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DECEMBER 1985

PROGRESS REPORT ON ROCKFISH RECRUITMENT STUDIES AT THE TIBURON LABORATORY

Prepared by: Staff of the groundfish analysis and groundfish communities investigations

Edited by: William Lenarz and Sharon Moreland

ADMINISTRATIVE REPORT T-85-02

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Not for Publication

INTRODUCTION

Objectives of Study

A long-term study on rockfish recruitment was initiated in 1983 by the Groundfish Analysis and the Groundfish Communities Investigations of the Tiburon Laboratory of the Southwest Fisheries Center, National Marine Fisheries Service. The study has three major objectives.

The first objective is to develop methods for predicting year-class strength of species of rockfish that are either important to the fisheries or are abundant. Most species of rockfish are not recruited to fisheries until the age of 4 to 10 years. We will attempt to estimate year-class strength in the first year of life and thus give fishermen and managers a basis for planning. Since analyses of data for several species of rockfish indicate that year-class strength can vary as much as tenfold, the goal is to be able to detect several-fold changes in year-class strength. Such precision has been shown to be appropriate for management purposes (e.g., Lenarz, 1971). The study area includes the coastal and offshore waters between Point Sur and Cape Mendocino, California. The study emphasizes seven species of rockfish that are important in the area: black rockfish (*Sebastes melanops*), blue rockfish (*S. mystinus*), bocaccio (*S. paucispinis*), chilipepper (*S. goodei*), shortbelly rockfish (*S. jordani*), widow rockfish (*S. entomelas*), and yellowtail rockfish (*S. flavidus*).

The second objective is to gain insight into factors that affect strength of recruitment. Recruitment strength is the most important factor underlying the success of fisheries, but factors that control recruitment strength are the least understood aspect of fish population dynamics. The fishery manager is faced with the fact that although there must be a relationship between recruitment strength and the quantity and quality of eggs or larvae produced by adults, that relationship is obscured by poorly understood environmental factors. We are attempting to gain a better understanding of environmental factors that affect recruitment strength.

The third objective is to develop a better understanding of the niches of juveniles of important species. About 60 species of rockfish occur in California and about 20 species are fairly abundant in the study area. These closely related species are similar in appearance in the juvenile stage. The ecology of some juvenile rockfish is fairly well known during the phase in which they inhabit nearshore waters, but little is known about the ecology of any species of rockfish when they inhabit offshore waters as juveniles. We are attempting to determine feeding habits and environmental factors that affect the distribution of juvenile rockfish during the pelagic stage, as well as adding to the existing knowledge of the nearshore stage.

Background

Data on juvenile rockfish are being collected during two phases of their life history. Some species are being studied in their pelagic offshore stage shortly before the time that they move into their next habitat. These species include bocaccio, chilipepper, and shortbelly, widow, and yellowtail rockfishes. Some species spend the next stage of their life in shallow nearshore waters and are being studied there; these include black rockfish,

blue rockfish, bocaccio, and yellowtail rockfish. Juvenile shortbelly and widow rockfishes are occasionally found in high numbers in shallow nearshore waters, but it is not known if this is a regular phase of their life history. Although small numbers of black and blue rockfishes occur in offshore samples, we do not believe that the offshore samples are representative of their abundance. Juvenile chilipepper are rarely found in shallow nearshore waters.

Juvenile rockfishes of the species of interest are most abundant in pelagic offshore waters between mid-May and mid-July in the study area. At this time most specimens are between 30 and 60 mm (SL). Most specimens of the important species are between 3 and 7 months old. The transition from the pelagic to the next phase usually peaks in late June and July for the important species. When juveniles first enter the nearshore habitat they have the silvery nondescript appearance of pelagic-phase fish, but rather quickly begin to take on the appearance of adults. The nearshore phase tends to last through fall, but there is considerable variability among species and years. Blue and black rockfishes spend a significant portion of their lives in shallow nearshore waters.

Sampling Methods

Samples in the offshore areas are collected with a midwater trawl that is a slightly modified version of the net used by the California Department of Fish and Game pelagic fish survey (Mais, 1974). The net has an 80-foot headrope and 1/2-inch mesh liner in the codend. Fifteen-minute tows are made during dark hours. Daylight tows were soon discontinued because of low catches. Standard warp is 30 m for tows in depths less than 50 fathoms and 90 m in deeper waters. The NOAA vessel David Starr Jordan is being used for the trawl surveys. Most of the work is conducted from late May through the end of June, although some work has been conducted in April.

SCUBA surveys are made in shallow nearshore water between Bodega Bay, Sonoma County, and Albion, Mendocino County. Between arrival of the juveniles (usually in May or June) and late October or early November, surveys are made every 2 to 3 weeks as weather permits. At locations judged to be in representative habitats, counts are made to depths of about 35 m. Here, two or three observers, equipped with SCUBA and marking slates, note the numbers of juveniles during timed segments along random courses. Data used in this report were grouped in 1-minute segments. Ecological and behavior notes are added, if judged significant. Three important species--black, blue, and yellowtail rockfishes--can be monitored effectively using this method.

Information of juvenile rockfish is also obtained by examining contents of predator stomachs. During 1984 and 1985, lingcod (Ophiodon elongatus), adult piscivorous rockfish, and chinook salmon (Oncorhynchus tshawytscha) were sampled. The results for lingcod and piscivorous rockfish were not encouraging. Juvenile rockfish were not a common food item and often were not identifiable to species. Chinook salmon feed heavily on juvenile rockfish during June (Merkel, 1957). Since 1984, only chinook salmon stomachs have been collected.

Objectives of Report

Analytical work is just beginning. This report contains analyses of some of the data collected during the first 3 years of the study. Very few juvenile rockfish were collected in 1983, an El Niño year. An M.S. thesis project will be started this fall by a staff member. It will be centered about a management model that incorporates predictions of year-class strength into fishery management.

There are two major objectives for this report. The first is to review progress to date. The second is to review project strategies with respect to the early results and to develop new strategies were appropriate.

PROGRESS IN IDENTIFICATION OF JUVENILE ROCKFISH

The recruitment project needs to identify all specimens of important species with a high degree of accuracy. In 1983 some work had already been published on the identification of rockfishes at the pelagic juvenile stage. Descriptions of bocaccio, shortbelly rockfish, and cowcod (S. levis), in addition to several other species not found in our study area, were published by Moser et al. (1977). Also in 1977, Allen published drawings of halfbanded (S. semicinctus), stripetail (S. saxicola), splitnose (S. diploproa), darkblotched (S. crameri), copper (S. caurinus), flag (S. rubrivinctus), redbanded (S. babcocki), vermilion (S. miniatus), olive (S. serranoides), greenstriped (S. elongatus), squarespot (S. hopkinsi), shortbelly, and blue rockfishes, and cowcod, chilipepper, bocaccio, and several other Southern California species. Moser and Ahlstrom (1978) produced a description of blackgill rockfish (S. melanostomus). Richardson and Laroche (1979) described darkblotched, canary (S. pinniger), and rosethorn (S. helvomaculatus) rockfishes. Laroche and Richardson in 1980 described yellowtail (S. flavidus) and black rockfishes. In 1981 they published descriptions of widow and sharpchin (S. zacentrus) rockfishes and clarified some of their previous work on head spines in juvenile rockfish.

There is a potential for some 44 species in Northern and Central California. With sometimes incomplete information on the 23 "known" species, there was room for confusion. To satisfy the project's need to identify all juvenile specimens of important species, a key was developed. It was decided to attempt to use meristics rather than the incompletely known pigment patterns for identification. Although there are published data on rockfish meristics, they are incomplete. Fortunately, the Tiburon Laboratory developed a large data base on the meristics of species in the study area during a study on adults. This meristic information was used to formulate a key for identification of juvenile rockfishes. When meristics produced uncertainties because of overlap, other characters such as head spines, form of anal fin spines, body shape, and pigment patterns were used.

A group of five important species (black, blue, olive, widow, and yellowtail rockfishes) proved difficult to identify to species in some cases because of overlap in meristics and incomplete descriptions. Additional characteristics were found for these species and it is now possible to identify almost all specimens positively.

The project has also developed methods to identify three species--brown (S. auriculatus), honeycomb (S. umbrosus), and rosy (S. rosaceus) rockfishes--that were not previously described in the literature as juveniles.

Members of the recruitment project are now able to identify more than 99% of sampled specimens. Several technicians have been trained in the use of the key, and their identifications--even in the field--have been found to be accurate.

The project and the Northwest and Alaska Fisheries Center have funded development of a field guide for larval and juvenile rockfish by an outside contractor. The guide is due to be completed at the end of FY86.

PROGRESS IN OFFSHORE MIDWATER TRAWL SURVEYS

Examination of Number of Replicates Per Station

It is often the case for surveys for marine organisms that the optimum number of samples per station (m_{opt}) is one. This is a consequence of the high variability among stations. Thus in designing the original sample plan for the offshore midwater trawl survey, it was assumed that m_{opt} would be one. Data are available now to examine that assumption. An aspect of the Groundfish Communities Investigation's studies is intensive sampling of the Gulf of Farallones. In 1985, six stations in the Gulf were sampled twice in a short period of time, and these data can be used for the estimation of m_{opt}.

Cochran (1963) shows that m_{opt} for a fixed cost can be estimated as

$$\hat{m}_{opt} = (s_2/\sqrt{s_1^2 - s_2^2/m})\sqrt{c_1/c_2} \ ,$$

where

s_1^2 = estimated variance among stations,
s_2^2 = estimated variance within stations,
m = number of replicates per station in pilot survey,
c_1 = cost per station, and
c_2 = cost per sample.

In this case, cost is ship time. We estimate that c_1 is between 0.5 c_2 and 1.0 c_2, and assume for this study that $c_1 = c_2$. As is often the case for data from marine organism surveys, the data are highly variable and the variance is related to the mean. Therefore the $ln(X + 1)$ transformation is used for this and most of the other estimates in the study as is often done for such data. Future analysis will further investigate the statistical distribution of the data and another transformation may be indicated, but it is likely that the $ln(X + 1)$ transformation will provide approximately correct results. Results of the calculations (Table 1) indicate that there should be only one replicate per station for routine survey purposes.

Examination of Depth of Tow

Prior to initiation of our work in 1983, no surveys had been conducted in offshore waters for juvenile rockfish. Consequently, little information was available for designing the field work. Several investigators who had incidentally captured juvenile rockfish believed that tows should be as close to the surface as possible. People with experience on the Jordan believed that there could be problems from the ship's wake if the warp were less than about 90 m. However, our experience revealed that the midwater trawl could easily be badly damaged during tows in shallow waters because of encounters with the bottom if warp were 90 m. Therefore, in waters less than 50 fathoms, warp is set at 30 m and in deeper waters it is set at 90 m. In order to verify that these depths are appropriate, replicate tows have been made at 30 m and 300 m when time allowed.

TABLE 1.--Estimates of optimum number of replicates per station (m_{opt}) for the offshore midwater trawl survey. Data are from two replicates of six stations in the Gulf of the Farallones during late May-early June, 1985. Data are transformed to $ln(X + 1)$.

	Widow rockfish	Yellowtail rockfish	Chilipepper	Bocaccio	Shortbelly rockfish	All rockfish
s_1^2	5.978	4.135	2.690	7.518	2.206	8.157
s_2^2	3.143	0.523	8.192	3.649	0.762	4.811
$\hat{m}_{opt}$	0.845	0.367	---	0.801	0.646	0.915

Insufficient pairs of 30-m and 90-m tows are available for meaningful analyses. A total of 15 pairs of 90-m and 300-m tows were made in 1984 and 1985. The results are shown in Table 2. Average untransformed catches of bocaccio, chilipepper, and shortbelly rockfish were higher in the 90-m tows than in the 300-m tows, and catches of widow and yellowtail rockfishes were higher in the 300-m tows than in the 90-m tows. The catch of all rockfish was higher in 90-m tows than in 300-m tows. The Wilcoxon signed ranks test was used to determine if the differences are significant. None are at commonly used levels of significance, but differences for bocaccio, chilipepper, and widow rockfish approach significance. Spearman's correlation coefficient was used to test the relationship between 90-m and 300-m catches. Correlations were significant for shortbelly rockfishes and all rockfishes.

The results suggest that 90-m tows are appropriate, because catches of three out of five target species were higher at that depth when compared to 300-m tows. However, the sample size is small and it is not yet possible to compare 30-m tows with 90-m tows. We will continue to collect data on the question.

Annual Estimates of Juvenile Rockfish Densities

Prior to 1985, the project had about 2 weeks of ship time in June. Beginning in 1985, the project has been assigned 31 days of ship time during late May and June. It was hoped that enough stations could be sampled to detect annual differences in juvenile rockfish densities.

Very few juvenile rockfish were captured in 1983, which was probably an extreme year because of El Niño conditions. Thus it was decided to examine the 1984 and 1985 data to determine if sample size is adequate to detect annual differences in density. Superficial examination of the data indicated that there were areal differences in density, but the differences were not consistent from year to year. The study area was divided into seven geographical strata--three nearshore, three offshore, and the Gulf of the Farallones. In 1985 it was possible to sample stations farther offshore and

TABLE 2.--Comparisons of catch rates of juvenile rockfish in replicate midwater tows made with 90-m and 300-m of warp in 1984 and 1985. The data are from 15 stations.

Species	Average warp 90 m	Average warp 300 m	Sign test probability	Spearman's P
Bocaccio[1]	41.4	4.2	0.068	0.616
Chilipepper[1]	3.0	0.4	0.109	0.725
Shortbelly rockfish	27.7	19.7	0.657	0.541*
Widow rockfish	1.2	4.3	0.107	0.497
Yellowtail rockfish	2.1	4.8	0.237	0.306
All rockfish	51.7	33.6	0.675	0.643**

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

[1] Only 1984 data from five stations are used, because overall densities were very low in offshore stations in 1985 and no catches were made at replicated 1985 stations.

farther north than in 1984 because of the additional ship time. These additional stations are not included in the analysis. Data collected by the Groundfish Communities Investigation in the Gulf of the Farallones are excluded from this analysis because they replicate stations sampled by the Groundfish Analysis Investigation while other stations were not replicated. Data were transformed to $ln(X + 1)$.

The results indicate sample size is sufficient to detect annual differences in the density estimates (Table 3). As will be shown later, the transformed data did not correct all problems with heterogeneity of variance, but analysis of variance is recognized as a robust test and the differences are estimated to be highly significant. The results also indicate that it is important to stratify because strata and the year x strata effects are often significant. Because the year x strata effect is sometimes significant, the results indicate that it is probably not desirable to base allocation of sampling effort to strata on average catches.

Catches made in the Gulf of Farallones area by the Groundfish Communities Investigation in late May and early June, 1985, were the highest of any made by the program. Catches often exceeded 1,000 juvenile rockfish. These stations were replicated at the end of June and no catches of juvenile rockfish were made at this time. It appears from these results and evidence

TABLE 3.--Results of two-way analysis of variance of juvenile rockfish catch data. The factors are year (1984 and 1985) and seven geographical strata. Data are transformed to $ln(X + 1)$. Data for the Gulf of the Farallones came from Groundfish Analysis Investigation samples.

Source	Df	Bocaccio	Chilipepper	Shortbelly rockfish	Widow rockfish	Yellowtail rockfish	All rockfish
Year	1	21.259***	19.194***	30.432***	0.041	4.021**	25.920***
Strata	6	4.336***	2.039	4.228***	2.133	1.068	4.341***
Year x strata	6	4.276***	2.039	1.452	1.503	2.497*	0.727
Error	98						

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

from chinook salmon stomach contents and nearshore studies that the transition from the pelagic offshore stage to the next stage occurred earlier than normal in 1985. In addition, it appears that the timing of the transition is more variable than expected and that the sampling scheme should take this into account. Therefore, it was decided to reduce the size of the area sampled in the future and to attempt to sample the entire covered area several times during the sampling period. Under this scheme annual estimates of abundance will be from the replicate with the highest average catch for the species.

The areal coverage has been reduced to the area between Carmel and the mouth of Tomales Bay (Figure 1). The new area is divided into seven strata with five stations each. The stations can be sampled in seven nights, if weather is good. Thus, under ideal conditions the area will be covered four times. It is more likely that time will be lost and the area will be covered two to three times.

Random stratified estimates of the averages and their variances are shown in Table 4 for data collected at the selected stations 1983-1985. The data were transformed to $ln(X + 1)$. The data for the Gulf of the Farallones in 1985 were from the samples collected by the Groundfish Communities Investigation. The data suggest that reproduction of the five important species of rockfish was a failure in 1983. Densities of juvenile widow and yellowtail rockfishes were higher in 1985 than in 1984. Densities of juvenile chilipepper and shortbelly rockfish were similar in 1984 and 1985. Densities of bocaccio were lower in 1985 than in 1984.

FIGURE 1.--Study area for future midwater trawl surveys for juvenile rockfish. The area is divided into seven strata: DN (Deep North), SN (Shallow North), GF (Gulf of the Farallones), DS (Deep South), SS (Shallow South), MO (Monterey Offshore), and MN (Monterey Nearshore). There are five stations represented as • for each station.

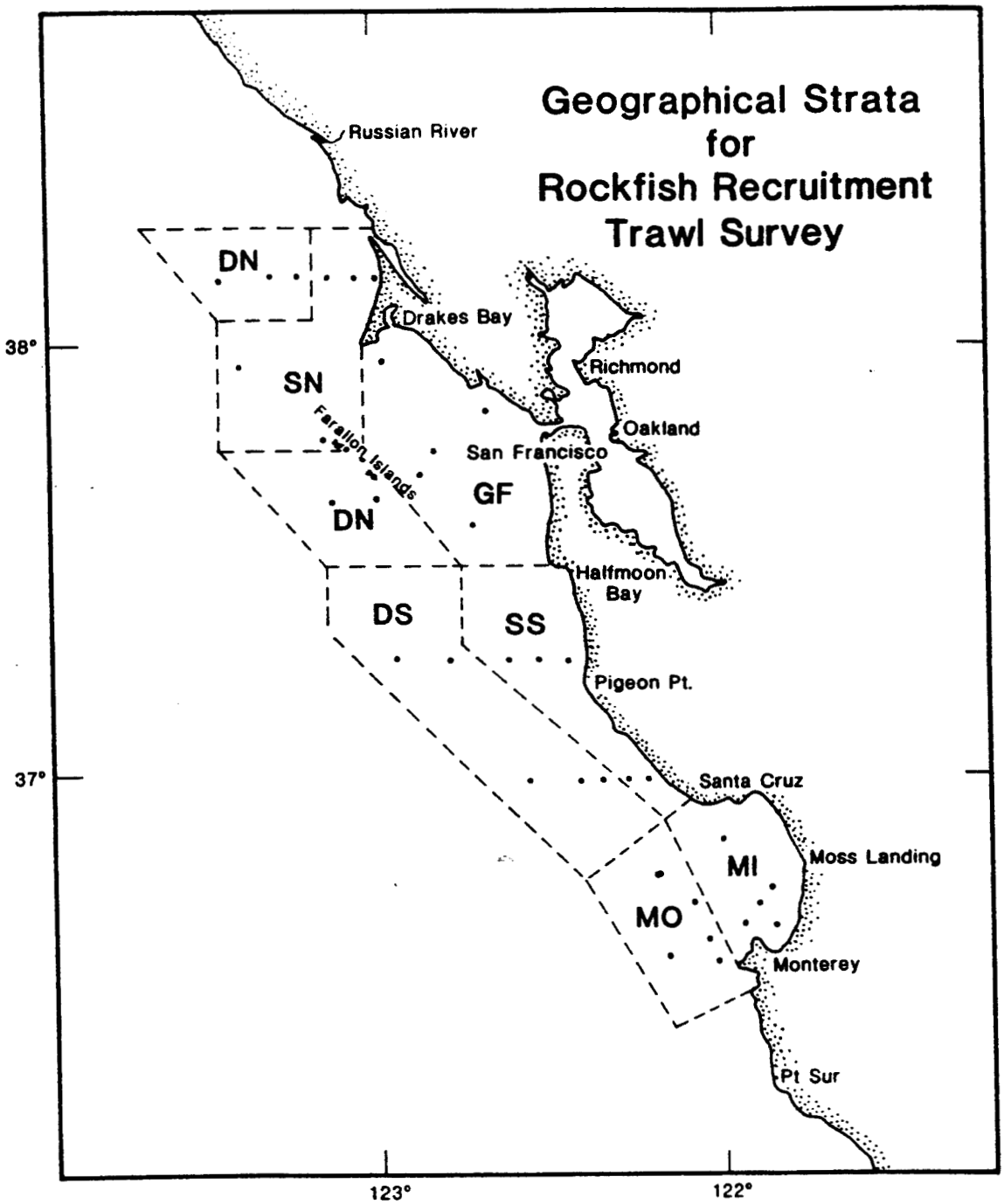
Geographical Strata
for
Rockfish Recruitment
Trawl Survey
Russian River
Drakes Bay
Richmond
Oakland
San Francisco
Farallon Islands
Halfmoon Bay
Pigeon Pt.
Santa Cruz
Moss Landing
Monterey
Pt Sur
DN
SN
DN
GF
DS
SS
MI
MO
38°
37°
123°
122°

TABLE 4.--Random stratified estimates of averages and variances of densities of juvenile rockfish, 1983-1985. Data are transformed to $ln(X + 1)$. Note that there are no data for 1983 for the Gulf of the Farallones stratum. Gulf of the Farallones data for 1985 came from Groundfish Communities Investigation samples.

Year/Area	Sample size	Bocaccio		Chilipepper		Shortbelly rockfish		Widow rockfish		Yellowtail rockfish		All rockfish	
		Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.
1983													
Deep North	3	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000
Shallow North	4	0.000	0.0000	0.000	0.0000	0.250	0.0633	1.000	1.0000	1.250	0.8960	2.500	4.7500
Gulf of the Farallones	0												
Deep South	2	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000
Shallow South	5	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000
Offshore Monterey	4	0.000	0.0000	0.000	0.0000	1.000	0.3333	0.000	0.0000	0.000	0.0000	1.000	0.3333
Nearshore Monterey	3	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000
Total	21	0.000	0.0000	0.000	0.0000	0.209	0.0662	0.167	0.1667	0.209	0.1493	0.583	0.8472

TABLE 4.--(CONTINUED)

Year/Area	Sample size	Bocaccio		Chilipepper		Shortbelly rockfish		Widow rockfish		Yellowtail rockfish		All rockfish	
		Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.
1984													
Deep North	2	0.000	0.0000	0.693	0.4802	1.869	3.4927	1.040	1.0804	0.973	0.9467	2.165	4.6879
Shallow North	4	0.000	0.0000	0.000	0.0000	1.171	0.5285	0.402	0.1620	0.866	0.1901	1.799	0.4907
Gulf of the Farallones	2	1.099	1.2075	0.347	0.1201	1.994	3.9790	1.199	1.4382	0.805	0.6475	2.239	5.0118
Deep South	5	2.322	0.6698	0.717	0.2407	2.322	1.0125	0.555	0.1152	0.627	0.3931	3.125	0.9955
Shallow South	5	0.850	0.2972	1.187	0.1627	2.519	0.6216	1.060	0.1620	1.130	0.3410	3.203	0.6749
Offshore Monterey	4	1.650	0.6708	0.173	0.0301	1.495	1.3421	0.000	0.0000	0.000	0.0000	2.460	0.8593
Nearshore Monterey	4	0.000	0.0000	1.006	0.4032	1.785	0.7517	0.173	0.0301	0.173	0.0301	2.389	0.5753
Total	26	0.846	0.4065	0.589	0.2053	1.879	1.6754	0.633	0.4268	0.653	0.3641	2.483	1.8993

TABLE 4.--(CONTINUED)

Year/Area	Sample size	Bocaccio		Chilipepper		Shortbelly rockfish		Widow rockfish		Yellowtail rockfish		All rockfish	
		Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.	Avg.	Var.
1985													
Deep North	4	0.000	0.0000	0.000	0.0000	1.151	0.4416	1.253	0.5300	0.486	0.2367	1.932	0.6790
Shallow North	5	0.000	0.0000	0.000	0.0000	0.967	0.5249	0.636	0.0314	0.139	0.0192	1.360	0.4393
Gulf of the Farallones	11	1.318	0.1396	3.152	0.6840	6.847	0.7509	6.055	0.6642	3.008	0.2686	7.515	0.8906
Deep South	4	0.000	0.0000	0.000	0.0000	2.194	0.2034	0.850	0.1156	0.275	0.0754	2.629	0.0847
Shallow South	5	0.000	0.0000	0.000	0.0000	2.168	1.0839	2.924	0.8160	1.847	0.4873	3.510	1.0876
Offshore Monterey	5	0.000	0.0000	0.000	0.0000	0.139	0.0192	0.139	0.0192	0.000	0.0000	0.886	0.1014
Nearshore Monterey	5	0.000	0.0000	0.000	0.0000	0.400	0.0601	4.000	5.7996	1.800	0.5399	6.600	9.1612
Total	39	0.1883	0.0199	0.450	0.0977	1.981	0.4406	2.265	1.1394	1.079	0.2324	3.489	1.7777

PROGRESS ON MEASURING RECRUITMENT FROM CHINOOK SALMON STOMACH CONTENTS

The principal goal of this study of the Groundfish Communities Investigation is to evaluate the impact of predation as a mechanism controlling populations of juvenile rockfish. A corollary to this is the possibility of using predator stomach contents to estimate year-class strength of juvenile rockfish. The focus of this project is to investigate chinook salmon predation on juvenile rockfish in the Gulf of the Farallones. Our studies show that in normal years there is a regular seasonal cycle in which chinook salmon prey heavily on juvenile rockfish from mid-May until mid-July. In 1983, 1984, and 1985, corresponding midwater trawls were made at appropriate stations to compare species composition and relative abundance of juvenile rockfish in the salmon's diet and in the pelagic ecosystem.

Although data collection for the project is still in progress, preliminary analysis has made several points clear. The first is that predator stomach contents can be used as a measure of year-class strength--at least to the level of whether this is a good year, a bad year, or somewhere in between. Greater definition of year-class strength may be possible when data analysis is completed. However, this measure of recruitment is only possible when the basic mechanisms of the predator's behavior and the normal cycle of the ecosystem are understood. Without this background information, changes in numbers of juvenile fish in the predator's stomachs cannot be interpreted accurately. The second point is that--at least in this case--species composition and relative abundance of juvenile rockfish in salmon stomachs approximate the trawl samples. Length frequencies have not yet been compared. The final point is that estimating recruitment from predator stomachs has several operational advantages. This method allows for the widest spatial and temporal coverage, an important consideration when sampling a process with as much uncertainty as this. This method of coverage is also the cheapest, partly because of the problems of uncertainty and coverage, and partly because it eliminates the need for ship time. It has definite limitations, basically those associated with any fishery-dependent sampling program, but it is an effective tool as a method of sampling juveniles of commercially important species.

PROGRESS IN UNDERWATER NEARSHORE SURVEYS

Analyses were conducted on data collected by underwater observers during the nearshore surveys to examine two questions.

The first analysis tests the hypothesis that the three observers doing the work produce similar estimates of total juvenile rockfish densities. The Wilcoxon paired observations test was used. The results for the three possible pairs of observers were nonsignificant (pair 1: $n = 19$, $P = 0.28$; pair 2: $n = 10$, $P = 0.62$; pair 3: $n = 7$, $P = 0.31$). The results indicate that the three observers produce similar estimates.

The second analysis examines the apparent year-to-year differences in numbers of juveniles by testing the null hypothesis that there are no annual differences in numbers of the three important species observed. One-way analysis of variance was used to test the hypothesis on the $ln(X + 0.001)$ transformed data. An observation is defined to be the average of all transects for a day's work. This analysis assumes that there are no important season and area effects. The results (Table 5) indicate significant differences among years for each of the species. A Tukey HSD post hoc analysis (Table 6) indicates that estimates of the blue and yellowtail rockfishes are significantly higher for 1985 than for 1984, and for 1984 than for 1983. It also indicates that while estimates of the black rockfish are significantly higher for 1985 than for 1983, the increase noted between 1983 and 1984, and between 1984 and 1985 are not significant.

TABLE 5.--One-way analysis of variance of nearshore survey estimates of juvenile rockfish densities. The effect is year (1983,1984 and 1985). Data are transformed to $ln(X + 0.001)$.

Source	Df	Black Rockfish	Blue Rockfish	Yellowtail Rockfish
Year	2	4.681*	33.337***	39.959***
Error	20			

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

There has been considerable variation in the time of first arrival, as well as the relative numbers during a given year. For example, the few juveniles observed in 1983 did not appear until late May, whereas the abundant juveniles of 1985 first arrived in April. Although the numbers have varied significantly from year to year, once established they have remained stable

until at least August--early September, never varying by as much as an order of magnitude.

TABLE 6.--Estimates of average density of juvenile rockfish by nearshore survey. Data are transformed to $ln(X + 0.001)$. Critical ranges are calculated using the Tukey HSD Post Hoc analysis with alpha = 0.05.

	Sample size	Average density		
		Black rockfish	Blue rockfish	Yellowtail rockfish
1983	7	-3.10	-2.86	-5.06
1984	7	-2.44	-0.17	0.46
1985	9	0.63	4.34	5.04
Critical range		3.39	2.31	2.90

DISCUSSION

Considerable progress has been made by the rockfish recruitment program at the Tiburon Laboratory. Since 1983, identification of juvenile rockfish in the area has progressed from incomplete information scattered throughout the literature and in file cabinets to a functioning key that allows technicians to readily identify almost all intact specimens captured in the area. In addition, a field guide for the entire West Coast should be completed by a contractor in about a year.

Considerable progress has also been made in estimating densities of juvenile rockfish. It appears that satisfactory estimates are being obtained for the important species in the area by midwater trawl. Chinook salmon stomach contents show promise for providing an even more efficient method of estimating abundance. The underwater counts appear to offer satisfactory estimates and also some ecological insights, but are limited to species that occur nearshore.

Two important questions remain to be answered. The first: Are estimates of juvenile abundance sufficiently correlated with eventual recruitment to the fishery in the area to prove useful as a tool for management and the fishing industry? The second: Are there major areal differences in recruitment success? That is, do recruitment estimates for northern and central California have any utility in a coastwide context?

It will take a number of years to answer both questions. It will be necessary to examine correlations between juvenile abundance and recruitment strength to answer the first question, and rockfish do not fully recruit to fisheries until they are 4 to 10 years old. The outlook is hopeful because there is qualitative evidence that year classes abundant in nearshore waters as juveniles persist as strong year classes until the age of recruitment. Data are becoming available from the fishery to answer the second question. For example, the 1970, 1971, and 1977 year classes of widow rockfish are important in landings in all three West Coast states.

Scientists from the Tiburon Laboratory, the Northwest and Alaska Fisheries Center, and the USSR are planning to conduct a cooperative midwater trawl survey from a Soviet vessel off the coast of Oregon in 1986. In addition to allowing comparisons of abundances off California and Oregon, the cruise will provide data on several important species that are not abundant in California waters.

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