SOUTHWEST FISHERIES SCIENCE CENTER

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES SCIENCE CENTER P.O. BOX 271 LA JOLLA, CA 92038

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# PROGRESS IN ROCKFISH RECRUITMENT STUDIES

Edited by

Peter B. Adams

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# PROGRESS IN ROCKFISH RECRUITMENT STUDIES

Staff of the Tiburon Laboratory

Edited by Peter B. Adams



Southwest Fisheries Science Center
National Marine Fisheries Science, NOAA
3150 Paradise Dr.
Tiburon, California 94920



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## INTRODUCTION

Rockfish (Sebastes spp.) make up a major portion of groundfish landings from the Pacific Coast groundfish fishery (40,509 mt in 1990, or 50% of the total groundfish landings exclusive of Pacific whiting). In this fishery, variability in year-class strength is a major source of uncertainty in management. This is the eighth annual report on studies conducted at the NMFS Tiburon Laboratory to measure this variation and to understand its source. This report covers the period from March 1991 to March 1992, and is the combined result of efforts from the Laboratory's three research Investigations: Groundfish Communities, Groundfish Analysis, and Groundfish Physiological Ecology. Research is summarized by life history stage: pelagic young-of-the-year (YOY) juvenile, benthic juvenile, and adult. Objectives, methods, and pervious results have been presented in earlier numbers of this series (Lenarz and Moreland 1985, Hobson et al. 1986, Larson 1987, Whipple 1988, Hobson 1989, Ralston 1990, and Whipple 1991).

## STUDIES OF PELAGIC JUVENILES

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

### Progress in Midwater Trawl Assessments

Since 1983 the Groundfish Analysis Investigation has fielded annual sea surveys designed to estimate the relative abundance of pelagic young-of-the-year (YOY) juvenile rockfish (Table 1). This series of cruises has been conducted aboard the National Oceanic and Atmospheric Administration (NOAA) research vessel David Starr Jordan between March and June, a time when pelagic stage YOY of most commercial species are sampled most readily. These surveys use a standard 26 x 26 m modified Cobb midwater trawl, with a cod-end liner of 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 (Fig. 1). As part of the survey design, the study area is subdivided into seven geographical strata, with 5-6 standard stations located within each.

During the past year, one pelagic juvenile survey cruise was conducted (DSJ-9105). This cruise spanned a 30-day period during May-June and resulted in three consecutive sweeps through the study area. At each station a 15-minute nighttime trawl sample was taken at standard depth (30 m where possible, 10 m at shallow stations) and a CTD cast was made. In addition, at some stations

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

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

standard trawls were made at 10, 30, and 100 m depth to provide information concerning the vertical distribution of pelagic YOY rockfishes (e.g., Lenarz et al. 1991). Supplemental CTD data were also gathered during the day along tracklines that criss-crossed the entire study area (Fig. 1, see also Schwing et al. 1990; Schwing and Ralston 1991). As in previous years, the data from the cruise were compiled, edited, and added to the midwater trawl database.

## Database Management

Project databases are now maintained on a single stand-alone IBM compatible 386 personal computer (PC) and copies are distributed to investigators upon request. Original raw data are recorded in field notebooks, from which electronic versions are created in either ASCII or dBase III files. Final, edited versions of the data are maintained using the SAS system. Data-

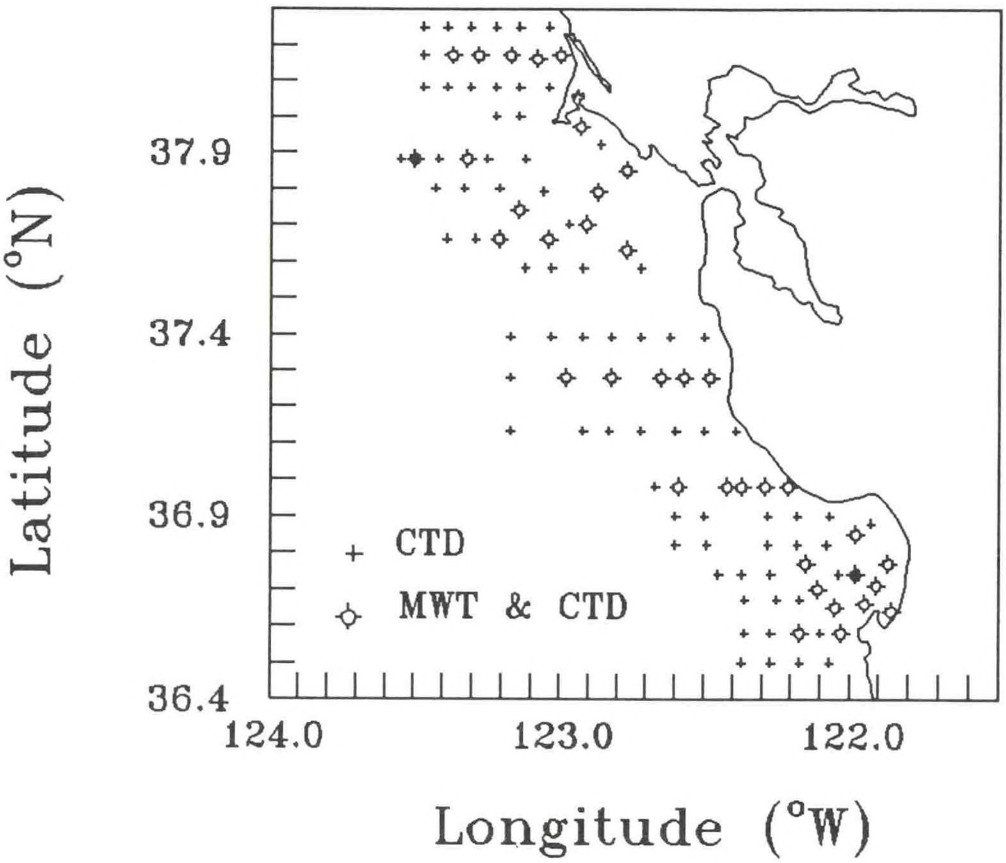


**Figure 1.** Juvenile rockfish survey area showing locations of standard midwater trawl (MWT) stations. Darkened symbols indicate two newly included stations.

base structures and naming conventions have been described previously (Reilly and Bence 1990).

Several modifications have been made to the databases in the last year. Users, both inside and outside the laboratory, should be aware of the fact that we no longer provide updates in the dBase relational database system. While we will continue to maintain raw unedited data in dBase III, all other functions, such as error checking, data storage, and analysis, have been implemented in the SAS system. Old versions of midwater trawl data previously obtained from our laboratory should be removed from service and updated files requested.

Minor refinements have been made to the existing database structure, such as the addition of a MATURITY field in the ORG database, thus eliminating the need for separate identification codes for different developmental stages of the same species. Also, unique station numbers were assigned to stations that were not part of the standard sampling plan. These non-standard stations had formerly been assigned the same number, regardless of location. We are in the process of updating the database documentation to describe the changes which have been made.

A prototype menu-driven interface to the midwater trawl database has now been developed to allow users easy access to the data. This retrieval and display system will access the data according to user specifications (e.g., selecting a particular species or subsetting for a specific time period) and prepare contour plots that depict distribution and abundance. Naive users with no knowledge of computer systems or the structure of the Investigation's data can use this system. The interface has features akin to the CalCOFI online system, but runs on a PC.

Databases are now established for sea surface temperature and salinity data collected as an adjunct to biological samples taken on research cruises. Surface profile data are continuously recorded from the vessel's thermosalinograph, whereas data at depth are collected by lowering a CTD to 500 m at a standard set of stations. Raw data are downloaded from the instruments and are maintained on the project computer in ASCII format. Error-checking routines have been developed in SAS to check for out-of-range values and for consistency between measurements taken by the thermosalinograph and the CTD at the same station. A new SAS database, DBTS, has been created for thermosalinograph data from cruises conducted since 1989. Earlier years are to be included once error-checking is complete. Since the raw CTD data occupy a considerable amount of disk storage space, SAS data sets are not routinely maintained. Instead we have developed software to retrieve subsets of CTD data into the SAS system from the raw ASCII files when they are needed for a particular analysis.

This year we have created a new database, with associated error checking routines, to describe plankton collections made with bongo gear. The database structure is patterned after the CalCOFI "net tow" database, which was provided to us by the Coastal Division at the La Jolla Laboratory. Data are entered into dBase files using CalCOFI data entry programs. Programs developed within the Task's rockfish recruitment program are then used to calculate standard haul factors, determine abundance statistics (numbers/$10^2$ m), and store the data. (D. Roberts)

## Identification of Black Dorsal Spot Group

Pelagic juveniles of widow rockfish (*Sebastes entomelas*), yellowtail rockfish (*S. flavidus*), black rockfish (*S. melanops*), and blue rockfish (*S. mystinus*) are morphologically quite similar to one another. These species are often collectively referred to as the "black dorsal spot" group due to the presence of a dark pigment blotch located on the dorsal fin of individuals larger than 35 mm SL. To help resolve species identifications of individuals within this group, measurements of seven variables commonly used in identification were recorded for the pelagic juveniles of these species collected from the 1991 midwater trawl survey and a cluster analysis was performed. The variables measured fell into several categories: meristic counts (number of dorsal, anal, and pectoral fin rays), the development of preocular and supraocular spines, and pigmentation patterns (dorsal fin and base of the anal fin).

Results of the cluster analysis (Table 2) showed that both S. mystinus and S. entomelas are well separated into distinct clusters with little contamination from other species (clusters 3 and 4, respectively). These findings illustrate that these two species are readily distinguishable. Although the majority of S. flavidus separate into cluster 1, and the majority of S. melanops segregate into cluster 2, there is considerable overlap between these two species, suggesting that unequivocal identifications are not yet possible. When specimens of both species are available for comparison, large fish (> 35 mm SL) are correctly identified with a high degree of confidence (95%) due to subtle differences in body pigmentation (i.e., S. melanops have a slight greenish tinge and are more uniform in coloration). Identifications of small fish (≤ 35 mm SL) are more difficult due to relatively sparse body pigmentation. (K. Sakuma)

Table 2.--Cluster analysis for the black dorsal spot group.

| Cluster | Species | Number | % of Cluster Due to Species | % of Species in Cluster |
|---|---|---|---|---|
| 1 | S. flavidus | 152 | 95.6 | 74.5 |
| | S. melanops | 7 | 4.4 | 15.6 |
| 2 | S. flavidus | 48 | 55.8 | 23.5 |
| | S. melanops | 38 | 44.2 | 84.4 |
| 3 | S. mystinus | 19 | 95.0 | 86.4 |
| | S. flavidus | 1 | 5.0 | 0.5 |
| 4 | S. entomelas | 235 | 97.5 | 100.0 |
| | S. mystinus | 3 | 1.3 | 13.6 |
| | S. flavidus | 3 | 1.2 | 1.5 |

## Estimates of Year-Class Strength

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

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

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

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

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

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

We report all indices, their standard errors and 95% confidence intervals, and back-transformations of the indices in Table 3 (see Whipple 1991 for further computational details). Note that abundance statistics have been developed for each of the 15 most commonly caught rockfish species taken during each sweep completed since 1983. Shown also are indices for the total catch of juvenile rockfish, and indices for two sets of species that tend to fluctuate in synchrony, i.e., the Sebastes entomelas PCA group and the S. jordani PCA group (Hobson 1989; Ralston 1990).

Although calculation of abundance statistics is performed in a manner identical to last year's report, we have added two new stations which have been sampled regularly since 1985, one each in the "Monterey Inside" and "Deep Northern" strata (Fig. 1). This change produced modest alterations in virtually all the indices reported previously. The reader should also be aware that we continue to explore new ways of estimating abundance and that we have reservations concerning the 1983-85 data, when only one sweep of an expanded study area was conducted. (S. Ralston)

Table 3.--Annual sweep-specific indices of abundance for 15 of the most common species of YOY Sebastes collected. Species/sweep combinations wherein a species was not collected at 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.

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| | | Sebastes auriculatus (Brown Rockfish) | | | | |
| 8401 | 1 | -1.13 | 0.27 | -1.82 | -0.44 | 0.23 |
| 8608 | 1 | -0.07 | 0.29 | -0.71 | 0.57 | 0.87 |
| 8608 | 2 | -0.40 | 0.32 | -1.08 | 0.27 | 0.61 |
| 8608 | 3 | -1.66 | 0.23 | -2.17 | -1.15 | 0.09 |
| 8703 | 1 | -1.47 | 0.23 | -1.95 | -1.00 | 0.13 |
| 8705 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| 8705 | 2 | -2.02 | 0.14 | -2.32 | -1.72 | 0.03 |
| 8705 | 3 | -2.10 | 0.11 | -2.35 | -1.85 | 0.02 |
| 8804 | 1 | -1.43 | 0.24 | -1.94 | -0.91 | 0.15 |
| 8904 | 1 | -2.15 | 0.10 | -2.41 | -1.88 | 0.02 |
| 9003 | 1 | -1.88 | 0.17 | -2.24 | -1.53 | 0.05 |
| 9005 | 1 | -1.87 | 0.15 | -2.20 | -1.53 | 0.06 |
| 9005 | 2 | -1.87 | 0.24 | -2.49 | -1.24 | 0.06 |
| 9105 | 1 | -1.83 | 0.15 | -2.18 | -1.48 | 0.06 |
| 9105 | 2 | -1.18 | 0.20 | -1.68 | -0.68 | 0.21 |
| 9105 | 3 | -0.83 | 0.36 | -1.61 | -0.05 | 0.36 |
| | | Sebastes crameri (Darkblotched Rockfish) | | | | |
| 8401 | 1 | -2.13 | 0.12 | -2.43 | -1.83 | 0.02 |
| 8703 | 1 | -2.03 | 0.16 | -2.37 | -1.69 | 0.03 |
| 8705 | 1 | -2.08 | 0.13 | -2.36 | -1.79 | 0.03 |
| 8705 | 2 | -2.22 | 0.09 | -2.46 | -1.97 | 0.01 |
| 8705 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8804 | 1 | -1.95 | 0.09 | -2.17 | -1.73 | 0.04 |
| 8806 | 1 | -2.14 | 0.12 | -2.42 | -1.85 | 0.02 |
| 8806 | 2 | -2.25 | 0.06 | -2.39 | -2.10 | 0.01 |
| 9005 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 9105 | 1 | -2.25 | 0.06 | -2.39 | -2.10 | 0.01 |
| 9105 | 2 | -2.04 | 0.15 | -2.36 | -1.71 | 0.03 |
| 9105 | 3 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| | | Sebastes entomelas (Widow Rockfish) | | | | |
| 8301 | 1 | -2.18 | 0.12 | -2.52 | -1.84 | 0.01 |
| 8401 | 1 | -0.72 | 0.52 | -2.24 | 0.80 | 0.46 |
| 8505 | 1 | -0.10 | 0.28 | -0.69 | 0.49 | 0.84 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| 8608 | 1 | -1.92 | 0.17 | -2.28 | -1.55 | 0.05 |
| 8608 | 2 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| 8703 | 1 | -1.83 | 0.17 | -2.21 | -1.44 | 0.06 |
| 8705 | 1 | 0.04 | 0.33 | -0.63 | 0.71 | 1.00 |
| 8705 | 2 | 0.78 | 0.33 | 0.11 | 1.45 | 2.21 |
| 8705 | 3 | -1.82 | 0.19 | -2.24 | -1.40 | 0.06 |
| 8804 | 1 | -1.40 | 0.25 | -2.09 | -0.72 | 0.15 |
| 8806 | 1 | -0.55 | 0.28 | -1.14 | 0.04 | 0.50 |
| 8806 | 2 | -0.07 | 0.22 | -0.54 | 0.40 | 0.85 |
| 8806 | 3 | -1.86 | 0.17 | -2.25 | -1.48 | 0.06 |
| 8904 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8904 | 2 | -1.68 | 0.18 | -2.09 | -1.26 | 0.09 |
| 8904 | 3 | -2.16 | 0.10 | -2.42 | -1.90 | 0.02 |
| 9005 | 1 | -1.66 | 0.29 | -2.30 | -1.02 | 0.10 |
| 9005 | 2 | -1.43 | 0.24 | -1.96 | -0.90 | 0.15 |
| 9005 | 3 | -2.08 | 0.12 | -2.36 | -1.80 | 0.03 |
| 9105 | 1 | -2.02 | 0.16 | -2.41 | -1.64 | 0.03 |
| 9105 | 2 | -1.19 | 0.26 | -1.73 | -0.64 | 0.22 |
| 9105 | 3 | 0.81 | 0.39 | -0.01 | 1.64 | 2.33 |
| | | *Sebastes flavidus* (Yellowtail Rockfish) | | | | |
| 8301 | 1 | -2.08 | 0.14 | -2.48 | -1.68 | 0.03 |
| 8401 | 1 | -0.77 | 0.51 | -2.14 | 0.61 | 0.43 |
| 8505 | 1 | -1.06 | 0.25 | -1.59 | -0.52 | 0.26 |
| 8608 | 1 | -1.97 | 0.13 | -2.29 | -1.65 | 0.04 |
| 8608 | 2 | -1.69 | 0.16 | -2.04 | -1.34 | 0.09 |
| 8608 | 3 | -2.03 | 0.17 | -2.47 | -1.59 | 0.03 |
| 8705 | 1 | -1.68 | 0.23 | -2.16 | -1.19 | 0.09 |
| 8705 | 2 | -0.92 | 0.26 | -1.45 | -0.39 | 0.31 |
| 8705 | 3 | -1.59 | 0.23 | -2.09 | -1.10 | 0.11 |
| 8804 | 1 | -2.11 | 0.14 | -2.42 | -1.80 | 0.02 |
| 8806 | 1 | -0.91 | 0.28 | -1.49 | -0.33 | 0.32 |
| 8806 | 2 | -1.41 | 0.23 | -1.88 | -0.94 | 0.15 |
| 8904 | 1 | -2.06 | 0.13 | -2.37 | -1.76 | 0.03 |
| 8904 | 2 | -1.67 | 0.19 | -2.08 | -1.27 | 0.09 |
| 8904 | 3 | -1.67 | 0.21 | -2.12 | -1.22 | 0.09 |
| 9003 | 1 | -2.17 | 0.13 | -2.59 | -1.75 | 0.02 |
| 9005 | 1 | -1.98 | 0.15 | -2.32 | -1.64 | 0.04 |
| 9005 | 2 | -1.72 | 0.22 | -2.40 | -1.03 | 0.08 |
| 9005 | 3 | -2.00 | 0.18 | -2.48 | -1.52 | 0.04 |
| 9105 | 1 | -1.85 | 0.16 | -2.21 | -1.49 | 0.06 |
| 9105 | 2 | -1.10 | 0.24 | -1.60 | -0.60 | 0.24 |
| 9105 | 3 | 0.10 | 0.31 | -0.56 | 0.75 | 1.06 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| | | | *Sebastes goodei* (Chilipepper) | | | |
| 8401 | 1 | -0.69 | 0.40 | -1.71 | 0.33 | 0.44 |
| 8608 | 1 | -1.40 | 0.21 | -1.86 | -0.95 | 0.15 |
| 8608 | 2 | -1.60 | 0.21 | -2.06 | -1.14 | 0.11 |
| 8608 | 3 | -2.03 | 0.15 | -2.38 | -1.68 | 0.03 |
| 8703 | 1 | -0.22 | 0.34 | -0.95 | 0.51 | 0.75 |
| 8705 | 1 | 0.55 | 0.28 | -0.04 | 1.15 | 1.71 |
| 8705 | 2 | -0.78 | 0.31 | -1.43 | -0.13 | 0.38 |
| 8705 | 3 | -1.52 | 0.20 | -1.96 | -1.08 | 0.12 |
| 8804 | 1 | 2.58 | 0.42 | 1.64 | 3.52 | 14.31 |
| 8806 | 1 | -0.14 | 0.40 | -0.99 | 0.71 | 0.84 |
| 8806 | 2 | -1.71 | 0.25 | -2.28 | -1.14 | 0.09 |
| 8806 | 3 | -2.02 | 0.22 | -2.54 | -1.50 | 0.04 |
| 8904 | 1 | -1.47 | 0.26 | -2.03 | -0.90 | 0.14 |
| 8904 | 2 | -2.19 | 0.07 | -2.37 | -2.00 | 0.01 |
| 9003 | 1 | -1.32 | 0.26 | -1.88 | -0.76 | 0.18 |
| 9005 | 1 | -1.40 | 0.28 | -1.98 | -0.81 | 0.16 |
| 9005 | 2 | -1.82 | 0.18 | -2.20 | -1.43 | 0.07 |
| 9105 | 1 | -2.07 | 0.13 | -2.38 | -1.77 | 0.03 |
| 9105 | 2 | -1.19 | 0.26 | -1.74 | -0.63 | 0.22 |
| 9105 | 3 | -0.81 | 0.26 | -1.36 | -0.27 | 0.36 |
| | | | *Sebastes hopkinsi* (Squarespot Rockfish) | | | |
| 8401 | 1 | -1.40 | 0.34 | -2.28 | -0.52 | 0.16 |
| 8505 | 1 | -1.74 | 0.23 | -2.26 | -1.22 | 0.08 |
| 8608 | 1 | -2.15 | 0.11 | -2.40 | -1.89 | 0.02 |
| 8608 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8703 | 1 | -1.98 | 0.15 | -2.32 | -1.64 | 0.04 |
| 8705 | 1 | -0.29 | 0.24 | -0.79 | 0.22 | 0.67 |
| 8705 | 2 | -0.98 | 0.27 | -1.54 | -0.41 | 0.29 |
| 8705 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8804 | 1 | -0.58 | 0.35 | -1.33 | 0.18 | 0.50 |
| 8806 | 1 | -0.65 | 0.32 | -1.31 | 0.01 | 0.45 |
| 8806 | 2 | -1.15 | 0.20 | -1.57 | -0.72 | 0.22 |
| 8806 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8904 | 1 | -1.97 | 0.16 | -2.34 | -1.61 | 0.04 |
| 8904 | 2 | -2.18 | 0.09 | -2.38 | -1.97 | 0.01 |
| 8904 | 3 | -2.10 | 0.08 | -2.33 | -1.86 | 0.02 |
| 9003 | 1 | -2.17 | 0.09 | -2.39 | -1.96 | 0.01 |
| 9005 | 1 | -1.81 | 0.27 | -2.47 | -1.15 | 0.07 |
| 9005 | 3 | -2.00 | 0.17 | -2.50 | -1.51 | 0.04 |
| 9105 | 2 | -2.18 | 0.09 | -2.45 | -1.92 | 0.01 |
| 9105 | 3 | -1.41 | 0.16 | -1.76 | -1.06 | 0.15 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| | | | Sebastes jordani (Shortbelly Rockfish) | | | |
| 8301 | 1 | -1.45 | 0.44 | -2.78 | -0.12 | 0.16 |
| 8401 | 1 | 1.18 | 0.75 | -0.88 | 3.24 | 4.22 |
| 8505 | 1 | -0.09 | 0.39 | -1.00 | 0.82 | 0.89 |
| 8608 | 1 | 0.94 | 0.45 | -0.00 | 1.89 | 2.75 |
| 8608 | 2 | 0.97 | 0.40 | 0.05 | 1.90 | 2.76 |
| 8608 | 3 | -1.09 | 0.37 | -1.92 | -0.26 | 0.26 |
| 8703 | 1 | -0.61 | 0.34 | -1.34 | 0.12 | 0.48 |
| 8705 | 1 | 1.85 | 0.37 | 1.07 | 2.63 | 6.71 |
| 8705 | 2 | 2.96 | 0.43 | 2.06 | 3.86 | 21.03 |
| 8705 | 3 | 0.35 | 0.38 | -0.46 | 1.16 | 1.43 |
| 8804 | 1 | 2.51 | 0.52 | 1.20 | 3.82 | 14.00 |
| 8806 | 1 | 2.22 | 0.48 | 1.20 | 3.25 | 10.28 |
| 8806 | 2 | 1.49 | 0.37 | 0.71 | 2.28 | 4.68 |
| 8806 | 3 | 0.69 | 0.42 | -0.21 | 1.58 | 2.07 |
| 8904 | 1 | 1.10 | 0.30 | 0.46 | 1.73 | 3.03 |
| 8904 | 2 | 0.57 | 0.30 | -0.06 | 1.20 | 1.75 |
| 8904 | 3 | -0.47 | 0.29 | -1.09 | 0.14 | 0.55 |
| 9003 | 1 | -0.80 | 0.27 | -1.36 | -0.23 | 0.37 |
| 9005 | 1 | 0.22 | 0.43 | -0.70 | 1.15 | 1.27 |
| 9005 | 2 | -0.40 | 0.33 | -1.09 | 0.28 | 0.60 |
| 9005 | 3 | -1.76 | 0.21 | -2.22 | -1.31 | 0.08 |
| 9105 | 1 | -1.28 | 0.29 | -1.91 | -0.65 | 0.19 |
| 9105 | 2 | -0.35 | 0.29 | -0.96 | 0.25 | 0.63 |
| 9105 | 3 | 2.32 | 0.33 | 1.64 | 3.01 | 10.67 |
| | | | Sebastes levis (Cowcod) | | | |
| 8505 | 1 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| 8608 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8703 | 1 | -2.15 | 0.11 | -2.41 | -1.88 | 0.02 |
| 8705 | 1 | -1.85 | 0.16 | -2.20 | -1.51 | 0.06 |
| 8705 | 2 | -2.20 | 0.10 | -2.48 | -1.93 | 0.01 |
| 8705 | 3 | -1.99 | 0.15 | -2.31 | -1.67 | 0.04 |
| 8804 | 1 | -1.47 | 0.20 | -1.90 | -1.03 | 0.14 |
| 8806 | 1 | -2.25 | 0.06 | -2.39 | -2.10 | 0.01 |
| 8904 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 9003 | 1 | -2.17 | 0.13 | -2.59 | -1.75 | 0.02 |
| | | | Sebastes melanops (Black Rockfish) | | | |
| 8505 | 1 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| 8608 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| 8705 | 1 | -1.94 | 0.14 | -2.26 | -1.62 | 0.04 |
| 8705 | 2 | -1.69 | 0.20 | -2.10 | -1.27 | 0.09 |
| 8705 | 3 | -2.09 | 0.12 | -2.37 | -1.81 | 0.02 |
| 8806 | 1 | -2.08 | 0.12 | -2.37 | -1.79 | 0.03 |
| 8806 | 2 | -1.75 | 0.18 | -2.15 | -1.36 | 0.08 |
| 8904 | 2 | -2.08 | 0.12 | -2.36 | -1.80 | 0.03 |
| 8904 | 3 | -2.19 | 0.11 | -2.68 | -1.70 | 0.01 |
| 9005 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| 9005 | 2 | -2.12 | 0.13 | -2.51 | -1.73 | 0.02 |
| 9105 | 1 | -2.19 | 0.11 | -2.54 | -1.85 | 0.01 |
| 9105 | 2 | -2.17 | 0.09 | -2.41 | -1.93 | 0.01 |
| 9105 | 3 | -1.39 | 0.24 | -1.91 | -0.87 | 0.16 |
| | | Sebastes mystinus (Blue Rockfish) | | | | |
| 8505 | 1 | -1.38 | 0.19 | -1.81 | -0.94 | 0.16 |
| 8608 | 1 | -2.08 | 0.12 | -2.36 | -1.80 | 0.03 |
| 8703 | 1 | -1.97 | 0.16 | -2.32 | -1.62 | 0.04 |
| 8705 | 1 | 0.13 | 0.30 | -0.49 | 0.75 | 1.09 |
| 8705 | 2 | -0.67 | 0.29 | -1.27 | -0.07 | 0.43 |
| 8804 | 1 | -0.28 | 0.27 | -0.89 | 0.32 | 0.68 |
| 8806 | 1 | 0.14 | 0.28 | -0.44 | 0.71 | 1.09 |
| 8806 | 2 | -0.22 | 0.20 | -0.64 | 0.19 | 0.72 |
| 8806 | 3 | -2.18 | 0.09 | -2.38 | -1.97 | 0.01 |
| 8904 | 1 | -1.36 | 0.25 | -1.89 | -0.83 | 0.17 |
| 8904 | 2 | -1.13 | 0.24 | -1.65 | -0.60 | 0.23 |
| 8904 | 3 | -2.00 | 0.15 | -2.32 | -1.68 | 0.04 |
| 9003 | 1 | -2.20 | 0.07 | -2.36 | -2.05 | 0.01 |
| 9005 | 1 | -1.49 | 0.23 | -1.98 | -1.00 | 0.13 |
| 9005 | 2 | -1.70 | 0.21 | -2.15 | -1.25 | 0.09 |
| 9005 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 9105 | 1 | -1.96 | 0.16 | -2.31 | -1.60 | 0.04 |
| 9105 | 2 | -1.16 | 0.20 | -1.58 | -0.73 | 0.22 |
| 9105 | 3 | -0.79 | 0.28 | -1.39 | -0.19 | 0.37 |
| | | Sebastes paucispinis (Bocaccio) | | | | |
| 8401 | 1 | -0.55 | 0.41 | -1.93 | 0.83 | 0.53 |
| 8505 | 1 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8608 | 1 | -0.98 | 0.26 | -1.55 | -0.41 | 0.29 |
| 8608 | 2 | -1.06 | 0.23 | -1.56 | -0.57 | 0.26 |
| 8608 | 3 | -1.99 | 0.19 | -2.44 | -1.54 | 0.04 |
| 8703 | 1 | -1.80 | 0.19 | -2.23 | -1.37 | 0.07 |
| 8705 | 1 | -1.27 | 0.26 | -1.81 | -0.73 | 0.19 |
| 8705 | 2 | -0.98 | 0.27 | -1.54 | -0.41 | 0.29 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| 8705 | 3 | -1.48 | 0.23 | -1.96 | -1.00 | 0.13 |
| 8804 | 1 | -0.58 | 0.20 | -1.01 | -0.15 | 0.47 |
| 8806 | 1 | -1.00 | 0.24 | -1.50 | -0.51 | 0.28 |
| 8806 | 2 | -1.75 | 0.20 | -2.16 | -1.33 | 0.08 |
| 8806 | 3 | -2.20 | 0.10 | -2.48 | -1.93 | 0.01 |
| 8904 | 1 | -1.78 | 0.18 | -2.18 | -1.38 | 0.07 |
| 8904 | 2 | -1.84 | 0.20 | -2.29 | -1.39 | 0.06 |
| 9003 | 1 | -2.25 | 0.05 | -2.37 | -2.13 | 0.01 |
| 9005 | 1 | -1.44 | 0.26 | -1.99 | -0.89 | 0.15 |
| 9005 | 2 | -2.02 | 0.20 | -2.54 | -1.49 | 0.04 |
| 9105 | 1 | -1.75 | 0.17 | -2.13 | -1.36 | 0.08 |
| 9105 | 2 | -1.53 | 0.22 | -1.99 | -1.06 | 0.12 |
| 9105 | 3 | -0.94 | 0.31 | -1.57 | -0.30 | 0.31 |
| | | *Sebastes pinniger* (Canary Rockfish) | | | | |
| 8401 | 1 | -0.53 | 0.53 | -2.00 | 0.94 | 0.58 |
| 8505 | 1 | -2.10 | 0.15 | -2.50 | -1.71 | 0.02 |
| 8608 | 1 | -1.26 | 0.19 | -1.69 | -0.84 | 0.19 |
| 8608 | 2 | -1.84 | 0.18 | -2.22 | -1.45 | 0.06 |
| 8608 | 3 | -2.17 | 0.13 | -2.74 | -1.60 | 0.02 |
| 8703 | 1 | -1.71 | 0.23 | -2.21 | -1.22 | 0.09 |
| 8705 | 1 | -1.60 | 0.20 | -2.02 | -1.18 | 0.11 |
| 8705 | 2 | -0.95 | 0.22 | -1.42 | -0.47 | 0.30 |
| 8705 | 3 | -1.67 | 0.22 | -2.16 | -1.19 | 0.09 |
| 8804 | 1 | -1.40 | 0.30 | -2.12 | -0.68 | 0.16 |
| 8806 | 1 | 0.03 | 0.28 | -0.55 | 0.61 | 0.97 |
| 8806 | 2 | -1.36 | 0.23 | -1.86 | -0.85 | 0.16 |
| 8806 | 3 | -2.05 | 0.15 | -2.43 | -1.67 | 0.03 |
| 8904 | 1 | -1.73 | 0.18 | -2.12 | -1.33 | 0.08 |
| 8904 | 2 | -1.53 | 0.18 | -1.92 | -1.14 | 0.12 |
| 8904 | 3 | -1.89 | 0.12 | -2.17 | -1.62 | 0.05 |
| 9003 | 1 | -2.22 | 0.09 | -2.49 | -1.94 | 0.01 |
| 9005 | 1 | -1.96 | 0.16 | -2.36 | -1.57 | 0.04 |
| 9005 | 2 | -1.62 | 0.23 | -2.16 | -1.08 | 0.10 |
| 9005 | 3 | -2.12 | 0.13 | -2.51 | -1.73 | 0.02 |
| 9105 | 1 | -1.19 | 0.21 | -1.63 | -0.74 | 0.21 |
| 9105 | 2 | 0.32 | 0.32 | -0.35 | 0.98 | 1.35 |
| 9105 | 3 | 1.16 | 0.33 | 0.47 | 1.84 | 3.26 |
| | | *Sebastes rufus* (Bank Rockfish) | | | | |
| 8705 | 1 | -1.82 | 0.17 | -2.18 | -1.46 | 0.06 |
| 8705 | 2 | -1.93 | 0.16 | -2.27 | -1.60 | 0.05 |
| 8705 | 3 | -2.25 | 0.06 | -2.39 | -2.10 | 0.01 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| 8804 | 1 | -1.59 | 0.28 | -2.30 | -0.88 | 0.11 |
| 8806 | 2 | -2.16 | 0.09 | -2.39 | -1.92 | 0.02 |
| | | *Sebastes saxicola* (Stripetail Rockfish) | | | | |
| 8401 | 1 | -1.56 | 0.28 | -2.40 | -0.73 | 0.12 |
| 8505 | 1 | -2.13 | 0.13 | -2.45 | -1.80 | 0.02 |
| 8608 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| 8703 | 1 | -0.98 | 0.23 | -1.47 | -0.48 | 0.29 |
| 8705 | 1 | -0.34 | 0.26 | -0.87 | 0.20 | 0.64 |
| 8705 | 2 | -1.66 | 0.18 | -2.04 | -1.28 | 0.09 |
| 8705 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8804 | 1 | 0.23 | 0.31 | -0.44 | 0.89 | 1.22 |
| 8806 | 1 | -1.09 | 0.26 | -1.62 | -0.55 | 0.25 |
| 8806 | 2 | -1.91 | 0.14 | -2.22 | -1.61 | 0.05 |
| 8904 | 1 | -1.95 | 0.15 | -2.27 | -1.63 | 0.04 |
| 9003 | 1 | -1.44 | 0.22 | -1.92 | -0.96 | 0.14 |
| 9005 | 1 | -1.52 | 0.23 | -2.01 | -1.03 | 0.12 |
| 9005 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 9105 | 1 | -1.89 | 0.16 | -2.23 | -1.55 | 0.05 |
| 9105 | 2 | -0.93 | 0.26 | -1.48 | -0.39 | 0.31 |
| 9105 | 3 | -1.15 | 0.25 | -1.67 | -0.63 | 0.23 |
| | | *Sebastes wilsoni* (Pygmy Rockfish) | | | | |
| 8401 | 1 | -2.05 | 0.19 | -3.17 | -0.93 | 0.03 |
| 8608 | 1 | -2.17 | 0.10 | -2.39 | -1.94 | 0.02 |
| 8703 | 1 | -1.69 | 0.19 | -2.10 | -1.27 | 0.09 |
| 8705 | 1 | -2.13 | 0.13 | -2.43 | -1.83 | 0.02 |
| 8705 | 2 | -1.97 | 0.16 | -2.32 | -1.62 | 0.04 |
| 8705 | 3 | -2.22 | 0.09 | -2.46 | -1.97 | 0.01 |
| 8804 | 1 | -0.16 | 0.40 | -1.37 | 1.05 | 0.82 |
| 8806 | 1 | -1.93 | 0.15 | -2.26 | -1.61 | 0.05 |
| 8806 | 2 | -2.25 | 0.06 | -2.39 | -2.10 | 0.01 |
| 8806 | 3 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8904 | 1 | -1.98 | 0.16 | -2.33 | -1.63 | 0.04 |
| 8904 | 2 | -2.23 | 0.07 | -2.42 | -2.04 | 0.01 |
| 8904 | 3 | -2.16 | 0.10 | -2.42 | -1.90 | 0.02 |
| 9005 | 1 | -1.90 | 0.14 | -2.20 | -1.60 | 0.05 |
| 9005 | 2 | -2.15 | 0.11 | -2.42 | -1.88 | 0.02 |
| 9105 | 1 | -2.06 | 0.14 | -2.40 | -1.73 | 0.03 |
| 9105 | 2 | -1.53 | 0.22 | -1.99 | -1.08 | 0.12 |
| 9105 | 3 | -1.54 | 0.21 | -1.99 | -1.10 | 0.12 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | 95% Confidence Bounds Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| | | | *Sebastes entomelas* PCA Group | | | |
| 8301 | 1 | -2.07 | 0.16 | -2.50 | -1.63 | 0.03 |
| 8401 | 1 | -0.01 | 0.61 | -1.71 | 1.68 | 1.09 |
| 8505 | 1 | 0.38 | 0.30 | -0.24 | 1.01 | 1.43 |
| 8608 | 1 | -1.49 | 0.24 | -1.99 | -0.99 | 0.13 |
| 8608 | 2 | -1.54 | 0.17 | -1.92 | -1.15 | 0.12 |
| 8608 | 3 | -2.03 | 0.17 | -2.47 | -1.59 | 0.03 |
| 8703 | 1 | -1.56 | 0.24 | -2.06 | -1.05 | 0.12 |
| 8705 | 1 | 1.63 | 0.26 | 1.07 | 2.18 | 5.15 |
| 8705 | 2 | 1.57 | 0.30 | 0.94 | 2.20 | 4.94 |
| 8705 | 3 | -1.22 | 0.26 | -1.77 | -0.67 | 0.21 |
| 8804 | 1 | 0.69 | 0.37 | -0.11 | 1.50 | 2.04 |
| 8806 | 1 | 1.31 | 0.30 | 0.69 | 1.93 | 3.77 |
| 8806 | 2 | 0.84 | 0.27 | 0.28 | 1.41 | 2.31 |
| 8806 | 3 | -1.72 | 0.20 | -2.14 | -1.29 | 0.08 |
| 8904 | 1 | -1.00 | 0.27 | -1.57 | -0.42 | 0.28 |
| 8904 | 2 | -0.44 | 0.26 | -1.00 | 0.13 | 0.57 |
| 8904 | 3 | -1.18 | 0.26 | -1.72 | -0.64 | 0.22 |
| 9003 | 1 | -1.99 | 0.17 | -2.39 | -1.59 | 0.04 |
| 9005 | 1 | -0.95 | 0.33 | -1.67 | -0.22 | 0.31 |
| 9005 | 2 | -0.72 | 0.30 | -1.42 | -0.03 | 0.41 |
| 9005 | 3 | -1.52 | 0.24 | -2.11 | -0.93 | 0.12 |
| 9105 | 1 | -1.48 | 0.22 | -1.95 | -1.02 | 0.13 |
| 9105 | 2 | -0.12 | 0.31 | -0.77 | 0.52 | 0.83 |
| 9105 | 3 | 1.61 | 0.32 | 0.94 | 2.28 | 5.17 |
| | | | *Sebastes jordani* PCA Group | | | |
| 8301 | 1 | -1.45 | 0.44 | -2.78 | -0.12 | 0.16 |
| 8401 | 1 | 1.89 | 0.72 | -0.39 | 4.17 | 8.50 |
| 8505 | 1 | 0.07 | 0.39 | -0.84 | 0.97 | 1.05 |
| 8608 | 1 | 1.71 | 0.40 | 0.86 | 2.57 | 5.91 |
| 8608 | 2 | 1.52 | 0.40 | 0.59 | 2.45 | 4.85 |
| 8608 | 3 | -0.68 | 0.41 | -1.57 | 0.21 | 0.45 |
| 8703 | 1 | 0.98 | 0.32 | 0.31 | 1.64 | 2.70 |
| 8705 | 1 | 3.04 | 0.26 | 2.49 | 3.60 | 21.59 |
| 8705 | 2 | 3.37 | 0.36 | 2.62 | 4.12 | 30.96 |
| 8705 | 3 | 0.87 | 0.36 | 0.11 | 1.62 | 2.44 |
| 8804 | 1 | 3.75 | 0.41 | 2.63 | 4.87 | 46.11 |
| 8806 | 1 | 3.00 | 0.41 | 2.13 | 3.87 | 21.72 |
| 8806 | 2 | 1.81 | 0.35 | 1.07 | 2.55 | 6.41 |
| 8806 | 3 | 0.80 | 0.43 | -0.10 | 1.71 | 2.35 |
| 8904 | 1 | 1.47 | 0.30 | 0.85 | 2.10 | 4.46 |

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

| Cruise | Sweep | Index | SE | 95% Confidence Bounds Lower | Upper | Back-Transformed Value |
|---|---|---|---|---|---|---|
| 8904 | 2 | 0.69 | 0.30 | 0.06 | 1.33 | 1.99 |
| 8904 | 3 | -0.11 | 0.29 | -0.73 | 0.50 | 0.83 |
| 9003 | 1 | 0.16 | 0.29 | -0.42 | 0.75 | 1.13 |
| 9005 | 1 | 1.24 | 0.35 | 0.45 | 2.04 | 3.58 |
| 9005 | 2 | 0.01 | 0.37 | -0.76 | 0.78 | 0.99 |
| 9005 | 3 | -1.66 | 0.24 | -2.19 | -1.14 | 0.09 |
| 9105 | 1 | -0.21 | 0.28 | -0.79 | 0.37 | 0.74 |
| 9105 | 2 | 1.75 | 0.26 | 1.19 | 2.30 | 5.84 |
| 9105 | 3 | 3.18 | 0.26 | 2.64 | 3.72 | 24.83 |
| | | Total Juvenile Sebastes spp. | | | | |
| 8301 | 1 | -1.02 | 0.49 | -2.33 | 0.29 | 0.31 |
| 8401 | 1 | 2.15 | 0.74 | -0.27 | 4.56 | 11.14 |
| 8505 | 1 | 1.22 | 0.29 | 0.59 | 1.84 | 3.42 |
| 8608 | 1 | 1.80 | 0.40 | 0.95 | 2.65 | 6.42 |
| 8608 | 2 | 1.75 | 0.35 | 1.00 | 2.49 | 5.98 |
| 8608 | 3 | -0.61 | 0.42 | -1.52 | 0.30 | 0.49 |
| 8703 | 1 | 1.31 | 0.29 | 0.70 | 1.91 | 3.75 |
| 8705 | 1 | 3.42 | 0.25 | 2.87 | 3.97 | 31.42 |
| 8705 | 2 | 3.66 | 0.35 | 2.92 | 4.40 | 41.22 |
| 8705 | 3 | 1.26 | 0.36 | 0.49 | 2.02 | 3.65 |
| 8804 | 1 | 3.93 | 0.40 | 2.86 | 5.00 | 54.98 |
| 8806 | 1 | 3.37 | 0.36 | 2.59 | 4.14 | 30.94 |
| 8806 | 2 | 2.49 | 0.30 | 1.86 | 3.12 | 12.51 |
| 8806 | 3 | 1.00 | 0.41 | 0.14 | 1.86 | 2.85 |
| 8904 | 1 | 1.71 | 0.30 | 1.08 | 2.33 | 5.66 |
| 8904 | 2 | 1.24 | 0.27 | 0.67 | 1.82 | 3.49 |
| 8904 | 3 | 0.19 | 0.33 | -0.51 | 0.89 | 1.18 |
| 9003 | 1 | 0.30 | 0.29 | -0.30 | 0.90 | 1.31 |
| 9005 | 1 | 1.55 | 0.31 | 0.84 | 2.26 | 4.83 |
| 9005 | 2 | 0.82 | 0.33 | 0.13 | 1.52 | 2.31 |
| 9005 | 3 | -0.93 | 0.28 | -1.54 | -0.33 | 0.31 |
| 9105 | 1 | 0.21 | 0.31 | -0.44 | 0.85 | 1.19 |
| 9105 | 2 | 2.05 | 0.26 | 1.47 | 2.63 | 7.92 |
| 9105 | 3 | 3.59 | 0.25 | 3.06 | 4.12 | 37.23 |

## Annual Trends in the Abundance of Pelagic Juveniles

As in years past, we used the maximum value of $\bar{y}_{str}$ across sweeps within May-June cruises (Table 3) as an annual estimate of the relative abundance of pelagic YOY rockfish. Results show that in 1991 abundances of the 15 most commonly sampled Sebastes spp. were generally much greater than in 1990 (Fig. 2). As has

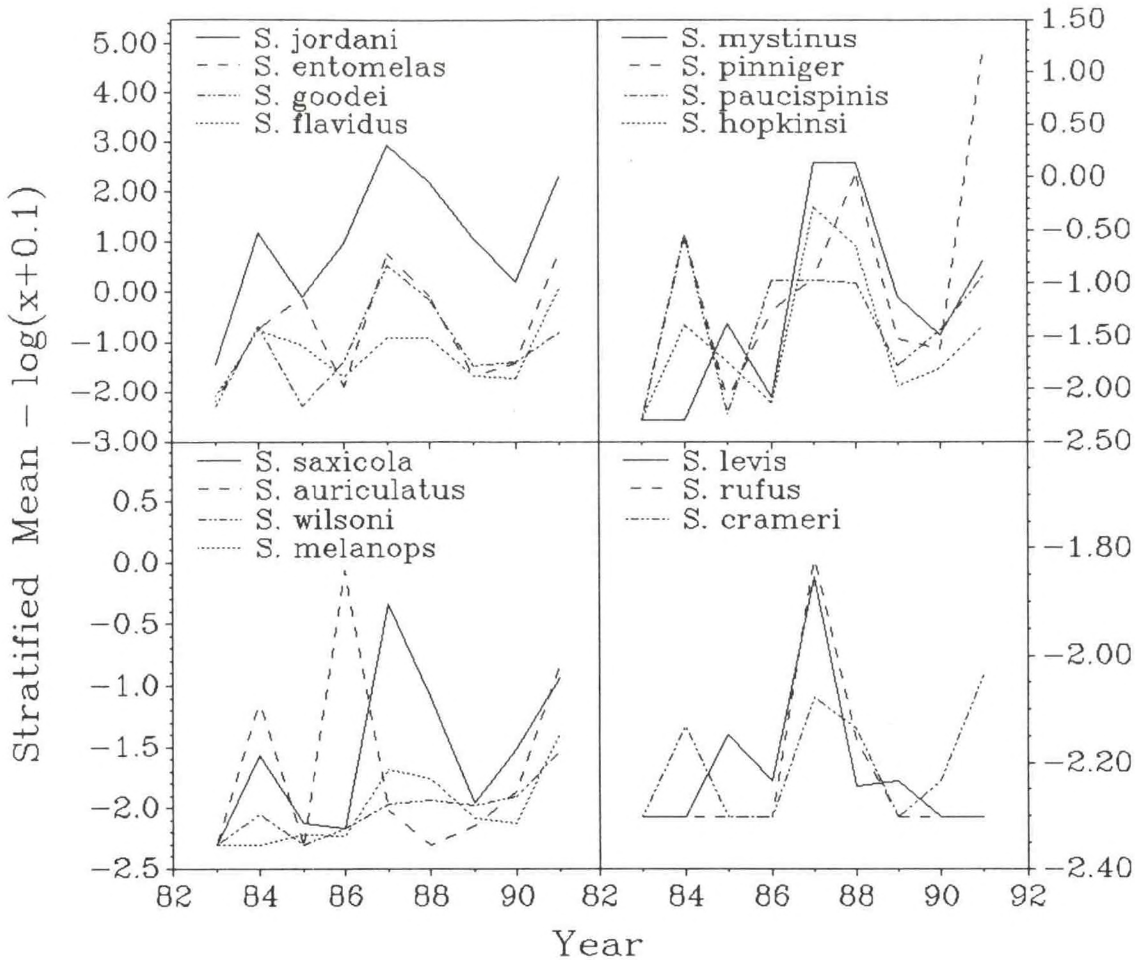


**Figure 2.** Annual (1983-91) estimates of pelagic juvenile relative abundance for 15 species of Sebastes taken by midwater trawl.

been the case since the inception of these surveys, catches of S. jordani outnumbered those of other species, although its numerical dominance in 1991 trawl catches was much diminished.

To better compare and contrast the annual abundance indices ($I_{sy}$) of the various species (s) in each year (y), the long-term (9 yr) means ($\mu_s$) and standard deviations ($\sigma_s$) were calculated. From these, species-specific standard scores were derived for each year from 1983 to 1991 according to $Z_{sy} = (I_{sy}-\mu_s)/\sigma_s$. Standard scores were calculated for the 10 most abundant species occurring in our trawl samples (i.e., S. jordani, S. entomelas, S. goodei, S. flavidus, S. mystinus, S. melanops, S. paucispinis, S. pinniger, S. hopkinsi, and S. saxicola). Of the five species excluded, one (S. auriculatus) correlates poorly with the trends of other species (see Fig. 2) and four are uncommon (S. wilsoni, S. levis, S. rufus, and S. crameri). Results are plotted against

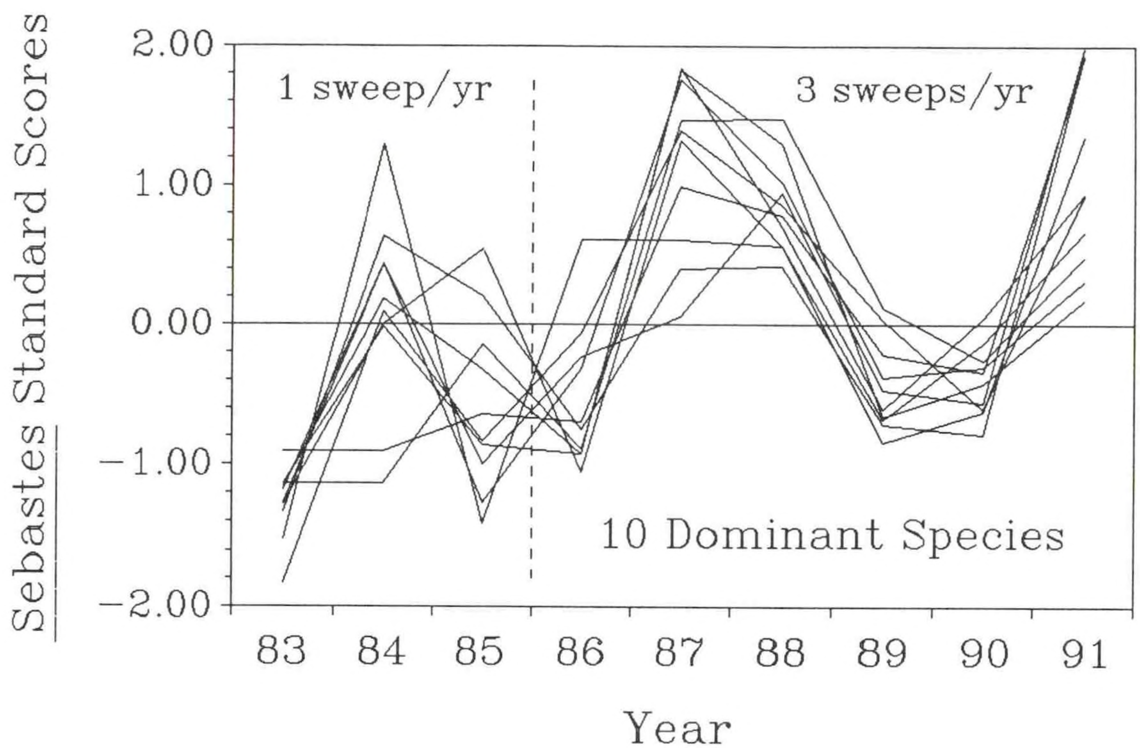


**Figure 3.** Normalized relative abundance trends for each of the 10 most commonly caught species of pelagic juvenile rockfish.

survey year in Fig. 3. Note that for the principal subset of 10 species, 1983 (an El Niño year) had very low levels of abundance. Conversely, 1987 and 1988 were very good years for these species; and catches were consistently moderate to poor in 1989 and 1990. Results for 1991 indicate a rebound to relatively high abundance levels once again.

One potential problem with these results is that we have not adjusted for interannual differences in age or size structure. For example, even though 1989 and 1990 are similar in terms of catch rates and $Z_{sy}$ values (Fig. 3), if the juveniles taken in one of these years were larger, they would be expected to produce a greater recruitment. Results presented in Fig. 4 demonstrate that such was the case, i.e., the juveniles sampled in 1989 were larger than those taken in 1990. Conversely, even though relatively high numbers of juveniles were taken in 1991 trawl samples (Fig. 2), they were generally small, an attribute that likely would discount the relative value of this year-class.

Plans are currently underway to assess the size selectivity of the midwater trawl gear. During the May-June cruise of 1992 (DSJ-9206), alternate haul data will be gathered, using 3/8" (9.53 mm) and 1/4" (6.35 mm) mesh inner-liners. These data will

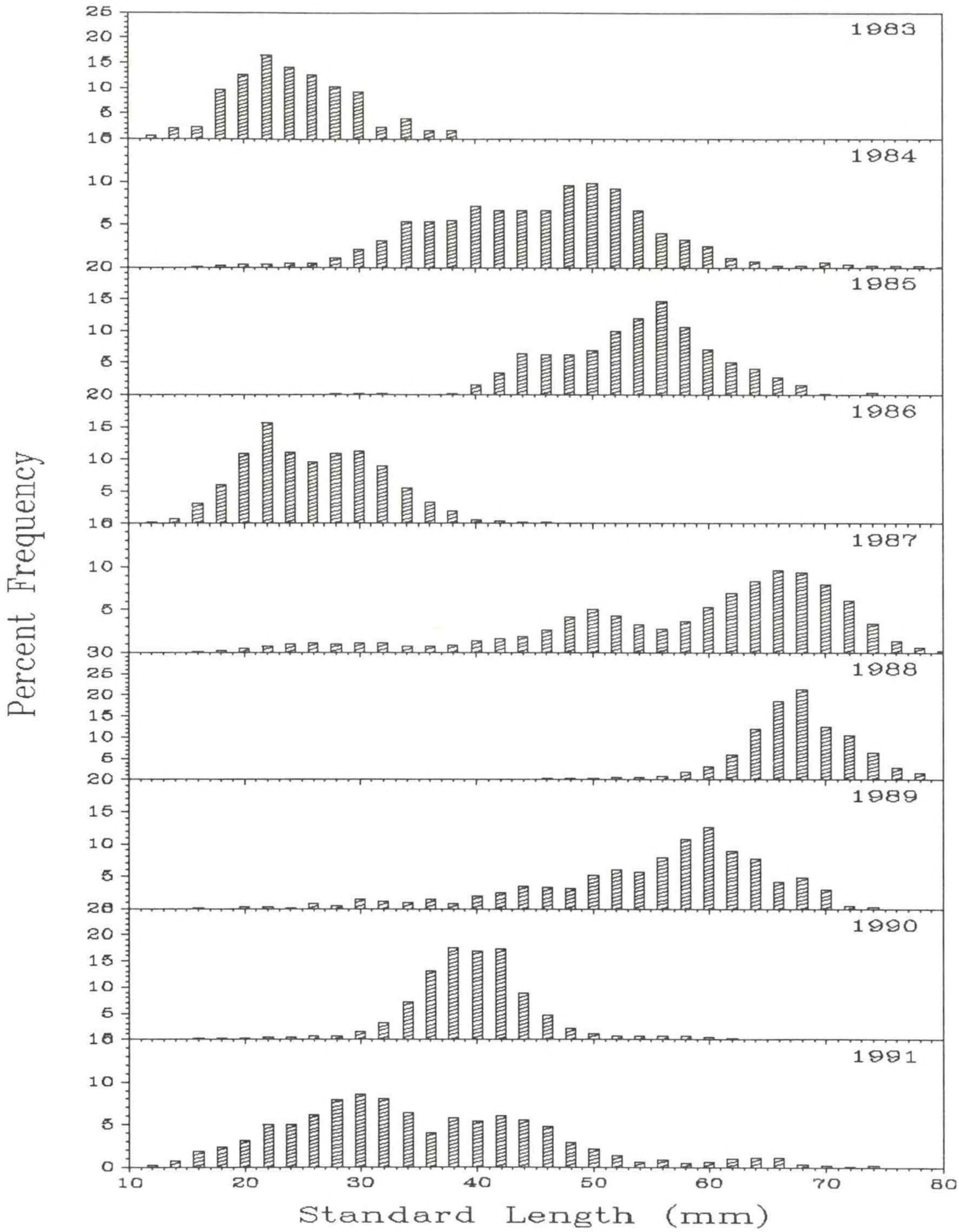


**Figure 4.** Length-frequency distributions of pelagic juvenile rockfish (1983-1991). Only May-June samples of the 15 species reported in Table 3 are reported.

assist in establishing the minimum size at which juvenile rockfish are sampled effectively. Adjustments to annual index values ($I_{sy}$) can then be made based upon estimated mortality rates and the observed size structure. (S. Ralston)

Mesoscale Distribution in Relation to Upwelling Fronts

During the first sweep of the May-June cruise (DSJ-9105, Table 1), it was evident that the abundance of pelagic juvenile rockfish was greater at the offshore stations. Consequently, prior to the beginning of the second sweep, two days of discretionary sampling were allocated to surveying the waters offshore of the Davenport line (36°59'N). Results indicated (Fig. 5) a spatial association between a strongly developed upwelling front and the occurrence of juvenile rockfish. The front was detected at a distance of ~65 km offshore and was in response to sustained northwesterly winds since the cruise began. Inside the front, catch rates averaged 0.33 fish/tow (N=3), whereas outside the front, catch rates averaged 225 fish/tow (N=3). These findings

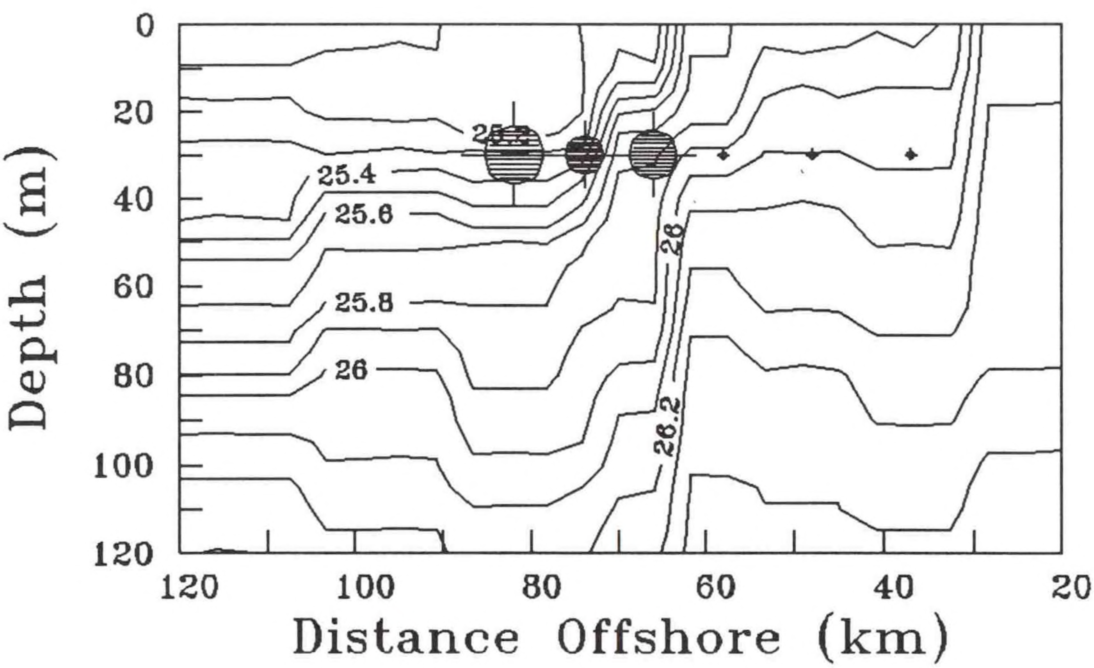


**Figure 5.** Density structure ($\sigma_t$) of the water column off Davenport (36°59'N) on May 22-23, 1991. Circular symbols are proportional in size to the catch of juvenile rockfish.

provided direct evidence supporting the hypothesis that Ekman transport of surface water during an upwelling event advects pelagic juvenile rockfish far offshore (Parrish et al. 1981).

To determine how pervasive a phenomenon this was, catch rate and CTD data from the 1987-90 juvenile rockfish surveys were summarized. If strong coastal upwelling advects pelagic juvenile rockfish offshore, the ratio of catches made at adjacent stations on transect lines running perpendicular to shore (e.g., Point Reyes, Pescadero, and Davenport) should depend on the strength of the density gradient of the water between the stations. A strong (+) gradient in water density at 30 m (defined as [onshore $\sigma_t$ - offshore $\sigma_t$] ÷ the distance between stations) should result in a high ratio of catches (offshore ÷ onshore). However, results for S. jordani (Fig. 6) showed no strong relationship between these variables.

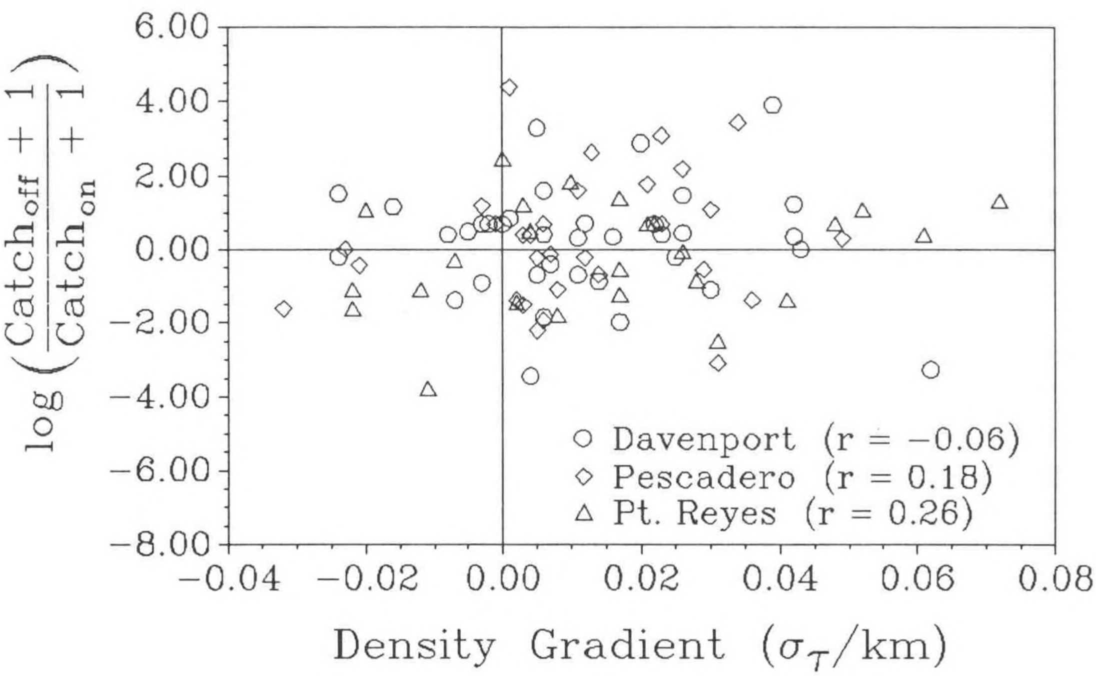


**Figure 6.** Relationship between the ratio of catch rates of Sebastes jordani taken at adjacent stations and the strength of the intervening front.

We continue to explore mesoscale distributions of pelagic juvenile rockfish in an effort to better understand physical mechanisms affecting their survival. Spatial analysis of the surface hydrography surrounding trawls that produced unusually large catches is planned next. (S. Ralston and W. H. Lenarz).

## Spatial Distributions of Fishes and Macro-invertebrates

We have recently analyzed the midwater trawl data from the May-June cruises to evaluate the spatial distribution of fishes and macro-invertebrates. This work was performed to assist the

Environmental Protection Agency in selecting a site for the disposal of dredge materials from San Francisco Bay. It marked the first extensive evaluation of our database for many of the invertebrates and non-Sebastes fishes.

Two complementary analyses were performed. In both we used a $\log_e(x+0.1)$ transformation. First we developed contour plots of abundance on a log-scale. To do this, standardized data were first combined across sweeps and years. Simple averaging of stations across sweeps was not feasible due to the fact that some stations in critical areas were sampled infrequently and simple averaging would confound spatial with temporal effects.

Our approach to standardization was to calculate Z-scores for $\log_e$-abundance data as follows. For a given sweep we calculated the mean, $M^*$, and the standard deviation, $s^*$, using only the data from standard stations (i.e., the stations sampled on each sweep). Then, $Z = (\log_e[x+0.1]-M^*)/s^*$. In these calculations the means and standard deviations were calculated based on standard stations only, so that changes in survey design over time would not introduce artifactual effects into the adjustment. Z-scores calculated from surveys where abundance was zero at all locations were not used. We next calculated a grand mean, M, and grand standard deviation, s, which were the averages of the $M^*$ and $s^*$ over surveys. In these calculations all surveys were used to compute M, but only surveys with at least one positive catch (for the species or group being analyzed) were used to calculate s. We then transformed our Z-scores back to a log-scale by calculating $x^* = sZ+M$. This simple linear transformation had no effect on our analyses, other than allowing us to express our results as mean $\log_e$-abundance rather than in standard deviation units.

We then estimated $\log_e$ abundance throughout the area using the minimum curvature algorithm of Surfer™. As an alternative procedure for estimating a surface area for $\log_e$-abundance over the study region, we used the linear kriging algorithm of Surfer™. General patterns in resulting contour maps were often similar for the two methods, although our kriged maps tended to show more fine-scale structure. In cases where the large-scale spatial pattern looked substantially the same for the two procedures, we used the contour maps produced by the minimum curvature algorithm; otherwise no contour map was presented.

In our second type of analysis, we used an ANOVA model that included sweep (i.e., time), three equal latitude categories, and four bottom depth categories (< 183 m = 100 fathoms, 183-915 m, 915-1830 m, and > 1830 m) as main effects, and allowed for interaction between depth and latitude categories (included if $P > 0.1$). The least-squares means of the $\log_e$ transformed data were calculated, and distributional patterns associated with depth and latitude were evaluated.

Here we present results for a select few taxa, choosing for these examples species or groups that display interesting spatial patterns, i.e., market squid, "other" squid, northern lampfish, juvenile Pacific hake, juvenile bocaccio, and juvenile chilipepper.

As well as showing some finer-scale features, the contour map for market squid indicates that higher abundances were inshore (Fig. 7). This is supported by an examination of least-squares means from the ANOVA. The ANOVA model included an interaction between depth and latitude because there were different rates of decline in abundance with depth at different latitudes.

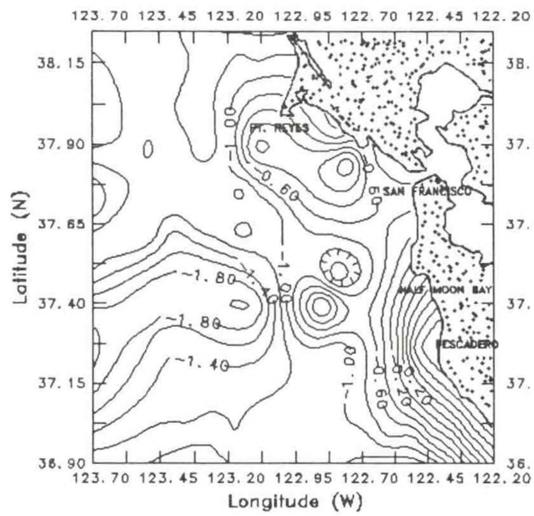


**Figure 7.** Contour map showing the spatial distribution of market squid (Loligo opalescens).

In contrast with market squid, the contour map for the pooled category of "other" squid (Fig. 8) tended to indicate higher abundances offshore with peak concentrations near the shelf break. Lowest abundances were seen inshore. The least-squares means indicated that abundance increased with bottom depth, in agreement with the contour map. Again, there was an interaction between depth and latitude reflecting different rates of increase in abundance with depth at different latitudes.

The contour map for northern lampfish (Fig. 9) illustrates a species that had an offshore distribution, and the least-squares means indicated higher abundances over greater bottom depths, and very little variation with latitude within the study area. Not surprisingly, this pattern of higher offshore abundances was seen for the other species of myctophids as well as for the family as a whole.

The contour plot of juvenile Pacific hake (Fig. 10) shows that they generally had higher abundances offshore, with an apparent peak in abundance near the center of the study region.

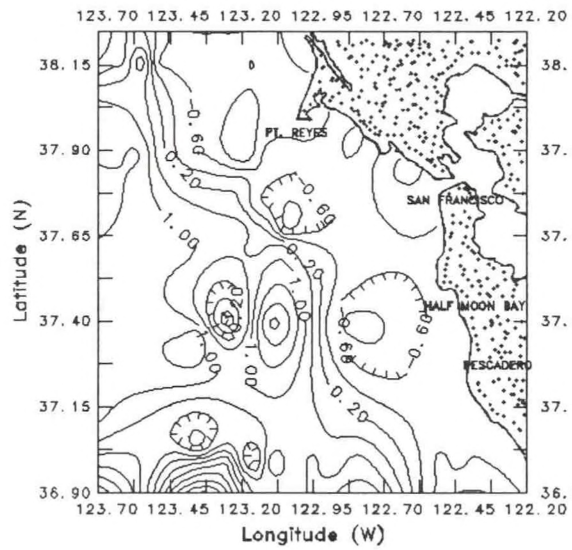


**Figure 8.** Contour map showing the spatial distribution of "other" squid (Teuthoidei).

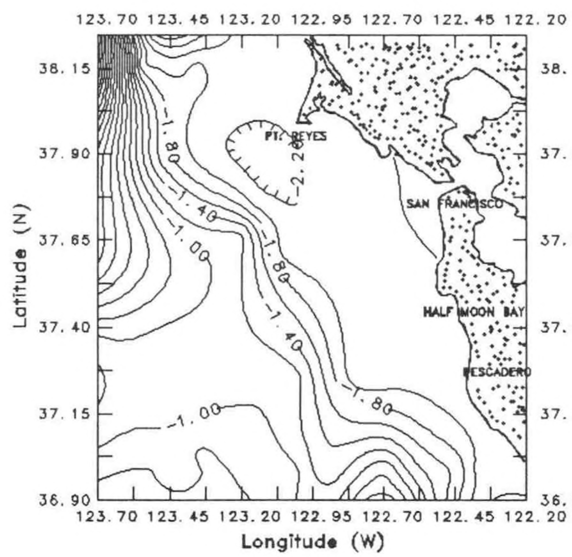


**Figure 9.** Contour map showing the spatial distribution of northern lampfish (<u>Stenobrachius</u> <u>leucopsarus</u>).

The indication of high abundance inshore at the Gulf of the Farallones appears to be the result of one very large catch in that area. The least-squares means indicated very low abundances shallower than 183 m (100 fathoms) and fairly uniform abundance over deeper bottom depths. There is a suggestion of a trend of abundance increasing to the north.

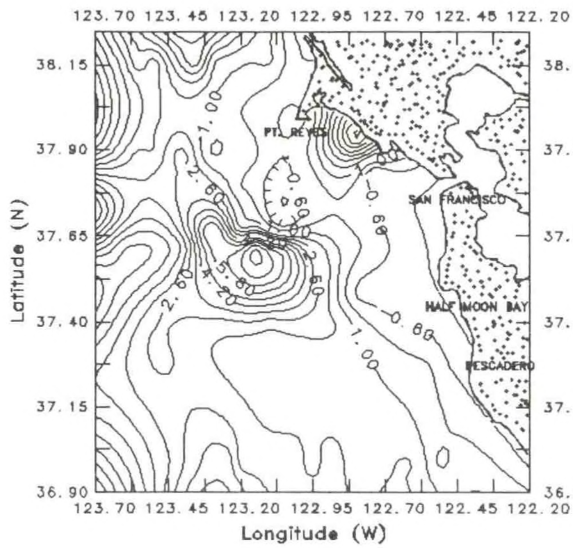


**Figure 10.** Contour map of the spatial distribution of Pacific hake (Merluccius productus).

The map of juvenile chilipepper distribution indicated generally low abundances far offshore and higher abundances inshore. However, there were areas of high abundance near the shelf break in the south and south-central areas (Fig. 11). The least-squares means show that abundance was highest in the

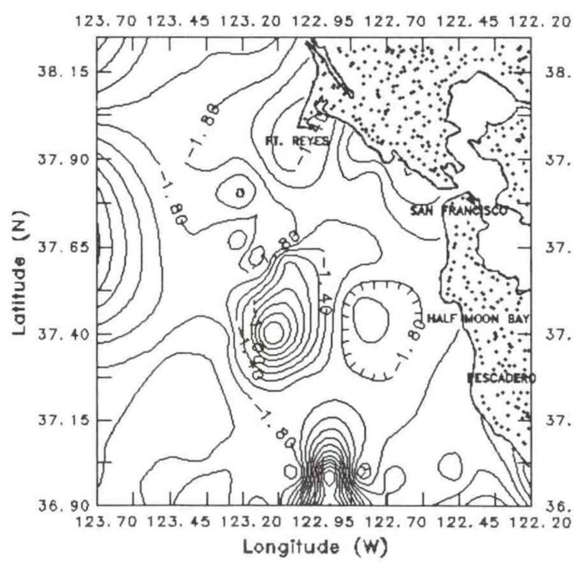


**Figure 11.** Contour map of the spatial distribution of pelagic juvenile chilipepper (Sebastes goodei).

shallowest depth category and lowest in the deepest, and indicate that abundances were highest in the south.

For bocaccio, the contour plots from the two different algorithms were substantially different so no map is presented. Least-squares means, however, show a very clear pattern of increasing abundance with distance offshore, and perhaps higher abundances in the mid-latitude portion of the study area.

It is clear that some taxa showed more extensive offshore distributions than others. Thus, in choices with regard to bottom depth of dredge disposal sites, biological (as well as other) tradeoffs will need to be made. These include the ubiquitous distribution of Pacific hake juveniles in waters deeper than 100 fathoms and the generally offshore distribution of northern lampfish (Myctophidae). Other myctophids we analyzed also had offshore distributions, and our analysis of CalCOFI larval data indicated an offshore distribution of myctophids at the larval stage also. These analyses have revealed patterns that could warrant further exploration. First, the contrast in depth distributions between market squid and other squid is striking. Second, the tendency for bocaccio to be found in waters over a deep bottom, in comparison with chilipepper, is of interest in light of results on larval distribution and the distribution in the water column of juveniles. Lenarz et al. (1991) found that juvenile bocaccio occurred at shallower depths in the water column than other juveniles (including chilipepper) in May and June, and they hypothesized that this could subject them to greater advection offshore due to Ekman transport. They noted that such advection might occur because others have found that the larvae of bocaccio tend to have an offshore distribution relative to other species of rockfish (MacGregor 1986; Moser and Boehlert 1991). (J. Bence, D. Roberts, and D. Pearson)

## Birthdate Distributions of Chilipepper Rockfish

For several years subsamples of common species of pelagic juvenile rockfish have been taken for daily age analysis. Ages are determined using techniques described in Woodbury and Ralston (1991). Back-calculated birthdate distributions of the fish that survived to time of sampling are then estimated by (1) regressing age on SL using the subsample of aged fish, (2) predicting the age of all specimens using the resulting regression equation, (3) back-calculating to the calendar date of birth, and (4) aggregating the data into frequency distributions.

The birthdate distributions for five of the most abundant species (shortbelly rockfish, bocaccio, chilipepper rockfish, widow rockfish, and yellowtail rockfish) show that there can be substantial interannual differences in the mean birthdate of the juveniles that survive until late spring. The data in Fig. 12

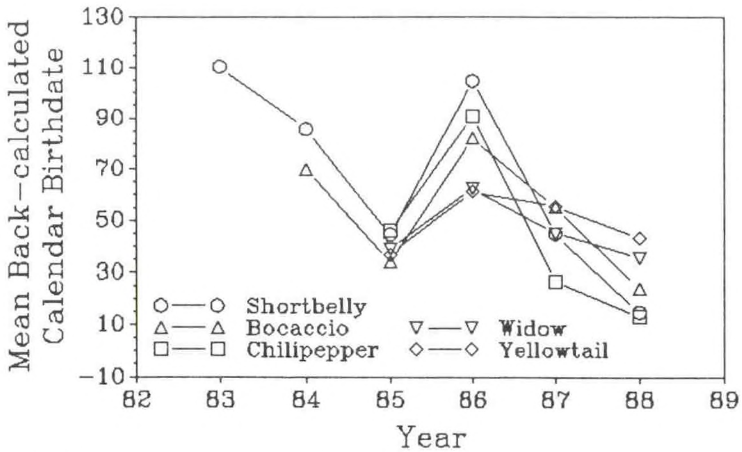


**Figure 12.** Interannual variation in mean back-calculated birthdates of pelagic juvenile rockfish collected during May and June.

show this variation for these five species. Notice the manner in which the species covary, i.e., species were late in 1986 and early in 1985 and 1988. Rockfish are viviparous; these five species copulate in the fall and have an extended parturition (spawning) season that lasts several months during the following winter and spring. To better understand the dynamics of these pelagic juvenile rockfish, we are attempting to determine whether the shifting of back-calculated birthdate distributions is due to higher survival during an optimal period within an extended parturition season or whether the parturition season itself undergoes interannual shifting.

In the winters of 1989-90 and 1990-91, a sampling program was in effect to determine when parturition of chilipepper larvae occurred. Chilipepper were selected due to the ease with which they can be sampled in commercial landings. Adult females were collected at Fort Bragg and at Bodega Bay from November to April during these years. Seven stages of ovarian development, from early vitellogenesis to spent condition, were recorded (i.e., early vitellogenesis, late vitellogenesis, fertilized eggs, eyed larvae, hatched larvae, recently spent, and recovering). Larvae in the eyed condition were returned to the laboratory for further examination; the date of parturition for females containing eyed larvae was then forecasted using a known developmental schedule.

Although sample sizes were small during the 1989-90 season, the incidence of recently spent and recovering ovaries in adult females collected at the two ports (Fig. 13) shows that ~75% of the fish had spawned by the end of January. Presented also is a predicted birthdate distribution based upon laboratory staging of larvae. Note that after January these samples were scarce. Still, when available, the data show good correlation with the ovarian stage data of the adults. The figure also shows the

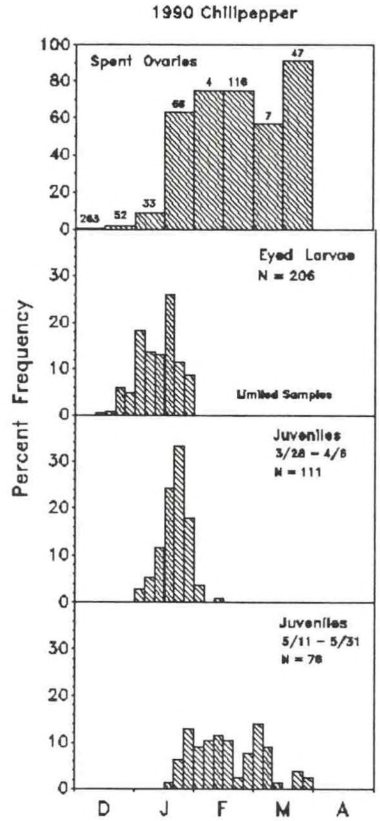


**Figure 13.** Estimated birthdate distributions of chilipepper from the 1989-90 parturition season.

back-calculated birthdate distributions of the juveniles collected during the offshore surveys. Note that data from the March-April survey likely provide a distorted representation of survivors, due to the fact that some parturition was still taking place and very young fish were not vulnerable to the gear. Conversely, birthdate distribu-tions calculated from samples collected during the second cruise were characterized by fish released much later in the season; fish spawned early in the parturition season were not well represented. Their low numbers may have been due to emigration, settlement, or differential mortality rates. Unfortunately, the catch of chilipepper during the two 1990 surveys was low, making it difficult to render definitive conclusions.

The incidence of spent ovaries in adult females sampled in the second year of the study (Fig. 14) suggests that ~80% of the fish sampled had spawned by mid-February. This is a few weeks later than the previous year. Also shown is the predicted birthdate distribution, based on larvae released during the parturition season. It shows a broad distribution, unlike that developed from spent ovaries. Lastly, the back-calculated birthdate distribution calculated from samples of juveniles taken during the May-June survey showed a strong peak similar to the period of adult parturition, but slightly later.

Comparisons of (1) the seasonal incidence of spent females and (2) forecasted distributions of eyed larvae, with the back-calculated birthdate distributions of the surviving pelagic juveniles collected in the spring, show that the data are skewed, with the majority of the parturition occurring in January to mid-February and reduced parturition through March. We have deter-

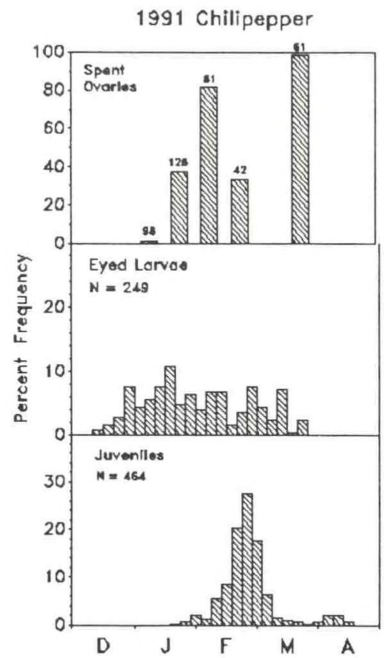


**Figure 14.** Estimated birthdate distributions of chilipepper from the 1990-91 parturition season.

mined that in 1990 and 1991 most chilipepper larvae were released during a fairly short period. However, we have yet to show whether shifting in the back-calculated data is due to shifts in spawning or to differential mortality. It will be most informative to have the back-calculated birthdate distribution data from the pelagic juveniles collected during the 1992 May-June survey, because El Niño conditions would predict a delayed distribution (e.g., 1983 & 1986), even though our current examination of ovaries and larvae suggests parturition occurred as usual during January and February. (D. Woodbury and A. McBride)

<u>Studies of Pelagic Juvenile Sanddabs</u>

Starting in 1987 pelagic juvenile sanddabs collected during the midwater trawl surveys were identified to species. Abundance statistics for Pacific sanddabs (Citharichthys sordidus) and speckled sanddabs (C. stigmaeus) were calculated using the same procedures outlined previously (Table 3), and the maximum index values from the May-June trawls of each year were used to estimate annual relative abundance. Plots of annual relative abundance for C. sordidus, C. stigmaeus, and total Sebastes spp. indicate that 1987 and 1991 were good years for all three groups (Fig. 15). However, whereas 1988 was a good year for total Sebastes spp., it was not for sanddabs. In addition, annual relative abundances of total Sebastes spp. and C. sordidus were low during 1989 and 1990, but C. stigmaeus was abundant during 1990. Lastly, the relatively low abundances of sanddabs in 1988 could be misleading, because they were abundant during the April midwater trawl survey of that year, suggesting that the majority of the juveniles of both species had settled prior to the May-June survey. The dissimilarity between the annual relative abundance statistics of C. stigmaeus and total Sebastes spp. may be due to protracted spawning by C. stigmaeus, which spawns from March through October, and possibly throughout the year (Goldberg

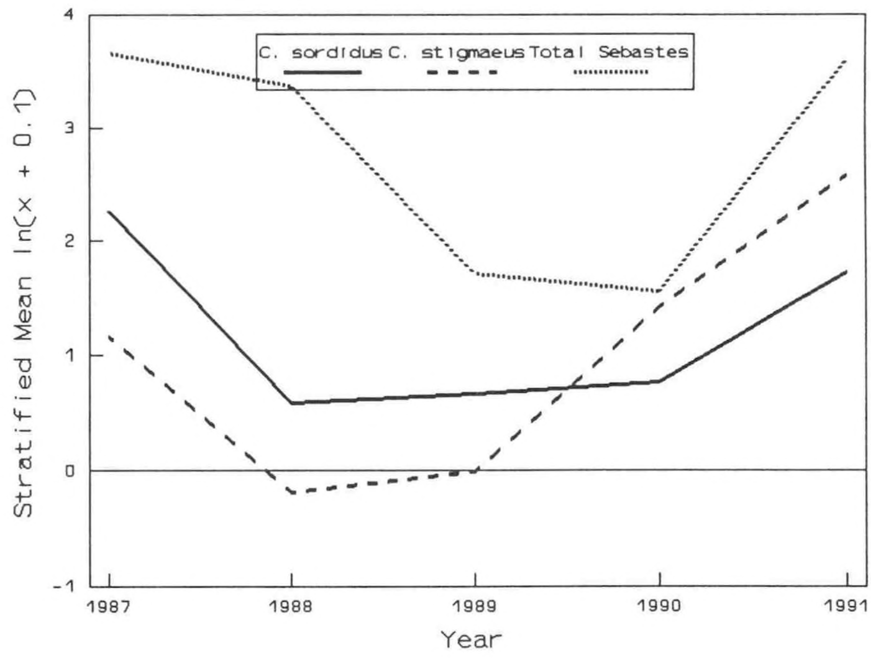


**Figure 15.** Annual (1987-91) estimates of relative abundance for pelagic juvenile sanddabs compared with the most commonly collected rockfish.

and Pham 1987). In contrast, most Sebastes spp. show a definite spawning peak during one season of the year (Wyllie Echeverria 1987). Moreover, both species of sanddabs are subject to egg mortality in the plankton, unlike Sebastes spp. which are extruded as larvae.

Relative metamorphic stages were recorded for C. sordidus and C. stigmaeus in 1990 and 1991. Metamorphic stages were assigned as follows:

stage 1 = position of left and right eyes equal on both sides of head
stage 2 = right eye has begun to move dorsally
stage 3 = upper edge of right eye within close proximity to the top of the right side of the head
stage 4 = right eye has begun to cross over to the left side of the head
stage 5 = right eye completely crossed over to the left side of the head, metamorphosis complete.

The absence of stage 1 individuals in the midwater trawls could be attributed to the small size of stage 1 sanddabs, allowing them to pass through the net. Abundances for each stage in each trawl were transformed by $\log_e(x+1)$. Using depth-stratified

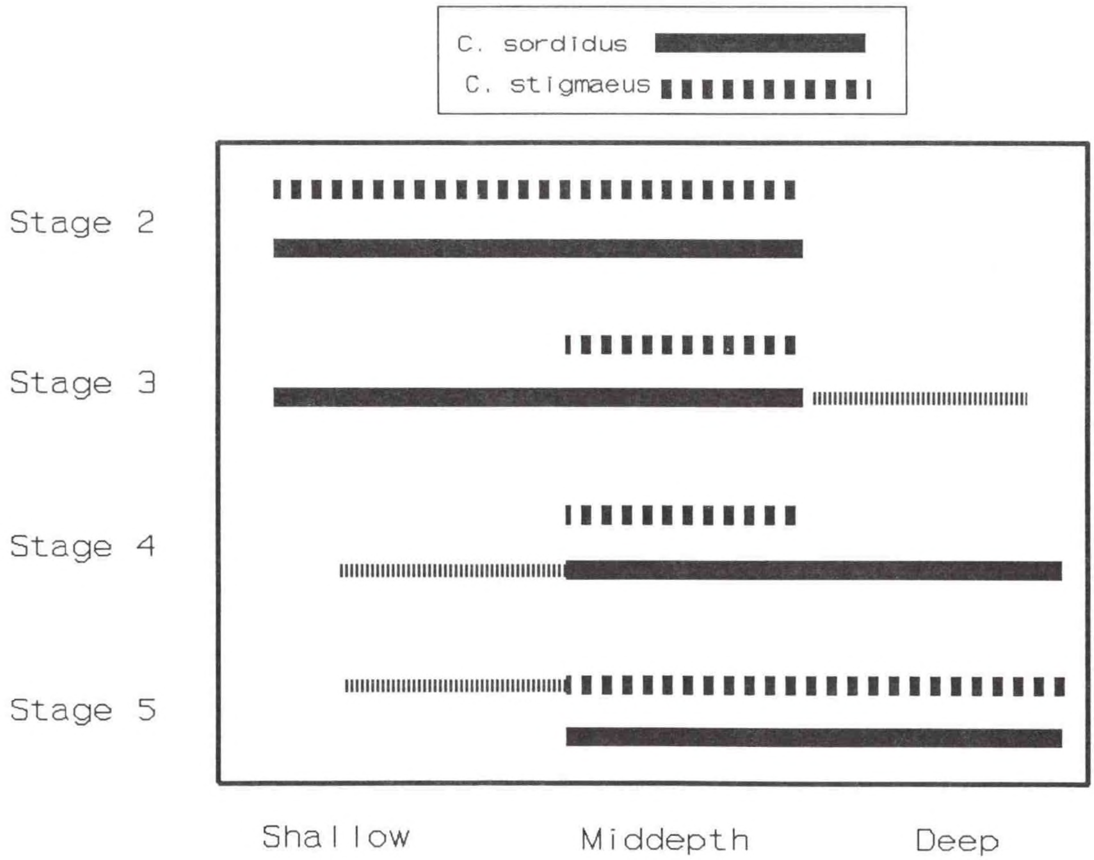


**Figure 16.** Depth distributions of pelagic juvenile sanddabs. Fine dashed lines represent non-significant (P > 0.05) changes in abundance.

trawl data, paired t-tests were performed on the transformed abundance data to determine at which depth each stage of each species was most abundant. Results presented in Fig. 16 show that, in general, the earlier stages of both species occur shallower in the water column, while the later stages occur deeper. Later stages of both species may occur deeper in the water column in preparation for settlement to the benthic environment. In addition pelagic juvenile C. sordidus are generally more abundant deeper in the water column than pelagic juvenile C. stigmaeus, probably because adult C. sordidus occur at deeper bottom depths than adult C. stigmaeus (Fig. 16). (K. Sakuma)

## Progress in Estimating Year-Class Strength From Composition of Predator Diet

### Estimates of Abundance of Juvenile Rockfish from Predator Diet

The 1991 assessment of pelagic juvenile rockfishes in the stomach contents of king salmon (Oncorhynchus tshawytscha) indicated that the numbers consumed (mean of 0.93 per stomach) were in the midrange of numbers consumed during previous years (Table 4), but that the species were very different. Shortbelly rockfish (Sebastes jordani), which in previous years has represented 50 to 80% of the identifiable juveniles in the diet, this year represented just 23% (0.14 per stomach). Furthermore, the canary rockfish (S. pinniger), which during all previous years was present in the stomachs only in very small numbers, this year represented 24% of those identified (0.15 per stomach) to just barely rank first among the species represented. Other species prominent among rockfish juveniles in the salmon stomachs were: widow rockfish (S. entomelas) 18%; bocaccio (S. paucispinis) 12%; black rockfish (S. melanops) 6%; yellowtail rockfish (S. flavidus) 3%; and squarespot rockfish (S. hopkinsi) 3%. In addition, the period when juvenile rockfish occurred in salmon stomachs this year--28 May to 28 June--was both later and shorter than periods of occurrence during all previous years except 1980, the first year of assessments, and 1983, the year of the El Niño. (P. Adams and K. Silberberg)

### Juvenile Rockfish Identification Manual

The studies of recruitment of rockfishes at the Tiburon Laboratory share the need to identify juvenile rockfish correctly. Identification is often difficult, because pigmentation and body shapes are usually different for juveniles than for adults, and juveniles from stomach contents of predators

Table 4.--Mean number of first year juvenile rockfishes (genus Sebastes) in the stomach contents of king salmon (Oncorhynchus tshawytscha) from the Gulf of the Farallones, 1980-1991 (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 |
| 1991 | 637 | 0.93 | 0.14 | 0.11 |

which may be damaged by digestion are even more difficult to identify. For these reasons, a number of researchers from the Groundfish Communities and Groundfish Analysis Investigations have worked to improve identification techniques at the Tiburon Laboratory, and these individual studies have been brought together and published as NOAA Technical Memorandum 166, "Methods used to identify pelagic juvenile rockfish (genus Sebastes) occurring along the coast of central California," edited by Thomas Laidig and Peter Adams.

The chapters of this manual were written to function independently of each other, but can used in combination, as is shown in the examples in the Introduction. The chapter titles and authorships are given below: 1) "Pigment patterns of juvenile Sebastes flavidus and Sebastes melanops useful in identification" by Thomas E. Laidig and Wayne M. Samiere; 2) "Identification of juvenile rockfish (genus Sebastes) using the cleithrum" by Kelly R. Silberberg; 3) "The use of the bones of the caudal complex to identify juvenile rockfish (Sebastes spp.)" by Thomas E. Laidig, Wayne M. Samiere, and Ralph C. DeFelice; 4) "A computerized 'Expert System' to aid in the identification of juvenile rockfish (genus Sebastes)" by Peter B. Adams and Wayne M. Samiere; 5) "Key to the juvenile rockfishes of central California" by Sharon L. Moreland and Carol A. Reilly. The use of these methods of identification has greatly improved the ability of researchers at the Tiburon Laboratory to identify both fresh specimens of juvenile rockfish and those from stomach contents of predators. (T. Laidig and P. Adams)

## STUDIES OF POST-PELAGIC JUVENILES

After several months in the pelagic environment, juvenile rockfish settle into benthic habitats, which are more typical of their adult life history. For the rockfishes which release their larvae during the winter, this occurs principally from May to July. During this period, juvenile rockfish are monitored in nearshore habitats using SCUBA transect surveys.

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

The yellowtail rockfish, Sebastes flavidus, and the blue rockfish, S. mystinus, have dominated among rockfish recruits monitored in northern California's nearshore habitats since 1983 by Ted Hobson, Tony Chess and Dan Howard of the Groundfish Communities Investigation. The assessments have been made at two locations--one in Mendocino county and the other about 100 km to the south in Sonoma county. Recruitment during the past seven years has evidenced a pattern (Tables 5 and 6). Although S. flavidus has tended to be more numerous in the north and S. mystinus more numerous in the south, a year of strong (or weak) recruitment for one has been a strong (or weak) year for the other and that relative level of recruitment has been evident at both sites.

This pattern was disrupted during 1991, however, when sharp differences between the two sites developed. Contrary to previous years, S. flavidus recruited in much larger numbers in the south than in the north; and while S. mystinus recruits were moderately numerous in the south, their numbers in the north were the lowest since 1983, the year of this century's strongest El Niño. It also may be that the Mendocino value for S. flavidus was inflated somewhat by several large aggregations that may have just happened to occur on the assessment route. As previously noted (Ralston 1990), when at least some Sebastes species experience poor recruitment, the relatively few present appear to have an increased tendency to aggregate. (E. Hobson, D. Howard and J. Chess).

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

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|---|---|
| Species | n=36 | n=57 | n=50 | n=103 | n=112 | n=62 | n=181 | n=99 | n=80 |
| _S. flavidus_ | 0.00 | 6.58 | 115.60 | 6.01 | 102.66 | 59.47 | 1.29 | 1.93 | 8.14 |
| | (0.00) | (2.29) | (21.26) | (1.50) | (11.08) | (10.23) | (0.35) | (0.90) | (3.04) |
| _S. mystinus_ | 0.27 | 1.49 | 70.56 | 7.83 | 181.04 | 75.89 | 6.08 | 0.76 | 0.64 |
| | (0.09) | (0.30) | (15.32) | (1.88) | (26.19) | (10.18) | (0.94) | (0.17) | (0.16) |
| _S. melanops_ | 0.41 | 0.31 | 4.34 | 9.52 | 7.58 | 5.94 | 3.14 | 0.84 | 1.22 |
| | (0.14) | (0.08) | (1.54) | (2.08) | (1.24) | (1.35) | (0.59) | (0.29) | (0.30) |
| Total | 0.68 | 8.38 | 190.50 | 23.35 | 291.67 | 141.29 | 10.49 | 3.53 | 10.00 |
| | (0.19) | (2.33) | (29.82) | (3.91) | (33.99) | (16.88) | (1.44) | (1.05) | (3.05) |

Table 6.--Mean number (standard error in parenthesis) 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 | 1991 n=79 |
|---|---|---|---|---|---|---|---|---|
| *S. flavidus* | 4.39 (1.48) | 135.17 (26.00) | 6.73 (2.29) | 89.39 (18.42) | 39.92 (7.94) | 1.54 (0.42) | 0.12 (0.05) | 38.33 (6.40) |
| *S. mystinus* | 4.89 (1.29) | 117.63 (19.50) | 15.27 (3.81) | 328.05 (52.15) | 175.06 (16.76) | 7.19 (0.93) | 0.66 (0.12) | 13.58 (1.82) |
| *S. melanops* | 1.63 (0.52) | 4.40 (1.17) | 3.00 (1.31) | 4.48 (1.70) | 6.40 (1.95) | 1.66 (0.39) | 1.03 (0.42) | 1.92 (5.18) |
| 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) | 57.09 (7.73) |

## STUDIES OF ADULTS

Adult rockfish are viviparous, meaning that they copulate. The female carries the larvae for some period and contributes some amount of energy to larvae while they are inside the female. The species dealt with here are winter reproducers. *Sebastes mystinus* is sampled in nearshore habitats by SCUBA divers using spears, and *S. flavidus* is sampled at Cordell Bank using hook-and-line.

### Progress in Studies of *Sebastes mystinus*

#### The Effects of Feeding Conditions on Physical Condition and Recruitment Success

The possibility that recruitment by the blue rockfish is influenced by feeding conditions experienced by the adults has been studied since November 1987 by Fishery Biologists Ted Hobson, Tony Chess and Dan Howard of the Groundfish Communities Investigation. Results through 1990, presented in last year's report of this series (Whipple 1991), showed that physical condition of adult females during the January-February spawning season is strongly influenced by feeding conditions during the previous summer and fall. There also were indications that recruitment resulting from the current spawning season is influenced as well.

Those findings have gained support from work done during the past year, when summer-fall feeding was considerably better than it had been during the same periods of 1989 and 1990 (Fig. 17). Furthermore, while the gut contents were slightly lower in volume than during 1988 (and the incidence of empty guts was somewhat increased), the quality of the diet was higher than during the three previous years. Gelatinous zooplankters are the preferred foods of this species, with plant materials taken when other foods are less available (Hobson and Chess 1988). For the first time during this study, these were the major foods.

That the improved feeding resulted in healthier fish was indicated by the three measures that have been used to assess physical condition (Fig. 18). The _visceral fat ranking_ is a subjective visual assessment on a relative scale, 0 to 5, whereas the _liver condition_ and _soma condition_ (with soma defined as body less viscera and gonads) are represented by Fulton's Condition Factor ($K = \text{weight}/\text{length}^3$). It remains to be determined, however, whether the improved physical condition indicated by these measures will translate into a greater number of recruits later this year. (E. Hobson, J. Chess, D. Howard).

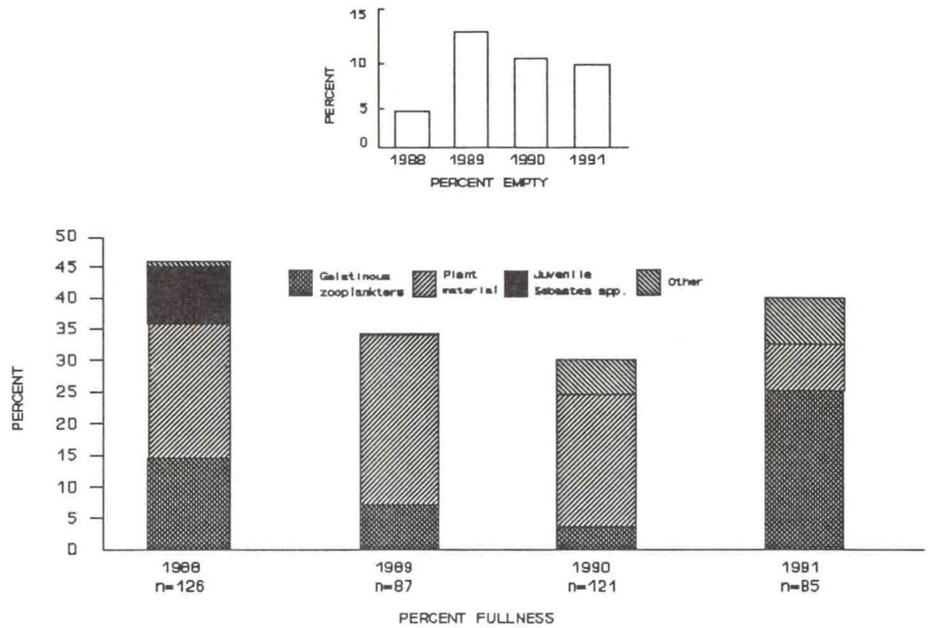


**Figure 17.** Feeding by adult female <u>Sebastes</u> <u>mystinus</u> from June to November.

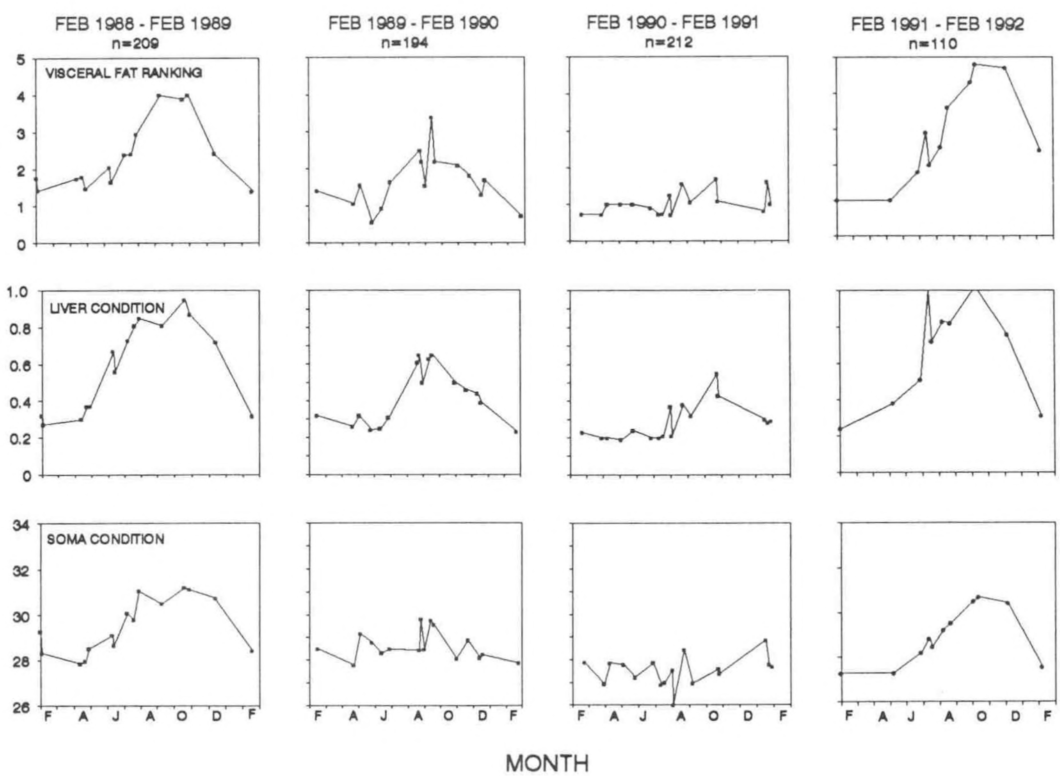


**Figure 18.** Condition indicators in female <u>Sebastes</u> <u>mystinus</u> >250 mm SL.

## Progress in Studies of *Sebastes flavidus*

In 1991 regular sampling of adult yellowtail rockfish from the seamount Cordell Bank, California, was completed. Interdisciplinary studies were initially designed to determine the relationships between physiological condition and reproduction, and how they were affected by environmental conditions. Subtasks within the overall objective resulted in a combination of laboratory and field studies that provided information on a variety of subjects that are important to efficient management, including reproductive life history, the annual reproductive cycle, oogenesis and spermatogenesis, atresia, ovarian maturity stages, blood and tissue nutrient dynamics, physiological conditions (including parasites and diseases), nutritional energetics, fecundity, and gestation rates. Since these studies have been conducted since 1985, temporal and spatial perspectives have been obtained with significant seasonal and interannual differences being found in many important characteristics such as nutritional states, fecundities, and conditions.

### Nutritional Energetics of Reproduction in Yellowtail Rockfish (*Sebastes flavidus*)

Reproductive success, or the production of healthy, energetic larvae, is influenced by several important factors including environmental conditions and the physiologic status of females. The physiologic state is, in turn, controlled by genetic, environmental, and nutritional factors that are fundamentally interdependent. That nutritional and energetic status influences fecundity and vitality of offspring is documented for some teleosts. Thus, we have studied the nutritional dynamics of reproduction in yellowtail rockfish (*Sebastes flavidus*) from Cordell Bank over the last seven reproductive cycles to determine the significant processes governing nutritional energetics of successful reproduction, and to elucidate components that may improve estimation of reproductive output.

In previous annual reports, we have described the relationships of time and stage of ovary maturation to lipid and protein metabolism during the annual reproductive cycle. The present report will provide a synthesis of data to describe the dynamics and energetics of nutrition involved with ovarian development.

When constructing a nutrient or energy budget, it is advantageous to evaluate quantities, rather than concentrations, of energetic components to compensate for variations of tissue mass due to fish size, seasonality, or reproductive state. Consequently, we converted all concentration data into quantities by determining the product of tissue mass and component concentration. Also, we were interested in determining the dynamics of the "typical" or representative male and female yellowtail rockfish from the Cordell Bank population. Therefore, all data were adjusted for variations in fish size by performing analysis of covariance (ANCOVA) using the ln (standard length [SL]) as a covariate. Across the database, the mean SL (±SE) for females and males was 36.5 ± 0.5 cm and 35.5 ± 0.3 cm, respectively. Although the difference in length between sexes was not significant ($P>0.05$), there was a difference in monthly means of length for females ($P<0.01$).

As in most vertebrates, the principal components of nutritional energetics in yellowtail rockfish are protein and lipid. Across all months of a reproductive cycle, lipid and protein quantities varied significantly in all tissues (liver, muscle, gonad, mesenteries) in both sexes ($P<0.0001$), except male muscle protein. Unlike many mammals and some fish species, carbohydrates are quantitatively insignificant in energy dynamics in yellowtail rockfish, comprising only about 1% of tissue mass and energy content (Table 7).

Total lipid quantities varied seasonally in all three somatic tissues: liver, muscle, and mesenteries (Fig. 19). Although all somatic reserves of lipids declined as ovarian lipid levels increased, the greatest source of lipid was from the mesenteries. The pattern of lipid change in male somatic tissues was similar to that found in females, but of lower amplitude.

Somatic tissue protein content varied inversely with ovarian development, similar to lipid; however, the pattern of accumulation and loss differed between the sexes to a greater extent (Fig. 20). Protein declined earlier in male liver tissue and there was an indistinct, but significant ($P<0.005$), pattern of change in muscle protein in males that was of lower amplitude than found in females.

The mass balance of nutritional energy dynamics from the perspective of the female annual reproductive cycle for yellowtail rockfish is summarized in Table 7. The analysis describes changes in nutrient quantity by tissue through ovarian development and gestation to parturition (August through March). Since males do not experience reproductive development at the same time as females, changes in nutrient quantities in males reflect accretion and depletion due to feeding and metabolic maintenance (i.e., respiration, locomotion, ionic and osmotic regulation, etc.). Also, male gonadal proliferation is considerably less than that of females when it does occur (September and October) and requires proportionately less mobilization and utilization of somatic energy reserves (Fig. 19). Thus, changes in nutrient components in males can be used to represent adult metabolic costs exclusive of reproduction.

Table 7. Mean net change in tissue components in relation to annual reproductive cycle of <u>Sebastes</u> <u>flavidus</u>. All values in grams (except where indicated) adjusted for size differences. Changes are maximum differences in quantities from start of ovarian development to parturition. Net gain (+) and loss (-) indicated.

| Tissue | Sex | Lipid | Protein | Glycogen | Total |
|---|---|---|---|---|---|
| A. Liver | ♀ | -15.5 | -3.4 | -1.6 | -20.5 |
| | ♂ | -10.1 | -3.6 | -1.2 | -14.9 |
| | diff | -5.4 | +0.2 | -0.4 | -5.6 |
| B. Muscle | ♀ | -14.6 | -37.4 | -0.04 | -52.0 |
| | ♂ | -11.1 | -27.6 | +0.01 | -38.7 |
| | diff | -3.5 | -9.8 | -0.05 | -13.3 |
| C. Mesentery | ♀ | -21.3 | | | -21.3 |
| | ♂ | -13.1 | | | -13.1 |
| | diff | -8.2 | | | -8.2 |
| A+B+C | ♀ | -51.4 | -40.8 | -1.6 | -93.8 |
| | ♂ | -34.3 | -31.2 | -1.2 | -66.7 |
| | diff (g) | -17.1 | -9.6 | -0.4 | -27.1 |
| | diff (kcal) | -161.6 | -54.2 | -1.6 | -217.4 |
| D. Ovary | (g) | +7.4 | +21.2 | +0.1 | +28.7 |
| | (kcal) | +69.9 | +119.8 | +0.4 | +190.1 |
| $\frac{-D}{\mathrm{diff}_{A+B+C}}$ | (g) | 0.43 | 2.2 | 0.25 | 1.06 |
| | (kcal) | | | | 0.87 |

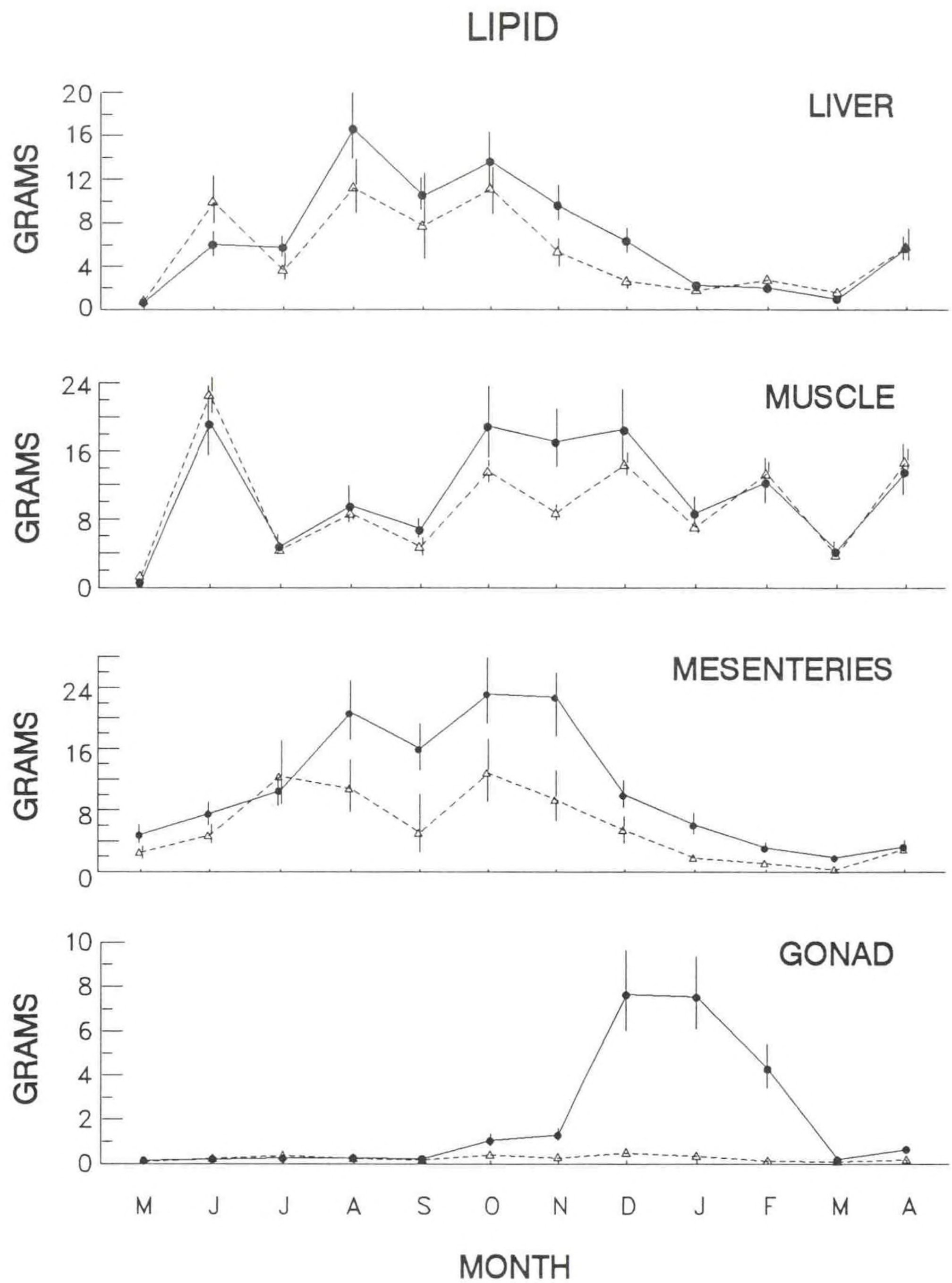


**Figure 19.** Patterns of total lipid content in somatic (liver, muscle, mesenteries) and gonadal tissues in <u>Sebastes</u> <u>flavidus</u> during annual reproductive cycle. Values are means (±SE) of females (•) or males (▵) adjusted for variation in size using ln (standard length) as the covariate.

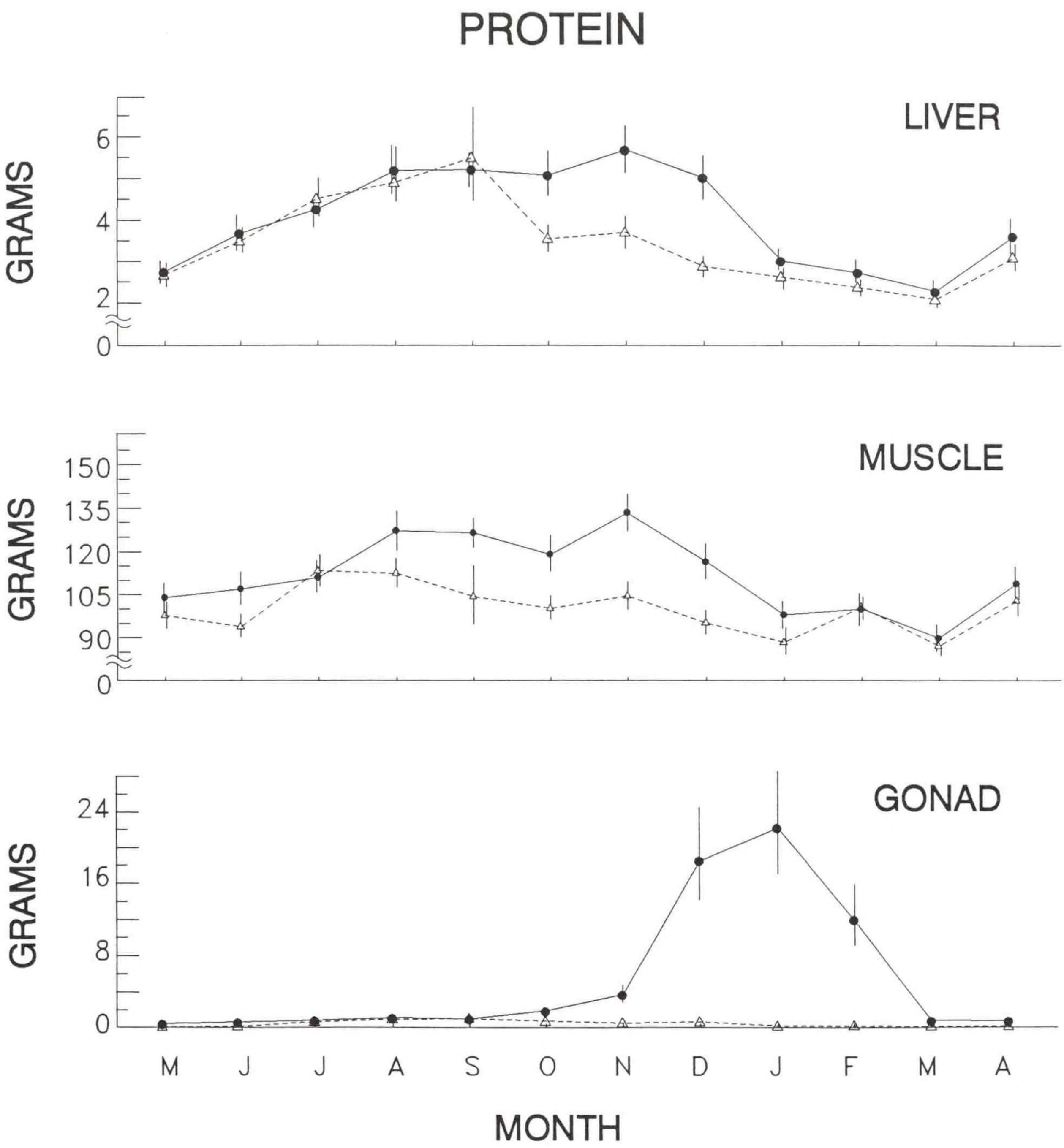


**Figure 20.** Patterns of protein content in somatic and gonadal tissues during annual reproductive cycle in S. flavidus. As in Figure 19, means for females (•) and males (▵) adjusted for size variation.

Differences between females and males may then be viewed as estimates of nutrition and energy requirements for female-specific reproductive purposes, including ovarian tissue proliferation, gametogenesis, embryogenesis, and associated energy-consuming processes related to increasing mass (e.g., locomotion, hydromineral balance).

Although lipids were depleted from all three somatic tissues, mesenteric deposits were the greatest source quantitatively (Table 7). Moreover, the typical female mobilized about 8 g more lipid from this source than did males. Overall, females utilized approximately 17 g more lipid from soma than did males during the annual cycle.

Protein loss was greatest in muscle in both sexes during the period of ovarian maturation (Table 7). Females mobilized about 10 g more muscle protein than males. Declines in liver protein were similar for both sexes. Mesenteric energy and nutrient stores are almost exclusively triacylglycerols (lipid) and not a source of protein. Female reproductive utilization of protein from somatic tissues was approximately 10 g.

Quantitatively, lipid was the most significant nutrient for female reproductive processes (Table 7). Lipid comprised 63% (17.1 g/27.1 g) of somatic reserves depleted during ovarian development. Applying energy-equivalent factors (lipid, 9.45 kcal/g; protein, 5.65 kcal/g; carbohydrate, 4.10 kcal/g) to component mass losses, lipid accounted for 74% (161.1 kcal/ 217.4 kcal) of the energy used for female reproduction. Of the lipid depleted for female-specific purposes, 43% (+7.4 g to ovary/ -17.1 g from soma) was incorporated into developing ovaries. Thus, in a net balance, 57% of lipid depleted was oxidized for energy-requiring female reproductive functions.

Protein increased greatly during ovary maturation in _S. flavidus_ (Table 7). This was expected, since substantial _de novo_ synthesis is required for oocyte and embryonic development. However, 21 g of protein accumulated in ovaries during the annual cycle while only 9.6 g were depleted from somatic tissues for reproductive processes. This represents a 220% net increase in protein during ovarian development and strongly suggests significant external sources of nutrition (i.e., feeding) during this time of the year, despite the relative paucity of prey.

In comparison to males, females used 27.1 g more somatic nutritional resources, indicating that 29% (27.1 g/ 93.8 g) of the organic mass lost was dedicated to reproduction (Table 7). Further, the ratio of ovarian tissue generated to somatic organic matter depleted (+28.7 g/-27.1 g = 1.06) suggested that biosynthetic and catabolic processes were balanced. Energetically, the net efficiency of organic matter depletion from female somatic tissues destined for reproductive functions to ovarian tissue synthesis was 87%.

These results support findings presented in previous annual recruitment reports, derived primarily from blood serum data, that lipids are the main source of energy for reproduction. The temporal dynamics of nutrient accumulation and depletion in somatic and gonadal tissues revealed an unexpected decline in muscle protein during the time of ovarian development, indicating muscle as an important source of nutrients. Also, the net synthesis of protein in ovarian tissue during gamete and embryogenesis suggests that feeding is an important source of protein during this time interval, and probably accounts for the surprising efficiency of net energy balance between somatic tissue depletion and ovarian tissue development. (B. MacFarlane and E. Norton)

## Interannual Variation of Fecundity In Yellowtail Rockfish

The reproductive life history of yellowtail rockfish at Cordell Bank has been studied since 1985 as part of a comprehensive research program designed to determine the relationship between environmental factors, fish physiological condition, and reproduction. One of the more meaningful measures of reproductive effort is fecundity. Research results from five previous reproductive seasons (i.e., 1985-86 through 1989-90) showed significant interannual differences in fecundities as they related to age, size, and conditions.

For the 1990-91 season we continued our studies of yellowtail rockfish fecundities at Cordell Bank and found further evidence of temporal variability. While female fish remained at similar average age (mean age = 14.8 years, Table 8) and lengths (mean standard length = 35.4 cm), their corresponding body weights were among the lowest of all six years of data (mean somatic wet weight = 1098 g). Whole body examinations to assess physiological conditions showed that ranked mesenteric fat deposits were next to the lowest previously recorded and less than the overall mean levels.

Fecundity measurements for the 1990-91 reproductive season did not show any negative effects from the smaller somatic tissue mass and low fat reserves (Table 9). Absolute fecundities were slightly less than the long-term average (i.e., 496,800 vs. 510,900 eggs per female, Table 9), while the relative fecundity was the highest of all six years. The latter condition reflected the lower average body weights. Evidently, yellowtail rockfish maintained average egg production despite reduced body weights. The result was higher relative fecundities.

Another perspective on interannual variability in yellowtail rockfish fecundity is provided by the linear model of fecundities in a standard fish, representing the typical age (15.5y) and size (36.4 cm SL and 1230 g somatic wt.) of the Cordell Bank

Table 8.--Summary statistics of age, standard length, total body weight, and somatic wet weight of all yellowtail rockfish specimens examined in reproduction.

| | | Age (yr.) | | | | Standard Length (cm) | | | | Total Wt. (g) | | | | Somatic Wt. (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | n | $\bar{x}$ | S.D. | Min. | Max. | $\bar{x}$ | S.D. | Min. | Max. | $\bar{x}$ | S.D. | Min. | Max. | $\bar{x}$ | S.D. | Min. | Max. |
| 85/86 | 22 | 18.6 | 5.8 | 9 | 31 | 38.6 | 3.2 | 32.5 | 44.0 | 1556 | 316.7 | 917 | 2367 | 1419 | 317.8 | 882 | 2257 |
| 86/87 | 79 | 16.3 | 7.6 | 6 | 48 | 37.3 | 3.8 | 28.5 | 46.0 | 1416 | 398.2 | 653 | 2388 | 1305 | 326.2 | 642 | 1989 |
| 87/88 | 74 | 13.5 | 7.2 | 6 | 36 | 35.1 | 4.3 | 28.5 | 46.0 | 1196 | 445.3 | 590 | 2627 | 1143 | 406.4 | 550 | 2083 |
| 88/89 | 66 | 16.4 | 8.8 | 5 | 38 | 36.9 | 4.0 | 27.0 | 44.5 | 1336 | 392.7 | 552 | 2159 | 1299 | 391.2 | 551 | 2095 |
| 89/90 | 105 | 14.9 | 7.5 | 5 | 33 | 35.9 | 3.9 | 29.0 | 44.5 | 1224 | 355.8 | 556 | 2182 | 1152 | 332.8 | 555 | 2048 |
| 90/91 | 102 | 14.8 | 6.5 | 7 | 41 | 35.4 | 3.2 | 28.0 | 42.0 | 1186 | 322.5 | 628 | 2162 | 1098 | 288.6 | 603 | 1835 |
| All | 448 | 15.3 | 7.4 | 5 | 48 | 36.2 | 3.9 | 27.0 | 46.0 | 1277 | 389.3 | 552 | 2627 | 1200 | 355.0 | 550 | 2257 |

Table 9.--Summary statistics of absolute and relative fecundities of yellowtail rockfish, 1985-1991.

| Year | Absolute Fecundity Mean | Absolute Fecundity S.D. | Absolute Fecundity Min | Absolute Fecundity Max | Relative Fecundity Mean | Relative Fecundity S.D. | Relative Fecundity Min | Relative Fecundity Max |
|---|---|---|---|---|---|---|---|---|
| 1985/86 | 630.4 | 221.5 | 167.6 | 1,197.0 | 436.95 | 96.15 | 190.13 | 572.41 |
| 1986/87 | 600.1 | 261.1 | 89.5 | 1,199.4 | 431.13 | 128.95 | 113.12 | 723.49 |
| 1987/88 | 408.4 | 295.3 | 56.9 | 1,221.0 | 325.12 | 138.25 | 96.17 | 686.05 |
| 1988/89 | 594.5 | 321.4 | 112.8 | 1,129.2 | 427.04 | 147.46 | 129.53 | 674.11 |
| 1989/90 | 471.0 | 198.0 | 147.0 | 978.2 | 407.12 | 86.75 | 212.60 | 636.76 |
| 1990/91 | 496.8 | 192.0 | 76.9 | 910.3 | 441.85 | 88.33 | 127.65 | 666.82 |
| ALL | 510.9 | 252.6 | 56.9 | 1,221.0 | 408.24 | 119.45 | 96.17 | 723.49 |

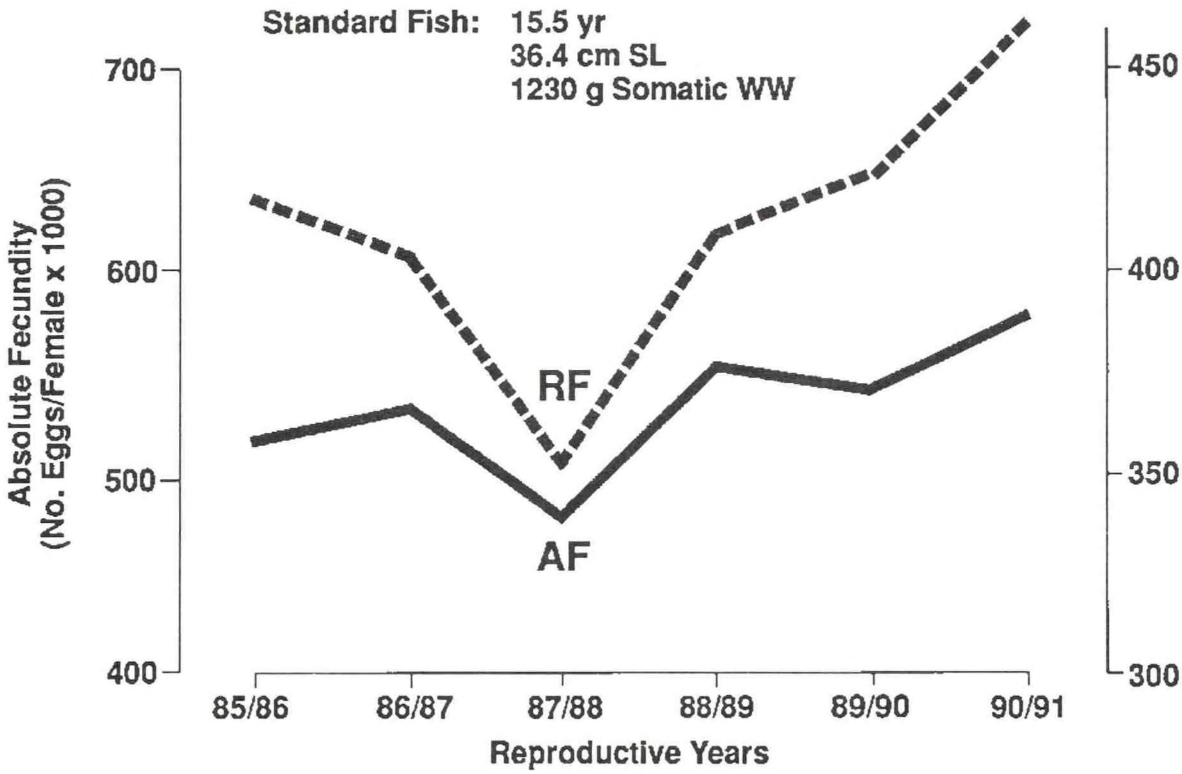


**Figure 21.** Linear model estimating absolute and relative fecundities for a standard yellowtail rockfish female from Cordell Bank, California, from the 1985-86 through 1990-91 reproductive year.

population (Fig. 21). Both absolute and relative fecundities increased in 1990-91, reaching the highest levels among the six years studied. This further illustrates our earlier findings that reproductive effort in yellowtail rockfish varies between and among years with possible links to the variation we see in recruitment. (M. Eldridge and B. Jarvis)

<u>Hook-and-Line Study of Cordell Bank, California, 1986-1991</u>

The principal method of specimen collection for our physiological ecology studies of rockfishes at the submerged seamount, Cordell Bank, was hook-and-line fishing from chartered commercial fishing boats. This method was preferred because it provided specimens in excellent condition with few catch-induced pathologies. Although fishing effort was directed at yellowtail rockfish, our main species of interest, catches reflected the fish community that was associated with yellowtail rockfish and vulnerable to capture. To better understand this community, records were kept on fishing effort, species and numbers landed, and the locations fished.

Between April 1986 and April 1991, 45 trips were made at approximate monthly intervals. For each of the calendar months, we averaged 3.8 trips over the five-year study (Table 10). The interannual effort was not consistent, however, as only 4 trips were made in 1989 and 3 in 1991 (Table 11). Complete samplings of all 12 months were possible during 1987 and 1990. The daily collections consisted of an average 3.9 hours of continuous fishing during midday (average start time 0949 to end time 1341). The mean number of fishermen over these trips was 11.5.

Cordell Bank is the northernmost of a series of seamounts located off the coast of California. It lies approximately 37 km from the coastline and is only 33 m at its shallowest depth. Collections of this study were mostly concentrated in the northern half of the bank, with an average bottom depth of 86 m (range = 62 - 135 m).

A total of 7,403 fish were landed with an average catch of 162 fish per trip (range = 48 - 472). The catch consisted of 28 different species, but the most represented on any given trip was 13 species (Table 12). The mean number of species was 10. No monthly differences in the number of species caught were found, but between-year differences were noted (ANOVA $P>.01$). The number of species was high in 1986 and low in 1987 and 1988. The fish community was dominated by rockfish species (i.e., *Sebastes* spp.). Of 28 total fish species, 21 were rockfishes; together they amounted to 95.6% of the catch. Yellowtail rockfish was the most abundant (47%), followed by *S. rosaceous* (9.8%), *S. paucispinis* (9.7%), *S. serranoides* (7.0%), and *S. chlorostictus* (5.1%). The only non-rockfish species that was numerous was lingcod, *Ophiodon elongatus*. Cordell Bank was found to have a diverse and productive fish community that was relatively stable on a temporal basis. As more accessible nearshore habitats become depleted of adult fish due to fishing and habitat degradation, we expect the importance of distant seamounts to increase. (M. Eldridge)

Table 10.--Catch and effort data by month for Cordell Bank hook-and-line charters, 1986-1991.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of Trips | 4 | 4 | 4 | 4 | 2 | 3 | 4 | 4 | 4 | 3 | 3 | 6 |
| Total Catch | 844 | 563 | 719 | 640 | 330 | 498 | 739 | 64 | 636 | 514 | 363 | 799 |
| $\bar{x}$ Catch/Trip | 211 | 141 | 180 | 160 | 165 | 166 | 185 | 160 | 159 | 171 | 121 | 133 |
| No. of Species | 14 | 13 | 14 | 19 | 13 | 16 | 17 | 15 | 16 | 14 | 15 | 17 |
| $\bar{x}$ No. of Spp./Trip | 10.5 | 8.5 | 11.5 | 10.8 | 9.0 | 10.7 | 12.3 | 11.1 | 9.3 | 8.7 | 9.3 | 11.3 |
| CPUE | 4.893 | 6.903 | 4.173 | 3.415 | 4.010 | 6.070 | 5.323 | 3.785 | 4.805 | 3.100 | 3.857 | 3.327 |

Table 11.--Catch and effort data for Cordell Bank hook-and-line study, 1986-1991.

| Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | All |
|---|---|---|---|---|---|---|---|
| No. of Trips | 7 | 12 | 7 | 4 | 12 | 3 | 45 |
| Total Catch | 889 | 1434 | 899 | 700 | 2890 | 473 | 7285 |
| $\bar{x}$ Catch/Trip | 127 | 120 | 128 | 175 | 241 | 158 | 162 |
| No. of Species | 18 | 18 | 17 | 15 | 19 | 16 | 26 |
| $\bar{x}$ No. of Spp./Trip | 10.7 | 9.2 | 9.4 | 10.0 | 10.5 | 10.3 | 10.0 |
| CPUE | 2.513 | 2.403 | 2.741 | 4.853 | 8.087 | 5.923 | 4.441 |

Table 12.--Names, total catches, mean catches per trip, and the maximum numbers caught per trip of fishes collected by hook and line at Cordell Bank, California, from 1986-91.

| Common Name | Scientific Name | Total Catch | Mean Catch Per Trip | Maximum Catch Per Trip |
|---|---|---|---|---|
| Spiny dogfish | Squalus acanthias | 1 | .02 | 1 |
| Chinook salmon | Oncorhynchus tshawytscha | 3 | .07 | 1 |
| Lingcod | Ophiodon elongatus | 287 | 6.38 | 33 |
| Greenspotted rockfish | Sebastes chlorostictus | 381 | 8.47 | 83 |
| Starry rockfish | S. constellatus | 143 | 3.18 | 9 |
| Greenstriped rockfish | S. elongatus | 32 | .71 | 15 |
| Widow rockfish | S. entomelas | 375 | 8.33 | 182 |
| Yellowtail rockfish | S. flavidus | 3492 | 77.60 | 247 |
| Chilipepper rockfish | S. goodei | 47 | 1.04 | 27 |
| Squarespot rockfish | S. hopkinsi | 2 | .04 | 1 |
| Cowcod rockfish | S. levis | 1 | .02 | 1 |
| Quillback rockfish | S. maliger | 2 | .04 | 2 |
| Vermillion rockfish | S. miniatus | 14 | .31 | 3 |
| Blue rockfish | S. mystinus | 36 | .80 | 15 |
| China rockfish | S. nebulosus | 1 | .02 | 1 |
| Speckled rockfish | S. ovalis | 134 | 2.98 | 34 |
| Bocaccio rockfish | S. paucispinis | 717 | 15.93 | 58 |
| Canary rockfish | S. pinniger | 308 | 6.84 | 82 |
| Redstripe rockfish | S. proriger | 1 | .02 | 1 |
| Rosy rockfish | S. rosaceus | 725 | 16.11 | 68 |
| Greenblotched rockfish | S. rosenblatti | 18 | .40 | 15 |
| Yelloweye rockfish | S. ruberrimus | 110 | 2.44 | 10 |
| Stripetail rockfish | S. saxicola | 2 | .04 | 2 |
| Olive rockfish | S. serranoides | 521 | 11.58 | 109 |
| Jack mackerel | Trachurus symmetricus | 25 | .56 | 12 |
| Pacific mackerel | Scomber japonicus | 14 | .31 | 14 |
| Pacific sanddab | Citharichthys sordidus | 1 | .02 | 1 |
| Rock sole | Lepidopsetta bilineata | 10 | .22 | 3 |

Physiological Condition and Reproduction of Adult *Sebastes flavidus*

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 results of previous spawning years (e.g., Ralston 1990, Whipple 1991). Some of the more recent results on condition and reproduction of adult female yellowtail rockfish are briefly summarized here.

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 beginning in 1989, we renewed sampling on a monthly basis in late 1989 in anticipation of a possible El Niño. Monthly collection of adults was continued in the 1991-1992 spawning year. In fact, El Niño conditions were delayed and we are just now experiencing the beginning of El Niño conditions in the study area. Sampling on a monthly basis will continue through this spawning year (1992-1993).

The sampling period discussed here includes the first six spawning years (1=1985-1986, 2=1986-1987, 3=1987-1988, 4=1988-1989, 5=1989-1990, 6=1990-1991). Data collected in year 7 (1991-1992) are still being analyzed. A spawning year is defined as beginning on April 1 of the first year and ending March 30 the following year. The means, standard deviations and anomalies of some of the major environmental, age, condition, parasite and disease, and reproduction variables are shown in Figures 22 to 26. Upwelling indices and anomalies were obtained from PFEG (Bakun 1975; Mason and Bakun 1986). Upwelling anomalies were based on 20 years of data. Temperature and salinity anomalies are based on Scripp's data from 1925 to 1989 (Scripps Institution of Oceanography 1989). Sea level anomalies were obtained from F. Schwing (pers. comm.) from the IGOSS Sea Level Program in the Pacific database. The anomalies for measurements made on fish were determined by subtracting the six-year monthly means from the monthly means of each year of this database.

Females collected in years 1, 2 and 3 (1985-1986, 1986-1987, 1987-1988) were comparable, with fish in spawning year 1 showing some differences, primarily because of more older fish in sample. Fish in years 2 and 3 were in good condition. Spawning years 5 (1989-90) and 6 (1990-1991) appear to represent years of poorer adult condition (1989-1990 and 1990-1991).

Preliminary examination of fish in year 7 (1991-1992) indicates that the body condition of fish improved, particularly in fish having larger amounts of mesenteric fat, except for the

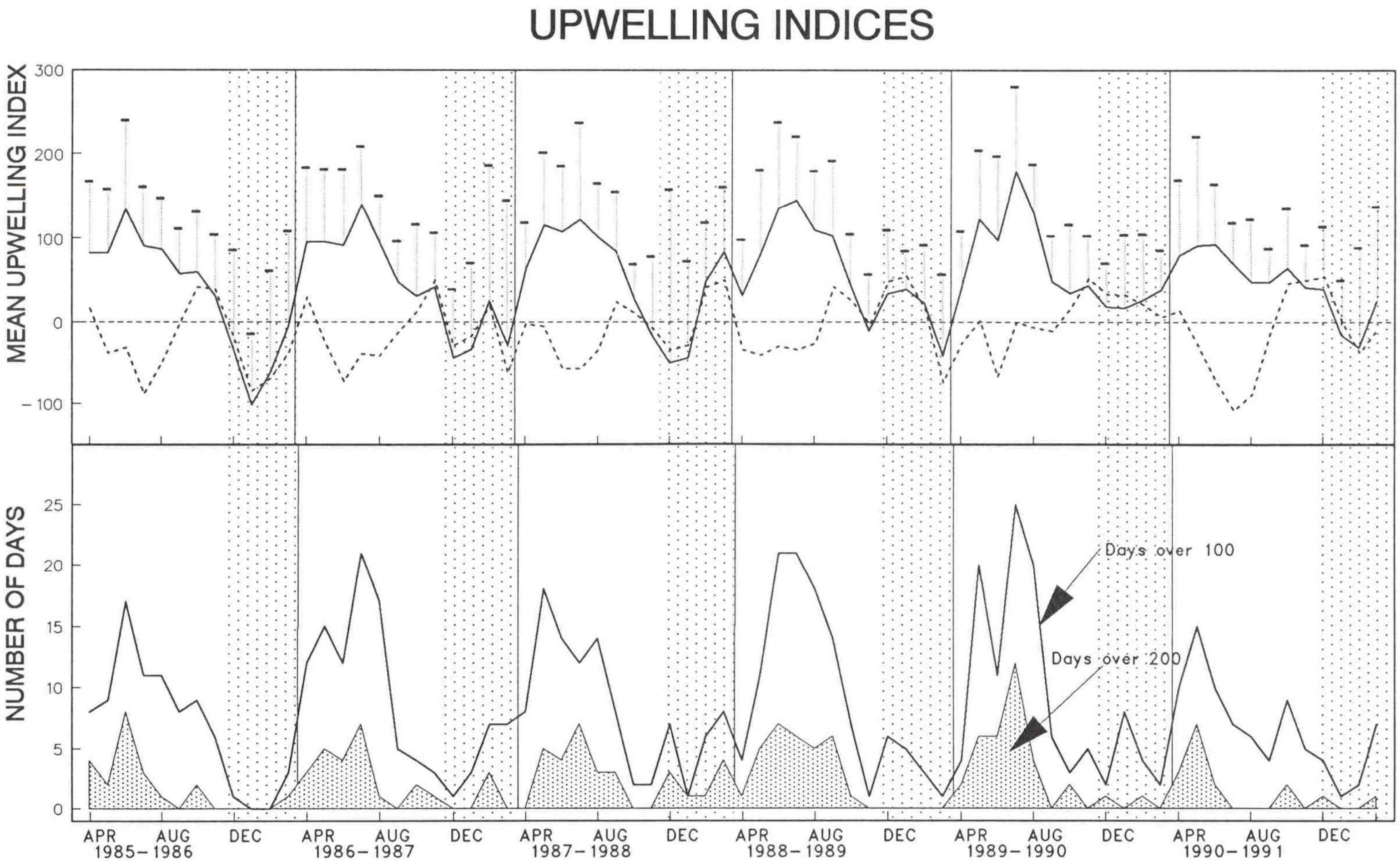


**Figure 22.** Means, standard deviations, anomalies and number of days upwelling index greater than 100 and greater than 200. Years separated by shaded area which corresponds to spawning season. Upwelling indices from Bakun (1975) and Mason and Bakun (1986).

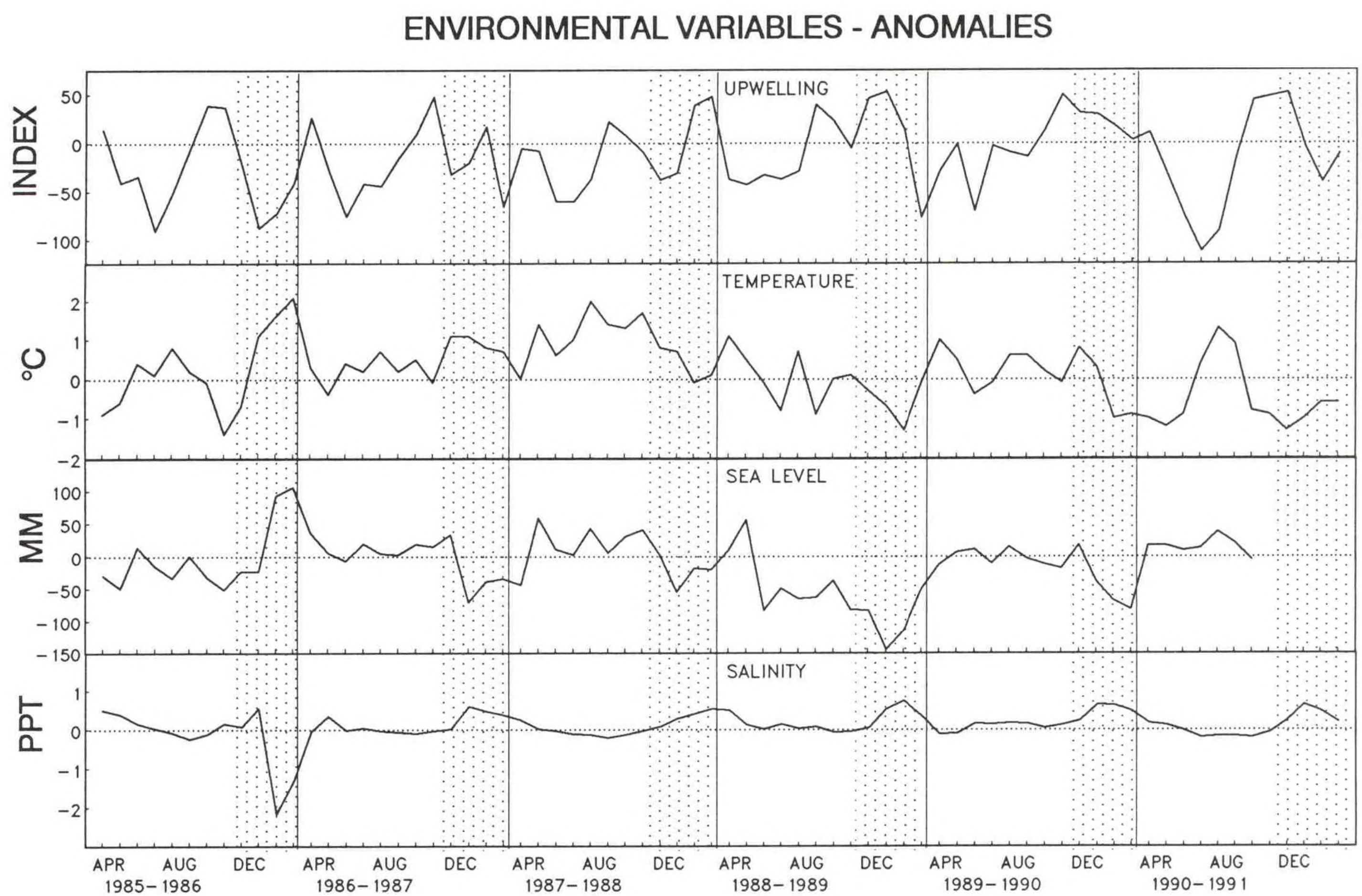


**Figure 23.** Anomalies of several environmental measurements for six years of study. Years separated by shaded area which corresponds to spawning season. Upwelling data are for 39° north latitude; temperature and salinity data are surface temperatures from the Farallon Islands. Sea level data are for the San Francisco area. (No daily in situ oceanographic measurements possible from Cordell Bank due to lack of instrumentation, buoys or stations. CTD data for times of collection being analyzed.)

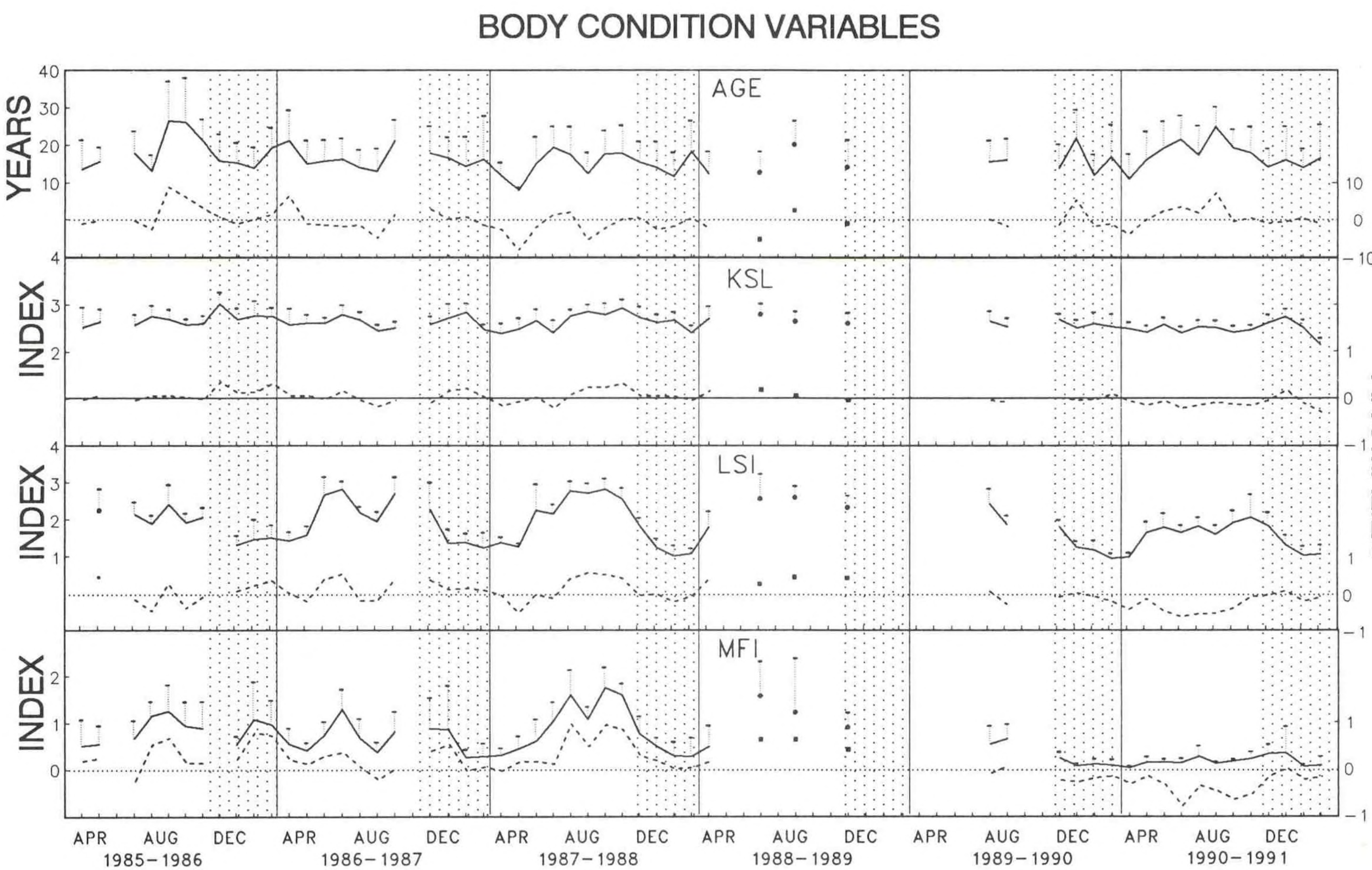


**Figure 24.** Means, standard deviations and anomalies of age and body condition variables of adult female yellowtail rockfish. Years separated by shaded area which corresponds to spawning season. KSL=Wet weight fish/(Standard length)$^3$, LSI=Liver somatic index=(Liver wet weight/fish wet weight) X 100, MFI=Mesenteric fat index=(Mesenteric fat wet weight/fish wet wt) X 100.

PARASITES AND DISEASES

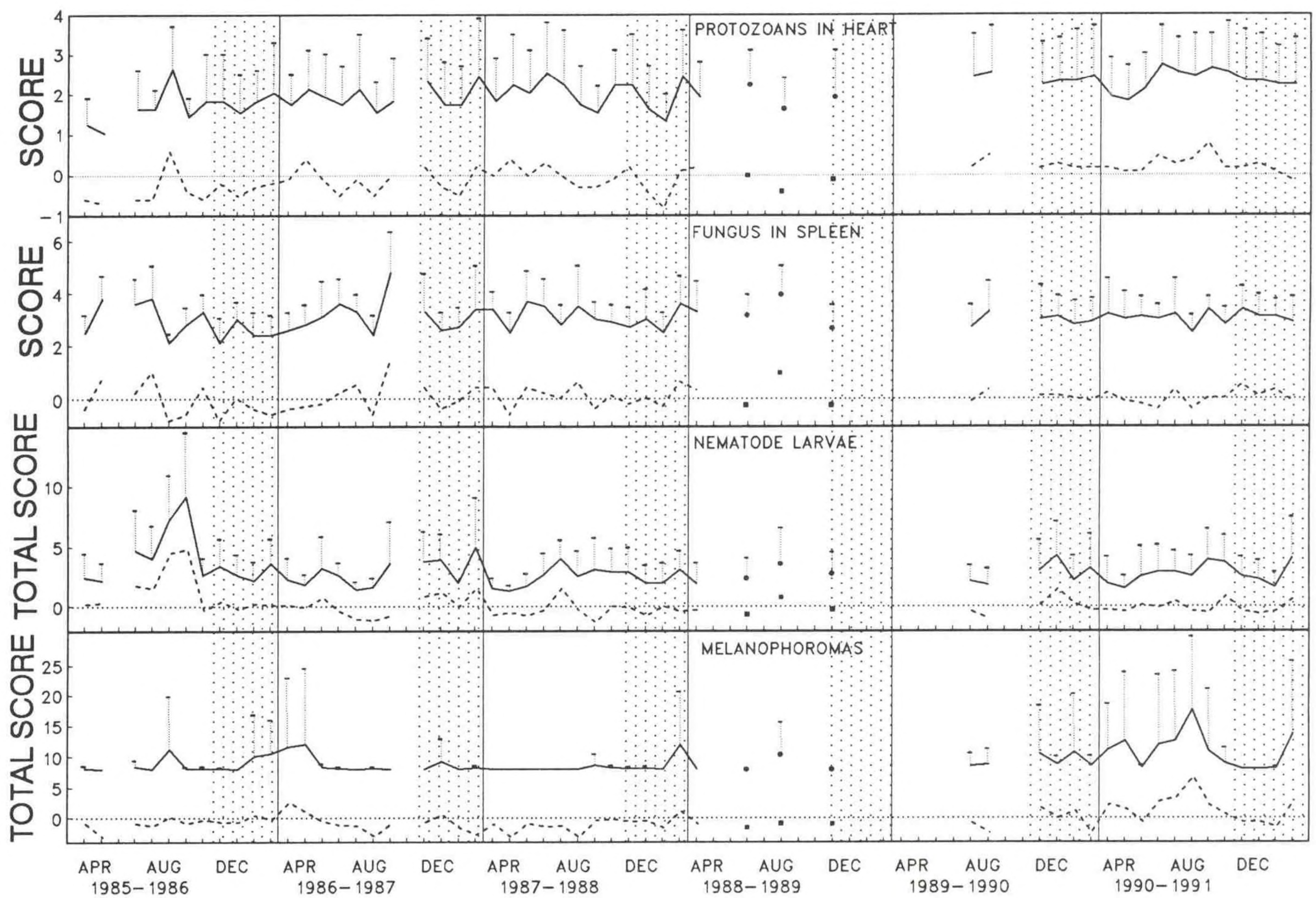


**Figure 25.** Means, standard deviations and anomalies of parasite and disease scores of adult female yellowtail rockfish. Years separated by shaded area which corresponds to spawning season. Scores per organ are 1 to 6. Score 1=0. Protozoans in heart=<u>Henneguya sebastoda</u>. Fungus in spleen=<u>Icthyophonus hoferi</u>. Nematode larvae=<u>Anasakis</u> sp. Total score all organs. Melanophoromas=Skin tumors with melanin pigment. Total score all quadrants.

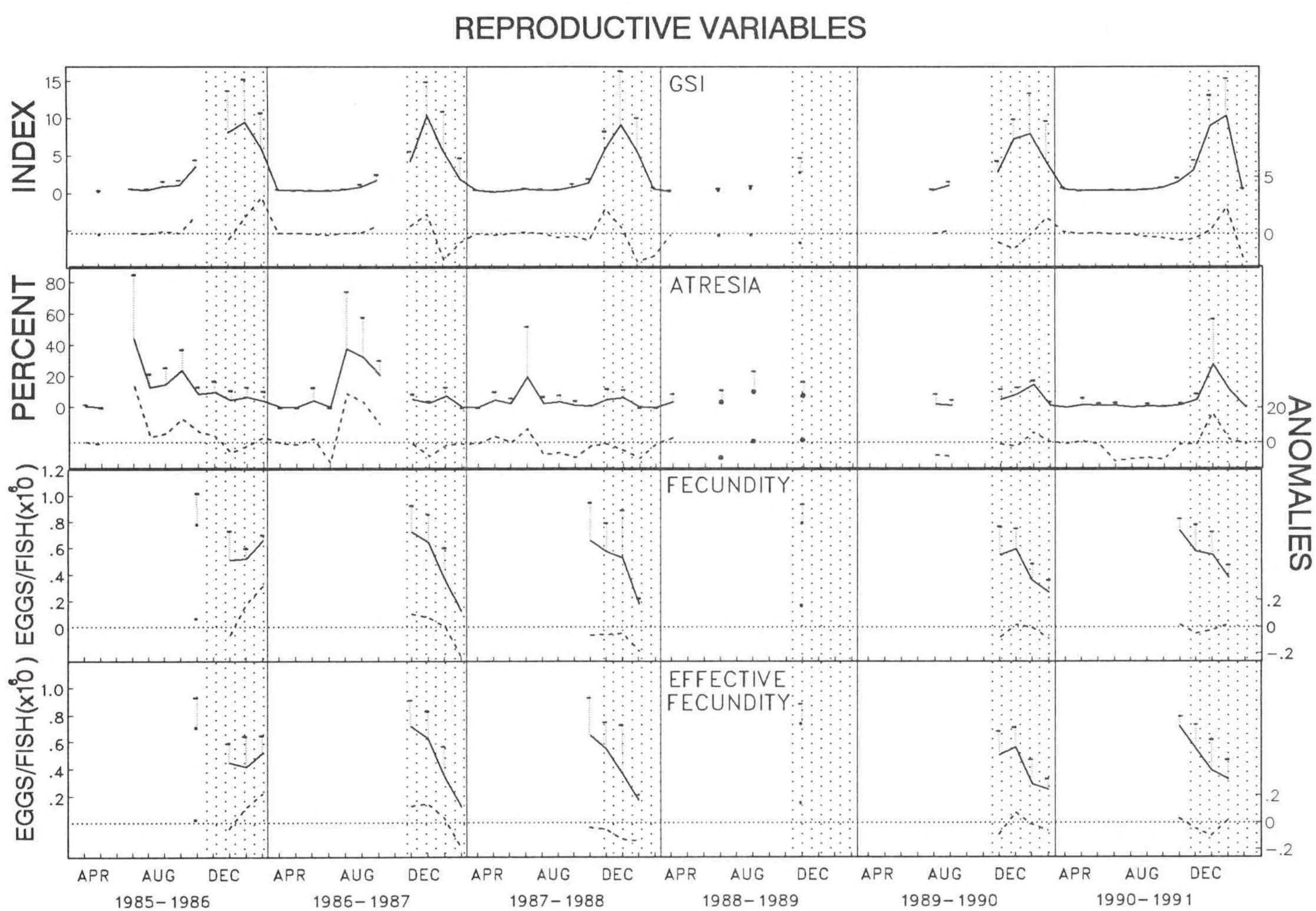


**Figure 26.** Means, standard deviations and anomalies of reproductive variables of adult female yellowtail rockfish. Years separated by shaded area which corresponds to spawning season. GSI=Gonad somatic index=(Ovary wet wt/fish wet wt) X 100. Atresia= Percentage of atretic eggs in ovary. Fecundity=Number of eggs/fish. Effective fecundity=Number of viable eggs/fish.

current month (March 1992) where fish appear to be in lower-than-normal condition. Assessment of reproductive parameters is currently being done for this spawning year. Condition of fish was significantly poorer in the last part of the spawning year 1989-1990 and in the beginning of 1990-1991. Previous analyses showed that for the month of August 1990, for example, condition of females (KSL, LSI, MFI) was significantly less than in previous years ($P<0.05$)(Whipple 1991).

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 1990).

Condition, particularly the amount of fat in liver and mesenteries, was poorer in 1989-1990, and this appeared to be reflected in lower GSI and effective fecundity in 1989-1990, particularly in older females (Whipple 1991). Effective fecundity is the total number of eggs per fish minus the number of atretic eggs and/or abnormal eggs and embryos.

A relationship of lowered body condition in females collected during summer months of 1990-1991 to reproduction did not occur. There was a recovery in body condition toward the end of the spawning year (December 1991). The age-specific fecundity measurements showed that fecundity was higher than all previous years, except for year 2 (1986-1987). In December, yellowtail rockfish fed heavily on an unexpected occurrence of euphausiids. It is interesting to note that the fish were able to recover in time to reproduce normally, at least in terms of ovary weights and fecundity. Serum and gonad proteins and lipids during and just prior to gestation also suggested high nutrient (energy) input into eggs and embryos. Apparently the lowered amount of reserve mesenteric fat did not affect size of ovaries or fecundity, as lipids went directly into eggs.

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. Tables 13 to 15 give the preliminary factor analysis results for selected variables in adult females for summer and winter seasons separately and together. Sampling in these years was comparable within these time periods, except for year 4 (1988-1989) which was eliminated from the analyses. Sets of variables contributing significantly to each factor are indicated with parentheses.

In the late summer (July, August, September) of later years, reduced upwelling was associated with lowered body condition variables (Table 13 - Factor 1: Yr-Upwelling). In older fish,

Table 13. Factor Analysis (Hintze 1990). Female yellowtail rockfish collected from Cordell Bank from spawning year 1 (1985-86) to spawning year 6 (1990-1991). Analysis on fish collected in late summer (July, August, September). Spawning year 4 (1988-1989) eliminated from analysis.

ROTATED FACTOR LOADINGS

| Variable | Factor 1 Yr-Upwell | Factor 2 Age | Factor 3 Mo-Upwell | Factor 4 Year | Communality |
|---|---|---|---|---|---|
| YEAR | (0.4755) | -.0728 | 0.1304 | (0.7135) | 0.7575 |
| MONTH | -.0382 | -.0979 | (0.9031) | 0.0454 | 0.8287 |
| UPWELLING | (.4839) | -.1418 | (-.6937) | -.1121 | 0.7481 |
| TEMPERATURE | 0.0840 | 0.0470 | (0.9276) | 0.1501 | 0.8921 |
| AGE | 0.0796 | (0.8587) | 0.1254 | 0.1039 | 0.7703 |
| KSL | (-.6870) | -.0592 | 0.0944 | 0.0091 | 0.4845 |
| LSI | (-.8383) | -.0243 | -.2315 | -.0234 | 0.7574 |
| MFI | (-.8243) | 0.1427 | -.0818 | -.1643 | 0.7335 |
| PROTOZOA | 0.1165 | (0.5120) | -.0566 | 0.2787 | 0.3566 |
| FUNGUS | -.0370 | (0.4197) | -.2595 | -.1508 | 0.2676 |
| NEMATODES | -.2437 | (0.7381) | 0.0071 | -.0915 | 0.6126 |
| TUMORS | 0.2185 | (0.3848) | 0.1821 | 0.3396 | 0.3442 |
| GSI | -.0389 | (0.5072) | (0.4362) | -.1827 | 0.4824 |
| ATRESIA | 0.1078 | -.0302 | -.0626 | (-.8423) | 0.7260 |

infections of the heart by protozoa, of the spleen by fungus, nematode larvae infections, and incidence of skin tumors (melanophoromas) were greater (Factor 2: Age). In a separate analysis not shown here, fecundity and effective fecundity also occurred within an age factor with variables similar to those mentioned above. During the latter part of summer (September), upwelling decreased, temperature increased and ovaries increased in size (Factor 3: Mo-Upwelling). During late summer, incidence of atresia in ovaries was greater in earlier years, while incidence of melanophoroma tumors was greater in later years (Factor 4: Year).

In the winter, during the spawning period (December, January, February and March) (Table 14) of year 6, there was more upwelling and lowered temperatures associated with lowered mean GSI, probably due to delayed spawning (Factor 1: Yr-Upwelling). Again, parasites and tumors were at higher levels in older fish (Factor 2: Age). In the later months of this period (e.g., March), GSI was lower, incidence of fungus lower, and incidence of tumors greater (Factor 3: Month). A separate analysis also showed lower fecundity in later spawning months as a result of younger fish spawning (fecundities uncorrected for age). In

Table 14. Factor Analysis (Hintze 1990). Female yellowtail rockfish collected from Cordell Bank from spawning year 1 (1985-86) to spawning year 6 (1990-1991). Analysis on fish collected in winter (December, January, February and March). Spawning year 4 (1988-1989) eliminated from analysis.

ROTATED FACTOR LOADINGS

| Variable | Factor 1 Yr-Upwell | Factor 2 Age | Factor 3 Month | Factor 4 Month | Factor 5 Condition | Communality |
|---|---|---|---|---|---|---|
| YEAR | (0.8283) | -.0085 | 0.1991 | -.2168 | 0.1534 | 0.7963 |
| MONTH | 0.0082 | 0.0364 | (-.7221) | (-.4976) | -.2195 | 0.8186 |
| UPWELLING | (0.7063) | 0.0948 | -.2999 | -.0920 | -.1475 | 0.6280 |
| TEMP | (-.8470) | -.0282 | 0.0409 | 0.2652 | 0.0159 | 0.7904 |
| AGE | -.0868 | (0.8591) | -.0688 | -.1950 | -.0541 | 0.7912 |
| KSL | -.2223 | -.1849 | 0.0908 | (0.5404) | (0.4721) | 0.6067 |
| LSI | -.1370 | -.0529 | 0.2610 | (0.8770) | 0.0259 | 0.8594 |
| MFI | (-.3594) | -.1317 | -.1610 | (0.7609) | -.0551 | 0.7545 |
| PROTOZOA | 0.3297 | (0.5280) | -.1564 | 0.2001 | 0.1387 | 0.4713 |
| FUNGUS | 0.1827 | (0.5256) | (0.3961) | -.1604 | -.2723 | 0.5664 |
| NEMATODES | -.0443 | (0.7874) | -.1382 | -.1029 | -.0222 | 0.6521 |
| TUMORS | 0.1055 | (0.3556) | (-.5841) | 0.0153 | -.0451 | 0.4810 |
| GSI | (-.4144) | 0.1425 | (0.3866) | 0.0170 | (0.5476) | 0.6417 |
| ATRESIA | 0.1640 | -.0623 | 0.0199 | 0.0133 | (0.8366) | 0.7313 |

earlier months of the spawning period, condition of fish was better (Factor 4: Month). Finally, body condition of fish and atresia appeared higher in females with higher GSI (Factor 5: Condition). The reason for these relationships remains unclear.

When the seasons were combined for analyses (Table 15), factors were similar except for Factor 4: Temperature. There was an apparent relationship in this factor of lower temperatures with increased fungus, fewer tumors and higher incidence of atresia. This factor needs further examination to make these relationships clearer. The comparison is probably reflective of seasonal differences since temperatures are generally lower earlier (summer) when significant upwelling is still taking place.

The years of highest fecundity in this study - year 2 (1986-1987) and year 6 (1990-1991)- appear to relate to higher juvenile abundance estimates of the Groundfish Analysis midwater trawl surveys (Table 3) with highest abundance indices occurring during those same years. Lower condition of adults may not affect reproduction in terms of numbers of eggs if abundant food is

Table 15. Factor Analysis (Hintze 1990). Female yellowtail rockfish collected from Cordell Bank from spawning year 1 (1985-86) to spawning year 6 (1990-1991). Analysis on fish collected in summer and winter combined (July to August; December to March). Spawning year 4 (1988-1989) eliminated from analysis.

ROTATED FACTOR LOADINGS

| Variable | Factor 1 Mo-Upwell | Factor 2 Age | Factor 3 Year | Factor 4 Temperature | Communality |
|---|---|---|---|---|---|
| YEAR | -.0795 | -.0522 | (-.7446) | -.1661 | 0.5911 |
| MONTH | (0.8479) | -.0061 | -.2518 | 0.0336 | 0.7836 |
| UPWELLING | (-.8902) | 0.0532 | 0.0745 | 0.2235 | 0.8508 |
| TEMPERATURE | 0.0105 | -.0115 | (0.4039) | (-.6924) | 0.6428 |
| AGE | -.0225 | (0.8581) | -.0107 | -.1515 | 0.7600 |
| KSL | 0.0282 | -.1601 | (0.6377) | -.0116 | 0.4333 |
| LSI | (-.5818) | -.0533 | (0.6562) | -.0046 | 0.7719 |
| MFI | -.2736 | -.0159 | (0.7808) | -.0321 | 0.6857 |
| PROTOZOA | -.0442 | (0.4925) | -.1735 | -.0379 | 0.2761 |
| FUNGUS | -.0550 | (0.4941) | -.0483 | (0.4214) | 0.4271 |
| NEMATODES | 0.0925 | (0.7967) | 0.1368 | 0.0193 | 0.6624 |
| TUMORS | -.0765 | (0.4088) | -.2120 | (-.5003) | 0.4682 |
| GSI | (0.7929) | -.0038 | 0.1538 | 0.0667 | 0.6568 |
| ATRESIA | -.0746 | -.0325 | 0.2361 | (0.5449) | 0.3593 |

available late in the year. However, abundance estimates of older juveniles by the Groundfish Communities' visual survey indicate that year 6 was not among the higher abundance estimates (Table 3). This may indicate that juveniles underwent increased mortality after the May-June trawl survey either because juveniles were in poorer condition or due to poorer environmental conditions. Additional work is being done in an attempt to evaluate the quality of eggs and juveniles. In addition, more analyses of environmental variables in relation to condition and reproduction of fish is in progress. (J. Whipple)

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