DISTRIBUTION, ABUNDANCE, AND RECRUITMENT OF SOFT-BOTTOM ROCKFISHES (SCORPAENIDAE: *SEBASTES*) ON THE SOUTHERN CALIFORNIA MAINLAND SHELF[1]

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ABSTRACT

Data from nearly 400 small-mesh otter trawls taken throughout the southern California borderland between 1969 and 1979 were examined to reveal spatial and temporal patterns in the abundance and distribution of rockfishes. Rockfishes were common in all samples taken between 15 and 450 m. Predictably, species composition changed with depth. Catches were numerically dominated by either *Sebastes saxicola* (from 1971-75) or *S. dalli* (from 1975-79) on the mainland shelf south of Point Dume and inshore of 60 m; variability in the recruitment of the young of these species was the major source of seasonal and year-to-year fluctuations in rockfish catches. These variations in recruitment were related to changing oceanographic conditions.

RESUMEN

Se examinaron los datos de casi 400 arrastres de fondo (con tablas), de malla pequeña, tomados en la zona fronteriza del sur de California entre 1969 y 1979, para presentar patrones especiales y temporales en la abundancia y distribución de peces del género *Sebastes*. Estos peces eran comunes en todas las muestras tomadas entre 15 y 450 m. Como se esperaba, la composición en especies cambió con la profundidad. Las capturas estaban dominadas numéricamente por *Sebastes saxicola* (de 1971-75) o *S. dalli* (de 1975-79) en la plataforma continental al sur de Point Dume y dentro de los 60 m de la costa; la variabilidad en el reclutamiento de los juveniles de estas especies fue la mayor causa de las fluctuaciones estacionales y de cada año en las capturas de *Sebastes*. Estas variaciones en el reclutamiento aparecen relacionadas con las variaciones en las condiciones oceanográficas.

INTRODUCTION

This report summarizes data on variations in the abundance, recruitment, and apparent growth of prominent rockfishes caught by small-mesh otter trawls on the southern California mainland shelf. It is intended to complement an earlier report on nearshore fish (Mearns 1979b).

Rockfishes (Genus *Sebastes*, Family Scorpænidæ) are among the most important groups of fishes in California. As adults, some rockfish (notably bocaccio, *Sebastes paucispinis*) make important contributions to recreational and commercial fisheries. In routine trawl surveys along the southern California coast between the 20- and 200-m isobaths, young and adult rockfishes are frequently the most abundant species and, over many seasons, are the most diverse family of fishes collected (Mearns 1977, 1979a). The young are an important food source for many fishes and seabirds. And, because they occur in a variety of habitats close to shore, they can affect, and have been affected by, man's coastal activities, including waste-water discharges (Sherwood 1979; Sherwood and Mearns in press).

Our interest in rockfishes was reinforced in 1975 when investigators conducting routine trawl-monitoring surveys reported a dramatic influx of previously "rare" calico rockfish (*S. dalli*) off Orange and Los Angeles Counties between depths of 15 and 60 m (Mearns 1977; John Stephens, Occidental College, personal communication). An initial investigation of trawl data collected by the Orange County Sanitation Districts (OCSD) and the Southern California Coastal Water Research Project (SCCWRP) revealed that prior to July of 1975 catches between 15 and 150 m were dominated by stripetail rockfish (*S. saxicola*); after the summer of 1975, *S. saxicola* were rare except in the deepest (130-140 m) samples, and through 1978, *S. dalli* dominated the inshore (20-60 m) rockfish catch (Mearns 1979a, 1979b).

Neither *S. saxicola* nor *S. dalli* is commercially harvested or of sportfishing interest in this area; thus, the cause of this dramatic change must be due to factors other than fishing. The area is the site of a 60-m deep sewage outfall (680 million liters/day), which had begun discharge four years earlier (April 1971); however, it is unlikely this discharge was the cause since the *S. dalli* influx was observed at distant sites (e.g. Santa Monica Bay, 20 to 50 km away). This leaves the possibility that the event was natural and in some way related to changing oceanographic or climatic conditions or to biological interactions. In fact, evidence has already been presented that suggests that recruitment of nearshore bottomfish is related to interannual variations in sea-surface temperature and turbidity (Mearns 1979a, 1979b).

As a result of these earlier findings, we felt a more rigorous analysis of spatial and temporal variations of rockfish assemblages was in order. Specific objectives of this study were to identify the most abundant species along the shelf during the 1970's, to determine depth and geographic distributions of certain species both before and after 1975, to seek out any correlations that might

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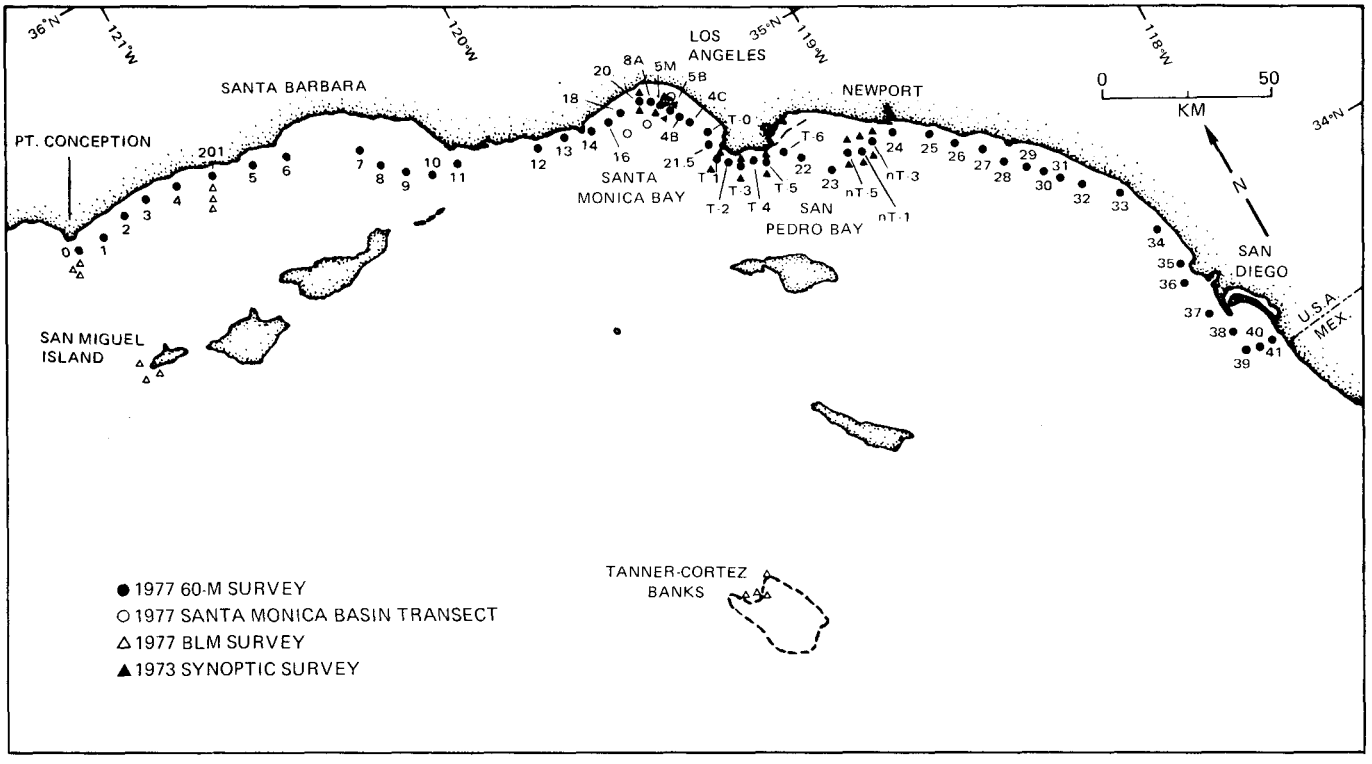

Figure 1. Trawl locations in the Southern California Bight, 1973-79.

exist between variations in rockfish catch and oceanographic changes, and to identify possible biological interactions between rockfish species.

METHODS

Rockfish catch and length-frequency data were compiled from several one-time geographical trawl surveys (one in 1973 and three in 1977, Figure 1) and from a series of quarterly trawl surveys taken between 1969 and 1979 off Orange County (Figure 2).

Trawl Gear and Towing Methods

Two kinds of otter trawls were used, one built by the Marinovich Trawl Company (Biloxi, Mississippi) and the other built by Mr. James Willis, Netmaker, Morro Bay, California. Both nets were 7.62-m (25-foot) headrope length, semi-balloon trawls, fitted with 1.27-cm (0.5-inch) stretch-mesh cod-end liners. However, the Willis nets and doors were constructed of heavier materials and had a slightly larger body mesh than the Marinovich nets (4.13 cm versus 3.81 cm, stretch).

In most cases, tows were taken along isobaths at a speed of 1.3 m/second (2.5 knots). On-bottom tow times were generally 10 minutes but ranged from 10 to 25 minutes (specified below).

This gear is not expected to catch many large, old, fast-swimming rockfish. However, in a comparative hook-and-line and trawl study in Santa Monica Bay, Allen et al. (1975) did demonstrate that this small otter trawl took the same upper size limits of rockfish also captured by hook-and-line (e.g. *S. paucispinis*, trawl to 500-mm standard length [SL], hook-and-line to 450-mm SL; *S. miniatus*, trawl to 260-mm SL, hook-and-line to 300-mm SL; *S. rosenblatti*, otter trawl to 420-mm SL, hook-and-line to 410-mm SL). However, the trawl did take a lower proportion of larger rockfish than did bottom hook-and-line gear (Allen et al. 1975).

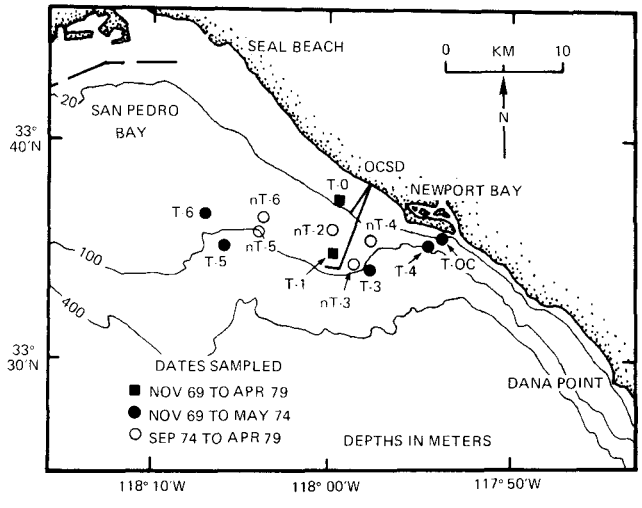

Figure 2. Sampling location for quarterly trawls off Orange County, August 1969 through October 1979.

Catch Processing and Identification

All fishes from these surveys were sorted aboard ship, identified, examined for external abnormalities and parasites, and measured to the nearest 0.5-cm standard length (SL). Catches from 1973 onward were also weighed by species. Voucher specimens and specimens of uncertain identity were preserved and returned to our laboratory for archiving and confirmation.

Juvenile rockfishes from these and other SCCWRP surveys were identified using keys and data in Phillips (1957), Chen (1971), and Miller and Lea (1972). Wherever possible, we also arranged fresh specimens in size series. This effort resulted in a guide which incorporated color as well as morphological features for juvenile rockfishes (Allen 1977). Using this information, we confirmed identification of all specimens collected from August 1971 through 1979. However, we were unable to confirm identifications of specimens collected by OCSD between August 1969 and May 1971.

Geographical Surveys

During the period 24-26 September 1973, SCCWRP conducted a synoptic trawl survey of the coastal shelf between Malibu, in Los Angeles County, and Newport Beach, in Orange County (Mearns and Greene 1974). Single trawls were taken during daytime at each of three depths (23, 61, and 137 m) at each of nine transects located in Santa Monica Bay, off Palos Verdes, and on the southern San Pedro Bay coastal shelf (Figure 1). All tows were 10-minute duration (on-bottom time) and were made aboard the R/V *Van Tuna* using a Marinovich 7.62-m otter trawl.

On 6 and 7 April 1977, SCCWRP sampled a series of seven depths in a transect extending due west of Marina del Rey across Santa Monica Bay and into Santa Monica Basin. Depths sampled were 18, 61, 137, 183, 305, 458, and 610 m (Figure 1). A single 10-minute (on-bottom time) haul was taken at each station.

During spring and summer (28 April to 9 August) 1977, SCCWRP conducted a trawl, grab, and water quality survey of the entire southern California mainland shelf (Point Conception to the U.S-Mexico border) along the 60-m isobath (Figure 1; see also Word and Mearns 1979). Fifty-three of 70 stations were each trawled once during daytime for bottomfish using the same Willis bottom trawl described above. Tows were made using several vessels, but mainly the M/V *Marine Surveyor* and the *Fury II* (Orange County Department of Education). Tows were 10 minutes (on-bottom time) at 1.3 m/second.

Also during 1977, SCCWRP conducted a series of trawl surveys at Tanner Bank, on the seaward shelf off San Miguel Island, off Point Conception and off Goleta Point (near Coal Oil Point) in Santa Barbara County (Figure 1). Sampling was conducted in March and July. Depth distributions of the samples were:

Tanner Bank	185, 185, 185, and 216 m	137, 183, and 274 m
San Miguel Island	183, 183, and 227 m	132, 183, 192, and 274 m
Point Conception	73, 135, 183, and 220 m	137 and 183 m
Coal Oil Point	73, 137, 174, and 185 m	137, 174, and 220 m

All samples were taken aboard the R/V *Velero* (University of Southern California) at 1.3 m/second (2.5 knots) but with on-bottom time ranging from 10 to 25 minutes.

Time Series 1969-79

During the period from August 1969 to the present, the County Sanitation Districts of Orange County (CSDOC) contracted and conducted a series of quarterly trawl surveys at six to eight stations on the southern San Pedro Bay coastal shelf off Huntington Beach and Newport Beach (Figure 2, Pamson et al. 1978; Mearns 1979a). At least one of us was on board to confirm identifications on all but one occasion between August 1971 and October 1979.

A single daytime tow with a Marinovich 7.62-m trawl was taken at each station during each survey. All tows were 10-minute (on-bottom time) and were made aboard the M/V *Fury II* (August 1969 to May 1970) and the R/V *Van Tuna* (August 1970 to October 1979).

Between November 1969 and May 1974, the survey grid included eight stations ranging in depth from 18 to about 150 m; in August 1974 the two deepest stations (133 and 148 m) were deleted, and several stations were rearranged; the result was a grid of seven stations ranging in depth from 18 to 64 m. However, a deep (150 m) site was resampled in January 1977 and October 1979.

Data Analysis and Interpretation

Abundance and length-frequency data on all rockfish was extracted from computerized site-species and species length-frequency matrices and recompiled to determine total species and numbers caught, depth distribution, and length-frequency distribution of selected species, both along shore (60-m survey of 1977) and over time (1971-79 time series).

This analysis is restricted to the genus *Sebastes*; data on other scorpænids (*Scorpaena guttata* and *Sebastolobus* spp.) were collected and will be reported later.

RESULTS

Species Encountered and General Abundance

Over 38,000 specimens of at least 27 species of rockfish were taken in the trawls examined for this report. Species taken, and their common names, are listed in Table 1.

Considering only the major coastal shelf surveys (22 to 137 m), rockfish catches were dominated by *S. saxicola* (19,521 specimens, 53.7% of the rockfish catch); *S. dalli* (25%); halfbanded rockfish, *S. semicinctus* (11.5%);

TABLE 1

Scientific and Common Names of Rockfishes Taken in Otter Trawls by the Southern California Coastal Water Research Project, 1973 to 1979, 78 to 458 m.

Scientific name	Common name
Sebastes aurora	Aurora rockfish
S. babcocki	Redbanded rockfish
S. caurinus[1]	Copper rockfish[1]
S. chlorostictus	Greenspotted rockfish
S. crameri	Darkblotched rockfish
S. dalli	Calico rockfish
S. diploproa	Splitnose rockfish
S. elongatus	Greenstriped rockfish
S. ensifer	Swordspine rockfish
S. eos	Pink rockfish
S. flavidus	Yellowtail rockfish
S. goodei	Chilipepper
S. hopkinsi	Squarespot rockfish
S. jordani	Shortbelly rockfish
S. levis	Cow rockfish
S. macdonaldi	Mexican rockfish
S. melanostomus	Blackgill rockfish
S. miniatus	Vermilion rockfish
S. mystinus	Blue rockfish
S. paucispinis	Bocaccio
S. rosaceus	Rosy rockfish
S. rosenblatti	Greenblotched rockfish
S. rubrivinctus	Flag rockfish
S. saxicola	Stripetail rockfish
S. semicinctus	Halfbanded rockfish
S. serranoides	Olive rockfish
S. umbrosus	Honeycomb rockfish

[1]We include here specimens of *S. vexillaris*, which Miller and Lea (1972) consider indistinguishable.

TABLE 2

The Abundance of *Sebastes* Species and Their Percentage of Total *Sebastes* Catch in Samples from Three Southern California Trawl Surveys, 1969-78.

(Number of samples) Scientific name	Orange County (*n*=286) Number	%	1973 Synoptic (*n*=27) Number	%	1977 60-m (*n*=53) Number	%	Total (*n*=365) Number/%
Sebastes saxicola	6889	(34.9)	4558	(83.4)	8074	(72.6)	19521 (53.7)
S. dalli	6252	(31.7)	13	(0.2)	2812	(25.3)	9077 (25.0)
S. semicinctus	4022	(20.4)	51	(0.9)	94	(0.8)	4167 (11.5)
S. diploproa	1491	(7.6)	494	(9.0)	5	(<0.1)	1990 (5.48)
S. miniatus	287	(1.5)	47	(0.8)	21	(0.2)	355 (1.8)
S. jordani	128	(0.7)	189	(3.4)	8	(0.1)	325 (1.7)
S. goodei	177	(0.9)	33	(0.6)	8	(0.1)	218 (1.1)
S. levis	93	(0.5)	26	(0.5)	49	(0.4)	168 (0.9)
S. crameri	95	(0.5)	27	(0.5)	1	(<0.1)	123 (0.6)
S paucispinis	49	(0.3)	20	(0.4)	5	(<0.1)	74 (0.3)
S. rosenblatti	32	(0.2)	16	(0.3)	7	(<0.1)	55 (0.3)
S. rubrivinctus	60	(0.3)	1	(<0.1)	1	(<0.1)	62 (0.3)
S. mystinus	37	(0.2)	0	(–)	2	(<0.1)	39 (0.2)
S. rosaceus	37	(0.2)	0	(–)	0	(–)	37 (0.2)
S. elongatus	10	(<0.1)	18	(0.3)	1	(<0.1)	29 (0.1)
S. chlorostictus	20	(0.1)	0	(–)	2	(<0.1)	22 (0.1)
S. caurinus	3	(<0.1)	1	(<0.1)	11	(0.1)	15 (<0.1)
S. serranoides	7	(<0.1)	0	(–)	3	(<0.1)	10 (<0.1)
Sebastes unidentified	16	(<0.1)	9	(–)	0	(–)	16 (<0.1)
S. flavidus	6	(<0.1)	0	(–)	0	(–)	6 (<0.1)
S. umbrosus	5	(<0.1)	0	(–)	0	(–)	5 (<0.1)
S. eos	3	(<0.1)	1	(<0.1)	0	(–)	4 (<0.1)
Sebastes (*Sebastomus*), unidentified	0	(–)	0	(–)	4	(<0.1)	4 (<0.1)
S. hopkinsi	1	(<0.1)	1	(<0.1)	1	(<0.1)	3 (<0.1)
S. macdonaldi	0	(–)	2	(<0.1)	0	(–)	2 (<0.1)
Total Species (Taxa)	22		16		19		25
Specimens	19720		5498		11109		36327

splitnose rockfish, *S. diploproa* (5.5%); vermilion rockfish, *S. miniatus* (1.8%); and shortbelly rockfish, *S. jordani* (1.7%; Table 2). The Orange County time series from 1968 through 1978 took 22 species with overall catches equally dominated by *S. saxicola* and *S. dalli*. The data indicate that *S. semicinctus* were abundant only during the period August 1969-May 1971. As noted above, this was prior to SCCWRP participation. Because of the similarity of juvenile *S. semicinctus* and *S. saxicola* and because of the *S. saxicola* dominance following our participation, we believe that the data for *S. semicinctus* could include many *S. saxicola*.

Data from our own independent 1973 synoptic survey (Table 2) indicate that catches between 18 and 137 m were dominated by *S. saxicola*, *S. semicinctus*, and *S. diploproa*; *S. dalli* were rare (0.2% of the catch; Table 2), confirming that they were generally absent from the Los Angeles-Orange Counties coastal shelf prior to the 1975 influx indicated above. However, when we conducted the 60-m survey of the entire coastal shelf in 1977, *S. dalli* made up 25.3% of the rockfish catch (third column, Table 2).

General Depth and Geographic Distributions

Data from surveys taken from March to July 1977 at Tanner Bank, San Miguel Island, Point Conception, Coal Oil Point, and in Santa Monica Bay and Basin were composited to gain insight into the general depth distribution patterns of prominent rockfish captured by our small otter trawls. Trawls in this set varied between 10- and 25-minute duration. Although not exhaustive and biased toward the northern half of the southern California borderland, these data suggest several important trends (Table 3). First, our trawls captured rockfish throughout the depth range 18 to 458 m, but none were caught in a single 610-m haul in Santa Monica Basin. Next, the number of rockfish species per individual haul was relatively constant with depth, ranging from 1.7 to 3.2 with slightly more species per haul inshore of 185 m. Abundance (mean number of specimens/haul) was highest inshore (80 fish/haul at 18-73 m), moderate between 132 and 305 m, and low beyond 458 m. The high catches between 18 and 185 m are due almost exclusively to large numbers of small fish.

These data (Table 3) suggest three major breaks in

TABLE 3

Composite Depth Distributions of Rockfish Taken in 37 7.6-m (Headrope-Length) Otter Trawl Hauls in Santa Monica Bay and Basin, and at Tanner Bank, San Miguel Island, and Point Conception, March-July 1977.[1]

Depth Interval (m)	18-73	132-137	174-185	192-227	275-305	458
Number of Trawls	7	7	13	5	3	1
Number Species ($\bar{x}$)	2.7	2.6	3.2	2.0	1.7	2.0
Number Specimens ($\bar{x}$)	80.1	60.6	60.9	15.0	38.0	12.0
Sebastes mystinus	0.14	----	----	----	----	----
S. semicinctus	0.14	----	----	----	----	----
S. miniatus	0.14	----	----	----	----	----
S. caurinus	0.57	----	----	----	----	----
S. dalli	2.43	----	----	----	----	----
S. levis	0.14	----	0.08	----	----	----
S. saxicola	75.9	18.6	24.3	4.0	----	----
S. jordani	0.14	15.4	11.5	0.60	----	----
S. ensifer	0.43	1.0	0.39	----	----	----
S. paucispinis	----	1.30	0.08	----	----	----
S. rosenblatti	0.14	0.29	0.39	0.20	0.30	----
S. elongatus	----	1.43	5.08	1.00	4.30	----
S. diploproa	----	22.3	17.6	4.00	30.3	11.0
S. crameri	----	0.29	0.77	----	----	----
S. babcocki	----	----	0.15	----	----	----
S. eos	----	----	0.15	----	----	----
S. macdonaldi	----	----	0.08	----	----	----
S. serranoides	----	----	0.08	----	----	----
S. goodei	----	----	0.23	5.4	----	----
S. melanostomus	----	----	----	----	0.30	----
S. aurora	----	----	----	----	----	1.0

[1]Data for species are average number fish per 10- to 25-minute haul (see text).

TABLE 4

Rockfish (*Sebastes*) Catch per 10-Minute Tow with a 7.6-m Headrope-Length Otter Trawl at Three Depth Intervals Sampled in September 1973 off Los Angeles and Orange Counties.

Depth (m)	23	61	137	Total
Number of Samples	9	9	9	27
Number of Specimens ($\bar{x}$)	4.44	288	318	204
Number of Species ($\bar{x}$)	0.89	5.00	5.11	3.6
Sebastes hopkinsi	----	0.11	----	0.04
S. rubrivinctus	----	0.11	----	0.04
S. caurinus	----	0.11	----	0.04
S. dalli	----	1.44	----	0.48
S. goodei	----	3.67	----	1.22
S. semicinctus	----	5.67	----	1.89
S. miniatus	1.30	3.89	----	1.74
S. paucispinis	0.89	0.56	0.77	0.74
S. saxicola	2.22	266	238	169
S. jordani	----	5.11	15.9	7.0
S. levis	----	0.89	2.00	0.96
S. crameri	----	0.22	2.78	1.00
S. elongatus	----	0.11	1.89	0.67
S. diploproa	----	----	54.9	18.3
S. rosenblatti	----	----	1.78	0.59
S. macdonaldi	----	----	0.22	0.07
S. eos	----	----	0.11	0.04

depth distribution of rockfish: the inshore group dominated by *S. saxicola* but characterized by other fish such as *S. dalli*, *S. caurinus*, *S. miniatus*, and *S. semicinctus*; an outer shelf assemblage (132-185 m) dominated by *S. saxicola* and *S. diploproa* but also characterized by *S. jordani* and, in part, *S. elongatus*; and a slope assemblage (192-305 m) dominated, in our catches, by *S. diploproa*, *S. goodei*, and *S. elongatus* but also characterized by a reduced abundance of *S. saxicola*.

The 1973 synoptic surveys off Los Angeles and Orange Counties provided some insight into rockfish depth distributions on the shelf prior to the 1975 influx of *S. dalli* (Table 4). During this survey, rockfish catches were low inshore (4.4 fish/tow at 23 m) but were very high at the 61- and 137-m depth intervals (288 and 318 fish/haul, respectively). Number of species was low inshore (0.89 species/tow) but increased dramatically at 61- and 137-m depth intervals (5.0 and 5.1, respectively). *S. saxicola* dominated catches at all depths (Table 4) and were, of course, the most abundant rockfish overall (84%; Table 2). In contrast, *S. dalli* occurred only at 61 m (Table 4) and were in very low abundance (0.2% of the catch; Table 2). Overall, the coastal zone between Point Dume and Newport (about 80 km) contained a *S. saxicola*-dominated rockfish assemblage inshore of the 61-m isobath.

The 1977 survey at 53 60-m deep stations indicated that *S. saxicola* was also the dominant rockfish at this depth between Point Conception and the U.S.-Mexico border (8,074 specimens, 74% of the catch; Table 2). However, as indicated above, *S. dalli* were no longer rare and, in fact, accounted for over 25% (2,812 specimens) of the combined rockfish catch. The next most abundant species were *S. semicinctus* (94 specimens, 0.8%), *S. levis* (49 specimens, 0.4%) and *S. miniatus* (21 specimens, 0.2%).

A north-to-south plot of the catch per unit effort of these major rockfish species revealed some fascinating trends (Figure 3). First, large numbers of rockfish were concentrated in three or four major regions of the mainland shelf; two areas on the Santa Barbara Shelf, one off southern Orange County, and another off San Diego County.

Sebastes saxicola dominated northern catches while *S. dalli* dominated catches south of Los Angeles (Figure 3). *Sebastes semicinctus* appeared to be generally distributed throughout the area (Figure 3). Other species such as cow rockfish, *S. levis*, and copper rockfish, *S. caurinus*, were mainly northern while still others such as vermilion rockfish, *S. miniatus*, were mainly southern (Figure 3). In general, more species were encountered in the north and central areas than in the south (Figure 3). Length-frequency plots of the two prominent species were examined. As shown in Figure 4, our survey apparently encountered a 1977 recruitment of *S. saxicola* into much of the coast. In fact, the coastal zone from Point Conception south to northern Santa Monica Bay (170-190 km) was nearly continuously occupied by small (25- to 55-mm SL) *S. saxicola* (Stations 0 to 20). Larger *S.*

saxicola (70- to 130-mm SL) were prevalent at this depth mainly in the coastal area between Coal Oil Point (Station 201) and Rincon Point (Station 7).

Sebastes dalli were rare north of Point Mugu (Station 11). However, from about Point Mugu south to the center of Santa Monica Bay (Station 20), medium-sized *S. dalli* (90- to 120-mm SL) became prominent. Farther south, in the San Pedro Bay and Orange County area, medium-sized *S. dalli* dominated the catches (Stations 22 to 25), with young of the year (35- to 65-mm SL) occurring at the two San Pedro Bay stations sampled in late July (Stations 22 and 23). South of Dana Point (Station 25), *S. dalli* were again rare, with *S. saxicola* once again dominating the catches. However, from La Jolla to the border, medium-sized *S. dalli* once again dominated catches, occasionally occurring together with young *S. saxicola.*

Overall, there was very little overlap in the length-frequency distribution of small *S. dalli* and *S. saxicola* at any station. Exceptions were at Stations 22 (San Pedro Bay) and 24 (off Newport Beach). The strongest overlap was for larger fish (e.g. 80- to 110-mm SL) at Station 39 off San Diego.

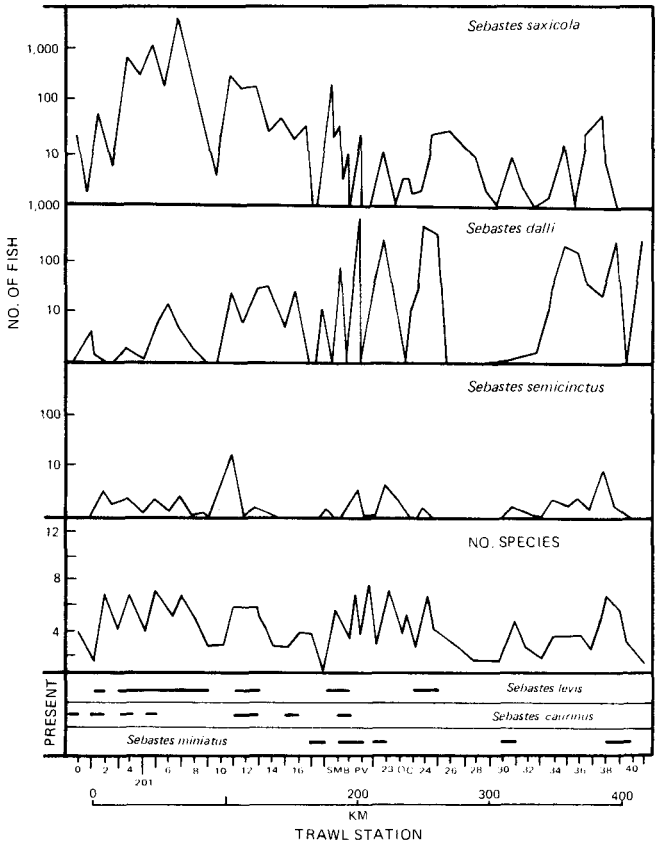

Figure 3. Coastal distribution of rockfish species during 60-m trawl survey in 1977 by the Southern California Coastal Water Research Project.

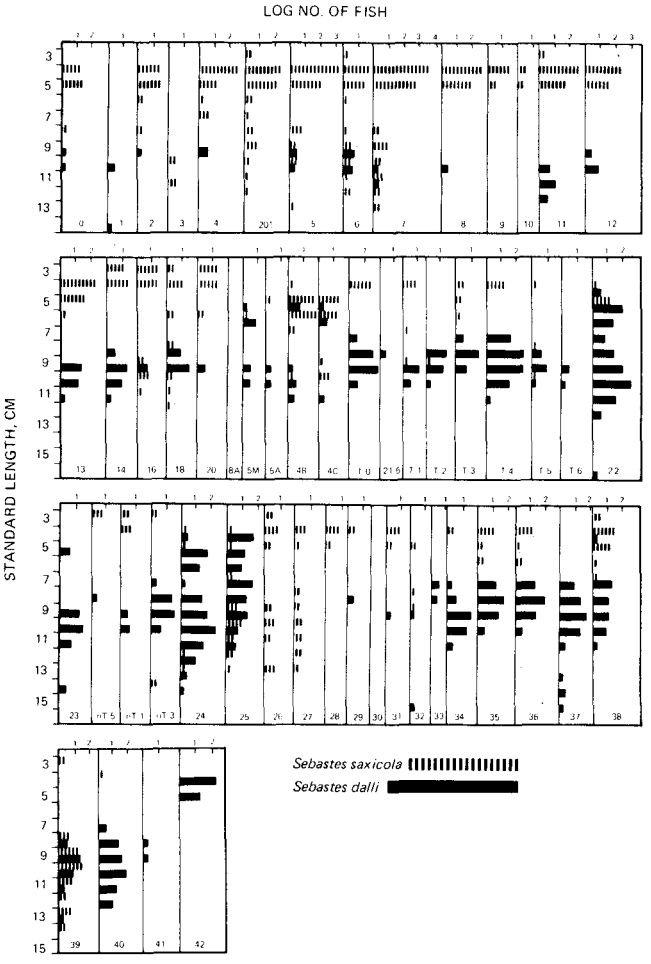

Figure 4. Length-frequency distributions of stripetail rockfish (*Sebastes saxicola*) and calico rockfish (*S. dalli*) at 55 trawl stations sampled in spring and early summer of 1977 between Point Conception (Station 0) and the U.S.-Mexico border (Stations 40-42). Data indicate a decrease in occurrence of small *S. saxicola* and an increase in the size distribution of *S. dalli* south of Santa Monica Bay (Stations 13 to 4c).

Fluctuations off Orange County

Mearns (1977, 1979b) summarized catch data from the first eight years of quarterly trawls off Orange County. An additional year of trawling (through October 1978) produced a total of 131,835 fish representing at least 112 species of sharks, rays, and bony fishes. This cumulative catch included over 19,000 specimens and 23 species of rockfishes (Table 2). Thus, rockfish accounted for 15% of the specimens and 21% of species taken in this area.

Over the full nine-year period, a total of 286 hauls were made during 38 quarterly surveys. Average catch per 10-minute haul was 459±24 SE fish[1]; the catch per unit effort for rockfish was 68.6±10.1 SE[1] (or about 15% of the total catch).

As shown in Table 2, the rockfish catch was dominated by *S. saxicola* (6,889 specimens, 24.9% of the rockfish

[1]Mean and standard error of 38 survey means.

catch) and *S. dalli* (6,252 specimens, 31.7% of the rockfish catch). Next in abundance was *S. semicinctus* (4,022 specimens, 20.4% of the catch), and *S. miniatus* (287 specimens, 1.5% of the catch). Species each contributing 0.5 to 1.0% of the catch were chilipepper, *S. goodei*; shortbelly rockfish, *S. jordani*; dark blotched rockfish, *S. crameri*; and cow rockfish, *S. levis*.

Fluctuations in catch over time were examined for total rockfish catch and for the three most abundant species. As shown in Figure 5a, there were major seasonal and year-to-year differences in rockfish catch per unit effort over the nine-year period. Highest catches generally occurred mid-year (late spring-early fall) and lowest catches in the winter. With the exception of 1969, odd-numbered years produced considerably higher catches than even-numbered years, with highest catches occurring in 1975, 1971, 1973 and 1977. In addition, a long-term trend of decreasing "baseline" catch is apparent during the period 1971 through 1978.

Data on the fluctuations in catch of the three most abundant species of rockfish show specific sources of the variations in total catch (Figure 5). During the four-year period from mid-1971 to mid-1975, *S. saxicola* dominated catches and also appeared to make the major contribution of the 1971, 1973, and 1975 odd-year peaks in total rockfish catch. Then, from mid-1975 through 1978, *S. dalli*, which formerly were rare, dominated catches and were major contributors to peaks in total rockfish catch in 1975 and 1977.

There is some concern that the change in stations and loss of deep-water stations (133-148 m) might affect the interpretation of these changes (i.e. perhaps *S. saxicola* abundance shifted to deeper water after 1974 and were undersampled). As shown in Figure 6, *S. saxicola* were indeed more abundant and occurred over a wider depth range than *S. dalli* prior to August 1974. However, during this period, peak abundance of *S. saxicola* did occur at the depth interval 51-64 m. Also the two influxes of *S. saxicola* (May 1973 and May 1974) were more prominent in the depth range of 34-64 m than at 133-148 m or in shallow water. Peak abundance of *S. dalli* during this period was also at the 51-64-m depth interval, but they occurred infrequently.

In September 1974 the deeper (137-146-m) stations were deleted from the survey grid. Nevertheless, the survey did sample a large influx of *S. saxicola* at both the 31-37-m and 51-64-m depth intervals in May 1975. But in July, there were few *S. saxicola* in any of the trawls; instead, the survey sampled a large influx of *S. dalli* at all depths between 15 and 64 m with the population persisting in abundance through 1978 and 1979 at the 51-64-m depth interval.

Although routine deeper sampling was officially discontinued, two single deep trawls (137-150 m) were taken recently; *S. saxicola* were abundant (105 in January 1977 and 25 in October 1979) and there were no *S. dalli*. These two catches average 65±49 (95% confidence limit) *S. saxicola* per haul. Previous (1971-74)

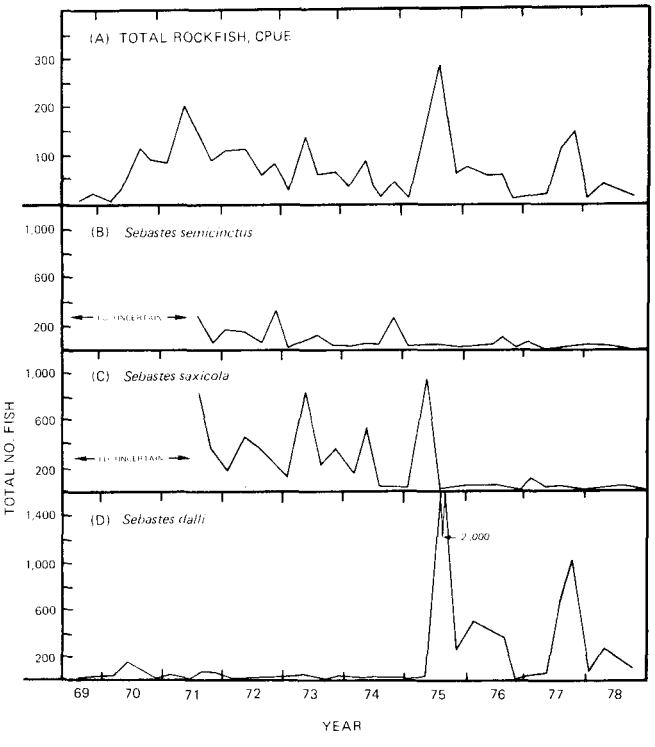

Figure 5. Long-term variations in catch per unit effort (CPUE; number per 10-minute haul) of total rockfish and of *Sebastes semicinctus*, *S. saxicola*, and *S. dalli* in quarterly trawls off southern San Pedro Bay by the County Sanitation Districts of Orange County.

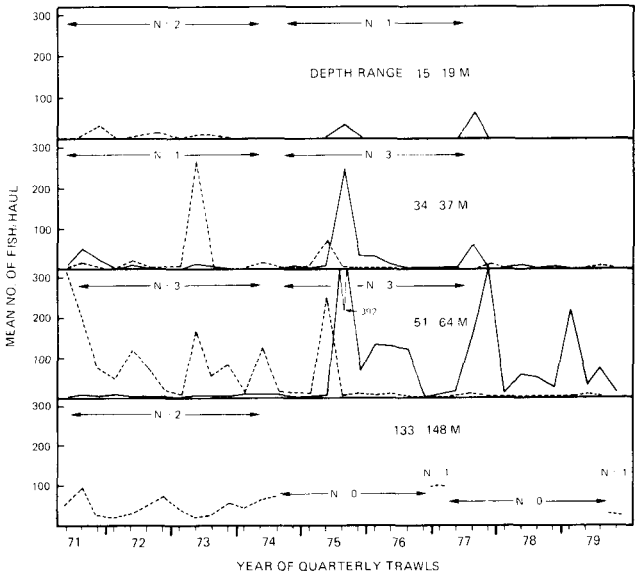

Figure 6. Long-term variation in abundance of *Sebastes saxicola* (dashed line) and *S. dalli* (solid line) at each of four depth ranges in quarterly trawls off Orange County, 1971-79.

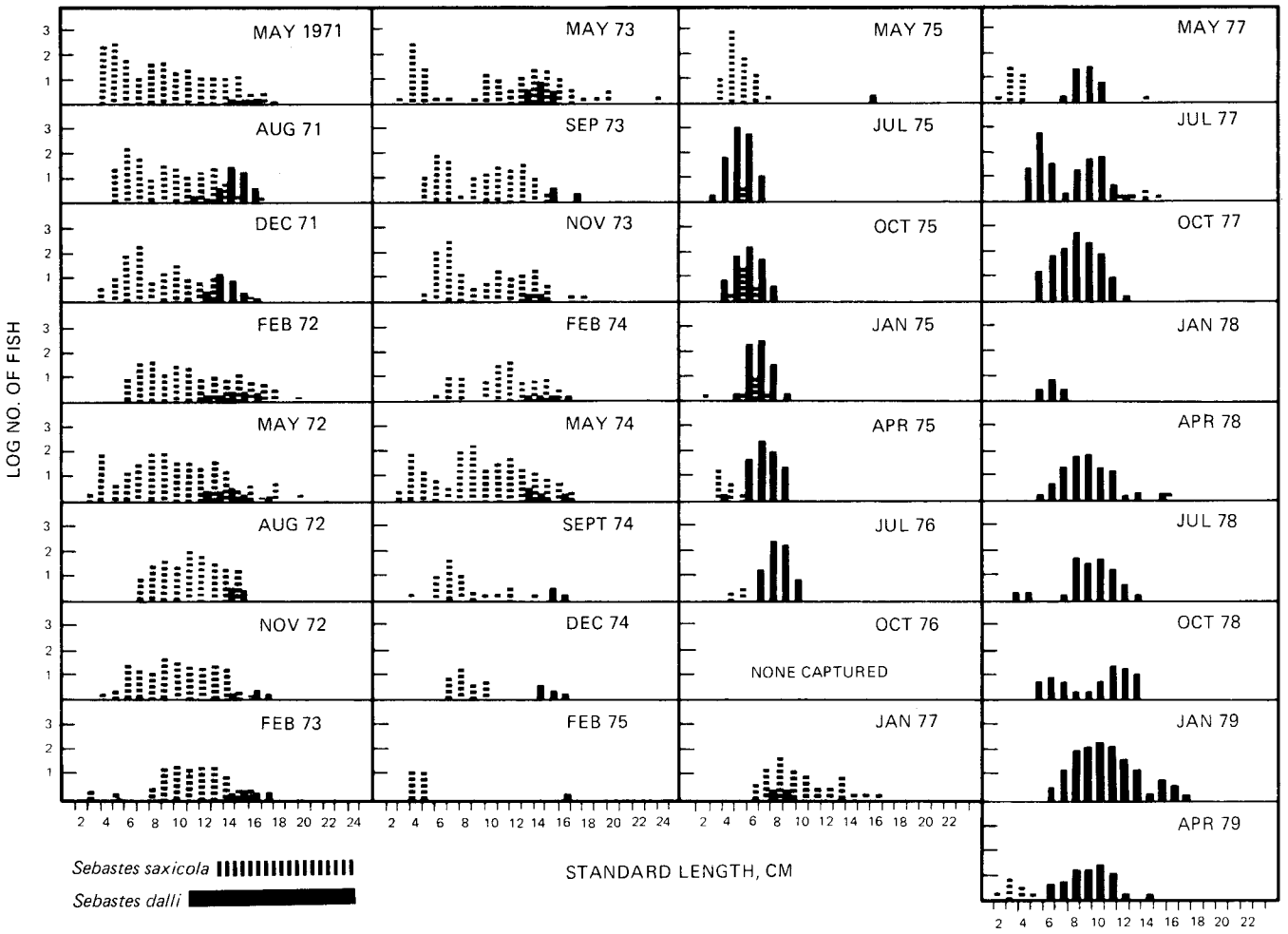

Figure 7. Length-frequency distribution of *Sebastes saxicola* and *S. dalli* in quarterly trawl surveys off Orange County, May 1971 through January 1979.

fall-winter catches at these depths captured 43±27 (95% CL) *S. saxicola* per haul ($N = 12$). Thus, there were slightly but not significantly more *S. saxicola* in deeper water after 1975 than before (1.5-fold increase), and there is only a remote possibility that the entire *S. saxicola* population moved to deeper water following the *S. dalli* influx.

The large increases in abundance of *S. saxicola* in 1971, 1973, and 1975, and of *S. dalli* in 1975 and 1977 were due to recruitment of very young fish into the survey area. As shown in Figure 7, *S. saxicola*, ranging in size from 25 to 45 mm (SL), were encountered during May trawls each year through 1977 with the largest recruitment episodes occurring in odd-numbered years. No young of the year *S. dalli* occurred any time during this period although there were always a few larger fish (120- to 160-mm SL). In contrast, the period from summer 1975 through 1979 was marked by two major odd-year (1975 and 1977) influxes of 25- to 45-mm young of the year *S. dalli* but few *S. saxicola*. The January 1978 deep trawl (137 m) contributed the only rockfish to that survey, and all were earlier year class *S. saxicola*.

Relation of Catch Variations to Oceanographic Conditions

The odd-year episodes in rockfish abundance and recruitment and the apparent shifts in dominant species stimulated a comparison between catch variations and variations in oceanographic conditions. Time series oceanographic data from this survey are limited. However, as indicated in the methods section (above) and in Mearns (1977, 1979b), a considerable detailed time series of weekly and monthly sea-surface temperatures and Secchi disk readings was available for Santa Monica Bay, some 30 to 50 km north of this survey area.

Comparison of catch variations with changes in physical data produced some interesting relationships (Figure 8). In terms of seasonality, highest catches occurred during or just following the month of lowest sea-surface temperatures (generally spring, Figure 8 middle). In

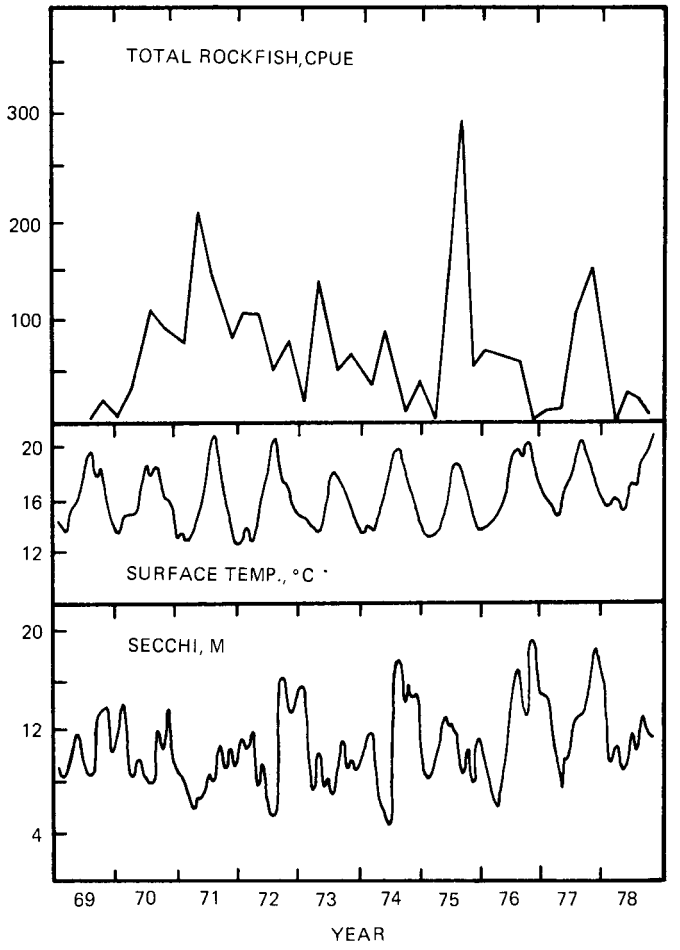

Figure 8. Comparison of (top) long-term fluctuation in abundance of rockfish catch off Orange County with (middle) average monthly sea-surface temperature and with (bottom) Secchi depth visibility in Santa Monica Bay, 1969-78.

addition, peak catches generally occurred during conditions of decreased visibility (increased turbidity), whereas poor catches occurred mainly during periods of increased visibility (low turbidity) as measured by Secchi disk depths (Figure 8 bottom).

As explained above, peak catches were due mainly to recruitment of the young *S. saxicola* and *S. dalli*. Thus, there are either more young recruiting into the area and the year during conditions of cool water and increased turbidity, or the young fish are avoiding gear during periods of warm water and low turbidity.

Some of the year-to-year differences may be related to longer term physical conditions. For example, the peak catch years of 1971, 1973, 1975, and 1977 followed fall and early winter periods of exceptionally low turbidity, which also occurred at two-year intervals (e.g. the fall-winter of 1972-73, 1974-75 and 1976-77, where Secchi depths averaged 15 to 18 m for periods of 3 to 5 months; Figure 8 bottom).

The long-term trend of decreasing "baseline" catch of rockfish also appears to relate to long-term changes in physical conditions. As shown in Figure 8 (middle), winter minimum temperatures were becoming increasingly cooler from 1969 to 1971-72 but increasingly warmer from 1972-73 to 1978. In fact, annual average rockfish catches were inversely related to annual sea-surface temperature over the range 15.3 to 17.4°C (Figure 9). Similarly, turbidity has undergone a general increase from 1971 through 1978. Thus, both the trend of increasing winter sea-surface temperature and increasing turbidity appear to be associated with generally decreasing catches of rockfish.

In addition, there appear to be temperature-related species groups; for example, catches, dominated by *S. dalli* ("c" in Figure 9), occurred during consecutive warm-water years of 1976, 1977, and 1978, which averaged 17°C or higher. In contrast, *S. saxicola* ("s"; Figure 9) dominated catches during years that averaged 16.2°C or lower; highest *S. saxicola* catches occurred during the two coldest years of 1971 and 1975 (15.8 and 15.3°C). Since large catches are mainly due to small recruiting fish, it appears that cooler years favor recruitment of *S. saxicola* into the area whereas warmer years favor recruitment of *S. dalli*.

DISCUSSION AND IMPLICATIONS

A diverse assemblage of rockfish inhabit waters of the softbottom coastal shelf of southern California. During the 1970's, this assemblage has included large numbers of relatively small species, mainly *S. saxicola* and *S.*

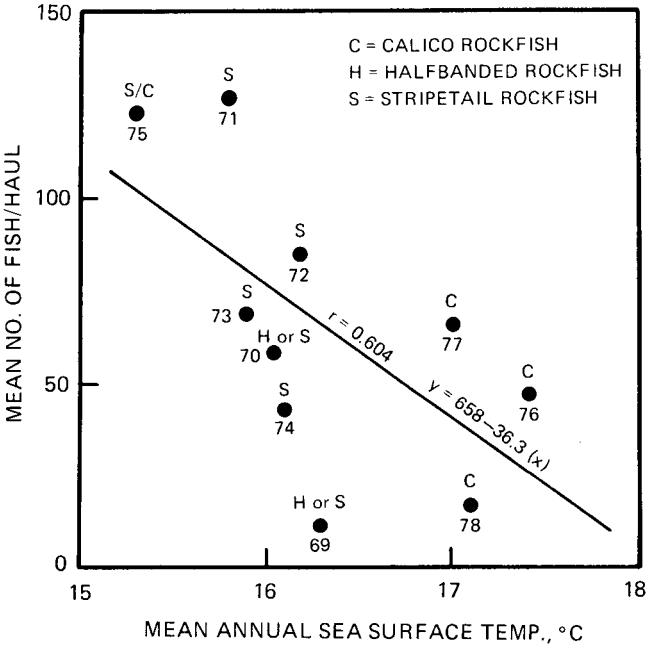

Figure 9. Average annual rockfish catch versus average annual sea-surface temperature. Year and species characterizing each point are indicated.

dalli, depending on the year, location, and depth. *S. semicinctus, S. diploproa, S. miniatus*, and *S. jordani* are also important, but secondary, near-bottom species, with importance dependent on depth and the number of recently settled young rockfish.

The relative abundance of trawl-caught rockfish species caught by small research otter trawls is markedly different than relative abundances landed in commercial and sport fisheries. For example, *S. levis, S. serranoides, S. caurinus, S. miniatus,* and *S. paucispinis* have dominated past party-boat landings in southern California, whereas *S. paucispinis, S. goodei* and *S. miniatus* dominated commercial trawl and set-line catches (Young 1969). Only *S. miniatus* is abundant in all three "fisheries." This fact, coupled with the lack of significant *S. saxicola* and *S. dalli* landings suggests that rockfish assemblages are more complex and diverse than reflected by any single sampling method and, further, that data taken by all these methods should be used to assess the ecology of local rockfish populations.

Obviously, *S. saxicola* and *S. dalli* are among the most important rockfish in southern California. According to Miller and Lea (1972), both *S. saxicola* and *S. dalli* are considered common in southern California. Both range from Sebastian Viscaino Bay, Baja California, north to San Francisco, but *S. saxicola* continues its range into southeastern Alaska; also, *S. saxicola* has a reported depth range that is greater than that of *S. dalli* (58 to 400 m and 18 to 255 m, respectively). These observations suggest that *S. saxicola* is a more northerly, cooler-water species than *S. dalli*.

The disappearance of *S. saxicola* and influx of *S. dalli* on the inner coastal shelf of central southern California in 1975 is an interesting ecological event that deserves further investigation. Neither species is subject to direct fishing pressure. Yet data presented here suggest that the event was, in fact, large-scale (in that it covered at least 100 km of coastline) yet limited to the coastal area south of Point Dume and inshore of the 60- to 130-m isobaths. In this region, at 130-150 m, *S. saxicola* populations were apparently not measurably impacted by the lack of inshore recruitment from 1975 to 1979.

The 1975 inshore switch in dominance from *S. saxicola* to *S. dalli* raises the question: Which condition, if either, is normal for this area? One is tempted to believe that conditions first observed are the "norm" and any change that follows is "abnormal." However, data from an earlier quarterly trawl survey in Santa Monica Bay (Carlisle 1969) indicate that *S. dalli* was more abundant than *S. saxicola* following the warm-water years of 1957-63. It is therefore possible that *S. dalli* dominance is more the norm than *S. saxicola* dominance.

However, *S. saxicola* appear to be more successful in cool-water years and *S. dalli* in warm-water years. There is a long history of warm- and cool-water episodes in southern California; these episodes are accompanied by occurrences and invasions and mass strandings of unusual species of fishes and invertebrates (Radovich 1961). It is unreasonable to assume that such physically triggered events are limited only to the pelagic species that have characterized them in the past (pelagic red crabs, jumbo squid, etc.). Profound ecological changes should be expected in the benthic fauna as well, and it is possible that southern California rockfish populations are continuously affected by such aperiodic but frequent oceanographic changes. Indeed, 1973 in southern California coastal waters was marked by invasions and mass strandings of pelagic red crabs (*Pleuroncodes planipes*; Mearns 1979) and, in deep water offshore, by an unusually heavy recruitment of a large benthic echiuroid, *Listriolobus peloides*, which persisted in larger numbers through 1977 and effectively bulldozed shelf sediments and increased benthic infaunal diversity at several locations (Word 1979). The following year, 1974, was marked not only by the change in rockfish species dominance but also by a major late spring red tide and an invasion of large jellyfish (*Pelagia* sp.; Mearns 1979a). The two years (1975 and 1976) were characterized by brief, but intense, mass strandings of subtropical jumbo squid (*Dosidiscus gigas*) and, later, by a strong catch of swordfish. With concurrent bottomfish and physical data now available, it would be worthwhile determining to what extent fluctuation in coastal zone fish populations is related to the larger scale oceanographic events that triggered these invasions.

Whichever rockfish species is dominant, successful recruitment has occurred only during odd-numbered years. This two-year "periodicity" is somewhat related to two-year episodes of turbidity, suggesting that the cause may be related to oceanographic conditions (such as plankton blooms) that have changed at two-year intervals. However, the cause may also be biological in origin, i.e. an inherent spawning cycle not unlike the two-year cycles experienced by Alaskan populations of pink salmon.

The 1974 switch in dominance from *S. saxicola* to *S. dalli* was an event clearly affecting the distribution and abundance of post-larval juveniles, not adults. This suggests the importance of carefully surveying juvenile rockfish populations in the future. The event also suggests that at least inshore, these two species are competing for food resources. Work is now in progress at the Coastal Water Research Project to determine feeding habits of the young of both species and to examine additional sources of data including an equally long time series off Palos Verdes and other southern California coastal sites.

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LITERATURE CITED

Allen, M.J. 1977. Southern California trawl-caught juvenile rockfishes. Proc. Taxonomic Standard. Prog. 5(4):25-32. Southern California Coastal Water Research Project, Long Beach, CA.

Allen, M.J., J.B. Isaacs, and R.M. Voglin. 1975. Hook-and-line survey of demersal fishes in Santa Monica Bay. Tech. Mem. 222, S. Calif. Coastal Water Res. Proj., Long Beach, CA 23 p.

Carlisle, J.G., Jr. 1969. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. Calif. Fish Game 55:26-46.

Chen, L-C. 1971. Systematics, variation, distribution and biology of rockfishes of the subgenus *Sebastomus* (Pices, Scorpænidæ, *Sebastes*). Scripps Inst. Oceanogr. Bull., 18:1-107.

Mearns, A.J. 1977. Abundance of bottom fish off Orange County. P. 133-142 *In* Coastal Water Research Project Annual Report 1977. Nat. Tech. Info. Serv., U.S. Dept. Comm.; PB 274463/AS, Springfield, VA, 253 p.

_____ . 1979a. Variations in coastal physical and biological conditions, 1969-78. P. 147-156 *In* Coastal Water Research Project, Annual Report 1978, S. Calif. Coastal Water Res. Proj., Long Beach, CA, 253 p.

_____ . 1979b. Abundance, composition and recruitment of nearshore fish assemblages in the southern California mainland shelf. Calif. Coop. Oceanic Fish. Invest. Rep. 20:111-119.

Mearns, A.J., and C.S. Greene (eds.) 1974. A comparative trawl survey of three areas of heavy waste discharge. Tech. Mem. 215, S. Calif. Coastal Water Res. Proj., Long Beach, CA, 76 p.

Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish Game, Fish. Bull. 157:1-249.

Pamson, G.T., M.L. Heinz, A.J. Ursic, C.A. Martin, J. Johnson, F.J. O'Brien, and T. Pesich. 1978. Annual Report, Vol. II, Marine Monitoring, 1977. County Sanitation Districts of Orange County, Fountain Valley, CA, 113 p.

Phillips, J.B. 1957. A review of the rockfishes of California (Family Scorpænidæ). Calif. Dept. Fish Game, Fish. Bull. 104:1-158.

Radovich, J. 1961. Relationships of some marine organisms of the Northeast Pacific to water temperatures, particularly during 1957 through 1959. Calif. Dept. Fish Game, Fish. Bull. 112:1-62.

Sherwood, M.J. 1979. The fin erosion syndrome. P. 203-221 *In* Coastal Water Research Project, Annual Report 1978. S. Calif. Coastal Water Res. Proj., Long Beach, CA, 253 p.

Sherwood, M.J., and A.J. Mearns (in press). Fate of post-larval bottom fish in a highly urbanized coastal zone. *In* Proc. Symp. on Early Life History of Fish, ICES, Woods Hole Oceanographic Inst., Mass., April, 1979.

Word, J.Q. 1979. The infaunal trophic index. P. 19-39 *In* Coastal Water Research Project, Annual Report 1978. S. Calif. Coastal Water Res. Proj., Long Beach, CA, 253 p.

Word, J.Q., and A.J. Mearns. 1979. 60-meter control survey off southern California. Tech. Mem. 229, S. Calif. Coastal Water Res. Proj., Long Beach, CA, 58 p.

Young, P.E. 1969. The California partyboat fishery, 1947-1967. Calif. Dept. Fish Game, Fish. Bull. 145:1-91.