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PROGRESS IN ROCKFISH RECRUITMENT STUDIES

By

Staff of the Tiburon Laboratory

ADMINISTRATIVE REPORT T-88-01

PROGRESS IN ROCKFISH RECRUITMENT STUDIES

Staff of the Tiburon Laboratory
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INTRODUCTION

Rockfishes (Sebastes sp.) make up a major portion of the groundfish fishery. As in other fisheries, year classes have varied in abundance resulting in problems for management. Understanding the causes of variation in recruitment presents a challenge to fishery scientists. The NMFS Tiburon Laboratory has been engaged in research designed to measure such variation early in the life cycle of rockfishes, and to determine some of its causes. Research objectives have been addressed in four general approaches that focus on different methods and on different ontogenetic stages.

The Physiological Ecology group has been assessing the condition and reproduction of adult fish. Their results will, among other things, help to determine how variation in reproductive performance affects variation in recruitment. Two studies address pelagic young of the year prior to settlement to post-pelagic habitats. One study, conducted largely by the Groundfish Analysis group, examines the distribution and abundance of pelagic juveniles using midwater trawl surveys. This project is also relating life history traits such as age, growth, and diets of pelagic juveniles. In another study, Groundfish Communities researchers are examining the occurrence of pelagic juveniles in the stomachs of a major coastal predator, the King salmon, in order to evaluate the use of predator stomach contents as an index of year class strength. Finally, members of the Groundfish Communities Investigation are using underwater observations to assess the abundance and distribution of postpelagic juveniles in nearshore habitats.

Previous administrative reports (Lenarz and Moreland 1985, Hobson et al. 1986, Staff of the Tiburon Laboratory 1987) presented the overall objectives, general methods, and previous results of the different tasks. This report provides an update of ongoing research during the last research year.

GROUNDFISH PHYSIOLOGICAL ECOLOGY INVESTIGATIONS

In October 1985, the Physiological Ecology Investigation staff initiated a task entitled the Physiological Ecology of Pacific Groundfishes. Research, consisting of integrated, multi-disciplinary studies, was designed to examine functional relationships between groundfishes and their environments. The emphasis was on determining the ability of individual populations to grow, reproduce, and survive in their environment. Both inherent and environmental factors directly affect these processes by influencing fish condition and reproduction. Understanding the factors which determine fish condition and subsequent reproductive effort and success contributes to our ability to assess the health of the stock and ultimately to forecast recruitment in the population.

Studies included monthly field collections and laboratory analyses designed to assess condition and reproduction of three species of rockfish (yellowtail, Sebastes flavidus, bocaccio, S. paucipinis, widow, S. entomelas). Fish were collected from Cordell Bank off northern California. Methods for collecting fish and analyzing samples were given in a previous report (Staff of Tiburon Laboratory 1987). Because of relative commercial importance and suitability for experimentation, initial emphasis was on yellowtail rockfish. Recently, three years of monthly sampling (April 1985 through March 1988) was completed. This report presents some of the results of studies on this species.

Progress in Assessments of Adult Physiological Condition

Field-caught rockfish specimens were given comprehensive examinations which included analyses at whole animal, organ, tissue, cellular and subcellular levels of biological organization. The following results are for 437 yellowtail rockfish ranging from 4 to 45 years of age. There were 340 females and 97 males; 41 immature and subadults and 396 adults.

Initial descriptive statistics and factor analysis of selected data were run on all fish to determine the interrelationships of variables. In brief, the major findings from this study show that approximately 77% of the variability in the data was accounted for by 8 factors associated with variables linked in order to body and liver conditions, age, wet weight, season, fat in the liver and mesenteries, year, sexual maturity and the presence of melanomas.

Covariance analyses were then performed to answer the following questions:

1. What is the effect of age and sex on fish condition? Is there evidence for senescence in older fish?

2. Are there seasonal differences in fish condition?

3. Are there interannual differences in fish characteristics which might relate to annual juvenile abundance and future recruitment?

Several characteristics of the fish varied with age as indicated with asterisks in Table 1. In particular, besides the expected increases in organ weight with age, older fish were found to have higher incidences of parasites and disease. The parasites discussed in this report were described previously (Staff of Tiburon Laboratory 1987). Results indicate that fungus Ichthyophonus sp. and melanoma tumors may affect growth and condition of yellowtail rockfish from Cordell Bank. Analyses showed that older fish were significantly more parasitized by fungus and had more melanomas than younger fish.

Table 1. List of variables selected for factor analysis, covariance and regression analyses and their unadjusted means and standard deviations. N = 487 yellowtail rockfish collected from 1985 to 1988; ages range from 4 to 45 yrs.; 41 Immature and Subadult, 396 Adult. Females = 340; Males = 97. *Significant effect of age (P<0.05).

VARIABLE	MEAN	STANDARD DEVIATION
Time		
Year (1 to 3)		
Season (1 to 4)		
Inherent Factors		
Life Stage (1-3)	3.0	0.15
Sex (1 - 2)	1.2	0.37
Age (4-45 yrs)	17.1	7.2
Condition Factors		
* Total Wet Weight (gms)	1412.	388.
Body Condition (KSL)	2.62	0.30
(K3)	2.36	0.24
* Liver Wet Wt (gms)	26.2	13.3
* Mesenteric Fat Wt (gms)	10.5	9.4
* Mesenteric Fat Rank (1-5)	3.0	1.2
* Liver Condition (LSI-1)	1.93	0.69
(LSI-2)	2.23	0.77
Mesenteric Fat Condition		
* (MFI-1)	0.73	0.55
(MFI-2)	0.92	0.65
(MFI-3)	36.6	23.1
Gonad Maturity Rank (1-7)	4.87	1.92
* Wet Weight Gonads (gm)	30.1	57.8
* Gonad Condition (GSI-1)	2.04	3.50
(GSI-2)	2.54	4.57
* Fecundity (Eggs/fish)	580,287	271085
Parasites & Diseases		
* Melanomas (Tot score; 8-72)	8.9	5.1
* Protozoans-Heart (Sev 1-6)	2.0	1.2
* Fungus-Spleen (Nodules)	14.8	11.0
* Fungus-Spleen (Sev 1-5)	3.0	1.0
* Cestodes (Sev 1-5)	1.8	1.3
* Nematodes (Sev 1-5)	2.9	2.5
Serum Nutrient Condition		
Glucose (mg/dl)	14.2	11.2
* Fatty Acids (Free)(Eq/l)	580.	359.
* Triglycerides (mg/dl)	423.	321.
Cholesterol (mg/dl)	197.	83.
* Phospholipid (mg/dl)	637.	187.
* Free Amino Acids (mmol/l)	3.40	0.95
Protein (Total) (g/dl)	4.42	0.74

Table 1. (Continued)

Definitions:

Year: 1 = April 1, 1985-March 30, 1986
2 = April 1, 1986-March 30, 1987
3 = April 1, 1987-March 30, 1988

Season: 1 = Spring (March, April, May)
2 = Summer (June, July, August)
3 = Fall (September, October, November)
4 = Winter (December, January, February)

Life Stage: 1 = Immature; 2 = Subadult; 3 = Adult

Sex: 1 = Female; 2 = Male

KSL = Total wet wt fish/Standard length**3 X 100
K3 = Total wet wt fish - Fisceral wet wt/Standard length**3 X 100

Rank or Severity: 1 = Absent; 2 = Scarce; 3 = Average;
4 = Abundant; 5 = Very Abundant

The following indices are percentages:

LSI-1 = Wet wt liver/Wet wt fish X 100
LSI-2 = Wet wt liver/Wet wt fish-Visceral wet wt fish X 100
MFI-1 = Wet wt mesenteric fat/Wet wt fish X 100
MFI-2 = Wet wt mesenteric fat/Wet wt fish-Visceral wet wt fish X 100
MFI-3 = Wet wt mesenteric fat/Wet wt liver X 100
GSI-1 = Wet wt gonads/Wet wt fish-Visceral wet wt fish X 100
GSI-2 = Wet wt gonads/Wet wt liver X 100

There was also a significant relationship of greater fungus infections with reduced mesenteric fat and body condition. It appears that variables related to age show effects of parasites and reduced condition beginning at about age 30.

Differences between sexes were relatively insignificant. There was no significant difference in age, but males were smaller than females. Most differences were related to seasonal variation between the sexes in maturation stages. There were no significant differences between sexes in parasitization by fungus or in incidence of melanomas.

Significant seasonal differences occurred with nearly every variable, and seasonal patterns varied among the three years sampled. Further analyses will determine the effects of seasonal variability on effective reproduction. It appears that seasonal patterns in several condition factors may be important in determining reproductive success.

The adjusted yearly means of variables tested are summarized in Figures 1-3. the means were tested for significance of differences among years and seasons (two - factor model), after first removing the effects of the covariates of stage, age and sex. In general, data showed that fish in the first year (1985-86) varied significantly from fish collected in the subsequent two years (1986-87 and 1987-88). Figure 1 shows that fish sampled during the first year of the study (1985-86) had significantly greater mean age and wet weight than in the second and third years. Figure 2 shows that fish sampled in 1985-86 also had significantly lower liver condition than fish from 1986-87. On the other hand, mesenteric fat appeared to be higher in 1985-86 fish than those collected from 1986-87. Fish collected this year also had higher mean mesenteric fat than 1986-87.

Figure 3 shows that although fish were of equivalent maturity in all three years, GSI indices were much higher in 1985-86 than in the last two years. This is probably a function of the older age of fish in the first year. Figure 3 indicates, however, that fish had significantly lower total gonad weight in 1985-86 as well as being slightly less fecund. There was an indication of higher percent abnormality of eggs in females in 1985-86, but sample size was too small to be significantly different.

Finally, the results so far are equivocal and additional years of sampling are necessary to come to conclusions about which characteristics are best predictors of reproductive success in yellowtail rockfish. There is an indication that the older age distribution of the fish sampled in the first year and the other significant differences in fish sampled in that year(1985-86) may relate to the lower year-class abundance observed by other tasks in 1986 than in 1987.

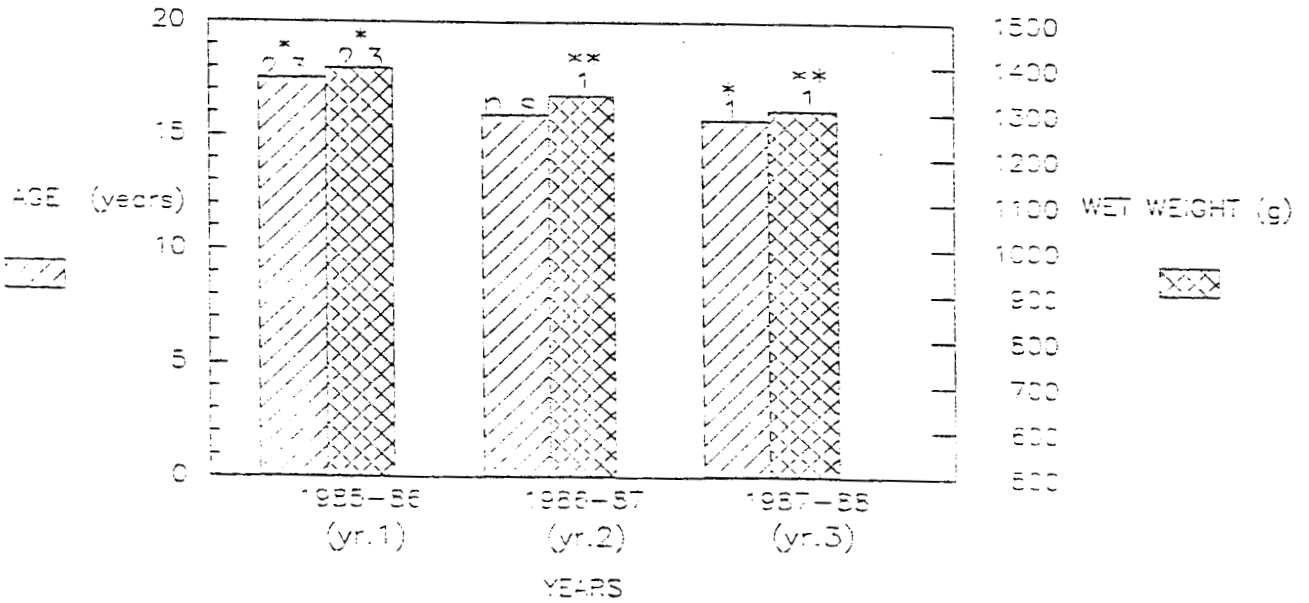


Figure 1. Yearly adjusted means of age and wet weight after removing the effect of sex. Notation over each bar indicates significance of difference between means of years using covariance analyses followed by range tests. * = P<.05, ** = P<.01.

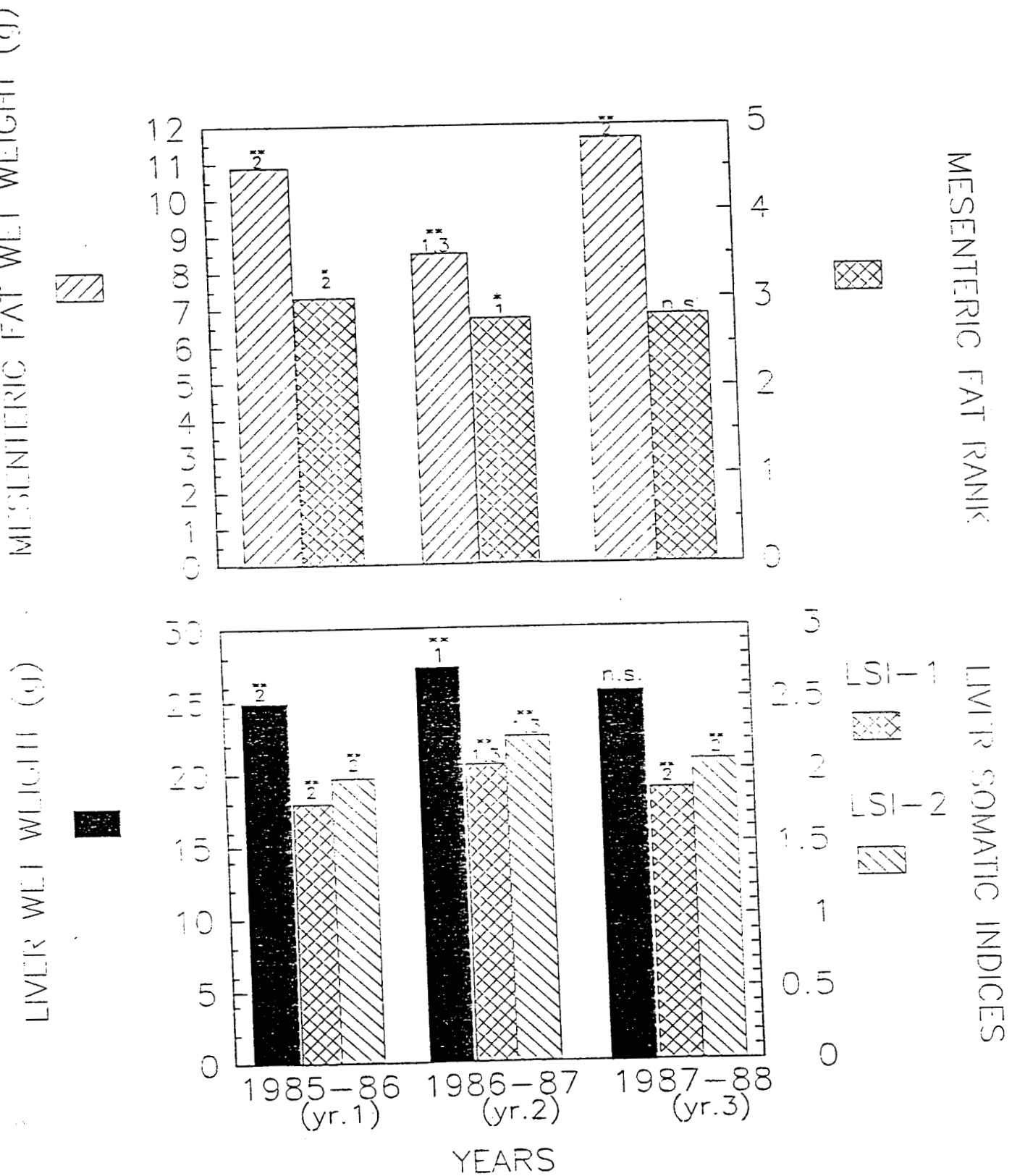


Figure 2. Yearly adjusted means of liver wet weights and mesenteric fat wet weights and ranks after removing the effects of life stage, age and sex. Notation over each bar indicates significance of difference between means of years using covariance analyses followed by range tests. * = P<.05, ** = P<.01.

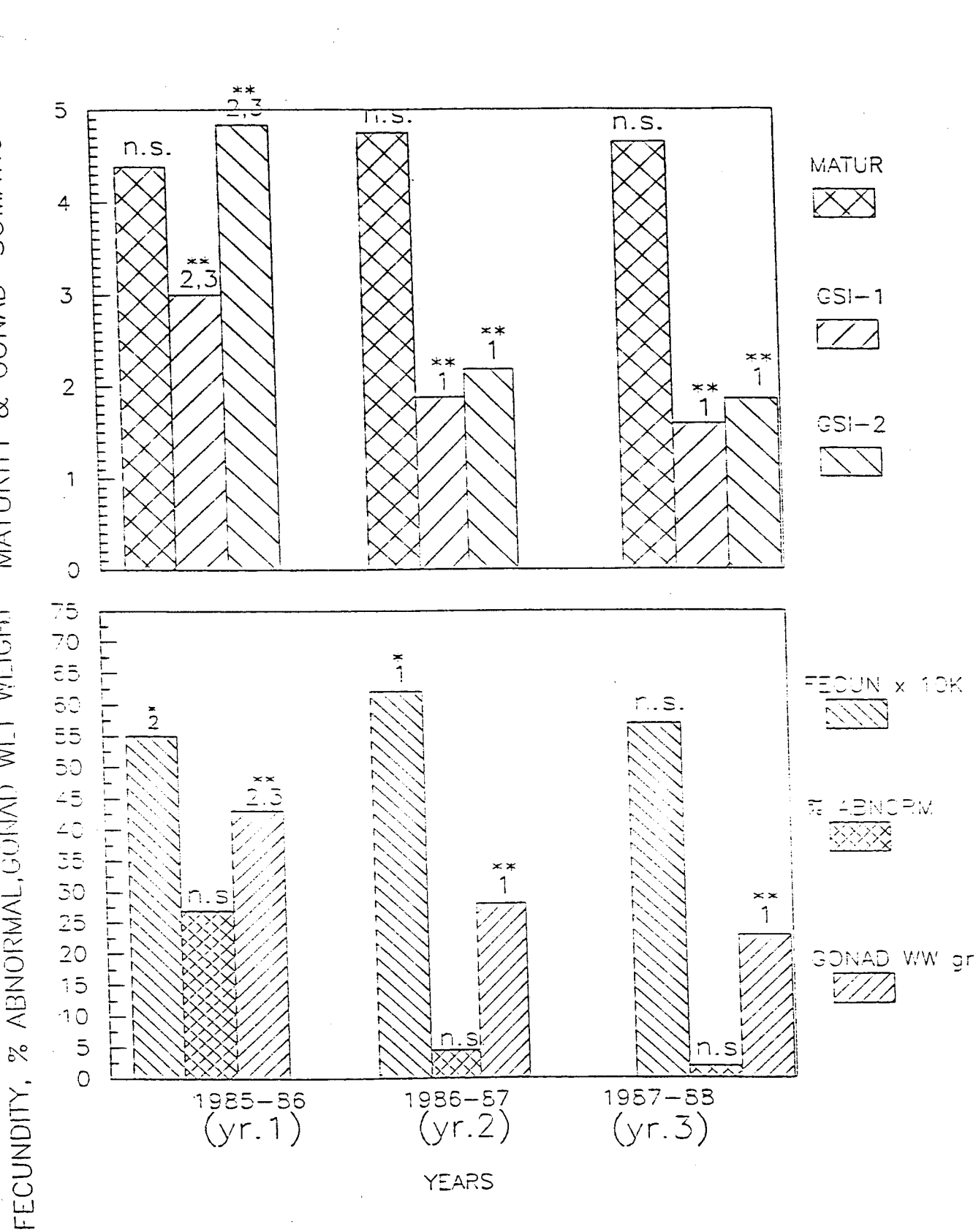


Figure 3. Yearly adjusted means of maturity stages, gonado-somatic indices, fecundities, percent abnormal eggs, and gonad wet weights after removing the effects of life stage, age and sex. Notation over each bar indicates significance of difference between means of years using covariance analyses followed by range tests. * = P<.05, ** = P<.01

Progress in Histological Analyses of Yellowtail Rockfish Ovaries

Histological analyses of monthly samples from the 1986-87 yellowtail rockfish reproductive season confirmed those observations reported for the previous reproductive cycle (1985-1986). Oocytes of S. flavidus were accurately classified using the staging system established for the 1985-86 reproductive season. Because of variation in shrinkage due to fixation and overlapping egg diameters, oocyte diameter measurements were found to be an inaccurate method for staging oocytes. Therefore, emphasis was placed on histological appearance and morphological structure to classify developmental stages for both years.

Temporal occurrence of oocytes and oocyte frequency distributions showed similar seasonal patterns between the two reproductive cycles found during 1985-86 and 1986-87. February and March appeared to be the months of peak parturition for both years.

Histological data from 1985-86 samples suggested that the Cordell Bank population of yellowtail rockfish produced two overlapping,but distinct batches of larvae. Oocytes in Stage V (tertiary yolk accumulation) were observed in some females concurrently with females in spent to recently parturitioned conditions. Estimates of final egg maturation and embryonic gestation indicated approximately 40 to 60 days between parturition dates of these two groups. Similarly, this occurrence was noted for the 1986-87 reproductive season. In addition, for both reproductive seasons the arrival of two size modal groups of yellowtail juveniles (based on two distinct size classes) was reported by divers from the Groundfish Communities Investigation in their nearshore habitat survey. Since histological samples were taken from the Cordell Bank and juvenile observations were in coastal northern California, it is tempting to speculate that this occurrence is a coastwide characteristic of yellowtail rockfish reproduction. Observations at the cellular (oocyte) and organismal (juvenile) levels suggest a prolonged reproductive season for yellowtail rockfish. Additionally, histological staging of oocytes appear to be useful in predicting the occurrence of distinct batches of juveniles prior to their arrival and occupation of nearshore habitats.

Temporal difference between parturient female yellowtail rockfish may be explained by age. Table 2 lists the distribution of gonadotropin-dependent egg stages (stage III through IV) and the predominant months of synchronous egg development in which they occurred. These various stages of development are listed with the mean ages of adults which composed the monthly samples. In all observations (with the exception of one female), older fish were in more advanced stages of egg development than younger females. Although sample size is insufficient for statistical analysis, the general trend that ova and larvae mature earlier in older fish appears consistent for both years. Since older fish are more fecund and appear from the data to spawn earlier than younger fish, their contribution to the population is vital.

Table 2.--Monthly distribution of the most advanced egg stage(s) observed histologically, and the mean age in years, +/- standard deviation and sample size (n) of adult female yellowtail rockfish within monthly samples. (III, Late perinucleolus; IV, Primary yolk accumulation; V, Tertiary yolk accumulation; VI, Migratory nucleus; E/L, embryo/ larval stages; SPT, spent gonad; R/D, recovering/devel- oping gonad.)

MONTH	EGG STAGE	1985/1986		1986/1987	
Jul	III	8.5 +/-2.67	(4)	17.2 +/-5.2	(10)
Aug	III			12	(1)
	IV	14.2 +/-4.4	(4)	14.4 +/-5.1	(3)
Sep	IV	20	(1)	9.2 +/-1.7	(6)
	V	31.7 +/-4.8	(4)	19.0 +/-6.0	(4)
Oct	III	15.2 +/-5.7	(2)		
	V	30.0 +/-12.6	(6)	21.2 +/-5.7	(10)
Nov	V	22.2 +/-7.3	(5)		
Dec	V	16.0 +/-6.3	(5)	18.4 +/-7.5	(11)
	VI	24.3 +/-5.8	(3)		
Jan	V	12.7 +/-3.1	(6)	8.9	(2)
	VI			17.0 +/-4.1	(4)
	E/L	15.3 +/-1.1	(3)	20.5 +/-3.4	(4)
	SPT	28	(1)		
Feb	V	11.5	(2)	10.3 +/-7.5	(3)
	VI	11	(1)	19	(1)
	E/L	17.0 +/-5.5	(6)	12	(1)
	SPT			26	(1)
Mar	VI	14.5	(1)		
	R/D	19.2 +/-6.4	(4)	23.0 +/-9.6	(3)
Apr	III	23.4 +/-7.0	(10)	12.3 +/-3.8	(9)
	R/D			9	(1)

Progress in Estimates of Fecundity of Yellowtail Rockfish

A third year was completed in the study of factors relating to fecundity in three species of northern California rockfishes (S. flavidus, S. entomelas, and S. paucipinis). By March 1988, 175 yellowtail, 64 widow, and 101 bocaccio rockfishes have been collected to enable us to determine their physiological and reproductive conditions relative to their reproductive capacities. Fecundities were estimated by gravimetric methods. Since in-depth physiological studies have focused on yellowtail rockfish this report is limited to preliminary results on that species.

Major differences were found in the mean ages, sizes and standard lengths of females over the three years (Table 3). Fish steadily declined in ages, total wet weights, and standard lengths. The causes for this reduction to younger, smaller size composition of the population are unknown. If accurate, this has implications for management.

Despite the above differences in ages and sizes over the last three years, no differences were observed in age-specific, weight-specific, or length-specific fecundities (Figure 4). The logarithmic equations describing these relationships are presented in Table 4. The best correlations were observed between total weight and fecundity, followed by age and length.

Results indicate that, even though age and size specific fecundities have not changed in yellowtail rockfish, the total population fecundity may have declined due to the decrease in the age/size composition of the population.

Also associated with the increased numbers of younger-smaller, less fecund fish has been a reduction in the proportion of fish observed with fertilized eggs (1985-86 = 40.1%,1986-87 =27.7%,1987-88 = 12.8%). While younger fish spawn and release young at later dates than older fish (see previous discussion), the effect of this reduction in fertilized eggs remains unclear.

Abnormalities and/or malformed embryos and larvae continued to compromise a significant portion of the spawning population (40%). Incidences in previous years were 55.5% and 42.5%. Sampling techniques were designed to eliminate post-mortem effects suggesting that the observed frequencies of observed malformed eggs were accurate.

Table 3. Mean ages, standard lengths and wet weights for fish sampled for three reproductive years in the fecundity study. S.D. = Standard Deviation.

	1985-86	1986-87	1987-88	All Yrs
Age (Yrs)				
Mean, S.D.	18.6±5.8	17.2±7.8	13.4±7.2	15.8±8.3
Range	9-31	6-48	5-36	5-48
Standard Length (cm)				
Mean, S.D.	38.6±3.2	37.8±3.7	34.7±4.3	36.6±4.2
Wet Weight (g)				
Mean, S.D.	1557±317	1484±389	1187±446	1365±438

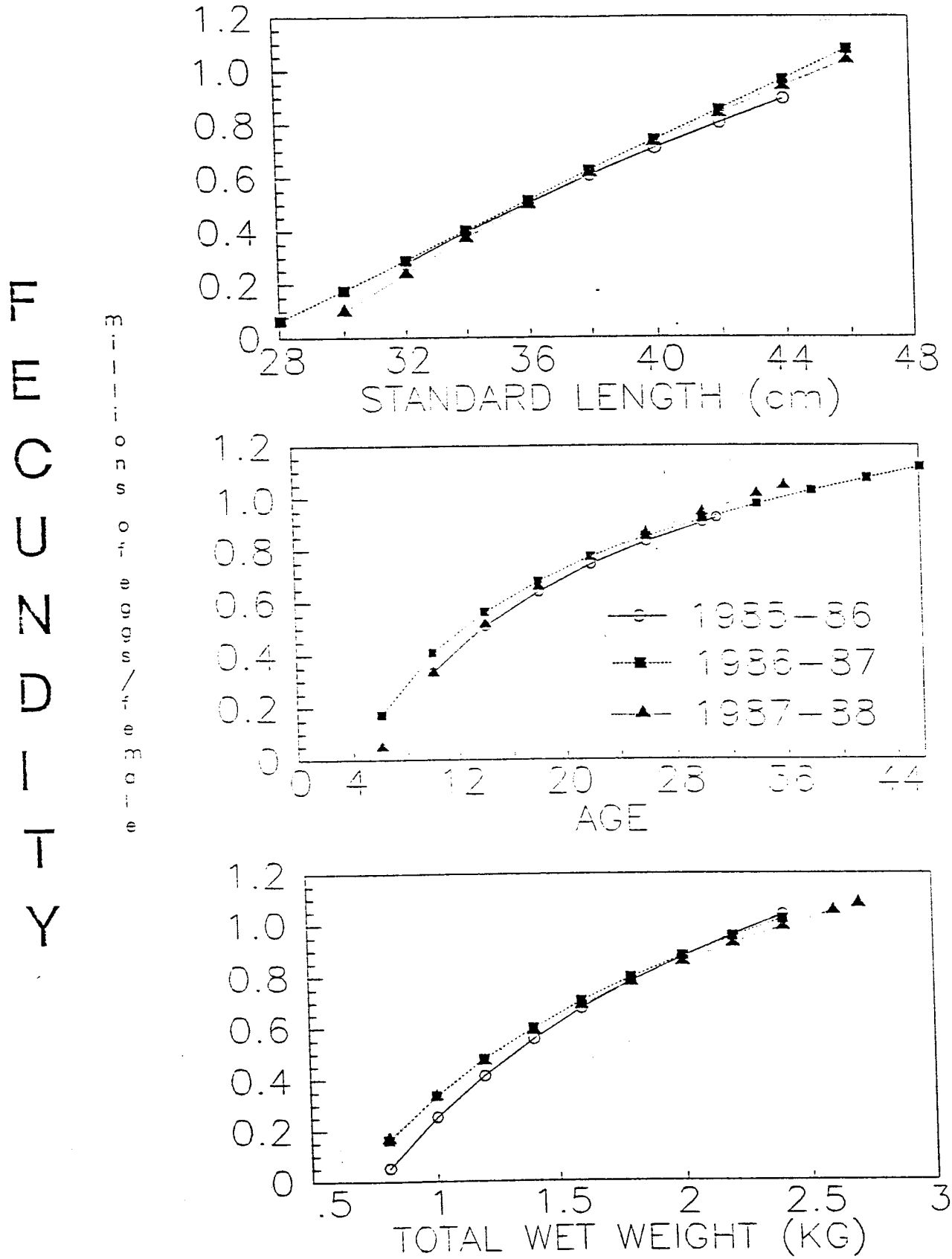


Figure 4. Fecundity of yellowtail rockfish in relation to age, total wet weight, and standard length.

Table 4. Equations describing the relationship of fecundity to age, standard length and wet weight. Y = a + lnX; X = fecundity in number of eggs/female; Y = age (yrs), standard length (cm) or wet weight (g).

	Age	Standard Length	Wet Weight
(1) (1985-1986)	Y= -862425+519369lnX r^2 = .58	Y= -6431700+1935294lnX r^2 = .54	Y= -5933884+895536lnX r^2 = .73
(2) (1986-1987)	Y= -657994+462793lnX r^2 = .69	Y= -1513015+ 56296lnX r^2 = .67	Y= -5066377+ 78197lnX r^2 = .80
(3) (1987-1988)	Y= -948874+555887lnX r^2 = .79	Y= -7367068+2194874lnX r^2 = .74	Y= -4840657+749150lnX r^2 = .85

Progress in Studies of Nutritional Aspects of Reproductive Development

Environmental factors and nutrition play important roles in the timing and success of teleost reproduction. This understanding comes mainly from studies on oviparous species; little is known on the relationship of nutrient dynamics and reproductive development in viviparous teleosts.

Investigation of temporal patterns of serum nutrients in adult female yellowtail rockfish during the period that included two reproductive cycles from April 1985 through August 1987, revealed a sequence of specific nutrient profiles that correlated with specific developmental events. Although there were differences in concentrations of serum nutrients between cycles, a generalized, consistent annual pattern was evident for the two years (Fig.5).

During March, April, and May, following parturition, most serum nutrient concentrations were low. Mesenteric fat deposits and liver lipids, the main form of energy storage in Sebastes, were also depleted during this period and reflect low food abundance and prior utilization by the female for reproductive development and maintenance. As food abundance and feeding activity increased from May through June and July lipid accumulated in the liver and mesenteries. Serum lipid (triglycerides, cholesterol, phospholipids) and protein (albumin, globulins) concentrations increased, reflecting increased feeding and metabolism.

During the summer months, female yellowtail rockfish were in a nutritionally charged state, evidenced by high tissue lipid levels and elevated serum nutrients. This period (particularly June and July) appeared to be a critical time for energy accumulation needed for subsequent maintenance and reproductive development. If food abundance is low during the summer, such as may occur during an El Nino, the pattern emerging from this study suggests that reproductive success would be jeopardized.

In July, oocytes in stage III (late perinucleolus) progressed into stage IV (primary yolk accumulation) and on to stage V (tertiary yolk accumulation). Ovarian recrudescence correlated with increased blood transport of glucose, albumin, protein, triglycerides, and vitellogenin (Table 6). Elevated serum nutrients along with vitellogenin, serve the energy requirements of the female and the developing oocytes as well as provide material for tissue synthesis in the ovary. The structural lipids, cholesterol and phospholipids were mobilized during the early stages of oocyte vitellogenic growth (September through November)and decline in concentrations during the period of the most rapid ovarian growth. It is probable that lower serum cholesterol and phospholipids during December and January were due to high utilization rates for membrane synthesis in ovarian and oocyte tissues. As the oocytes developed there were diminishing lipid reserves, evidenced by declining mesenteric fat

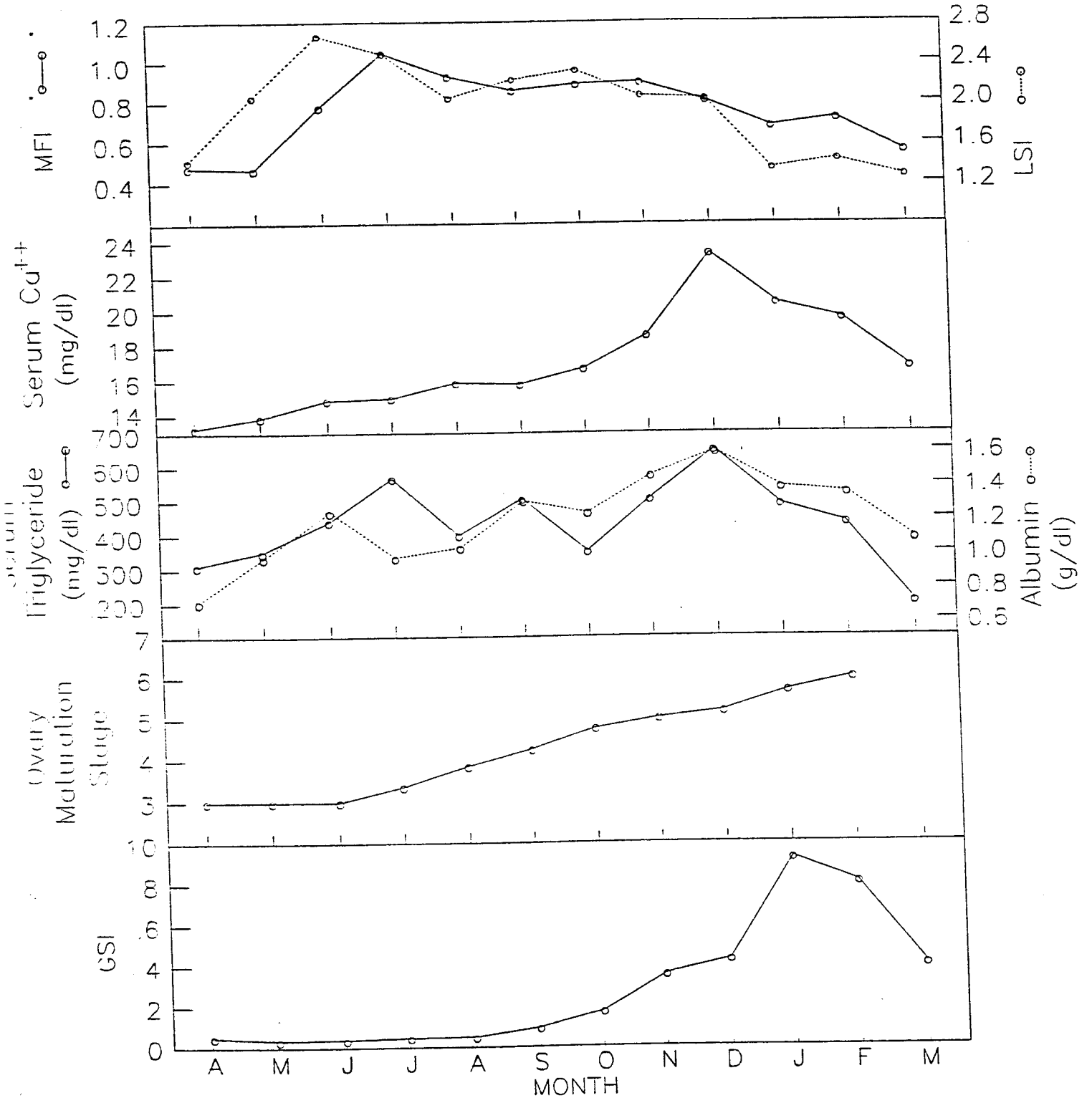


Fig. 5 Mean monthly values of some selected nutritional and reproductive variables in female yellowtail rockfish (Sebastes flavidus) from Cordell Bank illustrating interrelationships between these factors. Data are monthly means from April 1985 to April 1987. Ovary maturation stage is the monthly mean value of the most advanced oocyte stage within ovaries of each individual; serum Ca^{++} is a surrogate for vitellogenin (see text); MFI is the mesenteric fat index and LSI is the liver somatic index (both defined in footnotes of Table 1); GSI is the gonadosomatic index = [wt of ovaries(g)X100/body wt(g)].

Table 5. Correlations between nutritional and reproductive variables in female yellowtail rockfish (*Sebastes flavidus*) from Cordell Bank between April 1985 and August 1987.

Variable	GSI (n 225)	Ovary Maturation Stage (n 130)	% Stage V Ova (n 130)	% Stage VI Ova (n 130)	Fecundity (n 49)
Serum nutrient					
Glucose	0.17**	0.34***	0.29***	0.07	-0.26
Free Fatty Acids	0.04	0.12	-0.07	0.15	-0.03
Triglycerides	-0.03	0.35***	0.21**	0.28***	0.04
Cholesterol	-0.20**	0.18*	0.15	0.05	0.14
Phospholipids	-0.03	0.16	0.13	0.11	-0.01
Free Amino Acids	-0.15*	-0.15	-0.14	-0.05	0.24
Protein	-0.10	0.31***	0.35***	-0.02	0.08
Albumin	0.23***	0.55***	0.54***	0.20*	0.03
Calcium	0.39***	0.60***	0.58***	0.22**	-0.18
Tissue lipid indices					
LSI[1]	-0.39***	-0.02	0.07	-0.18*	0.12
MFI[2]	-0.03	0.10	0.11	0.03	0.03

*** $P<0.001$
** $P<0.01$
* $P<0.05$

1 LSI=liver somatic index [liver wt(g)X100/body wt(g)]
2 MFI=mesenteric fat index [mesenteric fat wt(g)X100/body wt(g)]

and liver somatic indices, and increasing serum triglyceride transport which was correlated to serum Ca++. The annual cycle of serum Ca++ was very stable between years with the maximum co-occurring with serum triglycerides and albumin maxima and preceding the maximum ovary size (GSI) by one month and parturition by three months. Both hepatic vitellogenin synthesis and triglyceride transport are promoted by estradiol, the primary estrogen in teleosts. Analysis of the serum estradiol annual rhythm, proposed for study next year, should provide an earlier estimate of the timing of reproductive events than Ca++, presently the best predictor.

GROUNDFISH ANALYSIS INVESTIGATIONS

Progress in Offshore Midwater Trawl Studies

The 1987 midwater-trawl sampling of pelagic age-0 juvenile rockfishes was organized much as in 1986, with temporally-replicated "sweeps" of all stations in the study area (Fig. 6). A full sweep of the area was carried out in April, facilitating the examination of seasonal trends in abundance and the comparison with 1985 and 1986 samples taken in the Gulf of the Farallones by the Groundfish Communities Investigation. Three sweeps of the area were carried out between May 23 and June 21. Additional stations (not illustrated in Fig. 6) were established on and near Cordell Bank (38° 00' N, 123° 24' W) and Pioneer Seamount (37° 20' N, 123° 25' W) to investigate the influence of banks on the abundance of pelagic juveniles. Additional oceanographic information was also gathered during the 1987 cruises. CTD casts were made at each trawl station and in the areas between station lines, and near-continuous records of temperature and salinity at 2 m of depth were automatically stored on the ship's computer.

This report summarizes information on the (a) bathymetric distributions, (b) seasonal occurrence, and (c) interannual variation in abundance of pelagic juvenile rockfishes sampled by midwater trawl in the years 1983-1987.

Bathymetric Distributions

Bathymetrically-stratified hauls were made at 36 stations in 1987, substantially expanding the pool of data on the vertical distributions of pelagic juvenile rockfish. Standard tows at most stations are targeted for a headrope depth of about 30 m, and at stations in shallow water they are targeted for a depth of 4- 10 m. The footrope hangs 12.5 m below the headrope. At about one station per night, tows targeting as many as three depths (about 10 m, 30 m, and 100 m) are made. To analyze the bathymetric distributions of selected species, catches were compared pairwise between 10 m and 30 m hauls, and 30 m and 100 m hauls conducted at the same stations. Hauls from different years were treated as equivalent, except that data were dropped for cruises in which a species was rare or absent.

Of the ten species analyzed, seven showed a significant difference in abundance with depth, and two others showed substantial, if non-significant, differences (Table 6). The species ranged from shallow-tending to deep-tending, in roughly the order of their appearance in Table 6. S. paucispinis was the shallowest of the species, being slightly (non-significantly) more abundant at 30 m than 10 m, and significantly more abundant at 30 m than 100 m. Two species, S. jordani and S. auriculatus, showed non-significant increases in abundance from 10 to 30 m, and non-significant declines from 30 to 100 m. S. goodei,

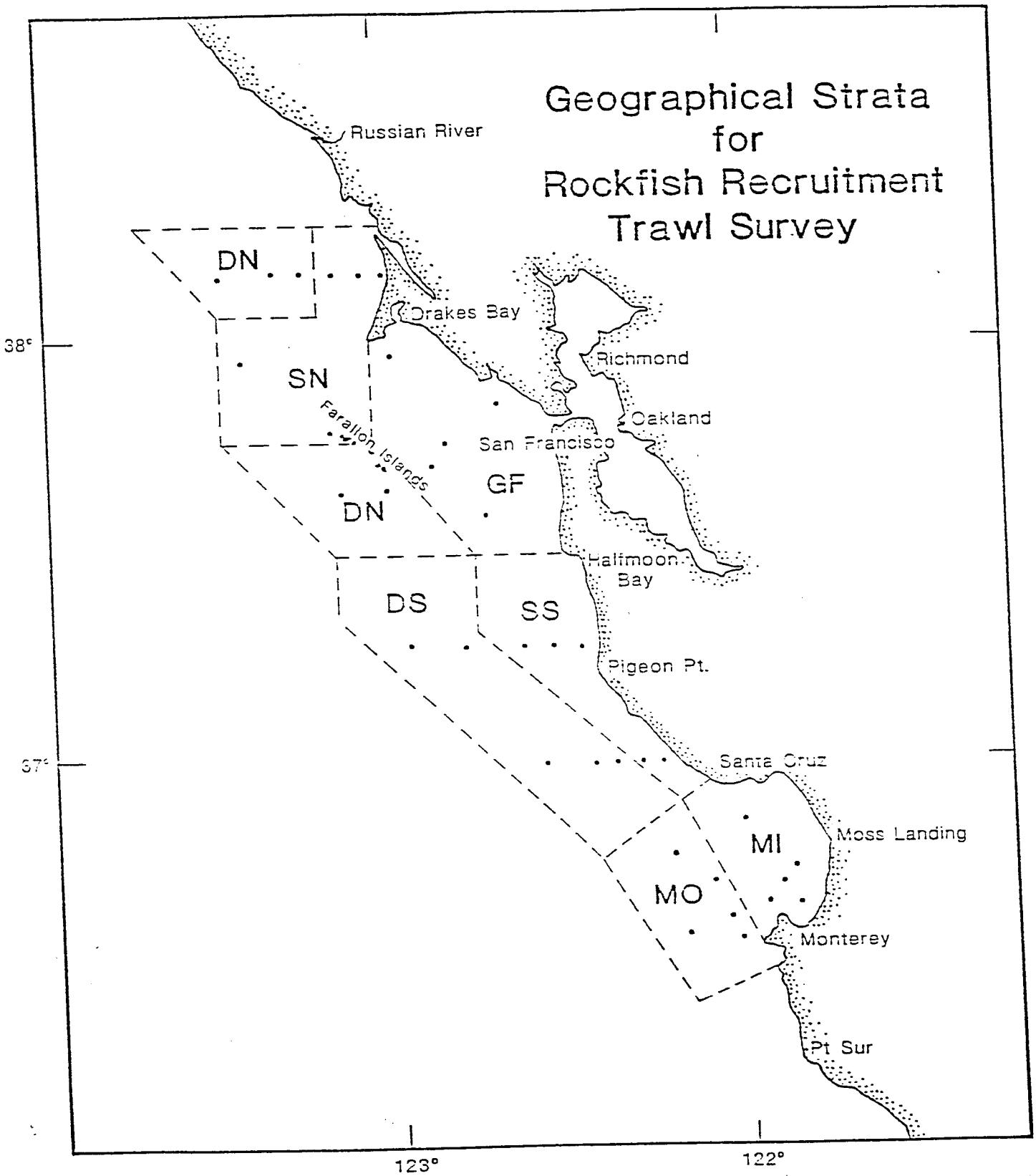


Figure 6. Locations of midwater trawls stations (points), and their groupings for statistical analysis (dashed lines). Codes for geographical strata: DN and DS = Deep North and Deep South, SN and SS = Shallow North and South, MI and MO = Monterey Inside and Outside.

Table 6. Comparison of catch rates of pelagic age-0 rockfishes in bathymetrically-stratified midwater trawls, 1984-1987. Catches were transformed to ln(x+1). Shown are (a) the overall means of catches in trawls targeting approximately 10 m, 30 m, and 100 m of depth when more than one trawl was made at a station, and (b) comparisons of paired tows at 10 m and 30 m, and 30 m and 100 m of depth. In the latter category, the mean difference of log-transformed counts in N comparisons between the the shallower and deeper depth is shown, along with the significance levels (P values) of a paired-comparison t-test (t) and a signed ranks test (SR). P values smaller than 0.05 are underlined.

				Paired Comparisons							
	Mean Catch at Depth			10 m - 30 m				30 m - 100 m			
					Mean	P values			Mean	P values	
Species	10 m	30 m	100 m	N	Diff.	t	SR	N	Diff.	t	SR
S. paucispinis*	0.66	0.81	0.47	37	0.13	.46	.42	31	0.37	.02	.04
S. jordani	1.61	2.06	1.44	47	-0.29	.18	.18	41	0.32	.14	.15
S. auriculatus*	0.04	0.31	0.18	37	-0.10	.14	.17	31	0.21	.06	.06
S. goodei*	0.62	0.84	0.53	37	-0.25	.03	.04	31	0.15	.29	.23
S. saxicola*	0.11	0.38	0.20	37	-0.33	.01	.01	31	0.08	.44	.40
S. pinniger*	0.05	0.37	0.33	37	-0.28	.01	.01	31	-0.05	.53	.40
S. hopkinsi*	0.43	0.40	0.30	47	0.04	.70	.95	41	-0.01	.90	.99
S. flavidus**	0.27	0.32	0.46	39	-0.03	.74	.70	35	-0.31	.05	.06
S. mystinus***	0.35	0.31	0.59	46	0.04	.68	.67	37	-0.43	<.01	.01
S. entomelas	0.42	0.60	0.96	47	-0.22	.13	.14	41	-0.59	.01	.01

* Data from 1985 not used because S. paucispinis, S. auriculatus, S. goodei, S. saxicola, and S. pinniger were absent or sparse at all depths.

** Data from April, 1987, not used because S. flavidus was absent from all samples.

*** Data from 1984 not used because S. mystinus was absent from all samples.

S. saxicola, and S. pinniger increased significantly in abundance from 10 to 30 m of depth, and did not differ much between 30 and 100 m. S. hopkinsi showed little tendency to differ in abundance with depth. S. flavidus, S. mystinus, and S. entomelas all increased significantly in abundance from 30 to 100 m. Catches of S. flavidus and S. mystinus were relatively low at both 10 and 30 m of depth, while the abundance of S. entomelas tended to increase progressively with depth.

The biological significance and and proximate causes of these differing bathymetric distributions remains to be determined. When these are considered, it will be interesting to note some apparent exceptions to the general pattern. There are a few instances in which two or more stations in an area differ strongly from the norm, with, say, nearly all species being much more abundant near the surface or all species being much more abundant in deeper water. At the moment we do not know what makes these areas distinctive.

Despite differences between depths, catches at different depths at the same station were often correlated (Table 7), suggesting that catches at different depths often varied in parallel between stations. Catches at 30 and 100 m of depth were significantly correlated in 9 of 10 species examined, in spite of frequent pairwise differences in counts. Correlations between catches at 10 and 30 m were less strong, significant values being largely limited to those species whose catches did not significantly differ between depths.

It appears that the standard-depth tows at 30 m (and 10 m when the water is shallow) do not seriously bias spatial and temporal comparisons of relative abundance within most species. The relatively small catches of most species at 10 m (at offshore stations) suggest that they are not usually restricted to shallow water, despite the observation of some species in the neuston (Shenker 1985). For the 7 of 10 species that were as or more abundant at 30 m than 100 m, the standard tow depth seems adequate for spatial and temporal comparisons. Standard-depth tows probably underestimate the relative abundance of the three deeper-living species, and they may affect spatial and temporal comparisons. However, two species (S. flavidus and S. mystinus) showed significant correlations between depths, so standard-depth tows may provide an accurate index of relative abundance. S. entomelas is apparently the species served worst by standard-depth tows at 30 m, since paired catches at 30 and 100 m of depth were not significantly correlated. However, seasonal and interannual differences in abundance are still apparent in this species (see below). To ensure accuracy, future analyses of spatiotemporal patterns in the three deep-living species should include analyses of catches in hauls made to 100 m of depth.

Table 7. Correlation between catches at different depths, based on bathymetrically-stratified hauls carried out at a number of stations between 1984 and 1987. Raw counts were transformed to ln(x+1) before the computation of product-moment correlation coefficients.

Species	Correlations between Depths over Stations		
	10 m vs. 30 m	30 m vs. 100 m	10 m vs. 100 m
S. paucispinis	0.31	0.80***	0.42
S. jordani	0.69***	0.79***	0.58***
S. auriculatus	0.14	0.83***	---
S. goodei	0.86***	0.74***	0.83***
S. saxicola	0.32	0.53**	---
S. pinniger	0.07	0.75***	0.46*
S. hopkinsi	0.75***	0.80***	0.72***
S. flavidus	0.44**	0.48**	0.04
S. mystinus	0.55***	0.59***	0.12
S. entomelas	0.43**	0.29	0.14

* P<.05
** P<.01
*** P<.001

Temporal Variation

The analysis of temporal (seasonal and interannual) changes in abundance presented here is based, with the exceptions noted below, upon a restricted, standardized set of data. We grouped certain stations into latitudinal/bathymetric "strata" (as in Fig. 6). For each stratum we computed the means and variances of ln(x+1)-transformed catches in tows made at standard depths. The mean over strata (the stratified mean) was used as an index of the relative abundance of rockfish species for temporal comparisons. One stratified mean was computed for each year from 1983-1985, when sampling was not stratified temporally. One stratified mean was computed for each "sweep" of the study are in 1986 and 1987. Stratified means and simple averages of catches made by the Groundfish Communities Investigation in the Gulf of the Farallones during April of 1985 and 1986 are presented in Table 8. These data are included for the analysis of seasonal patterns.

Seasonal Patterns

Overall catches of pelagic juvenile rockfish have usually declined sharply by late June. This was true in 1986 and 1987 (see Table 8 "All Species"), and was probably true in 1985 (see Larson 1987, p. 7). In 1984, however, catches remained high into late June (Larson 1987, p. 7). We attribute the usual late-June decline in abundance largely to the settlement of juveniles to the benthos, but cannot yet account for interannual differences in timing.

Species differ in the timing of their occurrence as pelagic juveniles in our study area. These differences are important, because they affect both our assessments of year-class strength and our inferences about the reasons for its variation. Based on data from April of 1985-1987 and May-June of 1986-1987 (from Table 8), we have qualitatively classified juveniles of several species of *Sebastes* as to their seasonal occurrence in midwater trawls (Table 9). Those species amenable to classification vary in two ways: in the duration of their occurrence as pelagic juveniles and in the timing of their occurrence.

Some species occur for an extended period of time in our samples. *S. pinniger*, *S. jordani*, and *S. paucispinis* were usually present in low to moderate abundance in April, and compared to other species remained moderately abundant through late June (Tables 9). Thus they occurred as pelagic juveniles for a longer time than other species. *S. mystinus*, *S. hopkinsi*, *S. entomelas*, and *S. flavidus* seemed to have shorter periods of occurrence as pelagic juveniles. Each of these species either declined rapidly in abundance during June or was relatively sparse in April, or both. They were apparently not near peak abundance in April, and passed their peak abundance early in June. The duration of occurrence of *S. wilsoni*, *S. saxicola*, and *S. goodei* is unknown, since each was usually quite abundant in April and we do not know how long they were abundant before then. Each of these species declined in abundance in June.

Table 8. Estimates of the stratified mean abundance (except where noted) of juvenile rockfishes captured in midwater trawls, 1983-1987. The strata are those illustrated in Fig. 6, except that one stratum each was left unsampled in 1983 and in the last series of samples in 1986. The total number of stations sampled during a time period is presented as an indication of sampling intensity. A single "sweep" of the study area was carried out in 1983-1985, while in 1986 and 1987 the study area was covered three times in May/June. A complete sweep of the area was also carried out in April 1987, and the Groundfish Communities Investigation gathered samples in the Gulf of the Farallons in April of 1985 and 1986. Means are based on trawls conducted at the standard depths of 30 m for most stations and 10 m for the most inshore of stations. Counts were transformed to ln (x+1), and the formulae of Snedecor and Cochran (1967, p. 520) were used to compute the stratified means and their standard errors.

	Stratified Mean Catch per Net Haul (and Standard Error)											
			1985		1986				1987			
YEAR	1983	1984										
DATES	6/8-24	6/12-27	4/10-16*	5/31-6/30	4/13-22*	6/3-11	6/11-18	6/20-25	4/10-20	5/23-6/1	6/2-12	6/12-21
STATIONS	N=18	N=25	N=18	N=37	N=22	N=33	N=28	N=28	N=34	N=33	N=34	N=33
S. entomelas	0.067 (0.067)	0.680 (0.251)	0.000 (0)	1.955 (0.2)	0.000 (0)	0.137 (0.064)	0.040 (0.028)	0.000 (0)	0.180 (0.081)	1.046 (0.178)	1.393 (0.167)	0.168 (0.073)
S. flavidus	0.099 (0.082)	0.691 (0.241)	0.000 (0)	1.075 (0.16)	0.000 (0)	0.122 (0.053)	0.201 (0.063)	0.078 (0.048)	0.000 (0)	0.188 (0.078)	0.504 (0.112)	0.272 (0.096)
S. goodei	0.000 (0)	0.656 (0.183)	1.857 (0.407)	0.364 (0.089)	0.167 (0.077)	0.345 (0.088)	0.268 (0.091)	0.092 (0.054)	1.193 (0.234)	1.327 (0.156)	0.694 (0.183)	0.357 (0.113)
S. jordani	0.180 (0.084)	1.965 (0.49)	1.175 (0.333)	2.096 (0.269)	0.171 (0.102)	1.934 (0.295)	1.938 (0.247)	0.574 (0.202)	0.948 (0.217)	2.342 (0.256)	3.235 (0.32)	1.268 (0.286)
S. paucispinis	0.000 (0)	0.846 (0.241)	0.281 (0.112)	0.180 (0.053)	0.000 (0)	0.567 (0.154)	0.482 (0.1)	0.098 (0.058)	0.207 (0.086)	0.407 (0.109)	0.445 (0.11)	0.376 (0.131)
S. pinniger	0.000 (0)	0.759 (0.258)	0.476 (0.173)	0.267 (0.081)	0.042 (0.042)	0.410 (0.084)	0.157 (0.063)	0.039 (0.039)	0.241 (0.105)	0.213 (0.065)	0.449 (0.089)	0.249 (0.092)
S. mystinus	0.000 (0)	0.000 (0)	0.102 (0.070)	1.033 (0.134)	0.276 (0.119)	0.071 (0.04)	0.000 (0)	0.000 (0)	0.105 (0.053)	0.958 (0.148)	0.720 (0.149)	0.000 (0)
S. hopkinsi	0.000 (0)	0.350 (0.132)	0.000 (0)	0.650 (0.137)	0.042 (0.042)	0.051 (0.037)	0.020 (0.02)	0.000 (0)	0.099 (0.05)	0.902 (0.128)	0.505 (0.132)	0.020 (0.02)
S. saxicola	0.000 (0)	0.205 (0.081)	0.323 (0.141)	0.077 (0.047)	0.202 (0.099)	0.040 (0.028)	0.000 (0)	0.000 (0)	0.534 (0.1)	0.821 (0.146)	0.182 (0.059)	0.031 (0.031)

(continued)

Table 8 (continued)

	Stratified Mean Catch per Net Haul (and Standard Error)											
YEAR	1983	1984	1985			1986			1987			
DATES	6/8-24	6/12-27	4/10-16*	5/31-6/10	4/13-22*	6/3-11	6/11-18	6/20-25	4/10-20	5/23-6/1	6/2-12	6/12-21
STATIONS	N=18	N=25	N=18	N=37	N=22	N=33	N=28	N=28	N=34	N=33	N=34	N=33
S. auriculatus	0.000 (0)	0.295 (0.12)	1.981 (0.382)	0.000 (0)	0.000 (0)	1.091 (0.177)	0.749 (0.182)	0.256 (0.103)	0.277 (0.078)	0.045 (0.032)	0.091 (0.046)	0.059 (0.096)
S. melanops	0.000 (0)	0.000 (0)	0.000 (0)	0.161 (0.053)	0.000 (0)	0.020 (0.02)	0.000 (0)	0.000 (0)	0.000 (0)	0.091 (0.041)	0.185 (0.068)	0.064 (0.037)
S. crameri	0.000 (0)	0.076 (0.057)	0.000 (0)	0.030 (0.03)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.102 (0.059)	0.076 (0.045)	0.000 (0)	0.020 (0.02)
S. levis	0.000 (0)	0.000 (0)	0.000 (0)	0.045 (0.032)	0.000 (0)	0.020 (0.02)	0.000 (0)	0.000 (0)	0.045 (0.032)	0.127 (0.052)	0.000 (0)	0.110 (0.055)
S. wilsoni	0.000 (0)	0.050 (0.05)	0.179 (0.099)	0.000 (0)	0.000 (0)	0.040 (0.028)	0.000 (0)	0.000 (0)	0.215 (0.073)	0.020 (0.02)	0.124 (0.061)	0.031 (0.031)
S. rufus	0.000 (0)	0.000 (0)	0.000 (0)	0.172 (0.06)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.145 (0.053)	0.122 (0.053)	0.020 (0.02)
ALL SPECIES	0.302 (0.109)	2.549 (0.524)	2.956 (0.428)	2.941 (0.248)	0.491 (0.193)	2.464 (0.274)	2.381 (0.255)	0.773 (0.224)	1.938 (0.225)	3.484 (0.215)	3.740 (0.279)	1.830 (0.284)

* Samples for April of 1985 and 1986 were gathered by the Groundfish Communities Investigation in the Gulf of the Farallones only. The statistics presented are simple means and standard errors for one stratum.

Table 9. Summary of the seasonal occurrences of 15 species of rockfish captured in midwater trawls, 1985-1987, based on data in Table 3. Species are classified qualitatively by their occurrence in April and by their pattern of occurrence in May/June.

	Pattern of Occurrence in May/June		
Abundance in April	Strong dropoff in mid-late June	Weak-moderate dropoff in mid-late June	Unable to say
Moderate to high	S. wilsoni* S. saxicola S. goodei		
Moderate		S. pinniger S. jordani	
Low to moderate	S. mystinus S. hopkinsi	S. paucispinis	
Absent to low	S. entomelas	S. flavidus	S. melanops
Variable		S. auriculatus	S. crameri S. levis
Unable to say		S. rufus	

* The occurrence of S. wilsoni in April is problematic, since this species was quite abundant in April of 1985 and 1987, but absent in April of 1986.

S. wilsoni, S. saxicola, and S. goodei are the earliest occurring of the species examined. Their abundances were usually as high in April as in June (Tables 8, 9). Of the species which occur as pelagic juveniles over short periods S. mystinus and S. hopkinsi seemed the earliest, being present in April and declining in June. S. entomelas also declined in early June, but was uncommon in April. S. flavidus appeared later. It was absent in April, and did not decline as rapidly in June as the previous three species. The species with lengthy occurrence, S. pinniger, S. jordani, and S. paucispinus, seemed to reach peak abundances in early June.

In addition to the general 1984 pattern several species showed temporal shifts during 1985-1987. The temporal occurrence of S. auriculatus was the most variable of the common species. It was absent in April of 1986 but very abundant in April of 1985, and showed complementary changes in June samples (Table 8). The occurrence of some of the early, short-duration species may have extended later than usual in June of 1985. S. mystinus, S. hopkinsi, and S. entomelas were moderately abundant into mid-June in 1985. Whether this represents a real temporal change or the tail of a very strong year class remains unknown.

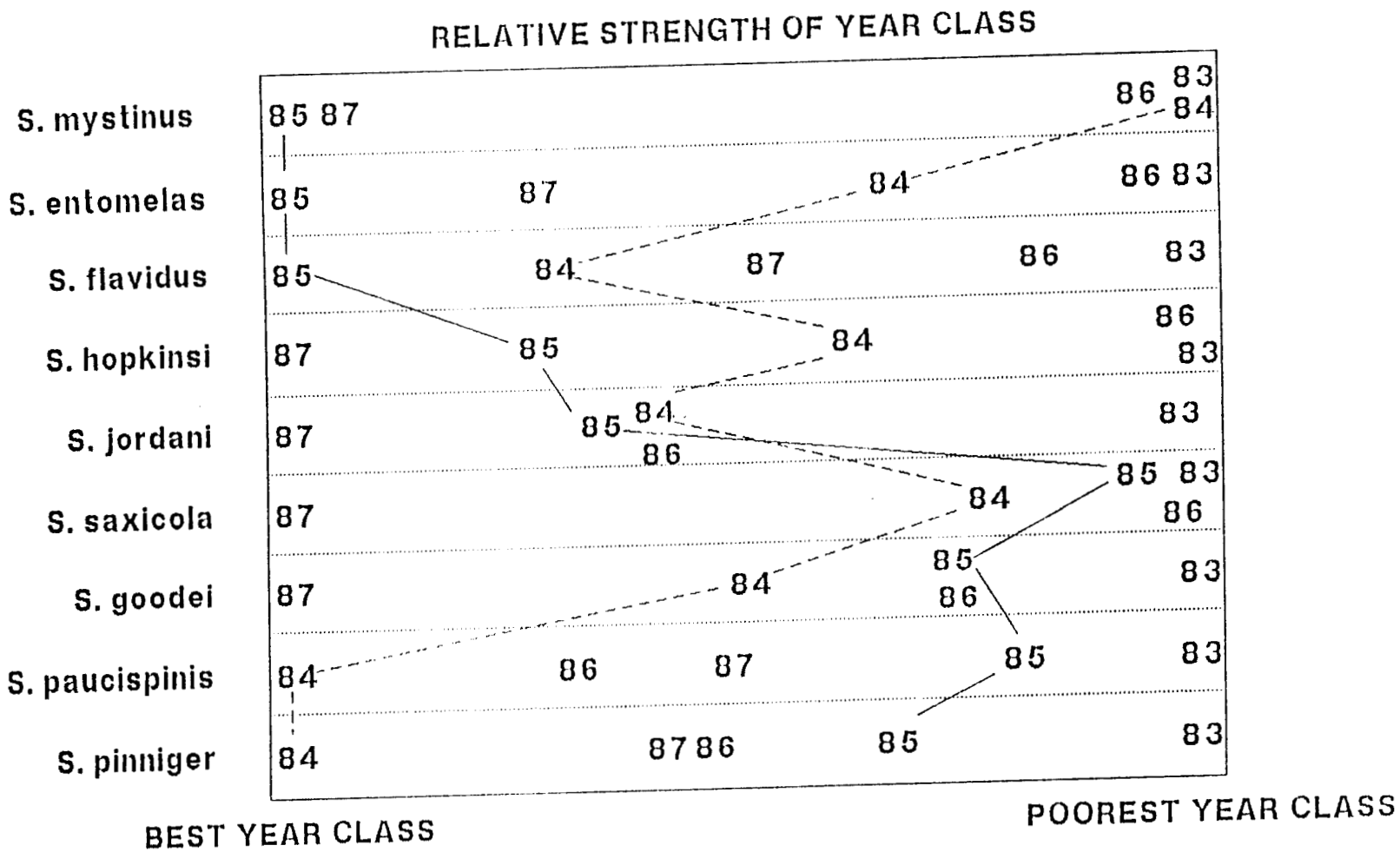
It is advisable to continue stratifying our sampling effort by time. This practice serves as a hedge against changes in the temporal occurrence of some species, and helps to assess species with different temporal patterns. It is also helpful to start our main sampling cruise the last week of May as opposed to the first week of June (as was done in 1987). This reduces the chance of missing the early-occurring species, and facilitates the detection of temporal pattern changes within some species. Nevertheless, early-occurring species, later-occurring species like members of the subgenus Sebastomus may be underrepresented in our normal sampling scheme. Our ability to analyze the temporal occurrence of species and its variation will be aided by the use of size-frequency data, which are now becoming available for use.

Interannual Variation

Most rockfish species were relatively abundant as pelagic juveniles in May/June 1987 (Table 8). Catches were relatively large in nearly all geographic areas until the last "sweep" of stations, when catches generally declined. Area-to- area patchiness observed in 1985 and 1986 (Larson 1987, p. 7) was not strongly evident in June of 1987.

Relative strengths of the 1983-87 year classes (as measured by catches in midwater trawls) differed among species, and certain groups of species tended to vary in concert (Table 8). An abstraction of data on the relative sizes of catches from year to year within species seen in Figure 7, is intended to aid in the detection of such relationships. The stratified mean abundance from the May/June cruise was used as the index of year-class strength in a species (the value for the highest sweep for a species was used to represent the 1986 and 1987 year classes).

Figure 7. Relative strengths of 1983–1987 year classes in nine species of rockfish, as measured by stratified mean abundance in midwater trawls (Table 8). "Year-class strengths" are scaled from the highest stratified means to the lowest for each species. Values for the highest sweeps for each species were were used to represent the 1986 and 1987 year classes. The horizontal scale is logarithmic. Solid and dashed lines connect the positions of the 1985 and 1984 year classes, respectively.



These indices were scaled to the highest annual value for a species, and the relative positions of the different years were arrayed in Figure 7. The relative positions of the 1984 and 1985 year classes were each connected by lines, and the species were arranged in descending order by the position of the 1985 year class and ascending order by the position of the 1984 year class.

The relative positions of some years did not vary much among species, while the positions of other years varied greatly (Figure 7). The El Nino year, 1983, was terrible for all species. The 1986 and 1987 year classes differed more among species, but the 1986 year class was poor in several species and the 1987 year class was relatively strong in most species. The positions of the 1984 and 1985 year classes differed the most among species, each varying from among the strongest for a species to among the weakest.

The positions of the 1984 and 1985 year classes (and to lesser extent the positions of the 1986 and 1987 year classes) allowed some groupings of species that tended to temporally covary. Groupings of species can be characterized by strong to very strong year classes in 1985 and 1987, weak year classes in 1986, and (usually) weak to moderate year classes in 1984. S. mystinus and S. entomelas were both very strong in 1985 and 1987, weak to moderate in 1984, and very weak in 1986 (Figure 7). S. flavidus and S. hopkinsi were somewhat similar to these species, with strong showings in 1985 and weak years in 1986, but different in that S. flavidus was stronger in 1984 than in 1987, and S. hopkinsi was stronger in 1987 than in 1985. S. rufus (not illustrated)may show a similar pattern to these species, having appeared in midwater trawls only in 1985 and 1987.

S. paucispinis and S. pinniger showed similar patterns of year-class success, and formed the extreme of another small grouping of species (Fig. 7). S. paucispinis and S. pinniger were distinctive in the apparent dominance of the 1984 year class. Unlike other species, these two also made relatively strong showings in 1986, roughly equivalent to their showings in 1987. Catches of both were relatively weak in May/June of 1985. S. jordani, S. saxicola, and S. goodei each shared different similarities with these species. S. saxicola and S. goodei were not abundant in May/June of 1985, S. jordani was relatively strong in 1986, and S. goodei was relatively strong in 1984. However, each of the latter three species differed in some major (and different) way from S. pinniger and S. paucispinis. Thus these three species do not seem to fit any pattern that is consistent with other species. The use of April catches may alter somewhat the picture in Fig 7. The biggest effect would be in the interpretation of the 1985 year class of the very early-occurring species (S. saxicola and S. goodei) and two of the species with lengthy periods of occurrence as pelagic juveniles (S. paucispinis and S. pinniger). All were relatively sparse in June of 1985, suggesting a weak year class, but, at least in comparison to other April samples, were relatively abundant in April of 1985 (Table 8). While the data from April of 1985 should be used with some caution (coming from only one

stratum), acknowledgment of these catches might raise the relative position of the 1985 year class for these species. The one most affected by this qualitative adjustment would be S. goodei, which was very abundant in the Gulf of the Farallones in April of 1985 (Table 8).

The factors causing covariation in year-class strength among species are not yet evident. Geographical range seems largely unrelated. It might be reasonable to expect species centered to the north or south of our study are to vary in concert due to large-scale changes in currents (cf. Cowen 1985), but each of the main groups contains species with very different ranges. In the first group, S. entomelas and S. mystinus range both north (mainly) and south of our area, and S. hopkinsi is found mainly to the south of our area (Gunderson and Sample 1980, Eschmeyer et al. 1983). Similarly, S. pinniger ranges largely to the north of our area while S. paucispinis ranges to the south (Gunderson and Sample 1980, Adams 1980, Eschmeyer et al. 1983). The duration of spawning period is somewhat correlated with the groupings according to year-class strength, in that both S. paucispinis and S. pinniger have long periods of occurrence as pelagic juveniles and the other four have short periods of occurrence. The relation between duration of occurrence and year-class groupings could conceivably work through the timing of spawning and subsequent ontogenetic stages. Pelagic juveniles of S. mystinus, S. entomelas, and S. paucispinis remain abundant later, suggesting differences in spawning, etc. However, S. flavidus appears to occur later than its correlated species, and other species (such as S. jordani) seem to occur at the same time as S. mystinus- S. entomelas group is also tied together by (a) the tendency of their pelagic juveniles to occur deep in the water column, and (b) their apparent phylogenetic proximity (Barsukov 1981).

It will be interesting to see how well these groupings hold up in the future. If real, the existence of covarying sets of species will be useful in at least two ways. First, relative year-class strength of easily-sampled species could be used as indices of year-class strength in species that are less easily sampled. Second, use of the parsimonious assumption that common factors are responsible for variation in year-class strength in covarying species will aid in the search for causes of year-class success and failure in these groups. For example, the groupings outlined above would suggest that annual shifts in the direction and/or strength of north-south currents do not account for the differences in year-class strength observed between 1984 and 1987.

FISH COMMUNITIES INVESTIGATIONS

Progress in Estimates of Relative Year-Class Strength From Nearshore *in situ* Assessments

Strong recruitment during 1987 by several species of *Sebastes* in northern Californian nearshore habitats continued to demonstrate substantial year-to-year variability. This conclusion is based on *in situ* visual assessments by members of the Groundfish Communities Investigation. Using scuba at permanent study site off the Mendocino coast, and at temporary sites off the Sonoma coast, they found the same three predominating species as during previous years: the yellowtail rockfish, *Sebastes flavidus*, the blue rockfish, *S. mystinus*, and the black rockfish, *S. melanops* (Table 10).

The total number of first-year juveniles of all species was greater during 1987 than during any other year since the assessments began in 1983. This greater total, however, resulted primarily from exceptionally strong recruitment by *S. mystinus*. *S. flavidus* was actually less numerous than in 1985, and *S. melanops* less numerous than in 1986 (the high years for these two species).

Thus, year-to-year variability identified in these assessments occurred both within and between species. It has become increasingly clear that years of strong recruitment for some species may or may not be years of strong recruitment for others.

As in 1986, *S. flavidus* recruited in two widely spaced pulses during the summer. Thus, first-year juveniles of this species collected in late October represented two distinct size-groups: one 40 to 50 mm SL, the other 60 to 70 mm SL.

As in previous years, *S. mystinus* was more numerous to the south, off Sonoma, than to the north, off Mendocino (Table 11). further, during 1987 the juveniles of this species off Sonoma were larger. Thus, during late summer those sampled off Sonoma were 55 to 68, x = 61 mm SL, while those sampled off Mendocino were 49 to 62, x = 54 mm SL (n=28, t = 4.14 P<0.001>. And during mid winter, those sampled off Sonoma were 66 to 85, x = 79 mm SL, while those sampled off Mendocino were 58 to 73, x = 66 mm SL (n=31, t=7.04, p<0.001>.

Differences among juvenile *S. mystinus* between Sonoma and Mendocino may reflect differences in their respective environments. Ocean conditions monitored by the Fish Communities Investigation off Mendocino have differed in certain features from those reported off Sonoma by the recent multi-agency C.O.D.E. (Coastal Ocean Dynamics Experiment) project, notably in direction of longshore currents. Comparisons between the two

Table 10.--Mean number (standard error in parentheses) of first-year juveniles counted/min off the Mendocino coast during the same 4-week periods (early August to early September) from 1983 to 1987.

N = number of 1-min observations.

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

Table 11.--Mean number (standard error in parentheses) of first-year juveniles counted/min during the same 4-week periods (early August to early September) over 4 years off the Sonoma and Mendocino County coasts.

	Mendocino				Sonoma			
Species	1984 N = 57	1985 N = 50	1986 N = 103	1987 N = 112	1984 N = 37	1985 N = 84	1986 N = 60	1987 N = 62
S. flavidus	6.58 (2.29)	115.60 (21.26)	6.01 (1.50)	102.66 (11.08)	4.39 (1.48)	135.17 (26.00)	6.73 (2.29)	89.39 (18.42)
S. mystinus	1.49 (0.30)	70.56 (15.32)	7.82 (1.88)	181.04 (26.19)	4.89 (1.29)	117.63 (19.50)	15.27 (3.81)	328.05 (52.15)
S. melanops	0.31 (0.08)	4.34 (1.54)	9.52 (2.08)	7.58 (1.24)	1.63 (0.52)	4.40 (1.17)	3.00 (1.31)	4.48 (1.70)
Total	8.38 (2.33)	190.50 (29.76)	23.35 (3.91)	291.67 (33.19)	10.91 (2.12)	257.20 (35.38)	24.97 (5.17)	442.48 (66.72)

versions have been weakened, however, by shortages of data from Sonoma. Until now, the Groundfish Communities Investigation has concentrated its work off Mendocino, and data from Sonoma have been limited and irregular. To add substance and regularity to the Sonoma assessments, and provide a sound basis for comparisons, a permanent station was established this year off the Sonoma coast (at 38° 36'N, 123° 22'W). With recording thermographs in place to monitor sea temperatures, it is anticipated that this station will provide the same range of data that has been provided for the past 6 years at the Mendocino station.

Progress in Estimates of Relative Year-Class Strength from Predator Stomach Contents

Work by the Groundfish Communities Investigation from 1983 to 1986 showed that occurrences of juvenile Sebastes spp. in predator gut contents can be used to estimate relative year-class strength (Larson 1987). That research, however, was a limited feasibility study done in the course of a major investigation of predation on juvenile Sebastes spp. As such, it was handicapped by a sampling plan designed to meet the needs of the predation study. The handicap was removed when the major study ended in 1986, enabling this years' year-class estimates to continue with a sampling plan modified for greater precision. As before, the stomachs were from the King Salmon, Oncorhynchus tschawtytscha.

Estimates of species composition were more precise owing to increased numbers of juveniles sampled. This was accomplished by taking most of the samples during May and June, other than throughout the year, as required previously by the predation study.

Increased attention has been given to improving prey identifications. This has resulted in identifying to species a greater proportion of the juveniles recovered from predator stomachs. The earlier predation study required identifying all items in the predator stomachs. As a result only two species of Sebastes were consistently distinguished: the shortbelly rockfish, S. jordani, and the widow rockfish, S. entomelas.

Juvenile Sebastes spp. in stomach contents are particularly difficult to identify, because the feature generally regarded as crucial in distinguishing the species--pigment patterns--usually is obliterated by digestion. Consequently meristic and/or other morphological characteristics are used instead. This requires developing special procedures.

The effectiveness of various morphological structures as diagnostic features has been increased by using histological stains. Each specimen is treated with Alizarin Red S, which has a high affinity for calcium and therefore stains bones red. This procedure has proved to be especially helpful in determining meristic counts in partially digested specimens.
A computer assisted key using artificial intelligence programs is being developed to further improve identifications. Existing

keys have proven inadequate because the characteristics upon which they depend often are destroyed by digestion. Using the computer assisted key, the investigator enters the specimen characteristics available and receives a list of possible species and the probabilities of each matching that combination of characteristics. The key will also search for characteristics that will further divide the possibilities. The basic structure of this key has been completed, but much testing remains before it will serve in practical use.

The 1987 research efforts have shown that there were more juvenile Sebastes spp. in predator stomachs during 1987 than during any other year since sampling began in 1983 (Table 12). This finding, agrees with results of the in situ assessments, reported above. Assessments of juvenile Sebastes spp. abundance based on occurrences in the predator stomachs were greatly enhanced by changes made in the sampling plan, and by increased efforts in identification. This is evident in the list of species present (Table 13), which is far more comprehensive than accountings of species composition from previous years (when only S. jordani and S. entomelas were consistently distinguished). Despite the limited species identifications of past years, however, it was found that Chilipepper, S. goodei was never before as numerous as in 1987, when it ranked second behind S. jordani.

Table 12.--Mean number of first-year juvenile rockfishes in the stomachs of King Salmon from the Gulf of the Farallones, 1983-1987.

N = number of stomachs examined

Species	1983 N = 413	1984 N = 503	1985 N = 760	1986 N = 243	1987 N = 416[1]
S. jordani	0.0	0.34	1.56	0.18	4.92
S. entomelas	0.0	0.02	0.13	0.02	0.30
All species	0.16	1.61	5.72	0.94	6.26

[1]analysis incomplete

Table 13.--Species composition of juvenile Sebastes spp. in stomachs of King Salmon during 1987 (N = 416[1]).

Species	Average Number/Stomach
S. jordani	4.292
S. goodei	0.444
S. entomelas	0.300
S. hopkinsi	0.242
S. wilsoni	0.062
S. mystinus	0.036
S. paucispinis	0.024
S. flavidus	0.006
S. pinniger	0.002
S. saxicola	0.002
S. semicintus	0.002
Unidentified Sebastes	0.850
Total	6.259

[1] Approximately half of the samples collected have been analyzed to date these cover the entire collection period.

DISCUSSION

Recruitment variability and the factors affecting it comprise one of the most central problems facing fishery science and management. The reorganization of the Tiburon Laboratory scientific staff to address this problem has resulted in considerable progress being made. This is especially true over the last year.

Through studies of the Physiological Ecology Investigations on yellowtail rockfish the effects of disease and parasites on adult condition and reproductive performance were assessed. Seasonal patterns in health and condition have been established and interannual changes in the ages and sizes of the population were noted. Through histological appearance and morphological structure of yellowtail rockfish ovaries we have established the seasonal pattern of the annual reproductive cycle. This provided a sensitive and accurate means of identifying temporally separate spawning periods. Fecundity studies showed that the age and size specific fecundities of the yellowtail rockfish have not changed over the past three years despite the decline in the mean age and size composition of the population. The annual patterns of nutrient fluxes in female rockfish throughout the reproductive cycle has not been determined. It was shown that lipid stores and serum nutrients were linked to food availability. Knowledge of these patterns helps us to monitor reproductive cycles and to estimate reproductive capacity and success.

The midwater trawl studies of the Groundfish Analysis Investigation revealed distinct vertical distribution patterns in pelagic juvenile rockfishes. Species could be characterized by their depth distributions. The standard depth tow methods developed over the years were found not to be spatially or temporally biased. Seasonal patterns of juvenile rockfishes were also established. It is now possible to classify species according to the duration and timing of occurrence during the April-May-June period. While 1987 was a particularly productive year for pelagic juvenile rockfishes the interannual variation of species showed that certain species groups covaried. The 1984 and 1985 year classes were useful in identifying these groups. The factors causing certain species assemblages to covary in year class abundance remain unknown. It does appear that factors associated with spawning and subsequent early life stages are possibly linked. The existence of covarying species assemblages are potentially useful in predicting interspecific year class size through indicator species. They will also aid in identifying factors influencing year class success.

The occurrences of first year juveniles in the nearshore habitats, and in the diets of predators, as determined by the Groundfish Communities' in-situ assessments and study of predator stomach contents, indicated exceptionally strong recruitment by Sebastes spp. in 1987. The recruitment of S. flavidus was found to occur in two distinct pulses, thus confirming the bimodal reproductive performances of this species noted by the Physiological Ecology group. Interannual variability in abundance occurred both within and between species. Species appeared to vary specifically and uniquely between years. Spatial as well as temporal distributions were found to be species specific. Differences were seen between Sonoma and Mendocino study sites in the relative abundance and distribution of various species. Studies of the environmental factors within these sites are underway to help identify causal relationships. The capability of identifying juvenile rockfishes in the stomachs of king salmon was greatly improved through new histological techniques and computer assisted identification keys. The predator studies supported findings of the in situ studies that reported successful recruitment of rockfishes in 1987.

The 1987-1988 research year of the Tiburon Laboratory showed considerable progress towards monitoring and predicting recruitment variability in rockfishes. It also demonstrated that through a dynamic, comprehensive, multifaceted, and interactive research approach we can greatly increase the identification and understanding of the factors which influence recruitment and causes of spatial/temporal variations.

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