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PROGRESS IN ROCKFISH RECRUITMENT STUDIES

by

Staff of the Tiburon Laboratory

ADMINISTRATIVE REPORT T-89-01

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PROGRESS IN STUDIES OF RECRUITMENT IN ROCKFISHES

MARCH 1989

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Edited by
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INTRODUCTION

This is the fifth in a series of annual reports on studies at the Tiburon Laboratory on recruitment in Pacific coast rockfishes. It summarizes work accomplished during the period from March 1988 to February 1989 by the Laboratory's three Investigations: Groundfish Analysis, Groundfish Communities, and Groundfish Physiological Ecology. The first deals primarily with the pelagic stage of first-year juveniles sampled directly from the environment. The second samples the pelagic stage from the gut-contents of predators, and also assesses the post-pelagic stage with underwater visual counts. The third considers the reproductive potential of the adults.

Objectives, methods and previous results have been presented in earlier numbers of this series (Lenarz and Moreland 1985, Hobson et al. 1986, Larson 1987, and Whipple 1988).

STUDIES OF PELAGIC JUVENILES

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

Progress in Midwater Trawl Assessments

Estimates of 1988 Year-class Strength

The 1988 midwater-trawl sampling of pelagic age-0 juvenile rockfishes was organized much as in preceding years (see Wyllie Echeverria and Lenarz, in prep.), with temporally replicated "sweeps" of all stations in the study area (Fig. 1). One full sweep was completed in April 1988 during cruise DS-88-04. In addition, three more sweeps were completed in May-June as part of DS-88-06. At each station a 15 minute trawl sample was taken at standard depth (30 m where possible, 10 m at shallow stations) and a CTD cast was made. Supplementary CTD data were also gathered during the day along tracklines that crisscrossed the entire study area.

The information resulting from these two cruises was compiled, edited and added to the midwater trawl data base, which now represents 6 yr of sampling effort composed of 16 sample sweeps of the study area (Table 1). In addition, abundance indices were calculated for each Sebastes sp. encountered, and these are presented in Table 2. A complete description of how indices are calculated has been presented previously (Larson 1987; Whipple 1988).

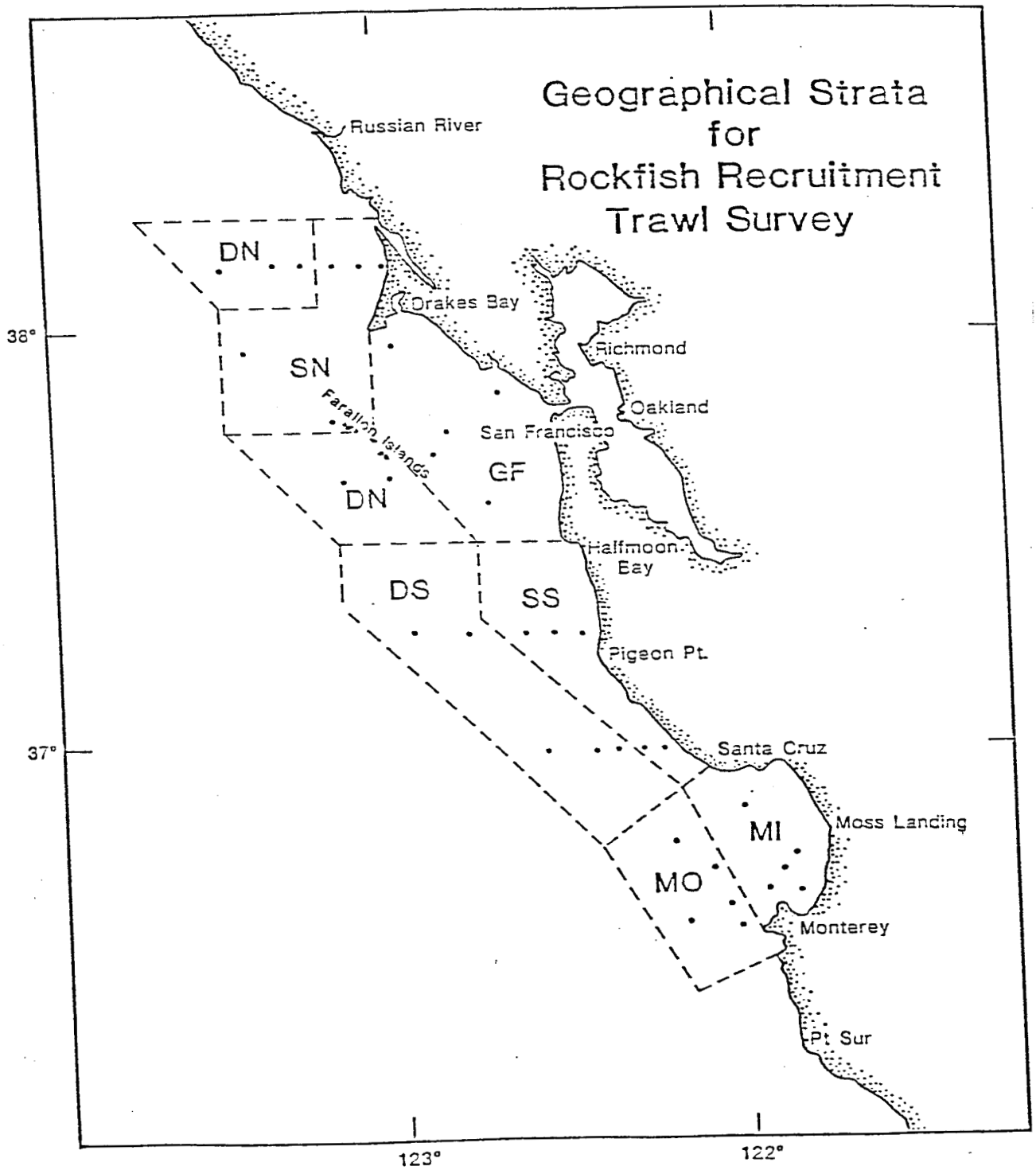

Fig. 1.--Locations of midwater trawl stations along the central California coast. Geographical groupings of stations refer to spatial strata.

Table 1.--Midwater trawl surveys for pelagic young-of-the-year rockfishes off central California coast (see Fig. 1).

Survey Code	Year	Sweep	Started		Ended	Number of Stations
J83	1983	1	June 8	--	June 24	18
J84	1984	1	June 12	--	June 27	25
A85	1985	**	April 10	--	April 16	18
J85	1985	1	May 31	--	June 30	37
A86	1986	**	April 13	--	April 22	22
J186	1986	1	June 3	--	June 11	33
J286	1986	2	June 11	--	June 18	28
J386	1986	3	June 20	--	June 25	28
A87	1987	1	April 10	--	April 20	34
J187	1987	1	May 23	--	June 1	33
J287	1987	2	June 2	--	June 12	34
J387	1987	3	June 12	--	June 21	33
A88	1988	1	April 16	--	April 22	28
J188	1988	1	May 22	--	May 31	33
J288	1988	2	June 2	--	June 9	33
J388	1988	3	June 11	--	June 18	31

** Trawls limited to the Gulf of the Farallons

Results show that 1988 was characterized by relatively high levels of juveniles in our trawl samples (Table 2, Fig. 2). Overall, maximum levels of abundance of the five predominant rockfish species (S. jordani, S. goodei, S. paucispinis, S. entomelas, and S. mystinus) were similar to results from 1987, although the seasonal occurrence of juveniles was shifted somewhat earlier in the year. For example, in 1988 the greatest numbers of S. goodei (chilipepper) were encountered during our April samples, whereas in 1987 they were most abundant in the first sweep of the June cruise. Likewise, this year shortbelly rockfish juveniles (S. jordani) were as abundant in the April cruise as they were in June. In contrast, in 1987 this species was much more abundant during the June cruise. A similar effect is evident in the data for bocaccio (S. paucispinis), although widow and blue rockfishes (S. entomelas and S. mystinus) showed little change from their 1987 seasonality.

Table 2.--Estimates of stratified mean abundance of juvenile rockfishes captured in midwater trawls. Means are based on trawls at specific stations (Larson 1987; Whipple 1988) conducted at standard 30 m depth (10 m at shallow stations). Actual counts were transformed to ln(x+1). Survey designations refer to codes given in Table 1. Below each stratified mean is the corresponding standard error.

	Survey															
Species	J83	J84	A85	J85	A86	J186	J286	J386	A87	J187	J287	J387	A88	J188	J288	J388
S. auriculatus	0.000	0.348	1.981	0.000	0.000	1.091	0.912	0.256	0.277	0.045	0.091	0.059	0.349	0.000	0.000	0.000
	0.000	0.091	0.382	0.000	0.000	0.177	0.182	0.103	0.078	0.032	0.046	0.031	0.102	0.000	0.000	0.000
S. crameri	0.000	0.071	0.000	0.030	0.000	0.000	0.000	0.000	0.102	0.076	0.000	0.020	0.091	0.069	0.000	0.000
	0.000	0.052	0.000	0.030	0.000	0.000	0.000	0.000	0.059	0.045	0.000	0.020	0.025	0.053	0.000	0.000
S. entomelas	0.067	0.683	0.000	1.955	0.000	0.137	0.040	0.000	0.180	1.046	1.393	0.168	0.304	0.759	1.000	0.137
	0.067	0.251	0.000	0.200	0.000	0.064	0.028	0.000	0.081	0.178	0.167	0.073	0.082	0.154	0.114	0.053
S. flavidus	0.099	0.691	0.000	1.075	0.000	0.122	0.201	0.078	0.000	0.188	0.504	0.272	0.020	0.581	0.292	0.000
	0.082	0.241	0.000	0.160	0.000	0.053	0.063	0.048	0.000	0.078	0.112	0.096	0.020	0.132	0.083	0.000
S. goodei	0.000	0.637	1.857	0.364	0.167	0.345	0.268	0.092	1.193	1.327	0.694	0.357	2.833	1.180	0.296	0.198
	0.000	0.182	0.407	0.089	0.077	0.088	0.091	0.054	0.234	0.156	0.183	0.113	0.388	0.283	0.196	0.175
S. hopkinsi	0.000	0.350	0.000	0.663	0.042	0.051	0.020	0.000	0.099	0.902	0.505	0.020	0.686	0.704	0.364	0.020
	0.000	0.123	0.000	0.138	0.042	0.037	0.020	0.000	0.050	0.128	0.132	0.020	0.172	0.193	0.089	0.020
S. jordani	0.180	1.967	1.175	2.096	0.171	1.934	1.938	0.574	0.948	2.342	3.235	1.325	2.696	2.744	2.119	1.657
	0.084	0.488	0.333	0.269	0.269	0.295	0.247	0.202	0.217	0.256	0.320	0.286	0.418	0.416	0.289	0.317
S. levis	0.000	0.000	0.000	0.045	0.000	0.020	0.000	0.000	0.045	0.127	0.000	0.110	0.272	0.017	0.000	0.000
	0.000	0.000	0.000	0.032	0.000	0.020	0.000	0.000	0.032	0.052	0.000	0.055	0.075	0.017	0.000	0.000
S. melanops	0.000	0.000	0.000	0.161	0.000	0.020	0.000	0.000	0.000	0.091	0.185	0.064	0.000	0.064	0.155	0.000
	0.000	0.000	0.000	0.053	0.000	0.020	0.000	0.000	0.000	0.041	0.068	0.037	0.000	0.035	0.290	0.000
S. mystinus	0.000	0.000	0.102	1.043	0.276	0.071	0.000	0.000	0.105	0.958	0.720	0.000	0.722	1.151	1.009	0.045
	0.000	0.000	0.070	0.137	0.119	0.040	0.000	0.000	0.053	0.148	0.149	0.000	0.132	0.181	0.098	0.032
S. paucispinis	0.000	0.846	0.281	0.180	0.000	0.566	0.482	0.098	0.207	0.407	0.455	0.319	0.498	0.504	0.157	0.040
	0.000	0.241	0.112	0.053	0.000	0.154	0.100	0.058	0.086	0.109	0.110	0.118	0.069	0.095	0.070	0.040
S. pinniger	0.000	0.759	0.476	0.267	0.042	0.410	0.157	0.039	0.241	0.213	0.449	0.249	0.345	0.986	0.386	0.078
	0.000	0.258	0.173	0.081	0.042	0.084	0.063	0.039	0.105	0.065	0.089	0.092	0.125	0.157	0.104	0.046
S. rufus	0.000	0.000	0.000	0.172	0.000	0.000	0.000	0.000	0.000	0.145	0.122	0.020	0.239	0.000	0.063	0.000
	0.000	0.000	0.000	0.060	0.000	0.000	0.000	0.000	0.000	0.053	0.053	0.020	0.108	0.000	0.038	0.000
S. saxicola	0.000	0.236	0.323	0.077	0.202	0.040	0.000	0.000	0.534	0.821	0.182	0.031	1.182	0.430	0.119	0.000
	0.000	0.083	0.141	0.047	0.099	0.028	0.000	0.000	0.100	0.146	0.059	0.031	0.163	0.093	0.042	0.000
S. wilsoni	0.000	0.050	0.179	0.000	0.000	0.040	0.000	0.000	0.215	0.020	0.124	0.031	0.865	0.127	0.025	0.020
	0.000	0.050	0.099	0.000	0.000	0.028	0.000	0.000	0.073	0.020	0.061	0.031	0.192	0.050	0.025	0.020

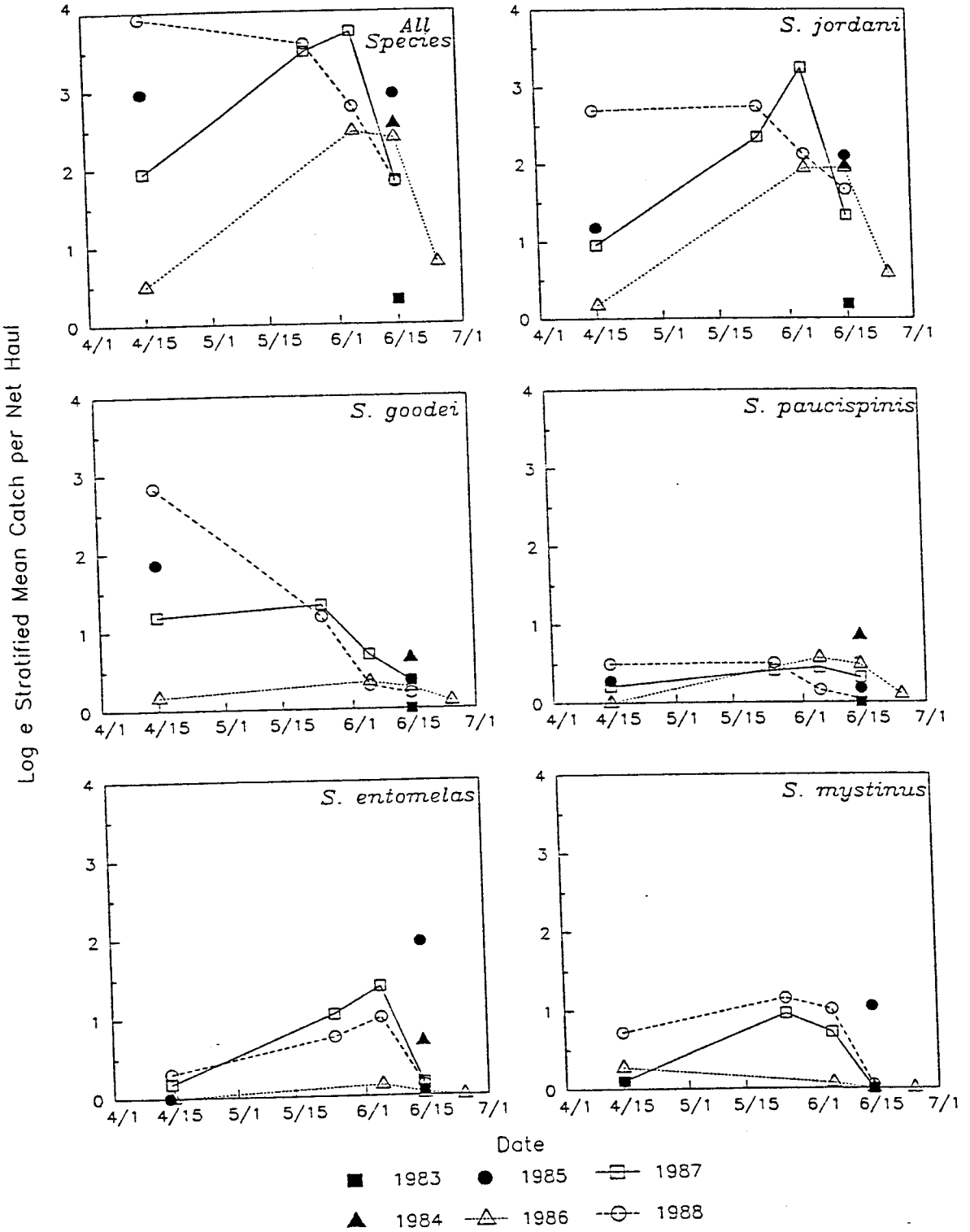

Fig. 2.--Seasonal (April-June) patterns of abundance of selected juvenile rockfishes in midwater trawl samples (1983-88).

That 1988 was a good year for the production of juvenile rockfishes is illustrated by the fact that the annual indices of species abundance (maximum across sweeps within a year of the log stratified mean catch per haul) were above their respective long-term means ($\bar{x}$) in 12 of 15 cases (Fig. 3). Plotted is the frequency distribution of 1988 standard scores for all 15 species, where a species' standard score (z) is calculated from its long-term mean and standard deviation (s) according to $z = (x-\bar{x})/s$. The three exceptions were S. auriculatus, S. levis, and S. rufus. Conversely, species that were unusually abundant in 1988 (i.e., standard scores > 1.0) were: S. goodei, S. mystinus, S. pinniger, and S. wilsoni.

Principal Component Analysis

The multivariate technique of principal component analysis (Green 1978) was utilized to resolve patterns of covariation among rockfish species spanning the 6 available years of survey data. For this purpose, annual indices of abundance (see above) were tabulated for each species in each year from 1983-88. Principal component analysis on the correlation mutrix was first conducted treating species as variables and years as cases. The converse situation (years as variables and species as cases) was also examined. In both analyses the species pool was restricted to the 10 rockfishes that are well sampled in our surveys (S. auriculatus, S. entomelas, S. flavidus, S. goodei, S. hopkinsi, S. jordani, S. mystinus, S. paucispinis, S. pinniger, and S. saxicola), although expanding the analysis to include all 15 of the species listed in Table 2 did not alter the conclusions.

Results from the former analysis (Tables 3-5, Fig. 4) show that there is broad positive covariation among the species of interest. The only species that consistently showed a negative correlation with other species in annual abundance (Table 3) was the brown rockfish (S. auriculatus). Note that in this analysis the first 3 principal components all had eigenvalues greater than 1.0, and together these explained 91% of the variation in the data (Table 4). Moreover, with the exception of S. auriculatus, the various species coefficients on the first principal component (Table 5) are all positive. This indicates that the dominant influence affecting the annual abundance of this assemblage of rockfishes, which alone accounts for over 56% of the total variation in the data (Table 4), affects the assemblage uniformly. Thus, a good year for one species is apt to be a good year for virtually any other.

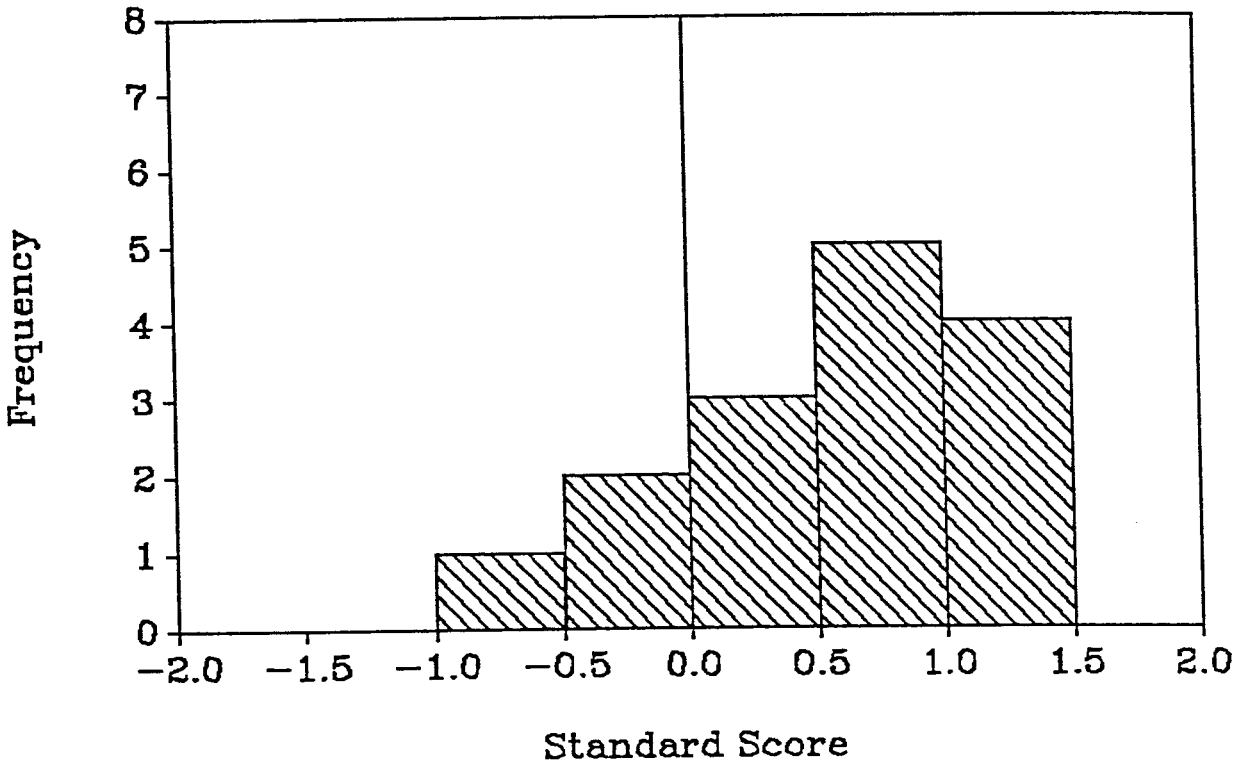

Fig. 3.--Frequency distribution of 1988 standard scores of 15 rockfish species based on their 1983-88 means and standard deviations.

Table 3.--Matrix of product moment correlation coefficients relating annual indices of abundance for the 10most common *Sebastes* spp. captured in midwater trawls: AUR = *S. auriculatus*; ENT = *S. entomelas*; FLA = *S. flavidus*; GOO = *S. goodei*; HOP = *S. hopkinsi*; JOR = *S. jordani*; MYS = *S. mystinus*; PAU = *S. paucispinis*; PIN = *S. pinniger*; SAX = *S. saxicola*.

	AUR	ENT	FLA	GOO	HOP	JOR	MYS	PAU	PIN	SAX
AUR	1.000	-0.519	-0.392	-0.236	-0.527	-0.003	-0.538	0.470	0.026	-0.307
ENT	-0.519	1.000	0.884	0.454	0.864	0.619	0.829	-0.073	0.158	0.426
FLA	-0.392	0.884	1.000	0.254	0.653	0.469	0.596	0.141	0.300	0.135
GOO	-0.236	0.454	0.254	1.000	0.830	0.895	0.658	0.466	0.703	0.934
HOP	-0.527	0.864	0.653	0.830	1.000	0.839	0.891	0.134	0.438	0.799
JOR	-0.003	0.619	0.469	0.895	0.839	1.000	0.696	0.531	0.650	0.789
MYS	-0.538	0.829	0.596	0.658	0.891	0.696	1.000	-0.149	0.332	0.565
PAU	0.470	-0.073	0.141	0.466	0.134	0.531	-0.149	1.000	0.769	0.308
PIN	0.026	0.158	0.300	0.703	0.438	0.650	0.332	0.769	1.000	0.437
SAX	-0.307	0.426	0.135	0.934	0.799	0.789	0.565	0.308	0.437	1.000

Table 4.--Eigenvalues and variance reduction for the first 5 principal components when species are variables and years are cases.

Principal Component	Eigenvalue	Proportion of Variance	Cumulative Proportion
1	5.64996	0.564996	0.56500
2	2.37790	0.237790	0.80279
3	1.08504	0.108504	0.91129
4	0.57269	0.057269	0.96856
5	0.31442	0.031442	1.00000

Table 5.--Eigenvector coefficients for the first 5 principal components when species are variables and years are cases. Species abbreviations as in Table 3.

	Principal Component Eigenvectors				
Species	1	2	3	4	5
AUR	-0.1759	0.4523	0.2320	0.6813	0.2119
ENT	0.3372	-0.3100	0.2917	0.2216	-0.1643
FLA	0.2722	-0.2198	0.6421	-0.0832	-0.2162
GOO	0.3744	0.2116	-0.3032	-0.0445	0.0255
HOP	0.4116	-0.1161	-0.0625	0.0737	-0.0996
JOR	0.3810	0.2088	0.0215	0.3574	0.0867
MYS	0.3596	-0.2397	-0.0494	0.1237	0.6207
PAU	0.1313	0.5649	0.2925	-0.1448	-0.3508
PIN	0.2560	0.3941	0.1656	-0.5467	0.4331
SAX	0.3378	0.1302	-0.4865	0.0962	-0.4087

Underlying this primary influence, however, is a secondary pattern which resolves itself on the second principal component (Tables 4 and 5). The large eigenvalue (2.378) associated with this affect suggests its importance. Based upon the signs of the coefficients from the second component, there is evidence that there are two groups that are inversely related to one another. In particular, after accounting for the primary positive association of all species, the data indicate that S. entomelas, S. flavidus, S. hopkinsi, and S. mystinus are negatively correlated with the remaining six species. The cause of this secondary pattern may relate to large scale oceanographic processes such as those described by Norton (1987) or to differences in depth distribution (see below) or both.

The reduction in dimensionality that characterizes principal component analysis allows a visualization of each year of survey data plotted against the first 2 principal components (Fig. 4). The figure shows that in general terms 1987 and 1988 were both good years for all species (high loadings on the first component) whereas 1983, an El Niño year, was poor for most species. The remaining three years (1984-86) were intermediate, being relatively good for the S. entomelas-S. flavidus-S. hopkinsi-S. mystinus group in 1985 and poor for this group in 1984 and 1986. Thus there is some evidence that over the period 1983-88 there has been a general increase in the abundance of juvenile rockfishes in our study area.

When the 6 sampling years are treated as variables and the 10 species as cases (Tables 6-8, Fig. 5) we see that there is broad positive correlation among years. This implies that the rank order of species abundance from year to year shows strong coherence. This is exemplified by the fact that uncommon species (e.g., S. auriculatus and S. saxicola) tend not to dominate the catch in any particular year, whereas species such as S. jordani and S. entomelas are consistently important year in and year out.

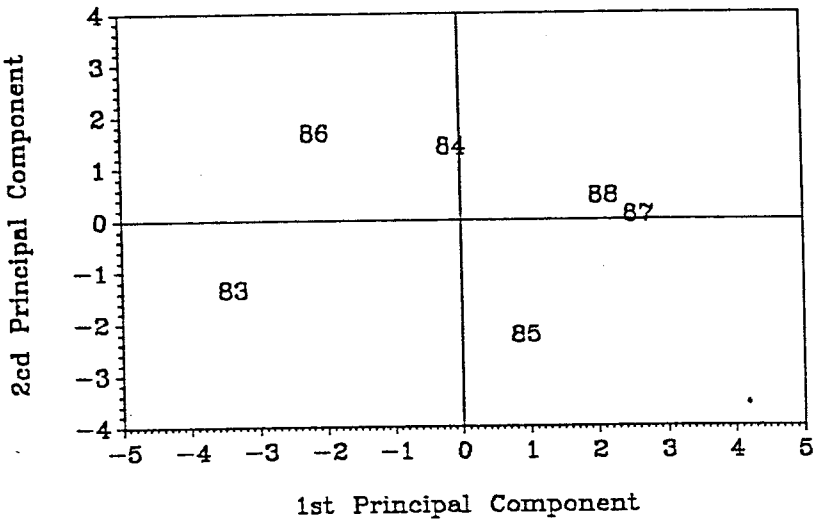

Fig. 4.--Yearly summaries of juvenile rockfish abundance plotted on the first two principal components (species = variables, years = cases).

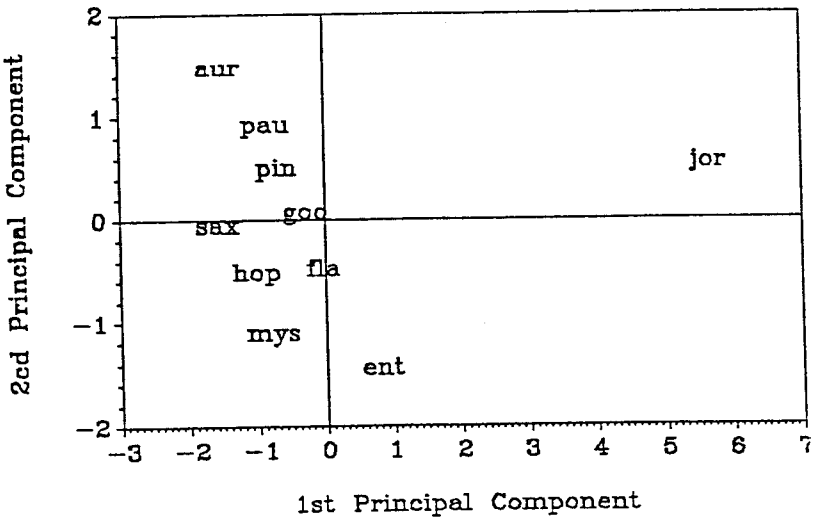

Fig. 5.--Species summaries of annual abundance plotted on the first two principal components (years = variables, species = cases). Abbreviations as in Table 3.

Table 6.--Matrix of product moment correlation coefficients relating annual indices of abundance of the 10 most common Sebastes spp. captured in midwater trawls (years as variables, species as cases).

	1983	1984	1985	1986	1987	1988
1983	1.0000	0.8138	0.8196	0.6236	0.7620	0.7225
1984	0.8138	1.0000	0.5508	0.7947	0.7500	0.7659
1985	0.8196	0.5508	1.0000	0.3036	0.7599	0.7261
1986	0.6236	0.7947	0.3036	1.0000	0.5847	0.5764
1987	0.7620	0.7500	0.7599	0.5847	1.0000	0.9407
1988	0.7225	0.7659	0.7261	0.5764	0.9407	1.0000

Table 7.--Eigenvalues and variance reduction for all 6 principal components when years are variables and species are cases.

Principal Component	Eigenvalue	Proportion of Variance	Cumulative Proportion
1	4.526	0.7544	0.754
2	0.813	0.1356	0.890
3	0.383	0.0638	0.953
4	0.159	0.0265	0.980
5	0.069	0.0115	0.992
6	0.048	0.0080	1.000

Table 8.--Eigenvector coefficients for all principal components when years are variables and species are cases.

	Principal Component Eigenvectors					
Year	1	2	3	4	5	6
1983	0.4288	-0.0882	0.5863	-0.0950	-0.5435	-0.3999
1984	0.4221	0.3461	0.1126	-0.7093	0.2827	0.3257
1985	0.3779	-0.5846	0.3220	0.3040	0.5129	0.2369
1986	0.3461	0.6971	0.0715	0.6072	0.1416	-0.0148
1987	0.4360	-0.1636	-0.4638	0.1308	-0.5328	0.5166
1988	0.4302	-0.1332	-0.5652	-0.0973	0.2397	-0.6408

There is less complexity to the correlative relationships among the annual data than there is among the species data. This is indicated by the single dominant eigenvalue (4.526) that alone accounts for 75% of the total variation in yearly abundance statistics (Table 7). Eigenvalues associated with the remaining 5 principal components are all less than unity, indicating little explanatory power (Green 1978).

When the information pertaining to the 6 yearly variables is collapsed onto the first two principal components the relationships among the 10 species become clearer (Fig. 5). Position along the first principal component clearly relates to rank abundance year in and year out. Thus S. jordani and S. entomelas are consistently dominants in the catch whereas S. auriculatus and S. saxicola are typically rare. More interesting is the separation that occurs along the second principal component. Here the inverse pattern of species covariation described earlier is evident, with the S. entomelas-S. flavidus-S. hopkinsi-S. mystinus group segregating out along the negative portion of this axis.

Depth Distributions

Results presented in Whipple (1988) provided a preliminary analysis of how the species of rockfishes encountered in our mid-water trawl surveys differ with respect to depth distributions. While trawls are typically conducted at a standard depth of 30 m, additional trawls are completed on a time available basis at shallower (10 m) and deeper (100 m) depths. Thus there are a number of stations in which it is possible to directly compare catches made at the standard depth with synoptic tows made at shallower and deeper depths. Results presented here are an extension and update of previous work (Whipple 1988).

An efficient way to compare the difference in means of paired replicates is the Wilcoxon signed rank test (Wilcoxon and Wilcox 1964). Pairing is appropriate based upon the common geographic and temporal characteristics of our dual depth samples. Likewise, a nonparametric test is desirable due to the substantial number of tows in which few fish were caught. Still, all comparisons of abundance with depth are based upon samples in which at least one of the tows captured the species of interest.

Results show (Table 9) that there are distinct patterns of abundance relating to depth of capture among the 10 species analyzed. For example, among paired samples widow rockfish (S. entomelas) was found to be more abundant in 100 m tows than in 30 m tows, although no difference was detected among paired 10 and 30 m tows. These results indicate that the center of juvenile widow rockfish abundance may be somewhat deeper than the standard

widow rockfish abundance may be somewhat deeper than the standard depth at which trawls are made. Likewise, bocaccio (S. paucispinis) produced higher catches in 30 m than it did in 100 m, and there was some indication (P = 0.13) that catches in 10 m exceeded those in 30 m.

Table 9.--Comparisons of standardized catches of 10 different Sebastes spp. by depth of trawl for synoptic stations using the Wilcoxon sign rank test. Positive sign rank statistic indicates higher numbers at first depth; negative statistic results when greater numbers are caught at the second depth. N is number of synoptic stations compared (+ occurrence at either or both depths); N≠0 gives number of non-ties.

Species (common name)	Comparison	Sign Rank	P	N	N≠0
Sebastes auriculatus	10 m - 30 m	-2.5	0.7187	7	(6)
(brown rockfish)	30 m - 100 m	14.0	0.0625	9	(8)
S. entomelas	10 m - 30 m	-29.0	0.6550	37	(36)
(widow rockfish)	30 m - 100 m	-127.0	0.0067	32	(30)
S. flavidus	10 m - 30 m	-5.0	0.8754	22	(22)
(yellowtail rockfish)	30 m - 100 m	-67.0	0.0079	20	(20)
S. goodei	10 m - 30 m	-54.5	0.2206	30	(28)
(chilipepper)	30 m - 100 m	33.5	0.3493	26	(24)
S. hopkinsi	10 m - 30 m	-42.5	0.3162	31	(27)
(squarespot rockfish)	30 m - 100 m	7.5	0.8253	26	(23)
S. jordani	10 m - 30 m	-117.5	0.3424	58	(56)
(shortbelly rockfish)	30 m - 100 m	155.0	0.0602	44	(43)
S. mystinus	10 m - 30 m	2.0	0.9646	30	(28)
(blue rockfish)	30 m - 100 m	-96.5	0.0112	29	(26)
S. paucispinis	10 m - 30 m	85.5	0.1284	40	(33)
(bocaccio)	30 m - 100 m	98.0	0.0314	31	(29)
S. pinniger	10 m - 30 m	-78.5	0.0001	22	(18)
(canary rockfish)	30 m - 100 m	-30.5	0.2580	22	(20)
S. saxicola	10 m - 30 m	-81.0	0.0014	20	(20)
(stripetail rockfish)	30 m - 100 m	20.0	0.3532	17	(17)

Using this approach it is possible to infer the depths corresponding to centers of abundance for the 10 species listed. The results (Table 10) indicate that chilipepper and squarespot rockfish are found equally throughout the sampled water column. Canary and stripetail rockfish are preferentially found in the 30-100 m range, whereas shortbelly and brown rockfish typically are most abundant in the 10-30 m zone. Three species (i.e., widow, yellowtail, and blue rockfishes) are most abundant only in the deepest tows (100 m). It is of interest to note that all three of these "deep" species showed a similar pattern of annual covariation from 1983-88 (see section on principal component analysis).

Table 10.--Depth related distributional patterns for 10 species of juvenile rockfishes sampled with the midwater trawl. A question mark indicates borderline probability levels from the sign rank test.

```
SHALLOW          MID-DEPTH          DEEP
 (10 m)            (30 m)          (100 m)
<--- Bocaccio ------> ?
<------ Shortbelly ---------------> ?
<--------- Brown -----------------> ?
  <--------------- Chilipepper ---------------->
  <--------------- Squarespot ---------------->
                <----------- Canary ----------->

                <--------- Stripetail --------->
                                <----- Widow ----->
                                <--- Yellowtail -->
                                <------ Blue ----->
```

One might conclude that, at least for those species found primarily in deep water, these results are damaging to standardized estimates of abundance derived from tows made only at 30 m. The results presented in Table 11 show, however, that all species (except S. auriculatus) show a highly significant correlation between the catch at both the 10 or 100 m depths and the catch at the standard depth of 30 m. This correspondence provides the basis for using abundance statistics obtained at 30 m as an index of abundance at some other more preferred depth. The greater the correlation coefficient (r), the better the statistical basis of this approach. With the exception of S. entomelas, S. flavidus, and S. mystinus, all species are relatively abundant at 30 m (Table 10). The correlation coefficients for these species, therefore, assume the greatest importance (0.332, 0.493, and 0.474, respectively). Because these are not particularly high, more attention needs to be devoted to this problem in the future.

Table 11.--Product moment correlation coefficients (r) relating abundance of 10 common rockfish species at standard depth (30 m) to abundance at 10 and 100 m. P = significance probability; N = the number of synoptic stations compared (includes negative occurrences at both depths).

Species (common name)	Correlation	r	P	N
Sebastes auriculatus	10 m - 30 m	0.018	0.9113	42
(brown rockfish)	100 m - 30 m	0.836	0.0001	35
S. entomelas	10 m - 30 m	0.452	0.0001	74
(widow rockfish)	100 m - 30 m	0.332	0.0079	63
S. flavidus	10 m - 30 m	0.316	0.0097	66
(yellowtail rockfish)	100 m - 30 m	0.493	0.0001	57
S. goodei	10 m - 30 m	0.880	0.0001	64
(chilipepper)	100 m - 30 m	0.699	0.0001	53
S. hopkinsi	10 m - 30 m	0.601	0.0001	74
(squarespot rockfish)	100 m - 30 m	0.663	0.0001	63
S. jordani	10 m - 30 m	0.770	0.0001	74
(shortbelly rockfish)	100 m - 30 m	0.748	0.0001	63
S. mystinus	10 m - 30 m	0.604	0.0001	73
(blue rockfish)	100 m - 30 m	0.474	0.0002	59
S. paucispinis	10 m - 30 m	0.467	0.0001	64
(bocaccio)	100 m - 30 m	0.673	0.0001	53
S. pinniger	10 m - 30 m	0.677	0.0001	64
(canary rockfish)	100 m - 30 m	0.799	0.0001	53
S. saxicola	10 m - 30 m	0.578	0.0001	64
(stripetail rockfish)	100 m - 30 m	0.700	0.0001	53

Age and Growth

An important component of the rockfish recruitment studies has been age and growth work utilizing daily growth increments in the otoliths. This research is now beginning to bear fruit as illustrated by results obtained for shortbelly rockfish (S. jordani), the most abundant species in our samples. Similar analyses for widow rockfish (S. entomelas), yellowtail rockfish (S. flavidus), and bocaccio (S. paucispinis) will soon be complete.

Examination of progressive daily age distributions of shortbelly rockfish from each sweep in 1988 (Fig. 6) provides a basis for tentative validation of our aging procedures. For example, the mean age of fish sampled in April was 96.0 d. By the first sweep in June mean age had increased to 133.8 d, a difference of 37.8 d. The actual amount of time elapsed between these sample periods was 38 d, providing strong evidence that (1) the two surveys sampled the same statistical population, and (2) the increments were daily in periodicity.

The data presented in Fig. 7 show the relationship between the standard length and age of shortbelly rockfish in each of the 6 years. The relationship is linear over the range of ages sampled, but analysis of covariance (Snedecor and Cochran 1967) shows there to be differences in slopes (1987 > {1983 = 1984 = 1985 = 1986 = 1988}) and elevations ({1985 = 1988} < {1983 = 1986} < 1984) of the regressions presented in Fig. 8. It is possible that differences in abundance from one year to the next (Table 2) may be caused by alterations in growth dynamics. Conversely, growth may be influenced by abundance. Obviously, these data will provide a critical link in our attempts to understand the factors that are most important to the survival of young-of-the-year rockfishes.

An additional application of these data is the back-calculation of birthdate distributions (Methot 1983) of the fish that survived up until the time of sampling (Fig. 9). There are clear year-to-year differences in these distributions (e.g., June 1985 versus June 1986), but little change occurs when different samples obtained within the same year are used to back-calculate (e.g., April versus June in 1987 and 1988). Also interesting to note is the minor influx of small fish that occurred in June 1987, apparently due to protracted parturition of S. jordani that year. While it is our goal to relate interannual shifts in birthdate distributions to oceanographic conditions, it is premature to speculate about whether or not the cause of these differences relates primarily to interannual variation in the temporal expression of mortality factors, or to differences in the seasonal occurrence of parturition. More work is needed to resolve this issue.

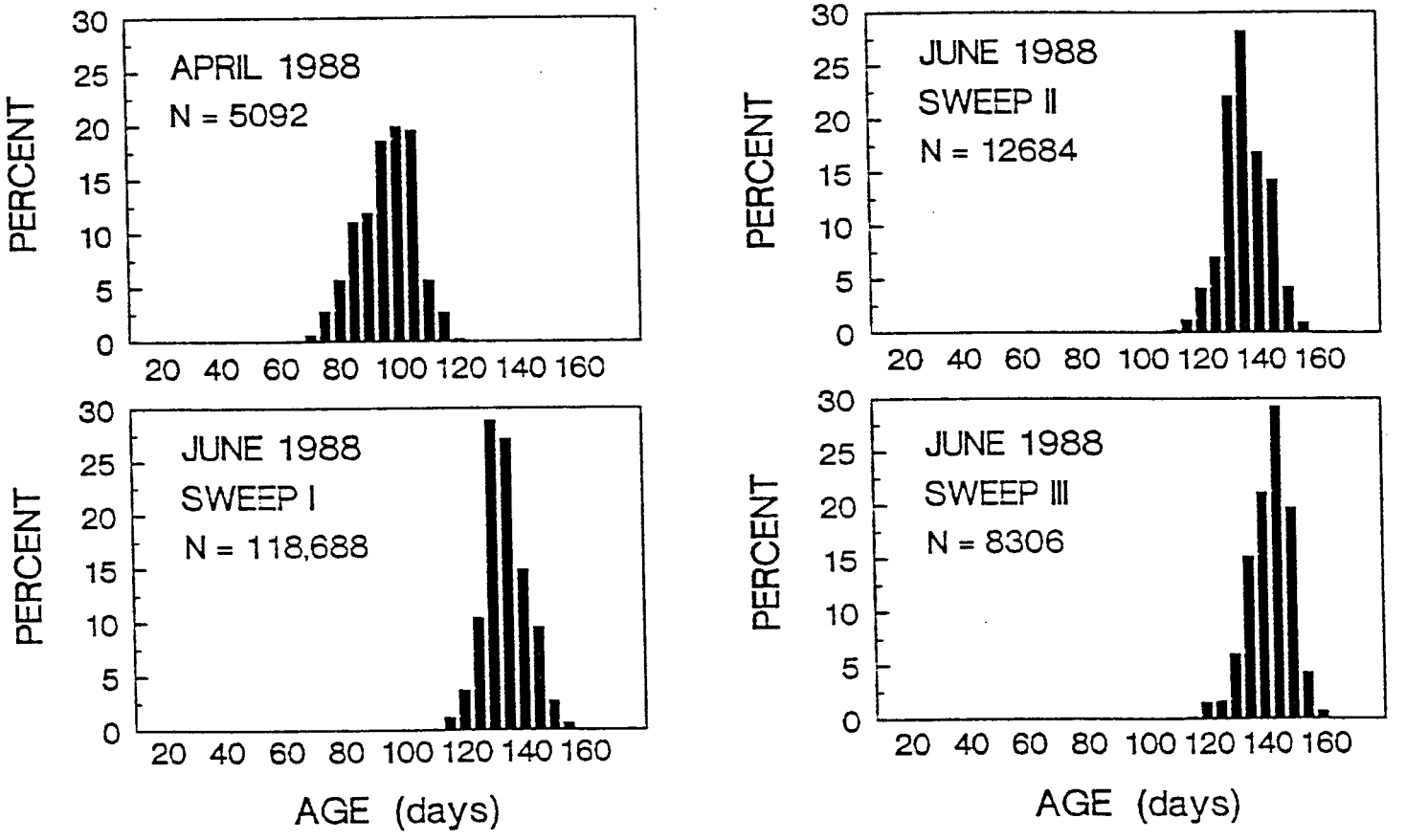

Fig. 6.--Daily age-frequency distributions of shortbelly rockfish juveniles sampled by midwater trawl during 1988 (April-June).

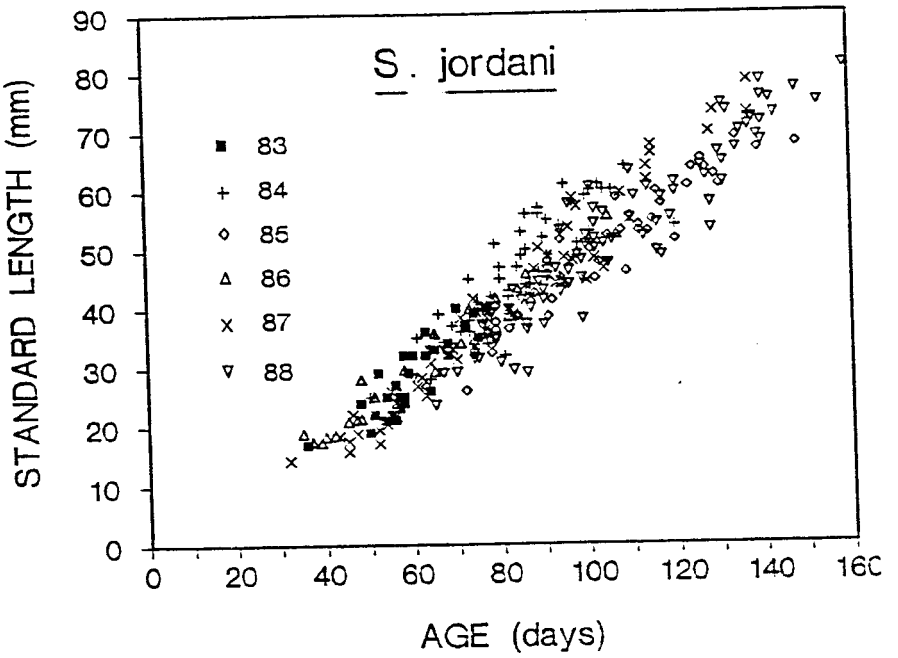

Fig. 7.--Relationship between standard length and age of shortbelly rockfish juveniles (1983-88).

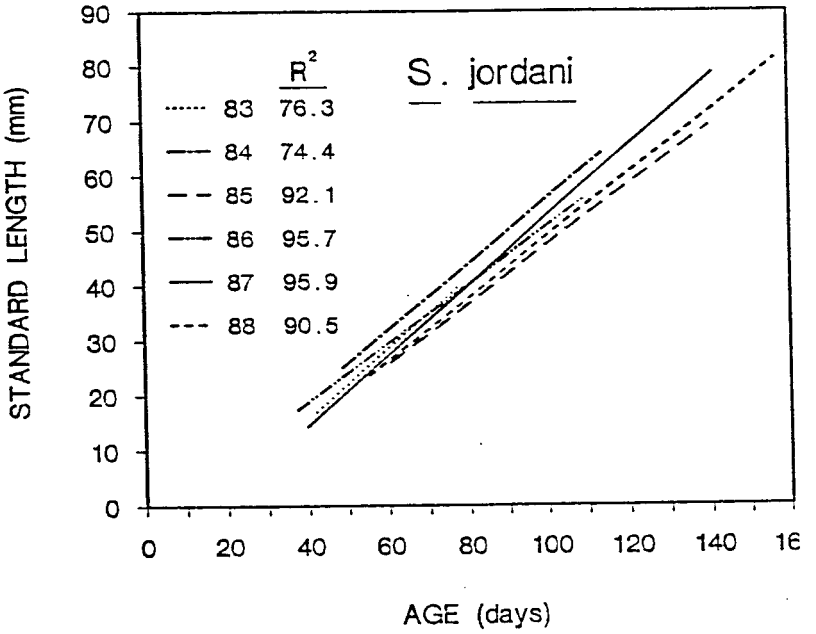

Fig. 8.--Linear regressions relating standard length to age of shortbelly rockfish juveniles (1983-88).

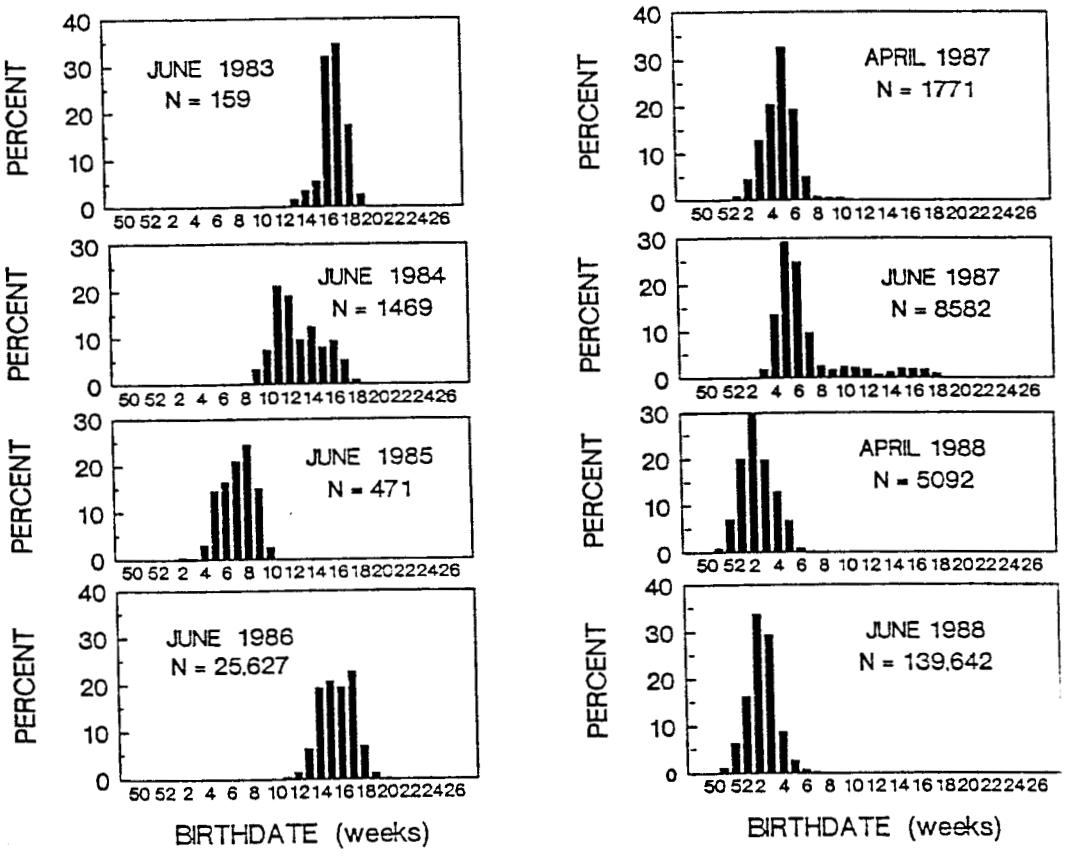

Fig. 9.--Back-calculated birthdate distributions of surviving shortbelly rockfish juveniles (1983-88).

Diet

Pelagic juvenile rockfish obtained during the survey cruises have also been used to examine the trophic biology of this life history stage. Samples have been analyzed for the period 1984-87 for the 5 principal species caught in the mid-water trawl (S. entomelas, S. flavidus, S. goodei, S. jordani, and S. paucispinis). The primary prey items during this time have been Calanus sp. copepods, juvenile copepods, unidentified copepods (too digested for further identification), furcilia (a larval stage of euphausiids), juvenile euphausiids and euphausiid eggs.

To quantify dietary overlap among all species within each year a coefficient of overlap described by Colwell and Futuyma (1971) was used. This coefficient has a minimum value of 0 when no overlap occurs and a maximum value of 1 when all prey types occur in the same proportion in the two rockfish being compared. Figure 10 shows the diet overlap for all species pairs for all four years. Overlap values are generally high (greater than .40) for species pairs in any given year, but vary more extensively among the 4 years. Typically, overlap values are higher for species pairs within years than for a species compared with itself between years. The great similarity of juvenile rockfish diets seems to imply that, for these 5 species, food is not actively partitioned in response to competition, at least in the pelagic juvenile lifestage. The diet is composed mainly of various lifestages of copepods and euphausiids which jointly comprise the major portion of the zooplankton during the months of the survey.

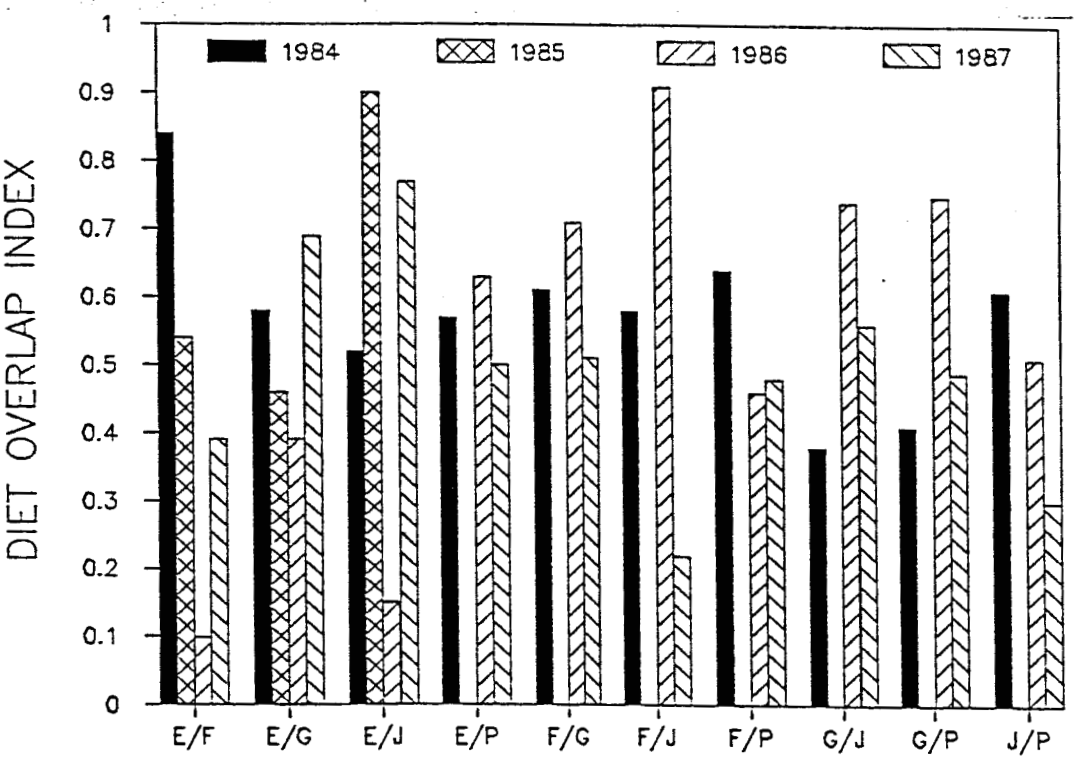

Fig. 10.--Dietary overlap of Sebastes sp. pairs (1984-87): E/F=S. entomelas/S. flavidus; E/G=S. entomelas/S. goodei; E/J=S. entomelas/S. jordani; E/P=S. entomelas/S. paucispinis; F/G=S. flavidus/S. goodei; F/J=S. flavidus/S. jordani; F/P=S. flavidus/S. paucispinis; G/J=S. goodei/S. jordani; G/P=S.goodei/S. paucispinis; J/P=S. jordani/S. paucispinis.

Mesenteric Fat Storage

Mesenteric fat storage is now being scored on a subjective scale of 1-5 for certain species (S. entomelas, S. flavidus, S. goodei, S. jordani, and S. paucispinis) during their pelagic juvenile lifestage. Mean fat scores vary somewhat between species and years, and have been highest in S. entomelas, S. flavidus, and S. paucispinis in 1984 and in S. goodei, and S. jordani in 1987. In 1983, an El Niño year, fat scores were the lowest observed in the two species measured (S. flavidus and S. jordani). In 1987 S. jordani did not accumulate mesenteric fat until reaching a size of about 40 mm standard length, after which fat increased with increasing length. S. paucispinis showed a similar trend in 1987, but did not accumulate as much fat as S. jordani.

More recently, 15 frozen S. jordani were analyzed by bomb calorimetry to determine caloric density, resulting in a mean caloric content of 5,953 calories/gm ash free dry weight. As expected, fat score and caloric density show a significant positive correlation. Fat scores can now be used on future samples to obtain statistics on the caloric condition of juvenile rockfish.

Progress in Estimating Year-class Strength From Composition of Predator Diet.

Estimates of 1988 Year-class Strength

Assessments of pelagic juveniles in the gut contents of king salmon, Oncorhynchus tshawytscha, indicated that 1988 was generally a strong year for recruitment in rockfish species (Table 12). Compared to the two other strong recruitment years, 1988 was similar to 1985, but weaker than 1987. The data show that 1988 was a strong year for shortbelly rockfish (Sebastes jordani) but a relatively weak year for the widow rockfish (S. entomelas). Although not enumerated in the table, the chilipepper rockfish (S. goodei) appears to have enjoyed an exceptionally strong year in 1988.

Table 12. Mean number of first year juvenile rockfishes (Genus Sebastes) in the stomach contents of king salmon (Oncorhynchus tshawytscha) from the Gulf of the Farallones, 1983-1988 (N = the number of stomachs examined with contents).

Year	N	All Species	S. jordani	S. entomelas
1983	413	0.16	0.00	0.00
1984	503	1.61	0.34	0.02
1985	760	5.72	1.56	0.13
1986	243	0.94	0.18	0.02
1987	416	6.26	5.72	0.30
1988	320	4.51	3.15	0.04

Predator Diet Compared To Trawl Sample as a Relative Measure of Recruitment

Measures of juvenile rockfish occurrences among the gut-contents of predators would seem an attractive, relatively inexpensive alternative to trawl samples in estimating relative abundances in the environment. To compare the relative merits of the two methods, however, we must consider how effectively each measures these abundances. An important part of this consideration is an evaluation of sampling bias. Previous reports dealt with sampling bias in the trawl assessments, here we identify sampling biases in the gut-content assessments that stem from predator behavior.

Obviously the predator's choice of prey has a particularly strong impact on the species composition of its diet, and an especially important facet of prey selection by the king salmon involves seasonal change. Generally, king salmon do not begin feeding on juvenile rockfish until May, and so generally fail to sample the earlier recruits. During trawl surveys in the Gulf of the Farallones study area (1983 to 1986; see earlier reports), the first juvenile rockfish sampled were taken in April, and usually included chilipeppers (S. goodei) and brown rockfishes (S. auriculatus).

When the predator selects prey from an array of organisms present in the environment, however, a major question is whether the selection is based on relative abundance of specific prey in the environment, or on relative vulnerability of specific prey to that particular predator. Probably both possibilities are in effect, but which has the most influence on prey selection and species composition of the diet? If the gut-content assessments are to offer a measure of numbers of juveniles in the environment the first possibility must predominate.

We lack knowledge needed to evaluate biases from predatory behavior directly, but there is another way to judge whether these biases seriously flaw estimates of year-class strength based on predator diet. This is by comparing estimates derived from gut contents with estimates based on trawl samples. Presumably there would be lack of consistency between them if either method was flawed by sampling bias.

Our comparison of estimates derived from results of the two sampling methods is based on collections made between 1983 and 1986 in the Gulf of the Farallones. A comparison between gut-contents and trawl-catch combining all species of juvenile rockfish is presented in Figure 11. The x axis used here is a log scale, so while the relationship appears to be a straight line it is actually an asymptotic approach curve where the numbers in the gut contents increase up to a maximum and then level off. This means that we lack resolution, particularly in the years when abundances are greater than the intermediate values shown here for 1984 and 1986. Resolution is sufficient, however, to recognize whether recruitment has been good, bad, or intermediate.

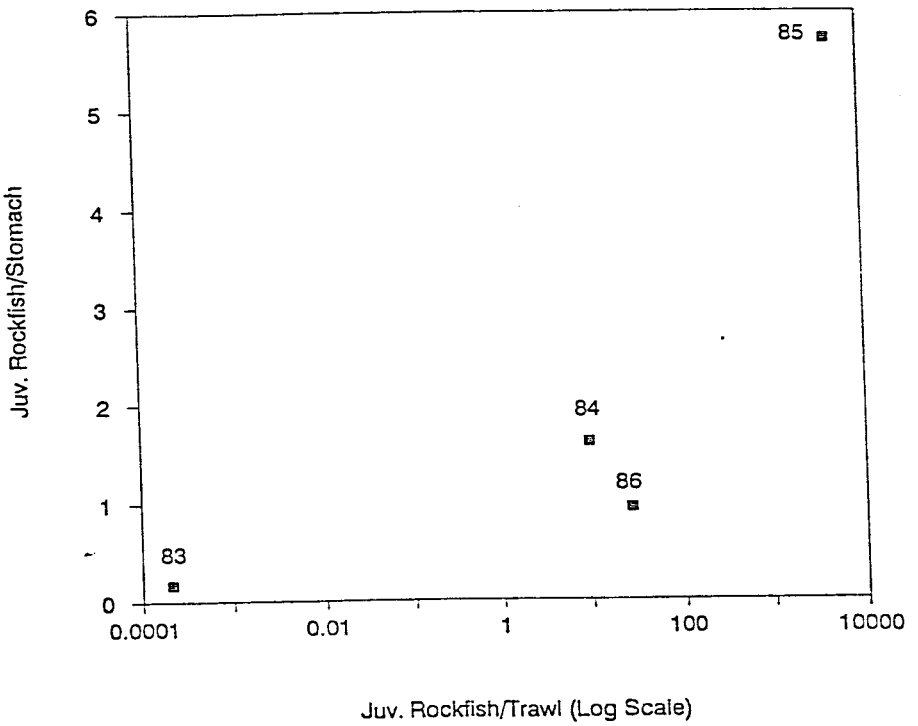

Fig. 11.--Average number of individuals of the eleven most common rockfish species (Sebastes auriculatus, S. entomelas, S. flavidus, S. goodei, S. hopkinsi, S. jordani, S. mystinus, S paucispinis, S. pinniger, S. saxicola, and S. saxicola) in stomach contents and trawls for the years 1983 to 1986.

The species composition of juvenile rockfishes in the diet is highly correlated (<1% level) to the species composition of the juveniles in the trawl during the last part of May and the first part of June (Figure 12). Both the gut-contents and the trawl produced data which indicate that the shortbelly rockfish and the widow rockfish were the most abundant species. The major difference between the results of the two methods involves the yellowtail rockfish, which is shown as prominent in the trawl catch, but virtually absent in the predator diet. This apparent difference, however, probably is due to damage done by digestion on characters needed to identify the yellowtail. As a result, yellowtail in the samples would be placed among the unidentified specimens (not represented here). Thus, problems from digestion limit the effectiveness of the predator-diet method for some species.

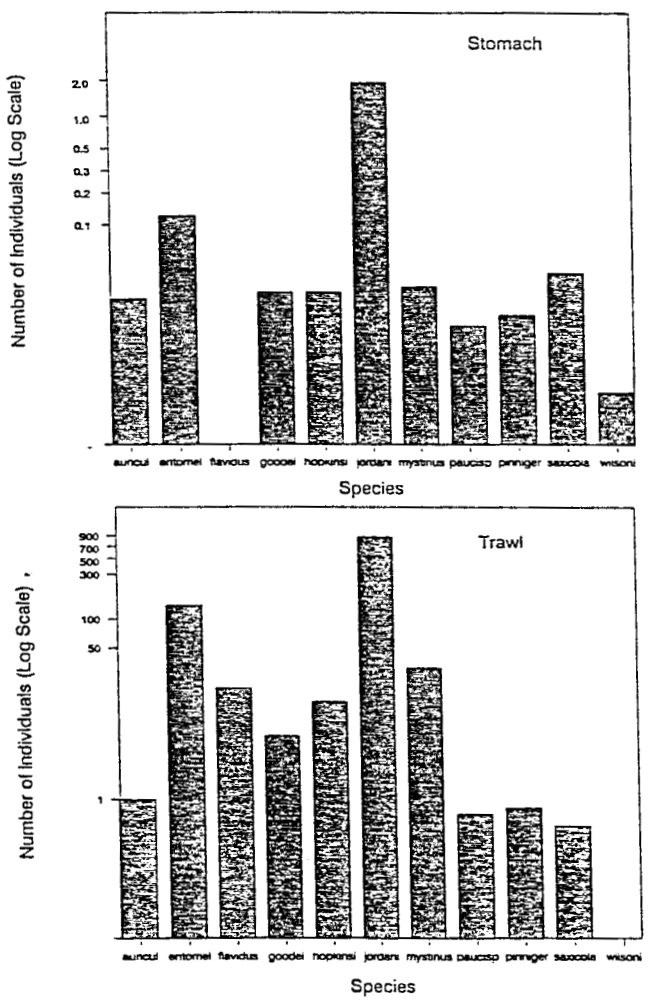

Fig. 12. Comparison of juvenile rockfish from stomach contents of king salmon versus trawls for rockfish species combined for the years 1983 to 1986.

STUDIES OF POST-PELAGIC JUVENILES

Post-pelagic juveniles are accessible to study in the nearshore environment, where they can be sampled and visually assessed by investigators in situ during their development in a habitat also occupied by their adults.

Progress in Visual Assessments

Estimates of 1988 Year-Class Strength

There continues to be substantial year-to-year variability in numbers of first-year juvenile rockfishes that settle in northern Californian nearshore habitats. This finding involves the same three species that predominated during previous years: the yellowtail rockfish, Sebastes flavidus, the blue rockfish, S. mystinus, and the black rockfish, S. melanops. And as before, the data come from underwater visual assessments using scuba at established sites off the Mendocino and Sonoma coasts (Tables 13 and 14).

The counts show that 1988 was another year of relatively strong recruitment. Compared to the other two strong recruitment years, 1988 was similar to 1985, but somewhat weaker than 1987. As before, S. mystinus and S. flavidus dominated, with S. melanops, ranking a distant third.

The first-year juvenile S. mystinus continued to be larger and more numerous off Sonoma than to the north off Mendocino, but the size difference developed after they settled in the nearshore habitats. Shortly after their arrival in June, 32 specimens collected off Sonoma had the same size-range and mean size as 16 specimens collected off Mendocino, i.e., 45-52, x = 48 mmSL at both locations. By late summer, however, the Sonoma fish were larger, e.g., 59-72, x = 66 mmSL (SE 0.81) for 18 individuals from Sonoma, compared to 54-61, x = 58 mmSL, (SE = 0.43) for 19 individuals from Mendocino ($t = 8.1507$, $p = 0.0001$). And this difference was still evident during midwinter, e.g., 62-76, x = 71 mmSL (SL = 1.15) for 13 individuals from Sonoma, compared to 56-80, x = 66mmSL (SE= 1.09) for 22 individuals from Mendocino ($t = 2.8613$, $p = 0.007$). Therefore, the difference in size of first-year juvenile S. mystinus between the two areas developed during their first few months in the nearshore habitat.

Although continued recruitment of S. flavidus through the summer had been a major feature of the 1987 recruitment season, there was no evidence of this in 1988. The counts indicated that initial recruitment of S. flavidus in June was relatively strong, i.e. 74 fish/min (SE=13.63) in 28 counts from Sonoma and 155 fish/min (SE= 22.81) in 41 counts from Mendocino. But the numbers

steadily declined thereafter, and during the rest of the summer we saw none of the silvery- hued recently arrived individuals that had been so noticeable at times during the summer of 1987. Because Tables 13 and 14 list numbers counted late in the summer, the relatively low values for S. flavidus reflect the lack of prolonged recruitment in 1988.

Table 13.--Mean number (standard error in parentheses) of first year juveniles counted/min off the Mendocino coast during the same 4-week period (early August to early September) from 1983 to 1988. n = number of 1-min assessments.

Species	1983 n=36	1984 n=57	1985 n=50	1986 n=103	1987 n=112	1988 n=62
S. flavidus	0.00 (0.00)	6.58 (2.29)	115.60 (21.26)	6.01 (1.50)	102.66 (11.08)	59.47 (10.23)
S. mystinus	0.27 (0.09)	1.49 (0.30)	70.56 (15.32)	7.83 (1.88)	181.04 (26.19)	75.89 (10.18)
S. melanops	0.41 (0.14)	0.31 (0.08)	4.34 (1.54)	9.52 (2.08)	7.58 (1.24)	5.94 (1.35)
Total	0.68 (0.19)	8.38 (2.33)	190.50 (29.82)	23.35 (3.91)	291.67 (33.99)	141.29 (16.88)

Table 14.--Mean number (standard error in parentheses) of first year juveniles counted/min off the Sonoma coast during the same 4-week period (early August to early September) from 1984 to 1988. n = number of 1-min assessments.

Species	1984 n=37	1985 n=84	1986 n=60	1987 n=62	1988 n=63
S. flavidus	4.39 (1.48)	135.17 (26.00)	6.73 (2.29)	89.39 (18.42)	39.92 (7.94)
S. mystinus	4.89 (1.29)	117.63 (19.50)	15.27 (3.81)	328.05 (52.15)	175.06 (16.76)
S. melanops	1.63 (0.52)	4.40 (1.17)	3.00 (1.31)	4.48 (1.70)	6.40 (1.95)
Total	10.91 (2.12)	257.20 (35.38)	24.97 (5.17)	442.48 (66.72)	221.38 (22.55)

Progress in Calculating Survival and Mortality Rates

An attempt is underway to determine survival and mortality rates of juvenile rockfishes, based on data from the nearshore underwater census counts. At present the effort concentrates on the blue rockfish because this species remains abundant and readily sampled after its initial appearance nearshore. Relevant data are available from two sites on the Mendocino coast (four years at Seal Cove, two years at Whitesboro), and one site on the Sonoma coast (one year at Horseshoe Point).

The rates are based on counts made from August (when the numbers of recruits stabilized) to the following April. When the data are plotted, regressions of the logarithm of the numbers of juvenile blue rockfish/time (in days) gives estimated rates of daily instantaneous mortality similar to those derived from catch-curve analyses. From these can be calculated monthly (30 days) instantaneous mortality rates as well as daily and monthly survival rates (Table 15, Figure 13).

That the daily and monthly survival and mortality rates vary little from year to year and from place to place (Table 15) indicates that annual and spatial influences on year-class strength are minimal during the August to April period.

Rates of annual (12-month) instantaneous mortality projected from these data range from 1.51 to 0.67, which can be compared to the generally accepted adult natural mortality rate of around 0.25.

Possible sources of error include net migration into the area, which would reduce the mortality estimates, and net migration out of the area, which would increase the mortality estimates. However, the consistency of the estimates, which are based on up to four years of data from three sites, argues against these possibilities. Finer-scale sampling are planned for the coming year to investigate this problem further.

Table 15. Daily survival, daily instantaneous mortality, monthly (30 days) survival and monthly instantaneous mortality rates for juvenile blue rockfish (Sebastes mystinus) for the period between the months of August to April for three locations by year.

Location	Year	Daily Survival	Instant. Daily Mortality	Monthly Survival	Instant. Monthly Mortality
Seal Cove	85/86	0.9977	0.0023	0.9354	0.067
	86/87	0.9979	0.0021	0.9408	0.061
	87/88	0.9968	0.0032	0.9112	0.093
	88/89	0.9941	0.0059	0.8423	0.112
Whitesboro	87/88	0.9955	0.0045	0.8774	0.131
	88/89	0.9915	0.0085	0.7807	0.247
Horseshoe Pt.	88/89	0.9926	0.0074	0.8062	0.150

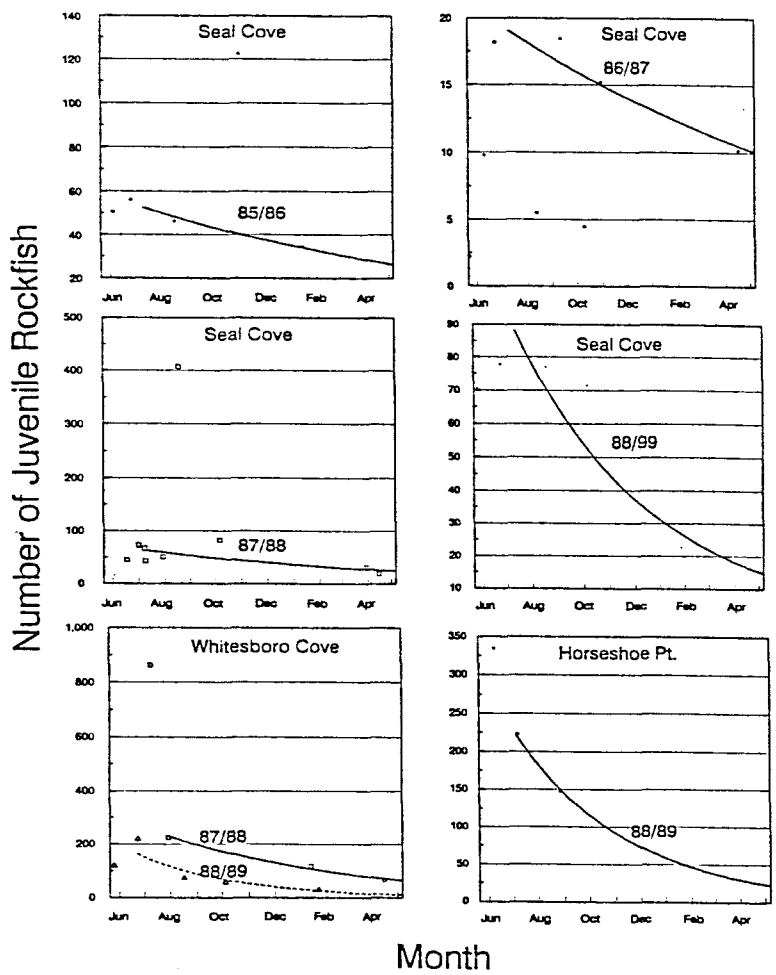

Fig 13. Survival and mortality estimates for juvenile blue rockfish (Sebastes mystinus) from four locations by year.

STUDIES OF REPRODUCTIVE POTENTIAL OF ADULTS

The physical condition and reproductive performance of the adult rockfishes during 1988, as determined by examination of specimens collected in coastal habitats throughout the year, would be expected to influence the 1989 yearclass.

Progress in Assessment of Adult Physiological Condition

Initial descriptive statistics and factor analysis of selected data were run previously on all fish (487 S. flavidus; 4 to 45 yrs of age; 390 females and 97 males; 41 immature and subadults and 396 adults) to determine the interrelationships of variables. In brief, the major findings from this analyses showed that approximately 77% of the variability in the data was accounted for by 8 factors associated with variables linked with age, wet weight, body and liver conditions, year, season, fat in liver and mesenteries, sexual maturity and the presence of fungus and "melanomas".

Additional covariance analyses of data collected on the condition of 317 adult females are reported here and are designed to answer the following questions:

1. What are the intra-annual (or seasonal) differences in temperature and upwelling and do they relate to variation in the age and condition of females?

2. Are there inter-annual differences in female characteristics which might relate to juvenile abundance and future recruitment?

3. Are there spatial (geographic) differences in the condition of S. flavidus which might relate to environmental variation and variation in juvenile abundance and recruitment in different areas?

Temporal Variability

Notable monthly (seasonal) differences occurred with nearly every variable measured for adult female S. flavidus, and seasonal patterns varied among the three years sampled. Seasonal variation in condition factors may relate to reproductive success.

In a covariance analysis of adult female S. flavidus, the adjusted yearly means of some of the more important variables tested are summarized in Figure 14. Means of variables were tested for significance of differences among years and months

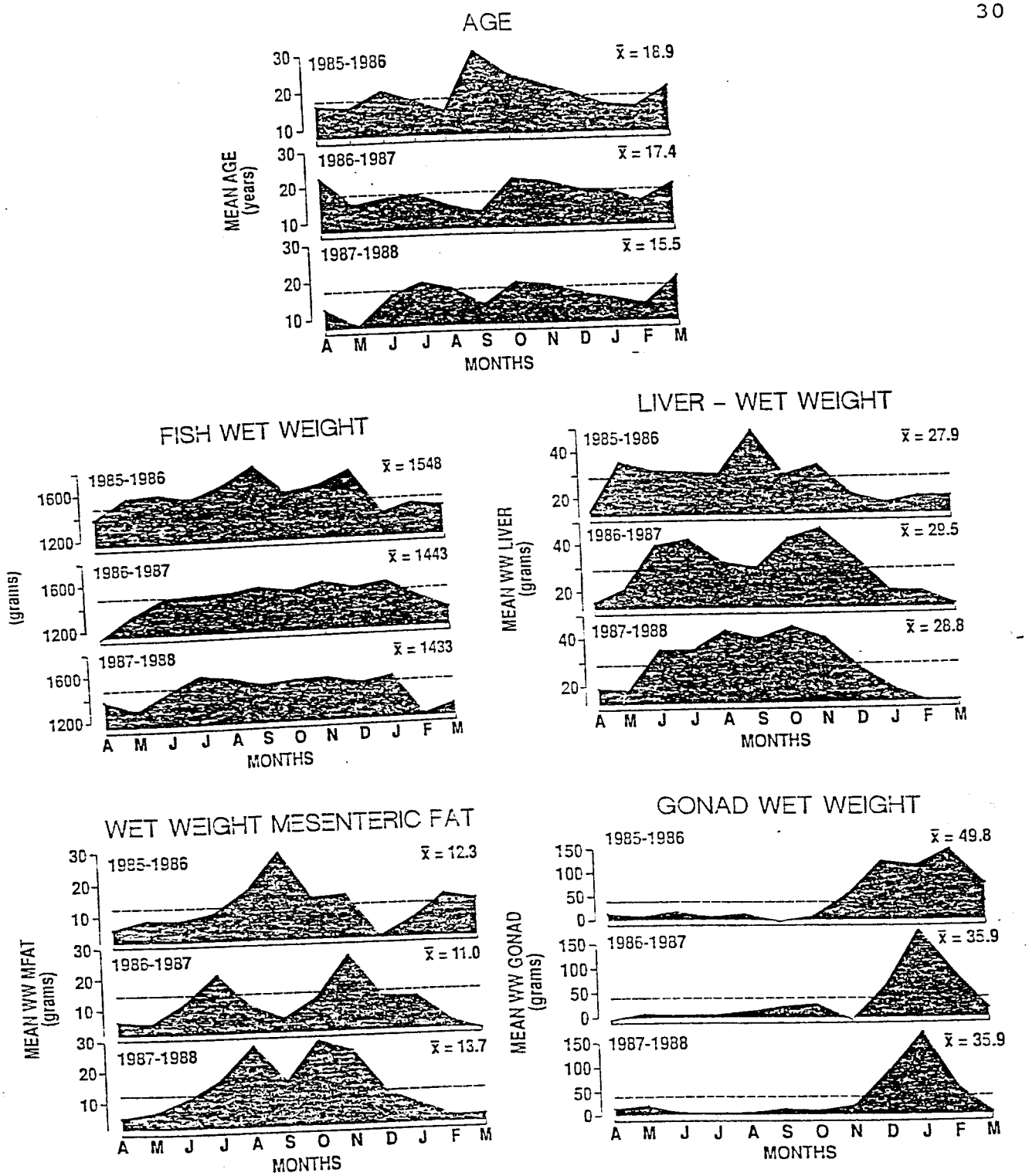

Figure 14.-- Distribution of means of measured variables by month for the three sampling years. Broken line in each panel represents mean for the three years.

(2-factor model), after first removing the effects of the covariate of age. For example, the monthly mean ages of females sampled during 1985-86 14) followed a different pattern than those sampled in 1986-87 or 1987-88 (Figure 14). The females sampled during September of that first sampling year were significantly larger than females sampled at any other time. To minimize the effect of variance due to regression of dependent variables on age, age was treated as a covariate for the remainder of analyses.

After adjustment for the covariate of age, almost all variables (listed in last report) displayed a significant ($P<0.01$) interaction between month and year, indicating different monthly (seasonal) patterns among years, even when the annual means were not significantly different.

A comparison of 1985-86 with the following two years also shows significantly greater mean wet-weight values ($P<0.01$) during that first sampling year for total body, liver, mesenteric fat, and gonads (Figure 14).

Despite the greater mean-weight of gonads during 1985-86, there was an indication of lower total fecundity and a higher percentage of abnormal eggs that year. As reported earlier, however sample sizes were too small to be sure of this. Larger samples taken specifically for fecundity measurements do not show significant inter-year differences (see Figures 21-24).

Our initial work had shown that the condition of females in the first year was somewhat different from females in the later two years, primarily due to their being older fish, but that other factors were involved because data were adjusted for age. Mean temperatures were also significantly lower in the first year (1985-86) than in the later two years (1986-1987, 1987-88). We can speculate that the pattern of greater mean age of fish in the first year may be due to a southward migration of larger older fish from the center of the population during the 1985-1986 period. Additional regression analyses showed that mean upwelling for 30 days prior to collection showed little relationship to condition factors. Other environmental variables may be more predictive of condition. For example, lipids and body fat are probably related to euphausiid abundance. We will, therefore, investigate various simple means of obtaining relative estimates of euphausiid abundance in the Cordell Banks area during the next year.

It is possible that the older age distribution of the fish sampled in the first year and the other significant differences in fish sampled in that year (for example the greater parasite burdens in older fish) may relate to the lower year-class abundance observed in 1986 by the other Investigations. For the most part, however, fish were not that different among the three

years of the study. Large interannual differences may be detected only when the environment changes more significantly, e.g. during an El Nino event. A summary of some of the mean annual differences is shown in Figure 15. Frequency of measurements of condition and reproduction of S. flavidus has been reduced to three times a year for future sampling and variables selected to measure were reduced to those showing most significant variability. Further analyses showing the relationship of condition to reproduction await the completion of ovarian sample analyses.

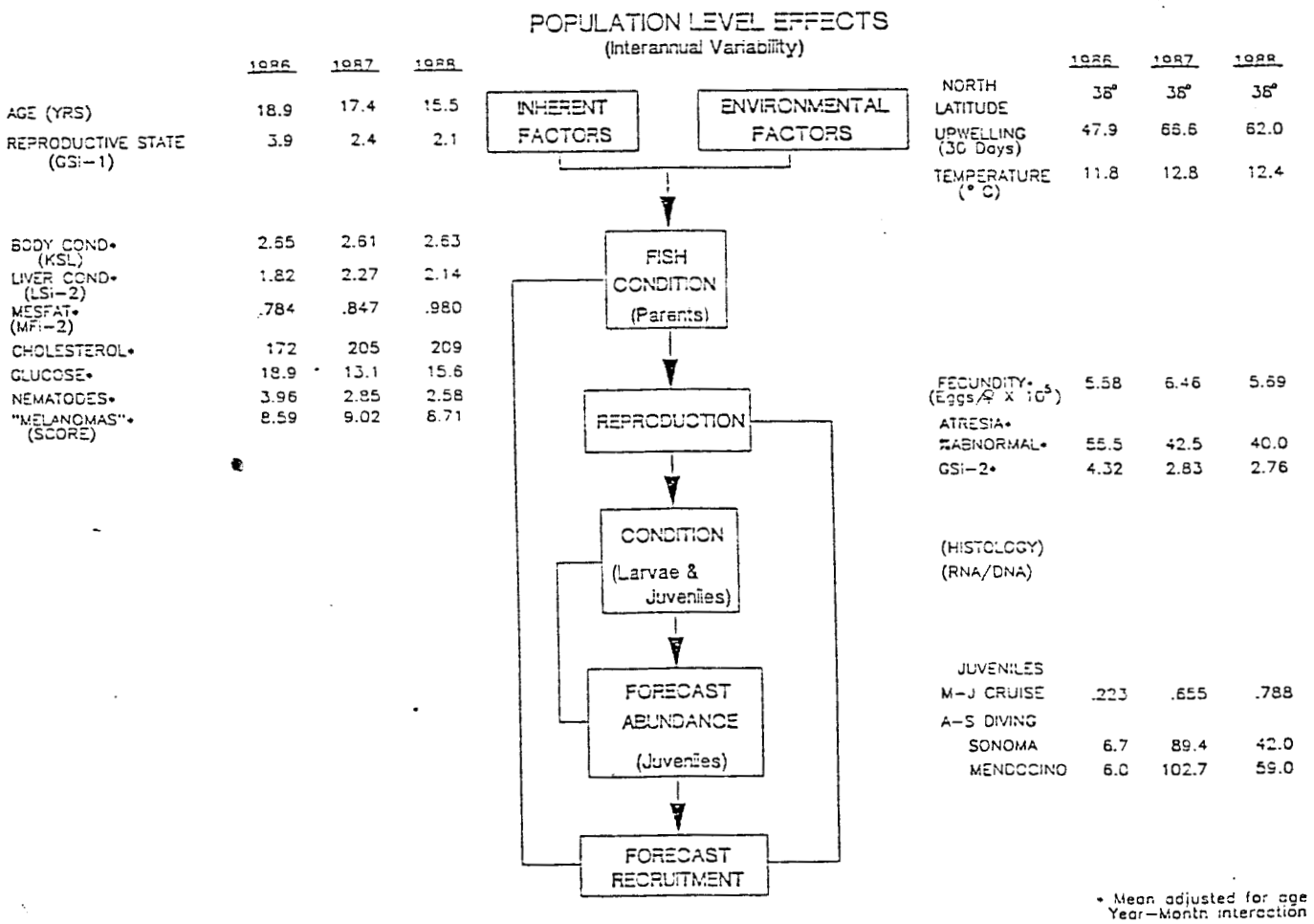

Figure 15.-- Summary of population level effects in yellowtail rockfish, with postulated interactions and examples of annual differences in some condition and reproductive measurements.

Spatial Variability

In the summer of 1986, Tiburon personnel joined the NWAFC Triannual Cruise off the west coast of California, Oregon and Washington. The purpose of this work was to collect yellowtail, bocaccio, and widow rockfish (Sebastes flavidus, S. paucispinus S. entomelas) from additional areas to compare with those collected from Cordell Bank off Bodega Bay, California. Approximately 20 of each species was collected from each of three areas: sections identified as (1) Monterey-California; (2) Columbia-Oregon and Washington; (3) Vancouver-Washington and British Columbia.

Fish were examined later at Tiburon Laboratory and several measurements such as age, size, and condition of organs and parasites were made, similar to those on fish from Cordell Bank. Data collected comparing S. flavidus with those collected at the same time at Cordell Bank were analyzed and are summarized in Table 16 and Figure 16. The means shown in the Table and Figure were adjusted through covariance analysis for the effect of time collected, sex and age. The fish were collected during July, August, and September, 1986; a non-spawning period when feeding is normally optimal.

Most of the characteristics of fish we measured showed clinal variation, with larger, deeper-bodied fish further north (Figure 20). Fish from the northernmost location were also at a later sexual development stage (Table 16; gonad wet weight).

Finally, significantly higher infections of the protozoan Henneguya sebasta in the heart and of the fungus Icthyophonus sp. in the spleen and kidney occurred in yellowtail from Cordell Bank. The black pigment patches (possibly melanomas) on the skin of yellowtail occurred only in fish from Cordell Bank, and were not seen in fish sampled further north.

The sample sizes compared above are still small and final conclusions will not be made until additional geographic comparative sampling is completed. Initial analyses, however, indicate population differences from south to north, with the more peripheral southern populations of S. flavidus showing indications of environmental stress which may affect their condition, growth and reproductive capacity. Sampling of a population off Washington state was initiated in the past year. We will continue with sampling from both areas three times a year during periods determined to be critical for optimal adult condition and reproduction.

Table 16. Summary of adjusted means for characteristics of yellowtail rockfish (Sebastes flavidus) collected from four geographic areas; July through September, 1986.

CHARACTERISTIC	Monterey	Bodega (Cordell)	Columbia	Vancouver
Age (yr)	8.8	13.8	11.3	14.6
Body Wet Weight (gr)	1200.0	1213.0	1470.0	1675.0
Standard Length (cm)	35.4	35.7	38.7	39.4
Body Depth (cm)	10.9	11.7	12.5	13.2
Liver Wet Weight (gm)	23.7	28.4	37.0	44.3
Mesenteric Fat (ranked 1-5) (1-5)	2.3	3.6	3.4	4.2
Gonad Wet Weight (gm)	10.1	6.5	10.6	13.0
Parasites (ranked by severity, 1-5)				
Heart Protozoans	1.3	1.7	1.2	1.0
Spleen Fungus	0.8	3.0	1.2	1.7
Kidney Fungus	0.12	3.11	1.18	2.00

Means adjusted through covariance analysis for effects of time sampled, sex and age. Factor=Location.

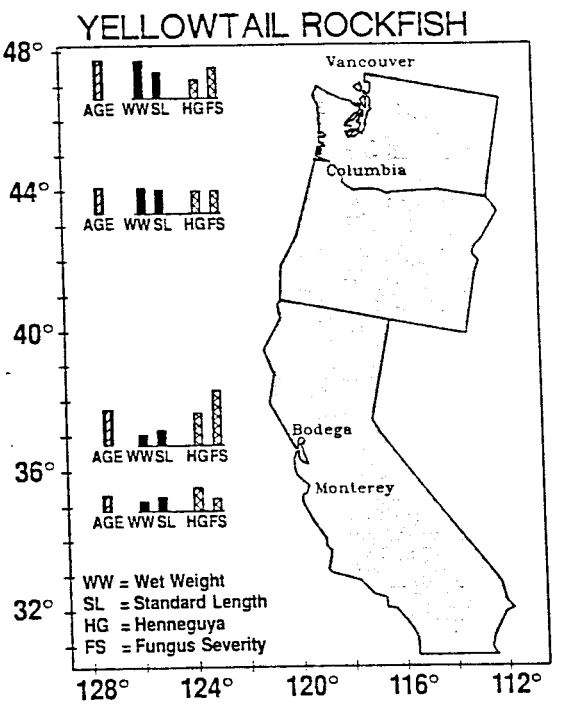

Figure 16.-- North to south distribution in means of some condition factors measured in yellowtail rockfish.

Progress in Fecundity Studies

Research emphasis in the fecundity study for the past four years was placed on the fecundity of S. flavidus because of its importance in the recreational fishery in northern California and its role as the major Sebastes species in the Oregon and Washington commercial groundfish fisheries.

Concern over recent sustained declines in yellowtail rockfish population abundances has increased the need for life history information relating to reproductive capacities and the factors effecting these essential life history performances. The 1988-89 reproductive season is the fourth year of an ongoing study of the reproductive biology of S. flavidus from Cordell Bank, California. This year differed from previous years in that we began sampling adult females from populations off Washington state and Vancouver Island, Canada for comparative purposes. To date 374 females have been collected by hook and line and trawl from November to March of each year and examined for their reproductive state and physiological condition. Fecundities were determined by gravimetric subsampling in triplicate. The following is a summary of our results:

- Ages, sizes, and weights of Yellowtail rockfish females progressively declined over the first three years of the study and presently appear to have stabilized (Table 17).

- The Washington state females examined were younger (mean age = 12.1) but larger (SL = 46.6, WW = 1979) than Cordell Bank S. flavidus.

- No significant differences among years were found in age-specific, or length-specific, fecundities (Figures 17, 18, 19.

- The Cordell Bank S. flavidus may have stabilized in size, but are younger, smaller, and less fecund females than in earlier years.

Table 17. Mean ages , standard lengths, and wet weights of females from fecundity studies of yellowtail rockfish S. flavidus) for four reproductive seasons.

	YEAR			
	1985-1986	1986-1987	1987-1988	1988-1989
AGE (yr)	18.6	17.2	13.4	15.5
LENGTH (cm)	38.6	37.8	34.7	37.2
WEIGHT (g)	1557.0	1484.0	1187.0	1406.0

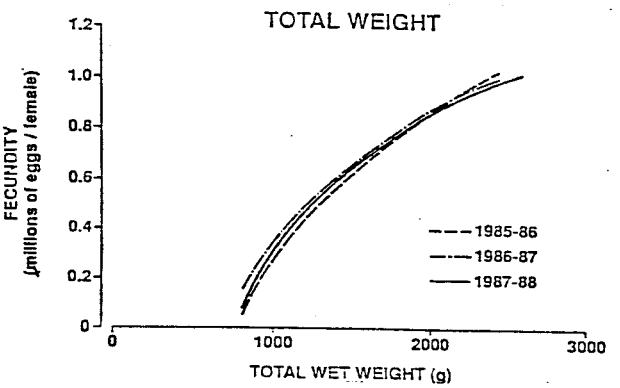

Figure 17.__ Fecundities of yellowtail rockfish by total body wet-weights (g) during three reproductive seasons.

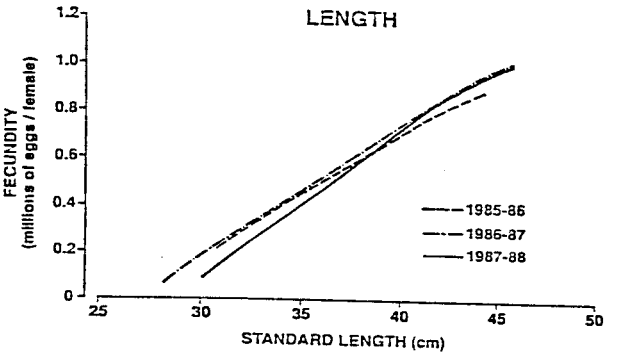

Figure 18.--Fecundities of yellowtail rockfish by standard length (cm) for three reproductive seasons.

Figure 19.-- Fecundities of yellowtail rockfish by age (yr) for three reproductive seasons.

Factor analysis of adult S. flavidus conditions and reproductive performances showed that:

1. Fecundity was closely associated with age, size and weight.

2. Mesenteric fat was inversely related to the extent of Ichthyophonus sp. fungus in kidneys and spleens.

3. The incidence of abnormal egg development was inversely related to the amount of mesenteric fat.

4. Potential and real fecundities appeared similar when fecundities of early developed, unfertilized ovaries were compared to fecundities of ovaries with fertilized eggs (Figure 20).

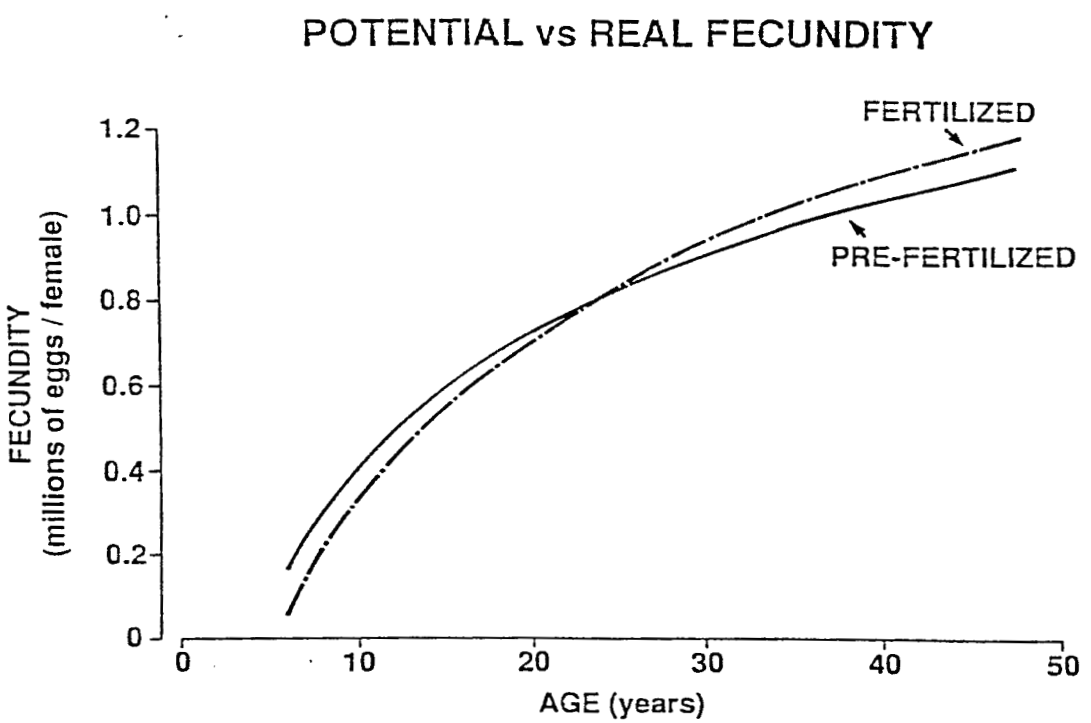

Figure 20.-- Fecundity estimates of pre-fertilized and post-fertilized yellowtail.

Additional research is planned to sample S. flavidus populations in Oregon, Washington, and Canada to cover their range of geographic distribution. Once this species has been sufficiently described and characterized we hope to extend our efforts towards other rockfish species.

Progress in Histological Studies of Ovaries

Histological analyses of monthly samples from the 1987-88 S. flavidus reproductive season are currently being compared with the two previous reproductive years (1985-86, 1986-87). While similar seasonal patterns were noted for the three consecutive reproductive years, some annual variation was evident.

Oocyte frequency distributions observed from the 1985-86 and 1986-87 reproductive seasons indicated that two overlapping, but distinct batches of larvae were produced by the Cordell Bank yellowtail rockfish population. Evidence for this occurrence was noted by the presence of oocytes in a tertiary yolk accumulation stage in some samples, to early embryonic stages in others. Ovaries with ova in these stages were collected concurrently with parturient female yellowtail rockfish and represented approximately 50% of the sample in January, February, and March, 1986. Similarly, ovaries from the succeeding reproductive season had these stage ova present in January and February, 1987, and represented greater than 50% of the sample for those two months. However, tertiary yolk accumulation was last observed in January for the 1988 samples, and represented less than 40% of the month's sample. Therefore, parturition for the 1987-88 reproductive season appears to have occurred over a shorter period of time as compared to the extended seasons of the two previous reproductive years.

The factors regulating developmental rates and eventual parturition at the population level, remain unclear. It would appear to be prudent for a species that release pelagic larvae during seasons of violent winter storms to prolong parturition over an extended period of time. This would allow at least a portion of the reproductive population to release larvae under the most advantageous environmental conditions. Our ability to analyze the extent of environmental influences on oocyte development and parturition times will greatly aid our efforts to understand the significance of these temporal variations. As more environmental data become available, comparisons between reproductive years will be a subject of future investigations.

A study of atretic oocytes, their presence, type, and quantity has been initiated. Histological samples from three consecutive reproductive seasons are being compared. Since the rates of atresia appear to be quite rapid, oocytes undergoing this process are not easily staged. The preliminary analysis was greatly enhanced by separating the observed atretic oocytes into two easily recognizable categories: Yolked and Non-yolked oocytes. An attempt to identify the original oocyte type (stage) was abandoned. Total counts for all three years have yet to be determined. However, atresia in yolked oocytes appears to occur in greater frequency than non-yolked, and this remains consistent for all three years. In addition, once fertilization has occurred, the incidence of atresia declines. From the

preliminary data, it appears that the majority of atretic oocytes occurred in yolked oocytes during the months where early to mid-yolk accumulation (stages IV and V) is observed. Evidently, once an oocyte reaches a migratory nucleus stage (stage VI) or becomes fertilized, its chances for continued development are greatly increased. The incidence of atresia in non-yolked oocytes is less often observed, and appears to be mostly associated with physical injury, or small, localized necrotic areas.

Progress in Studies of Nutrition

Monthly serum and tissue nutritional data, from April 1985 through April 1988, were obtained from adult yellowtail rockfish, Sebastes flavidus, collected from Cordell Bank. These data are being analyzed to determine maternal nutritional requirements for reproductive success and the environmental factors which influence this relationship. A goal of this study is to identify early predictors of year-class strength.

The data to be evaluated include morphometrics, serum nutrients, tissue proximate composition, ovarian reproductive variables, and environmental variables. Most of the data have been entered into computer files; however, chlorophyll, euphausiid, and atresia databases are incomplete, but are presently being filled. Consequently, at this stage, only trends and qualitative comparisons can be observed.

During summer and fall months (June through November) heavy feeding is reflected by elevated concentrations of serum nutrients. Data analyses (presented in the 1988 Recruitment Report) indicated that the extent of energy accumulation during this time interval is an important factor in oocyte maturation and reproductive development. By comparing serum nutrient concentrations of female Sebastes flavidus between the three reproductive cycles (i.e., 1985-86, 1986-87,1987-88) it appears that fish were in the best nutritional state during the 1987-88 reproductive year. For example, triglycerides, a primary energy source in fishes, were found in relatively greater concentrations in S. flavidus serum during the summer and early fall of 1987 than during the previous two years (Figure 21). This was particularly true in September when serum triglycerides reached an impressive mean of 1979$\pm$152 mg/dl (n=10). Serum concentrations of cholesterol, phospholipids, free fatty acids, and albumin also were found at relatively greater levels during the summer and fall of 1987 compared to 1986 and 1985. Based on the serum nutrient concentration profiles observed, female S. flavidus were in the best nutritional condition during the 1987-88 reproductive cycle, with lower energy status in 1985-86, and the lowest during the 1986-87 reproductive year.

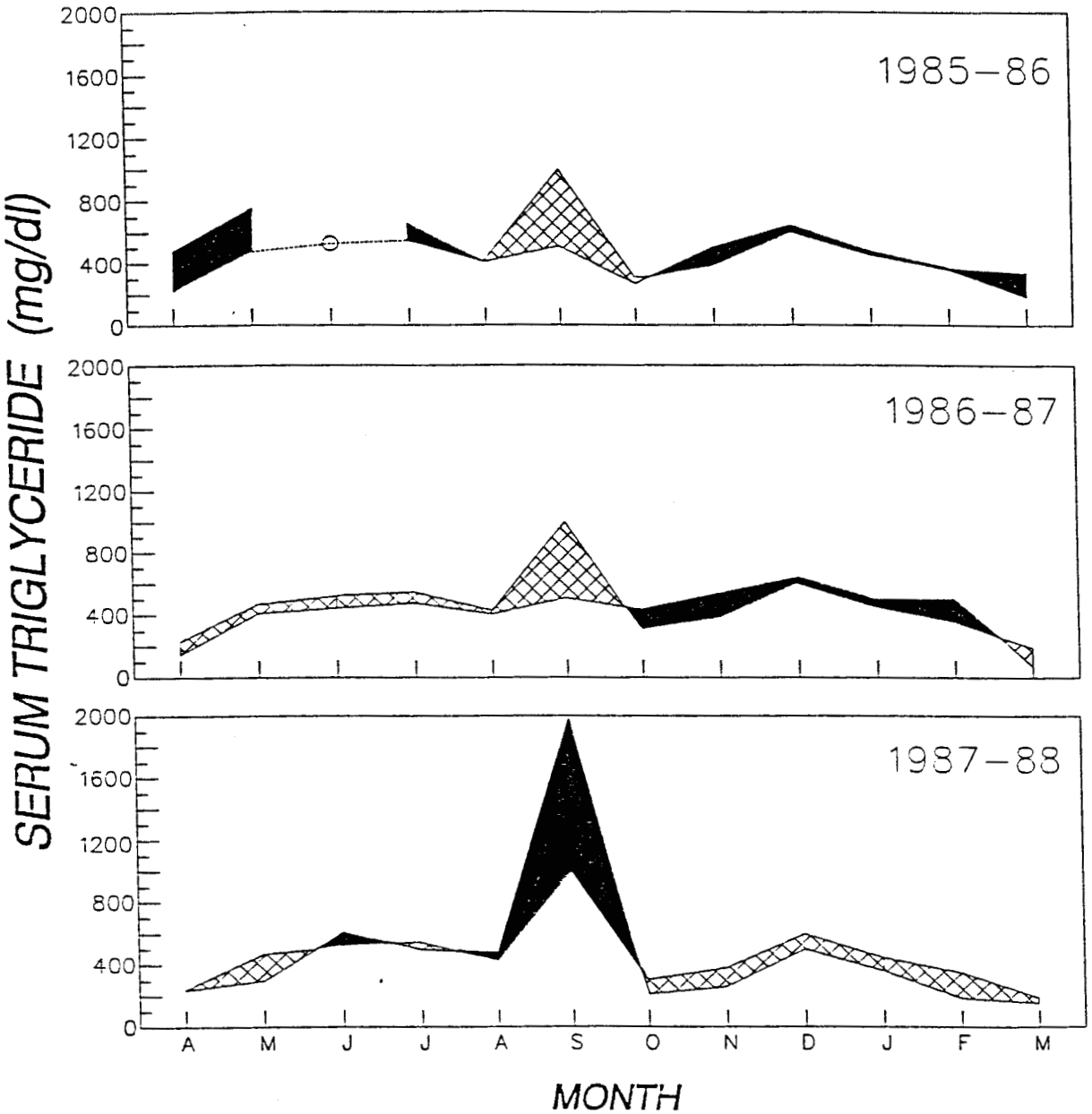

Fig. 21.-- Comparison of serum triglyceride concentrations in female Sebastes flavidus from three reproductive cycles. Each graph consists of two lines, monthly means for the year indicated and monthly means for the three years. Polygons formed by lines are filled where values in a year indicated exceed three-year means and cross-hatched where triglyceride concentrations are less than for the three-year means. Note very high serum triglyceride levels in September 1987 and greater than three-year means during summer months of 1985.

The ranking of nutritional state by serum nutrient concentrations is similarly observed in tissue lipids. A primary fat storage depot in S. flavidus is the intestinal mesenteries which accumulate lipids (mostly triglycerides) during the summer and early fall (Figure 22). Calculating the mean mesenteric fat indices (i.e., percent of body weight in the form of mesenteric fat) for all females collected from June through November of each year shows that there was greater lipid storage in 1987 (1.31±0.07, n=60) than in 1985 (0.91p0.08, n=43) or 1986 (0.81±0.06, n=50).

Liver also accumulates energy during the summer period and is indicated by elevated liver somatic indices (LSI) (Fig. 22). The increase in liver weight is primarily attributable to increased lipid (Figure 23). The mean LSI values for female S. flavidus collected during the summer and fall of 1987 were greater than those from females obtained in 1985 or 1986.

The serum and tissue nutritional data obtained from the three reproductive cycles show a consistent pattern of energy accumulation during the intense feeding period of summer and fall and subsequent mobilization to the developing ovaries from late fall through parturition (January to March) (Figures 22 and 23).

The influences of environmental variables on the nutritional state and reproductive success of females are as yet unclear. This is, in part, due to the limited amount of environmental data obtained to date, but also, to the difficulty of quantifying some important variables. Initial analyses of sea surface temperature and upwelling suggest that the three years of the study were somewhat similar. The annual pattern of sea surface temperatures was stable between the three years with no large interannual variation except perhaps during the months of September, October, and November when temperatures departed from the three-year means by as much as 2.5°C. Statistical analyses, however, revealed no relationship between sea surface temperature and nutritional status or measures of reproductive development. This is not unexpected since S. flavidus inhabit depths (≥50 m) where temperatures are more stable and do not vary by more than 1 to 2°C annually during typical years (e.g., non-El Niño).

The interannual variability of upwelling between years was minimal for 1985 through 1987. The duration of the season (38 to 41 weeks/yr) and intensity (mean weekly index values during season = 76 to 82) for the three years were quite similar. Review of the weekly upwelling indices does, however, indicate that the upwelling season started earlier in 1985 and 1987 relative to 1986. Weekly mean values in excess of +100 occurred six weeks earlier in those years and may be an important factor in the productivity of the central California coastal waters.

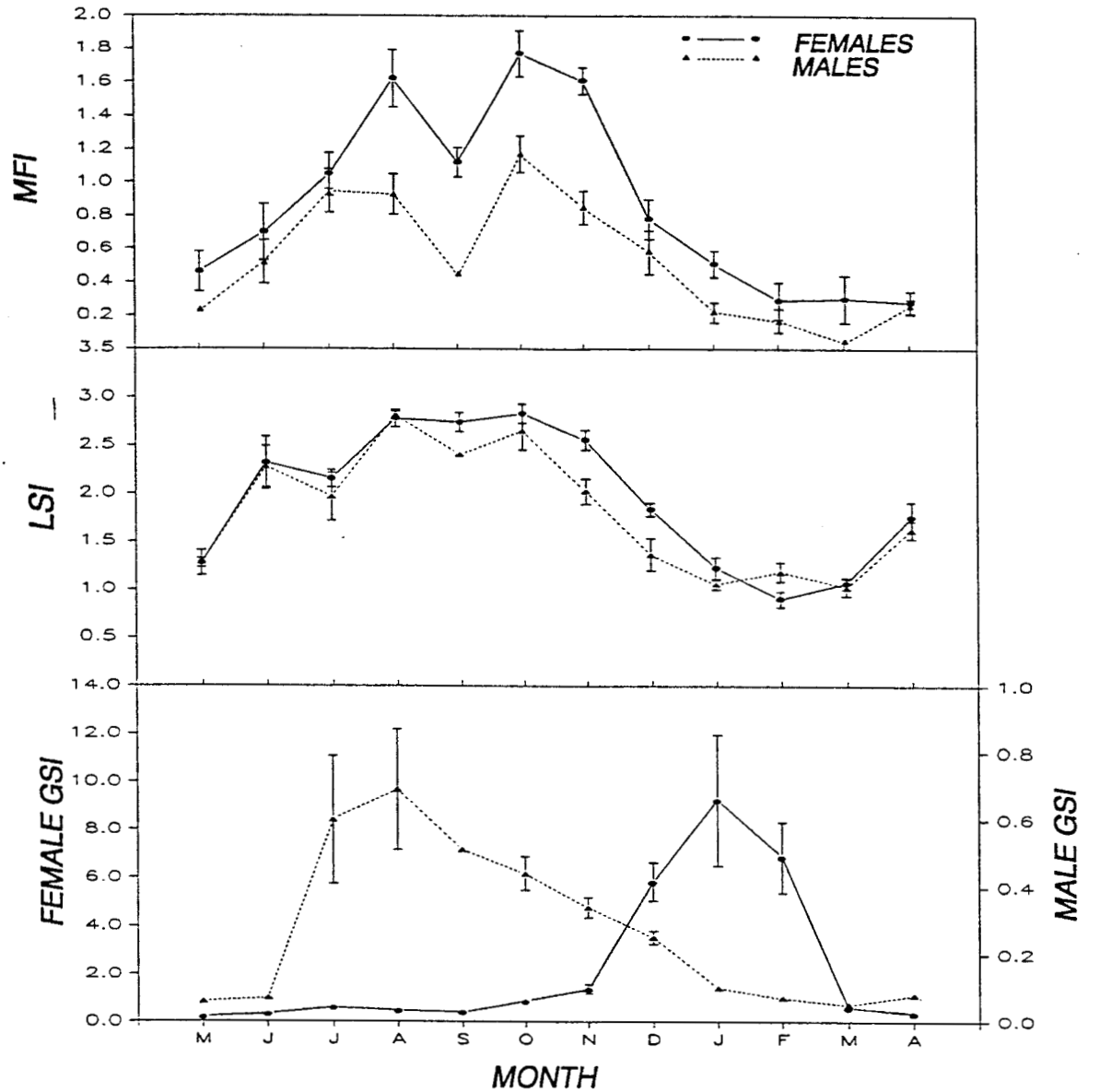

Fig. 22. Temporal patterns of mesenteric fat, liver and gonad weights relative to body weight in Sebastes flavidus from May 1987 to April 1988. Data from males presented to distinguish changes specific to female processes. Pattern indicated increased mesenteric fat and liver weight (mainly lipids) during summer and fall (period of intense feeding) followed by depletion through metabolism for ovarian development during the winter. MFI (mesenteric fat index) = [mesenteric fat (g)/body weight (g)] x 100; LSI (liver somatic index) = [liver weight (g)/ body weight (g)] x 100; GSI (gonadosomatic index) = [gonad weight (g)/ body weight (g)] x 100.

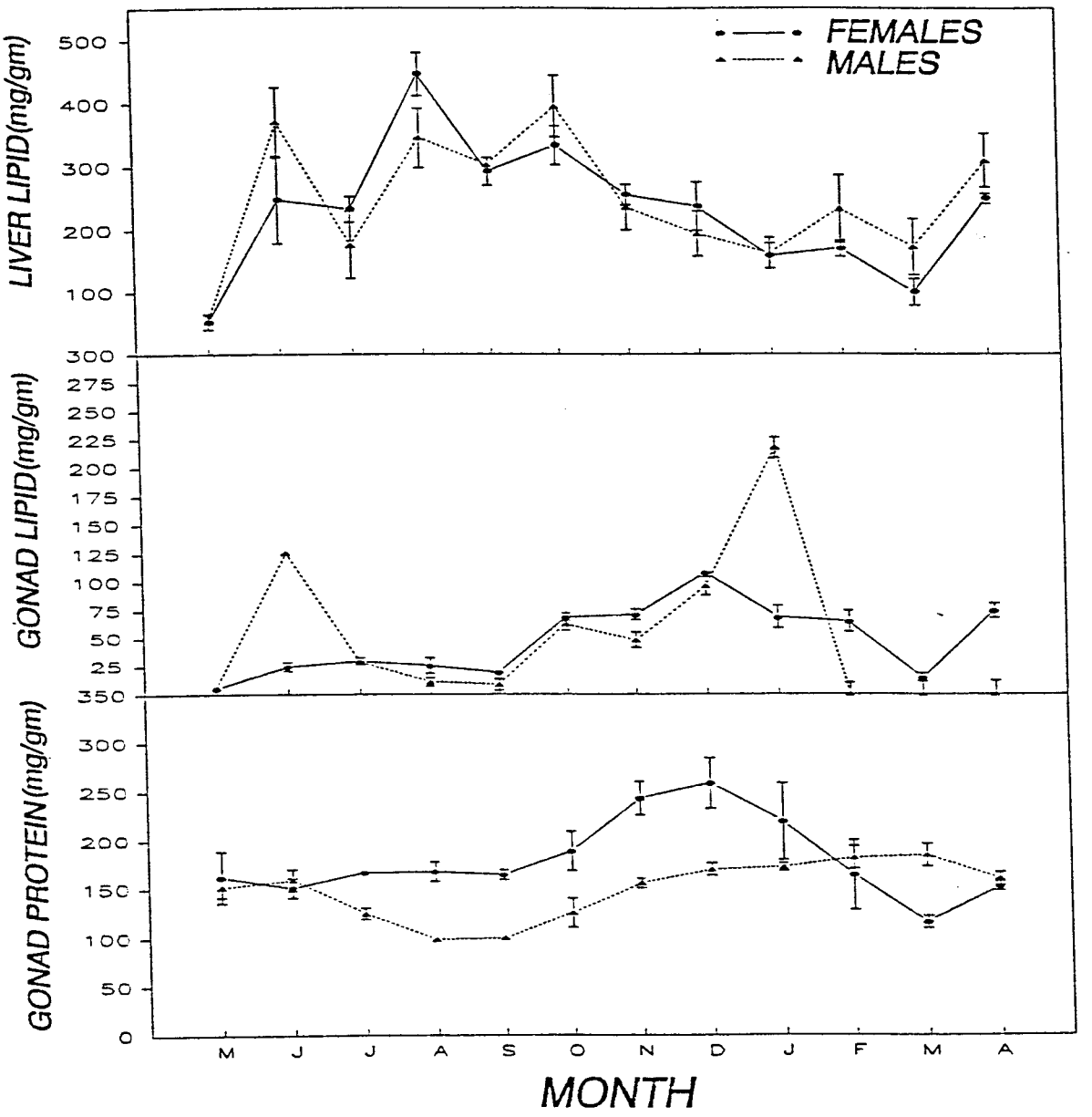

Figure 23.--Temporal patterns of lipid and protein concentrations in tissues of Sebastes flavidus. Liver lipid concentrations increased during period of heavy feeding and decreased during late fall and winter. Lipid and protein concentrations increased in ovaries coincident with increasing ovary size during egg/larval maturation.

There is little information on euphausiid abundance from 1985 through 1987. What is available is largely semi-quantitative and observations of fishermen and marine scientists working in the area. These sources indicate that euphausiids were present in atypically large numbers during the upwelling season of 1987, abundant during 1985, and at lower levels of abundance during 1986. This sequence is reflected in the nutritional status of S. flavidus which, based on stomach contents, utilizes euphausiids as a primary food source. Greater understanding of the significance of euphausiids on the nutritional status of S. flavidus will be gained with increased assessment of yearly euphausiid production, which is presently being planned.

The link between nutritional dynamics and reproductive success has not yet been established. This relationship will be elucidated when data on the extent of ovarian atresia and progeny physiological condition are added to the database. The quantitative assessment of atresia from histological slides of ovarian tissue from S. flavidus collected over the three years of the study is in progress. An evaluation protocol for progeny physiological condition has been developed and will be applied to juvenile S. flavidus on a yearly basis starting during the summer of 1989 as part of the ongoing monitoring program.

To date, the data from the first three years of the study on the reproductive biology of S. flavidus indicate that nutritional dynamics and environmental variables were similar. Although there was some interannual variability, it was not great, and thusly will allow these data to be used to establish normal variability of nutritional processes during typical environmental conditions along the central California coast.

REFERENCES

Colwell, R. K., and D. J. Futuyma. 1971. On the measurement of niche breadth and overlap. Ecology 52(4):567-576.

Green, P. E. 1978. Analyzing multivariate data. Dryden Press, Hinsdale, Ill. 519 p.

Hobson E., P. Adams, J. Chess, D. Howard and W. Samiere. 1986. Temporal and spatial variations in the numbers of first-year juvenile rockfishes off northern California. Southwest Fisheries Center Admin. Rpt. T-85-02, 16p.

Larson, R. J. (ed.). 1987. Progress in rockfish recruitment studies. Southwest Fisheries Center Admin. Rpt. T-87-01, 31p.

Lenarz, W. and S. Moreland. 1985. Progress report on rockfish recruitment studies at the Tiburon Laboratory. Southwest Fisheries Center Admin. Rept. T-85-02, 19p.

Methot, R. D., Jr. 1983. Seasonal variation in survival of larval northern anchovy, Engraulis mordax, estimated from the age distribution of juveniles. Fish. Bull., U. S. 81(4):741-750.

Norton, J. 1987. Ocean climate influences on groundfish recruitment in the California current. In B. R. Melteff (ed.), Proceedings of the International Rockfish Symposium, p. 73-98. University of Alaska, Alaska Sea Grant Report No. 87-2.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames, Iowa. 593 p.

Whipple, J. A. (ed.). 1988. Progress in rockfish recruitment studies. Southwest Fisheries Center Admin. Rpt. T-88-01, 40p.

Wilcoxon, F., and R. A. Wilcox. 1964. Some rapid approximate statistical procedures. Lederle Laboratories, Pearl River, N. Y. 60 p.

Wyllie Echeverria, T., and W. H. Lenarz. In prep. Survey of the abundance and distribution of pelagic young-of-the-year rockfishes off central California. NOAA Tech. Report.