 | 1.0 | 2.35 |
| **Osteicthyes** | | | |
| Myctophidae<br>Stenobrachius leucopsaurus | 2.0 | 2.0 | 7.23 |
| Misc. Fish<br>Citharicthys sordidus<br>Merluccius productus<br>Unidentified eggs and larvae | 3.4 | 1.3 | 4.13 |

The predominant foods in terms of frequency of occurrence (F.O.) were euphausiids and salps. Of these, euphausiids are usually found in stomachs during spring and summer upwelling periods; salps during the winter spawning season. Other species occurred throughout the year. Although mean weight of salps per stomach was greater, nutrition from euphausiids is probably more important to the rockfish. The amount of lipid in euphausiids was found to be approximately 50 mg/g whole body tissue (E. Norton, pers. comm.). Proximate analyses of nutrients in salps will be performed this winter.

Mean total wet weight of euphausiids (all species) per stomach was determined for August, September and December of 1989 and January, February of 1990 (1989-1990 spawning year) and for all months of 1990 and January, February of 1991). Analyses showed that the mean weight of euphausiids in stomachs related to the mean upwelling index (Bakun 1975) in 1990 (Fig. 27). Mean weights for 1989 were all less than 0.5 g/stomach and are not shown on the graph. Note the high mean weight of euphausiids in October and December 1990. This occurrence of euphausiids during the winter was unusual and coincided with a period of increased upwelling during December of last year. This increased feeding may have resulted in the fish compensating for earlier loss of energy reserves. (J. Whipple)

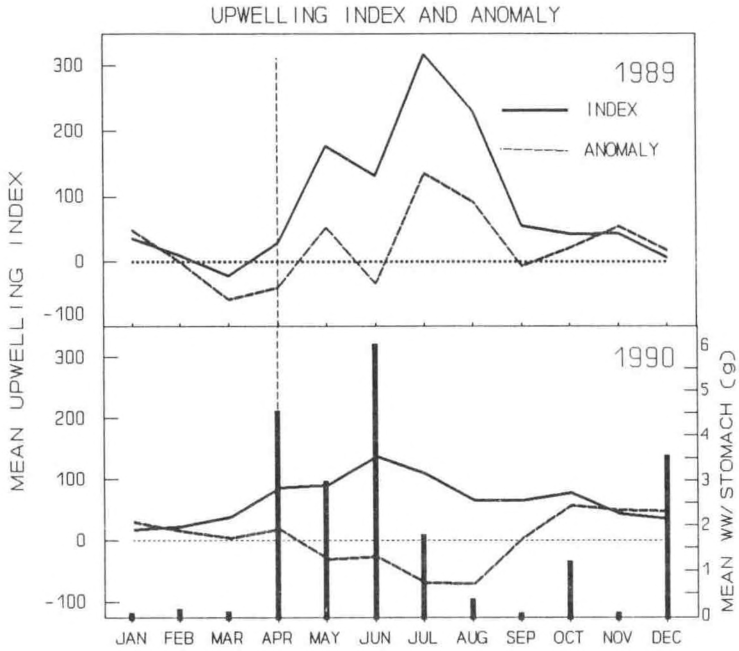


**Figure 27.** Mean upwelling index and anomaly 39° N (variation in 20-yr mean, Bakun 1975) for 1989 and 1990. Solid bars in 1990 are mean wet weight of euphausiids (all species) per stomach of yellowtail rockfish.

## Progress in Relating Adult Condition and Reproduction to Juvenile Abundance

In summary, the most important factors affecting reproductive success and production of the year-class are (1) the inherent factor of age distribution of spawning fish , (2) the environmental conditions affecting condition of females prior to and during spawning and (3) the environmental conditions during development of larvae and juveniles. All three conditions must be optimal for the largest year-classes and conversely, all must be suboptimal for smallest year-classes (Fig. 28).

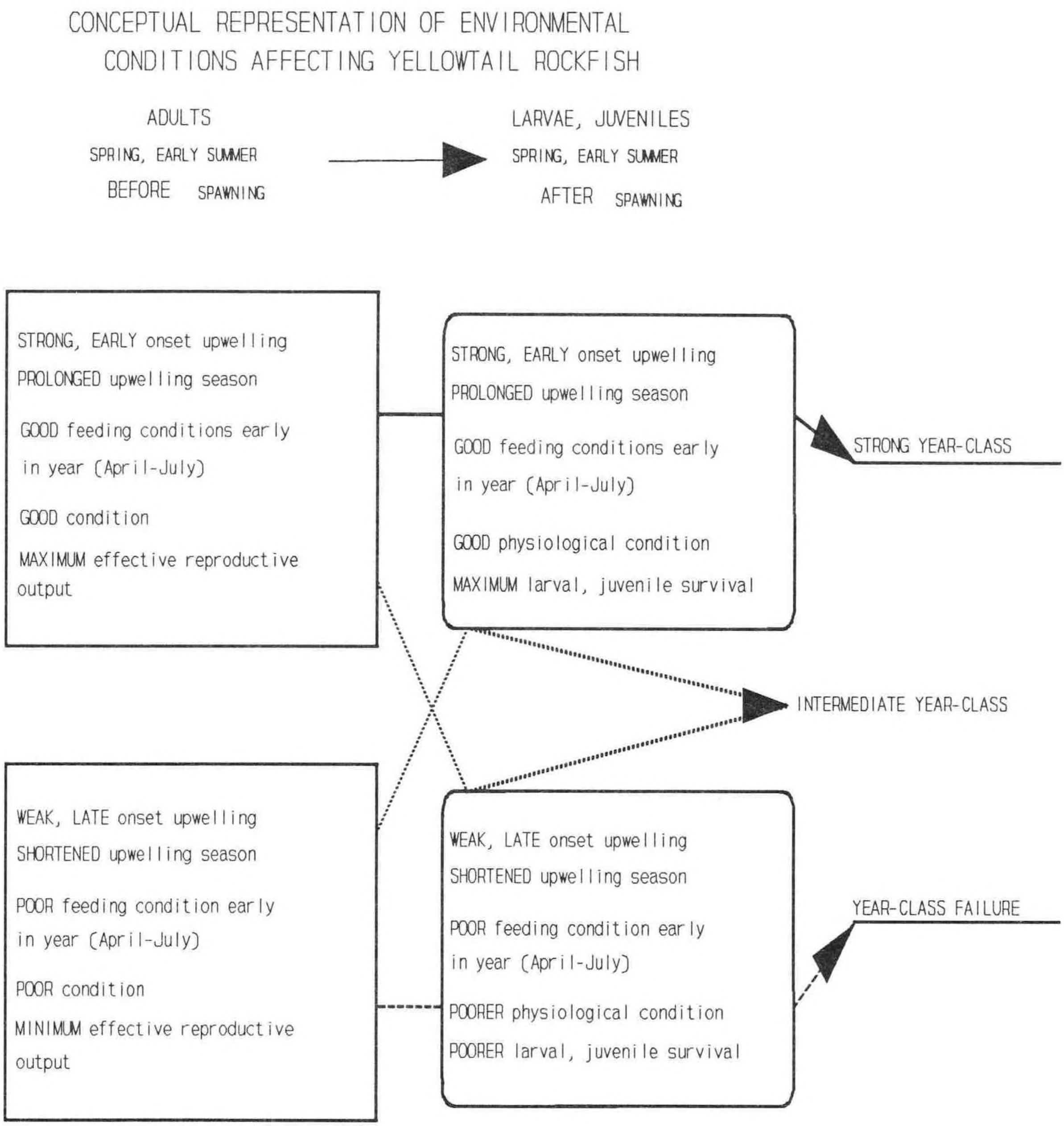


**Figure 28.** Conceptual representation of how environmental variability may affect condition and reproduction of *Sebastes flavidus*.

A good year-class occurs when more older, larger fish occur in the spawning population, feeding conditions are good for the adults during the spring and summer prior to egg maturation, and finally, feeding conditions are good for larvae and juveniles in early spring and summer. These environmental conditions are met when the beginning of upwelling is coincident to the end of the spawning period (end of March in yellowtail rockfish) and beginning of planktonic larval stage.

A delay in the onset of upwelling, fewer days and less intense upwelling or shortened periods of upwelling may result in a poor year class, both by reducing condition of the spawning population and by providing inadequate food for larval and juvenile survival. Symptoms of poor feeding in adults are empty stomachs, low fat reserves and higher disease levels. The amount of some lipids and mesenteric fat are probably related to euphausiid abundance.

Our initial work showed that the condition of females in the first year (1985-1986) was somewhat different from females in the next two years, primarily due to their being older fish, but that for the first three years of this study (1985-1986, 1986-1987, 1987-1988) fish were relatively similar and exemplified typical conditions for yellowtail rockfish. These results are reflected in the abundance estimates for both pelagic and post-pelagic juveniles (see above Figs. 2-4; Tables 3 & 4). In the first year, temperatures were lower, and we can speculate that the pattern of greater mean age of fish in the first year may be due to a southward migration of larger older fish from the center of the population during the 1985-1986 period.

During the 1988-1989 spawning year, condition of adult females was very good for most criteria we have measured to date. Even though environmental conditions were very good for the adults in that year, with good upwelling and feeding conditions in the spring and summer of 1988 prior to spawning, upwelling was delayed for a considerable time in the spring of 1989 (Fig. 29). It is probable that feeding conditions for the larvae and juveniles in that year were poor as reflected in the juvenile abundance estimates for that year (see above Figs. 2-4, Table 3 & 4).

In the 1989-1990 spawning year, adult yellowtail rockfish exhibited poorer condition than previous years. Environmental conditions were anomalous during the part of this year, for example, higher temperatures were observed near Cordell Bank and other areas offshore. The poorer condition and somewhat lower fecundity of older yellowtail rockfish during 1989-1990 were coincident to low juvenile abundance estimates in 1990 (see above Figs. 2-4, Table 3 & 4).

Finally, in the last spawning year of this study (1990-1991) somatic condition of fish was for most of the year the poorest seen. Although reproductive measurements are incomplete, we would have expected a lower reproductive output. The late and unusual feeding of yellowtail rockfish on euphausiids in October and December in 1990, however, may have provided sufficient energy for egg production and normal reproduction. If this was the case, then feeding in fall may also be critical to yellowtail rockfish. If not, we may anticipate another poor year-class in 1991. The results of feeding and condition in S. flavidus adults are similar to those observed in S. mystinus by the Groundfish Communities Investigation (see above Fig. 13). (J. Whipple and B. Jarvis)

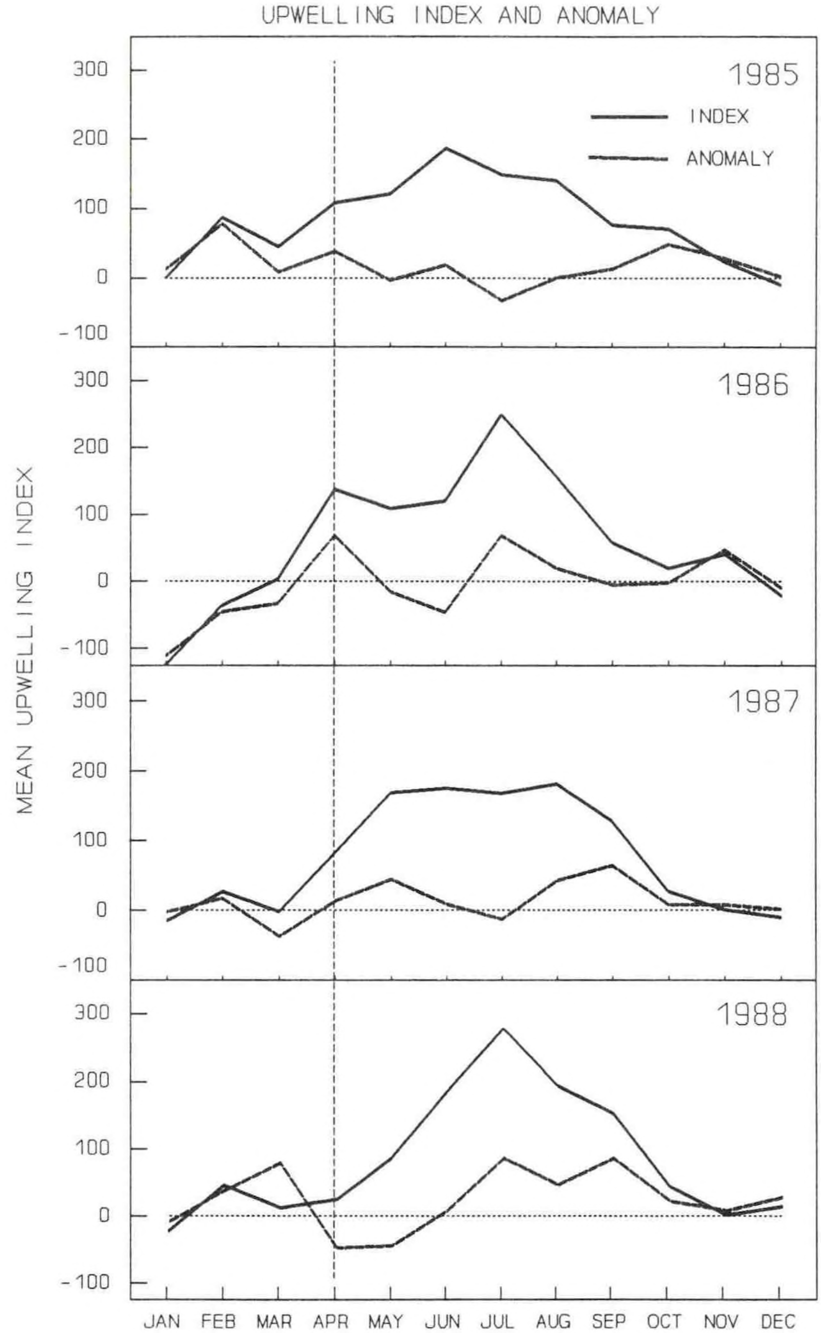


**Figure 29.** Mean upwelling index and anomaly 39° N (variation in 20-yr mean, Bakun 1975) for 1985, 1986, 1987 and 1988.

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