ABUNDANCE, COMPOSITION, AND RECRUITMENT OF NEARSHORE FISH ASSEMBLAGES ON THE SOUTHERN CALIFORNIA MAINLAND SHELF.

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ABSTRACT

Data on coastal fishes taken during a 8-year time-series of trawl surveys of northern Orange County (southern San Pedro Bay), California, were examined to determine how variable catches have been and whether or not they have changed in accordance with variations in such basic oceanographic conditions as temperature and transparency. Nearly 120,000 specimens of more than 112 species of fishes, sharks, and rays, and an equally large number of shrimp, crabs, echinoderms, and other invertebrates were collected during the quarterly trawl surveys at depths between 18 and 200 m. During this period (1969-77), fish abundance in the survey area varied about 4-fold. The variation was largely due to episodic recruitment of mixed assemblages of juvenile fishes. Most episodes of recruitment to the coastal shelf occurred during the onset of increasing turbidity and just following the coldest periods of the year. Alternating years of strong and weak year classes of rockfish and other species were observed and appeared to be directly influenced by oceanographic conditions.

It is suggested that further analysis of these and other coastal trawl survey records might help in understanding dynamics of mixed species populations and offer insight into approaches for assessment of multispecies management problems.

INTRODUCTION

For many years a number of local government agencies have conducted coastal fish surveys using small, fine-mesh, otter trawls at depths ranging from 5 to more than 200 m. In southern California, these surveys have produced a large amount of data on the abundance, distribution, health, and diversity of more than 150 species of marine fishes (Southern California Coastal Water Research Project 1973; Allen and Voglin 1976). Analysis of some of these data has helped identify disease epicenters (Mearns and Sherwood 1974) and some important features of structure and depth zonation of mainland shelf fish assemblages (Mearns 1974; Mearns and Smith 1976; Allen 1977a). However, much of the data from these and ongoing surveys remains unanalyzed and unused by fishery biologists. This is partly because, in the past, trawls have not been considered particularly quantitative or efficient sampling tools and partly because many fishery biologists may not be aware of the kind and quality of data that is now being taken in coastal monitoring programs.

The purpose of this paper is, first, to demonstrate the kind of analyses that are possible from contemporary local trawl surveys and, second, to identify some possible sources and causes of year-to-year variation in catches of nearshore fish populations.

My analyses are based on data from an 8-year time-series of quarterly trawl surveys conducted in southern San Pedro Bay off Orange County. Early in the work, it became apparent that year-to-year differences in the recruitment, growth, and survival of juvenile fishes were primarily responsible for year-to-year differences in total catch. Thus, I focused attention on young fishes and their particular relationship to variations in oceanographic conditions.

A major question now facing many local government agencies is: How much sampling is enough? Thus, I have also included in this report a retrospective analysis of the kind of information acquired during consecutive years of trawling at this particular site.

METHODS

This study is based on analysis of data on fishes captured during an 8-year time-series of trawl surveys on the mainland shelf in southern San Pedro Bay off northern Orange County, California (Figure 1). This part of the mainland shelf is characterized inshore (20 m) by a silty-sand soft bottom, grading offshore (to 100 m) to a soft bottom composed of sandy silt and olive-green mud. Centers of hard-bottom substrate inshore include an artificial sportfishing reef, power plant intake and discharge lines (at Huntington Beach), and an abandoned 1.6-km (1-mile) sewage outfall. Located offshore are an oil platform and the terminus of an active 8-km (5-mile) wastewater outfall, operated by the County Sanitation Districts of Orange County (CSDOC). This outfall began operation in 1971 and discharges 180 million gallon/day of primary-treated domestic sewage through a long, multiport diffuser located at a depth of 60 m. As described elsewhere (Mearns et al. 1976; Pamson et al. 1978), the principle effect of the outfalls has been to increase the relative abundance of several flatfish species at a station closest to the new outfall and to reduce fish abundance at a shallower site near an outfall abandoned in 1971.

The quarterly trawl program was initiated in August

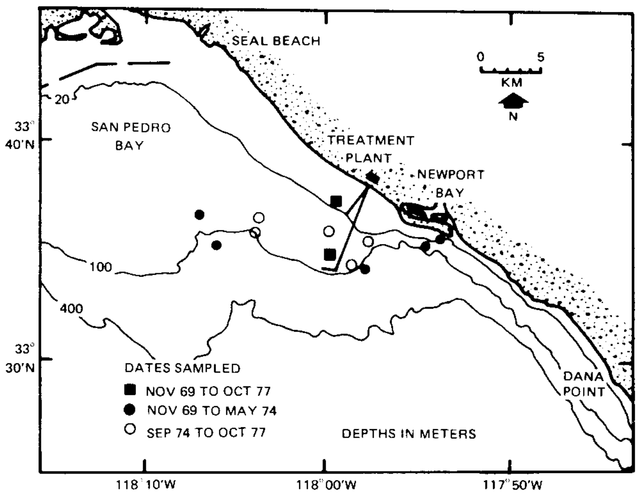

Figure 1. Trawl survey stations in southern San Pedro Bay, California, 1969 through 1977.

1969 by Marine Biological Consultants, Inc., of Costa Mesa under contract to the Orange County Sanitation Districts (OCSD). Six stations were sampled that month (20-60 m). Beginning in November, a fixed grid of eight stations (20-170 m) was sampled, with 1 haul/station, quarterly through May 1974. In 1974, the Santa Ana Regional Water Quality Control Board ordered a change in location of several stations and deletion of the deepest. Quarterly trawling has continued at these seven fixed stations with an occasional deep trawl (170 m) as ship time permits. Stations and their changes are shown in Figure 1.

Important changes taking place during the survey period included 1) a change of vessels (*Fury II* to *Van Tuna*) in August 1970, and 2) diversion of effluent (at the time 130 MGD) from a shallow (18 m) 1-mile outfall to the deep (58 m) 5-mile outfall in April 1971. Beginning in November 1971, biologists from this project have participated in all but one survey.

A 7.6-m (25-foot) head rope-length otter trawl fitted with a 3.8-cm (1½-inch) stretch mesh bag and a 1.3-cm (½-inch) stretch mesh cod end was used in all surveys. Detailed characteristics of this gear were reported by Mearns and Stubbs (1974). On most occasions, the net was towed with a pair of 14-m (46-foot) bridles. Measurements at sea confirmed that the nets were opening 4.9-5.2 m (16-17 feet, door spread) during towing.

Trawls were taken along isobaths and generally downswell. Boat speed during trawling was 4.6 km/hour (2.5 knots). Trawls were ten minutes in duration, measured from the time the cable was fully deployed to the time retrieval was begun. In actual practice this meant that the trawl was probably on bottom somehwat longer (e.g. up to 15 minutes). Scope ratios used on the *Van Tuna* were high, ranging from 8:1 at 18 m, 4 or 5:1 at 46-55 m, to 3.3:1 at 90 m.

Upon retrieval, all animals were sorted and larger organisms identified and counted. Most fishes were readily identified in the field, but juvenile rockfishes and sanddabs (*Citharichthys*) required special examination (Allen 1976, 1977b). Beginning in 1969 fishes were examined for external diseases, and the range of sizes (largest and smallest) were reported. Beginning in 1971 all fishes were measured to the nearest cm standard length (SL), and beginning in 1975 fishes and invertebrates were weighed in lots by species.

Marine Biological Consultants, Inc. (1974) published quarterly and annual reports of the total catches through May 1974, with CSDOC taking over this task beginning with the September 1974 survey. Data taken on all fishes have been coded, keypunched, and summarized in a computer format by the Southern California Coastal Water Research Project (SCCWRP). For my analysis, I considered each survey as a unit of effort for examining long-term trends and each sample within a survey for examining variation within that survey.

RESULTS

Catch Composition

Over 119, 700 fishes, representing 112+ species and 37 families of sharks, rays, and bony fishes were collected in the 258 samples taken between August 1969 and October 1977. The rather diverse fauna (Table 1) was dominated by rockfishes (Scorpaenidae, 25+ species), pleuronectid flatfishes (10+ species), surfperch and sea perch (Embiotocidæ, 8 species), bothid flatfish (7+ species) and sculpins (Cottidæ, 7+ species). Other well-represented families included the cusk eels and eelpouts (Ophidiidae and Zoarcidae), the greenling family (Hexagrammidæ), poachers (Agonidæ), and croakers (Sciænidæ). The most abundant and most frequently occurring species throughout the period (summarized in Table 2) included the speckled and Pacific sanddabs (*Citharichthys stigmaeus* and *C. sordidus*, respectively), yellowchin sculpin (*Icelinus quadriseriatus*), and Dover sole (*Microstomus pacificus*). These as well as the bigmouth sole (*Hippoglossina stomata*), English sole (*Parophrys vetulus*), horny-head turbot (*Pleuronichthys verticalis*), and the California tonguefish (*Symphurus atricauda*) were present in all surveys.

Young and adult fish of a number of economically important species were captured in these surveys. As shown in Table 3, there were frequent catches of northern anchovy (*Engraulis mordax*), California scorpionfish (*Scorpaena guttata*), petrale sole (*Eopsetta jordani*), chilipepper (*Sebastes goodei*), California halibut (*Paralichthys californicus*), cow rockfish (*Sebastes levis*),

TABLE 1
Scientific and Common Names of Fishes Captured in Southern San Pedro Bay during Quarterly Trawl Surveys, August 1969 through October 1977, Depth Range 18 to 150 m.

Scientific Name	Common Name	Total Number Caught	Occurrence in Surveys (34)
Myxinidae			
Eptatretus stouti	Pacific hagfish	1	1
Carcharhinidae			
Mustelus californicus	Gray smoothound	3	2
Squalidea			
Squalus acanthias	Spiny dogfish	25	6
Rhinobatidae			
Platyrhinoides triseriata	Thornback	5	2
Rhinobatos productus	Snovelnose guitarfish	15	6
Torpidinidae			
Torpedo californica	Pacific electric ray	10	9
Rajidae			
Raja kincaidi	Sandpaper skate	3	3
Myliobatidae			
Myliobatis californica	Bat ray	1	1
Chimaeridae			
Hydrolagus collei	Ratfish	12	8
Ophichthidae			
Ophichthus zophochir	Yellow snake eel	1	1
Engraulidae			
Anchoa compressa	Deepbody anchovy	12	1
Engraulis mordax	Northern anchovy	1,566	16
Argentinidae			
Argentine sialis	Pacific argentine	39	3
Synodontidae			
Synodus lucioceps	California lizardfish	561	22
Batrachoididae			
Porichthys myriaster	Specklefin midshipman	127	19
Porichthys notatus	Plainfin midshipman	4,503	32
Moridae			
Physiculus rastrelliger	Hundredfathom codling	13	4
Merlucciidae			
Merluccius productus	Pacific hake	62	11
Ophidiidae			
Chilara taylori	Spotted cusk eel	252	27
Otophidium scrippsae	Basketweave cusk eel	14	6
Otophidium sp.		2	2
Zoarcidae			
Aprodon cortezianus	Bigfin eelpout	65	5
Lycodopsus pacifica	Blackbelly eelpout	1,961	26
Lyconema barbatum	Bearded eelpout	95	9
Sygnathidae			
Sygnathus californiensis	Kelp pipefish	25	11
Sygnathus exilis		18	7
Scorpænidae			
Scorpaena guttata	California scorpionfish	312	29
Sebastes chlorostictus	Greenspotted rockfish	20	5
Sebastes crameri	Darkblotched rockfish	95	8
Sebastes dalli	Calico rockfish	5,768	31
Sebastes diploproa	Splitnose rockfish	1,491	17
Sebastes elongatus	Greenstriped rockfish	10	9
Sebastes eos	Pink rockfish	3	2
Sebastes flavidus	Yellowtail rockfish	6	1
Sebastes goodei	Chilipepper	177	13
Sebastes hopkinsi	Squarespot rockfish	1	1
Sebastes jordani	Shortbelly rockfish	128	12
Sebastes levis	Cow rockfish	93	20
Sebastes miniatus	Vermillion rockfish	287	25
Sebastes mystinus	Blue rockfish	37	8
Sebastes paucispinus	Boccacio	48	11
Sebastes rosaceus	Rosy rockfish	37	4
Sebastes rosenblatti	Greenblotched rockfish	31	13
Sebastes rubrivinctus	Flag rockfish	48	20
Sebastes saxicola	Stripetail rockfish	6,888	27
Sebastes semicinctus	Halfbanded rockfish	4,019	29
Sebastes serranoides	Olive rockfish	7	5
Sebastes serriceps	Treefish	1	1
Sebastes umbrosus	Honeycomb rockfish	5	3
Sebastes vexillaris	Whitebelly rockfish	3	3
Sebastes sp. (unid.)		7	4
Sebastes (Sebastomus) sp. (unid.)		2	2
Sebastolobus alascanus	Shortspine thornyhead	122	8
Hexagrammidae			
Ophiodon elongatus	Lingcod	3	3
Oxylebius pictus	Painted greenling	5	5
Zaniolepis frenata	Shortspine combfish	632	26
Zaniolepis latipinnis	Longspine combfish	1,571	32
Anoplopomatidae			
Anoplopoma fimbria	Sablefish	58	18
Cottidae			
Artedius notospilotus	Bonyhead sculpin	1	1
Chitonotus pugetensis	Roughback sculpin	1,582	28
Icelinus quadriseriatus	Yellowchin sculpin	12,728	34
Icelinus tenuis	Spotfin sculpin	5	1
Leptocottus armatus	Pacific staghorn sculpin	15	4
Radulinus asprellus	Slim sculpin	37	5
Scorpaenichthys marmoratus	Cabezon	2	2
Cottidae, unid.		1	1
Agonidae			
Agonopsis sterletus	Southern spearnose poacher	18	8
Odontopyxis trispinosa	Pygmy poacher	291	33
Xeneretmus latifrons	Blacktip poacher	779	15
Xeneretmus triacanthus	Bluespotted poacher	56	12
Percichthyidae			
Stereolepis gigas	Giant sea bass	1	1
Serranidae			
Paralabrax maculatofasciatus	Spotted sandbass	4	2
Paralabrax nebulifer	Barred sandbass	7	5

Scientific Name	Common Name	Total Number Caught	Occurrence in Surveys (34)
Branchiostegidae			
Caulolatilus princeps	Ocean whitefish	13	7
Sciaenidae			
Cheilotrema saturnum	Black croaker	3	3
Genyonemus lineatus	White croaker	6,371	33
Menticirrhus undulatus	California corbina	13	9
Seriphus politus	Queenfish	1,546	23
Embiotocidae			
Amphistichus argenteus	Barred surfperch	3	3
Cymatogaster aggregata	Shiner perch	986	26
Embiotoca jacksoni	Black perch	110	22
Hyperprosopon argenteum	Walleye surfperch	112	15
Phanerodan furcatus	White seaperch	385	30
Rhacochilus toxotes	Rubberlip seaperch	7	4
Rhacochilus vacca	Pile perch	8	9
Zalembius rosaceus	Pink seaperch	3,446	33
Bathymasteridae			
Rathbunella sp. A	Bluebanded ronquil	8	3
Rathbunella hypoplecta	Smooth ronquil	12	4
Uranoscopidae			
Kathetostoma averruncus	Smooth stargazer	15	7
Clinidae			
Neoclinus blanchardi	Sarcastic fringehead	1	1
Stichaeidae			
Plectobranchus evides	Bluebarred prickleback	4	3
Poroclinus rothcocki	Whitebarred prickleback	2	1
Gobiidae			
Coryphopterus nicholsi	Blackeye goby	25	8
Lepidogobius lepidus	Bay goby	67	22
Trichiuridae			
Lepidopus xantusi	Pacific scabbard fish	1	1
Stromateidae			
Icichthyes lockingtoni	Medusa fish	5	3
Peprilus simillimus	Pacific pompano	73	9
Bothidae			
Citharichthys fragilus	Gulf sanddab	150	7
Citharichthys sordidus	Pacific sanddab	16,742	34
Citharichthys stigmaeus	Speckled sanddab	20,485	34
Citharichthys xanthostigma	Longfin sanddab	449	26
Citharichthys unid.		55	1
Hippoglossina stomata	Bigmouth sole	539	34
Paralichthys californicus	California halibut	146	29
Xystreurys liolepis	Fantail sole	53	15
Pleuronectidae			
Eopsetta jordani	Petrale sole	268	6
Glyptocephalus zachirus	Rex sole	1,605	20
Hypsetta guttulata	Diamond turbot	48	13
Lyopsetta exilis	Slender sole	2,606	21
Microstomus pacificus	Dover sole	7,436	34
Parophrys vetulus	English sole	2,182	34
Pleoronichthys coenosus	C-O sole	37	15
Pleuronichthys decurrens	Curlfin sole	323	24
Pleuronichthys ritteri	Spotted turbot	11	8
Pleuronichthys verticalis	Hornyhead turbot	891	34
Pleuronichthys unid.		2	2
Pleuronectiformes unid.		54	2
Cynoglossidae			
Symphurus atricauda	California tonguefish	5,633	34
	Total	119,764	

Pacific hake (*Merluccius productus*), and sablefish (*Anoplopoma fimbria*). A young giant sea bass (*Stereolepis gigas*) was also captured in one trawl.

Species and their relative abundances are similar to those reported from Santa Monica Bay by Carlisle (1969).

Catch Statistics

Overall, the average haul in these surveys took 15.9 species and 469 specimens with a Shannon-Weaver diversity of 1.62 (Table 4). Previous calculations indicated that average fish biomass in these hauls was 10.7 ± 4.4 (standard error) kg (Allen and Voglin 1976). Single surveys (of 7 or 8 hauls) actually took from 1570-6344 fish (average 3544) and 23-65 (average 44.1) species. Comparison of catch parameters using coefficients of variation (CV) of survey means indicated that Shannon-Weaver diversity and number-of-species per haul were the least variable parameters (CV = 12.3 and 18.5%, respectively) and that total number-of-fish per haul was the most variable (ranging from CV = 27.7% for catch-minus-smallest fish to 71.8% for the small fish alone, Table 4). These "between survey" variations were considerably lower than "within survey" variations caused by differences among individual samples. In fact, coefficients of variation within surveys averaged 25.1% for diversity, 26.3% for number-of-species per haul, and 62% for total-catch per haul. Thus the survey as a unit of effort was about one-half as variable as a single haul as a unit of effort.

Long-Term Trends and Species Acquisition

As indicated in Figures 2a, b, and c, average catch per unit effort, diversity, and number-of-species per haul underwent both seasonal and longer-term episodes of increases and decreases. Largest catches (500-800 fish/haul) occurred in 1969, 1971, 1973, 1974, 1975, and 1977; there were extremely low catches (less than 300 fish/haul) in 1970 and again in 1976. The extremes in total catch were only partially accompanied by similar fluctuations in Shannon-Weaver diversity and number-of-species per haul (especially from 1975 onward). Diversity was higher in 1971, 1972, 1973, 1975, and 1977, lower in other years, with peak values occurring in the spring or early summer.

Species acquisition curves are frequently used to evaluate the completeness of sampling programs in describing

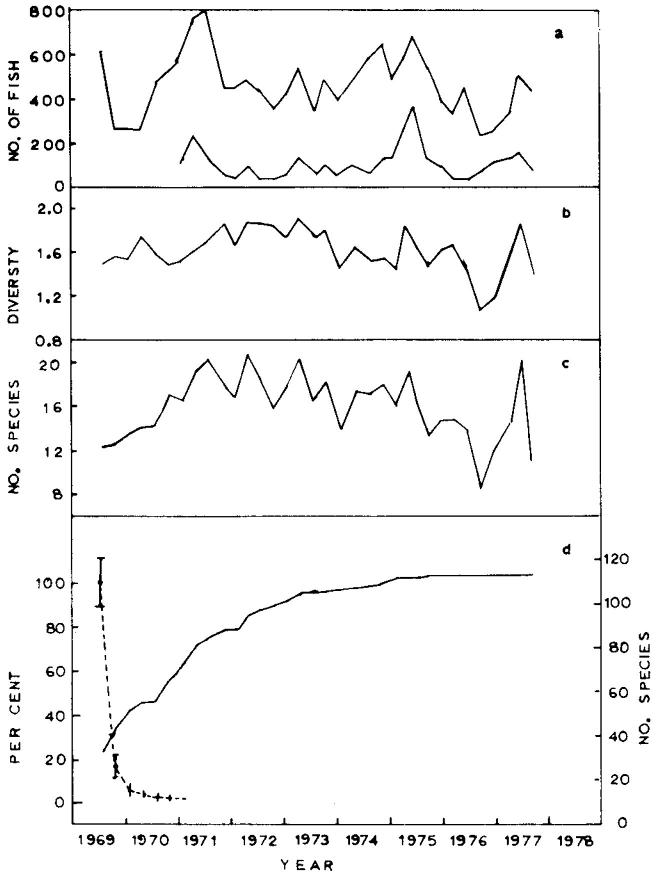

Figure 2. Fluctuations in (a) average catch per haul for all fish (upper line) and for fish ≦ 55 mm standard length (lower line); (b) Shannon-Weaver diversity index (c) average number-of-fish-species per haul for 34 quarterly surveys. Lowest figure (d) shows species acquisition curve (solid line) and percent of catch composed of new species averaged from six surveys drawn at random from the data (dashed line).

the fauna present at a given locality. As shown in Figure 2d, acquisition of the 112 species required about six years of quarterly surveys; approximately 30% of these were encountered in the first survey (representing 2.3% of the samples); by the fifth survey (15% of the samples, 1¼ years into the time series), approximately 50% of the species were encountered, and by the 15th survey, 90% of the species were acquired. At present, new species are being encountered at a rate of less than 1/year. This indicates that the ichthyofauna at this site has been more than adequately described within six years of quarterly trawling.

A second approach, using what may be termed a "species-abundance curve" (after a procedure in Word 1977), indicates that acquisition of those species that account for most of the abundance occurred at a much faster rate than species acquisition alone (Figure 2d). For example, at the second survey, 15% of the individuals were represented by new species added by that survey. In the fourth survey, less than 3% of the specimens were represented by newly acquired species, and by the sixth survey new species contributed less than 2% to total abundance. Extrapolation indicates that two years of quarterly trawling were sufficient to encounter those species responsible for 99% of the total catch.

Juveniles as Source of Variations

As shown in Table 4 and in Figure 2a, large fluctuations in the catch of very young fish (≤ 55 mm standard length [SL]) was one factor contributing to year-to-year differences in total catch. For most of these species, fish 5.5 cm (SL) or less in size are only a few months old, and fluctuations in their abundance probably represent their success in recruiting into, and surviving in, the survey area. As indicated above, the coefficient of variation for average survey catches of these small fish was high (78%; Table 4); occasionally catches of these "young of the year" accounted for one-half of the total catch (average 20%; range 7.2-55.4%), and over half (69) of the 112 species (62%) were at one time or another represented by their young. However, as shown in the last column of Table 2, 28 common and abundant species were not equally represented by their young. Young of the speckled and Pacific sanddabs, yellowchin sculpin, pink sea perch (*Zalembius rosaceus*), and stripetail rockfish were present in 70% or more of the surveys. Common and abundant species such as white croaker (*Genyonemus lineatus*), calico rockfish (*Sebastes dalli*), English sole (*Parophrys vetulus*), northern anchovy (*Engraulis mordax*), queenfish (*Seriphus politus*), and shiner perch (*Cymatogaster aggregata*) were only occasionally represented by their young (8.8-34% of the surveys), suggesting that the primary rearing or brooding areas were located outside this survey area (i.e. inshore or offshore or in nearby bays and estuaries). In other words, most of the fishes of these species caught were somewhat older migrants from elsewhere. Low frequencies of occurrence of several deepwater species (such as rex sole [*Glyptocephalus zachirus*]) were due in part to deletion of one deep water station in 1974.

Recruitment Patterns

As summarized in Figure 3a, young fish appeared in abundance in the survey area on only a few episodic occasions during the 8-year period. Largest catches occurred during the spring and early summer of 1975 when more than 4,500 young (50% of the total catch) of more than 20 species were caught. The next largest periods of "recruitment" detected occurred in the winter or spring of 1971. The years 1972, 1974, and 1976 showed rather poor catches of young fish.

Periods of "recruitment" were not due only to single species. The average number of species represented by specimens ≤55 mm SL was 12.7; however, during major

TABLE 2
Percent Abundance and Frequency of 28 Fish Species that Account for 96% of the Catch in 34 Quarterly Trawl Surveys off Orange County, August 1969 through October 1977.*

Common Name	% of Total Catch	Frequencies of Occurrence in Surveys: All fish	Young only
Speckled sanddab	17.1	100	100
Pacific sanddab	14.0	100	97
Yellowchin sculpin	10.6	100	97
Dover sole	6.2	100	62
Stripetail rockfish	5.8	79	71
White croaker	5.3	97	32
Calico rockfish	4.8	91	24
California tonguefish	4.7	100	41
Plainfin midshipman	3.8	94	68
Halfbanded rockfish	3.4	95	38
Pink seaperch	2.9	97	79
Slender sole	2.2	62	47
English sole	1.8	100	12
Blackbelly eelpout	1.6	77	8.8
Rex sole	1.3	59	24
Roughback sculpin	1.3	82	44
Longspine combfish	1.3	94	18
Northern anchovy	1.3	47	5.9
Queenfish	1.3	68	8.8
Splitnose rockfish	1.2	50	38
Shiner perch	0.82	76	12
Hornyhead turbot	0.74	100	12
Blacktip poacher	0.65	44	12
Sportspine combfish	0.53	77	5.9
California lizardfish	0.47	65	8.8
Bigmouth sole	0.45	100	18
Longfin sanddab	0.37	77	24
White seaperch	0.32	88	18
Total Specimens	115,351		
Additional 84+ species	4,413		
Total	119,764		

*Frequency of occurrence of young fish ($\leq$55 mm SL) is given in last column.

TABLE 3
Summary of Abundance and Grequency of Occurrence of some Economically Important Fish Species* from 34 Trawl Surveys off Orange County, California 1969-1977.

Common name	Number captured	% Occurrence in surveys
Pacific sanddab	20,485	100
White croaker	6,371	97
Queenfish	1,546	68
Northern anchovy	1,566	47
California scorpion fish	312	85
Petrale sole	268	18
Chilipepper rockfish	177	38
California halibut	146	85
Cow rockfish	93	59
Pacific hake	62	32
Sabelfish	58	53
Boccacio	48	32
Lingcod	3	9

*Nearly all are young of the species.

TABLE 4
Summary of Survey Averages of Shannon-Weaver Diversity, Number-of-Species, and Number-of-Fish per Haul, for 34 Surveys off Orange County, 1969-1977: Coefficients of Variation (CV, %) Calculated for Means Among Surveys Are Compared to Average CVs from within Survey (between Sample) Variations.

	Mean/Survey ±Standard Error	Range of Survey Means	Coeffients of Variation (%): Among surveys	Between samples
Shannon-Weaver Diversity/haul	1.62 ± 0.034	1.06−1.91	12.3	25.1
Number Species/haul	15.9 ± 0.51	8.6−20.8	18.5	26.3
Total-Catch/haul	469 ± 24	224−793	29.9	62
Catch-fish/haul > 55 mm SL* (n=28)	381 ± 20	164−622	27.7	NC
Catch-fish/haul $\leqslant$ 55 mm SL* (n=28)	104 ± 14.7	28−376	71.8	NC

*Standard Length.

periods of recruitment (May 1973, 1975, and 1977), the average was 23 species. Flatfish (mainly *Citharichthys stigmaeus, C. sordidus,* and *Microstomus pacificus*), rockfish (mainly *Sebastes saxicola, S. dalli, S. semicinctus,* and *S. diploproa*), and sculpins (mainly *Icelinus quadriseriatus*) did dominate the catches of young.

Relations to Basic Oceanographic Conditions

Visual examination of data suggested that changes in catches of young fish were related to seasonal and year-to-year changes in oceanographic conditions. To explore this in more detail, I reviewed available data on temperature and water transparency. Transparency, as measured by secchi disk depths, was chosen since other routine measurements indicative of food and productivity (i.e. plankton volumes, nutrient measurements, chlorophyll) were either not measured or not readily available for analysis. For the past five years, the trawl surveys themselves were accompanied by measurements of surface and near-bottom water temperature and by secchi disk (transparency) readings. A brief examination of the data suggested that the largest catches occurred in cold water of low transparency. More detailed physical data was required to confirm this association, but none was available from the Orange County monitoring programs. I searched elsewhere, and found a wealth of inshore and offshore temperature and secchi disk data from 19 stations in Santa Monica Bay from weekly sampling for nearly twenty years by the staff of the Hyperion Treatment Plant. Monthly mean sea surface temperatures and secchi disk readings were calculated and plotted for the period January 1969 through April 1977 (Figures 3b and c). Regression anlysis of secchi disk data collected during the same weeks by both OCSD and Hyperion revealed a moderately good correlation ($r = 0.51$, $0.1\ p < 0.05$), which improved substantially ($r = 0.7, p < .01$) when we used Hyperion values interpolated two days prior to the quarterly Orange County trawls and compared the new sets of data. This indicated that changes in transparency at Orange County were similar to those in Santa Monica Bay and that the Hyperion records were, over the long term, representative of changes in San Pedro Bay.

Several trends were noted in the physical data. First, during the past eight years there has been a trend of increasing temperature and with notably warmer winter temperatures occurring since 1972 (Figure 3b). Secondly, only the years 1973 and 1975 showed seasonal trends that were somewhat similar; otherwise, every year appeared to have its own pattern of warming and cooling.

Variations in secchi disk readings were more interesting, however (Figure 3c). For example, the years 1969 through early 1972 were marked by relatively turbid water with only occasional periods of clear water (secchi disk depth averaged about 9 m); the spring of 1971 was particularly turbid (6 m), but clearing increased gradually into the winter of 1971-72. Beginning in 1972, three episodes of very turbid summer water (i.e. 4-5 m) followed by rapid autumn and winter clearing (to 15 m) occurred at approxiamtely 2-year intervals (fall 1972,

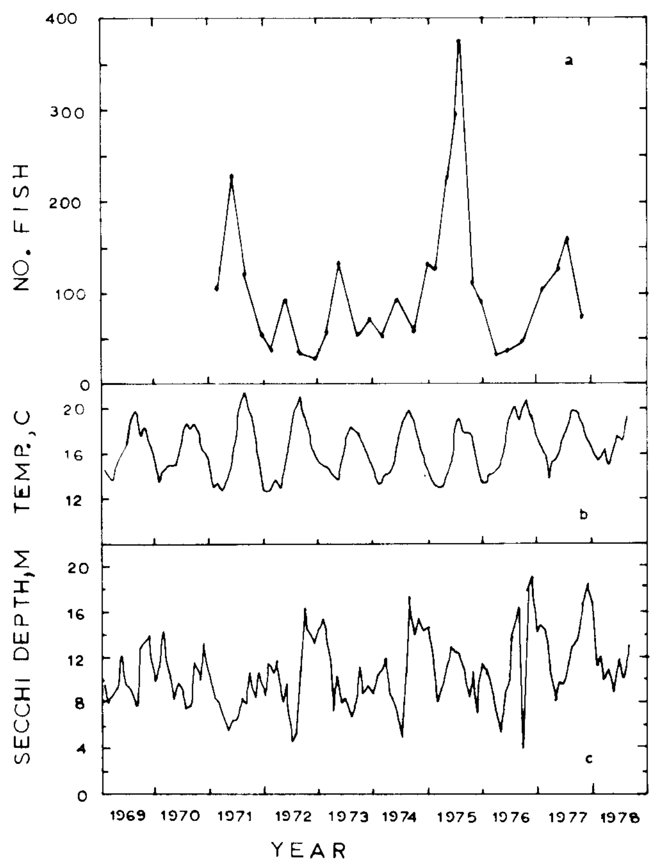

Figure 3. Fluctuations in (a) average catch per haul of all fish ≦55 mm standard length, (b) monthly averages of sea surface temperatures taken weekly in Santa Monica Bay and (c) monthly averages of weekly secchi disk depths from the same 19 stations.

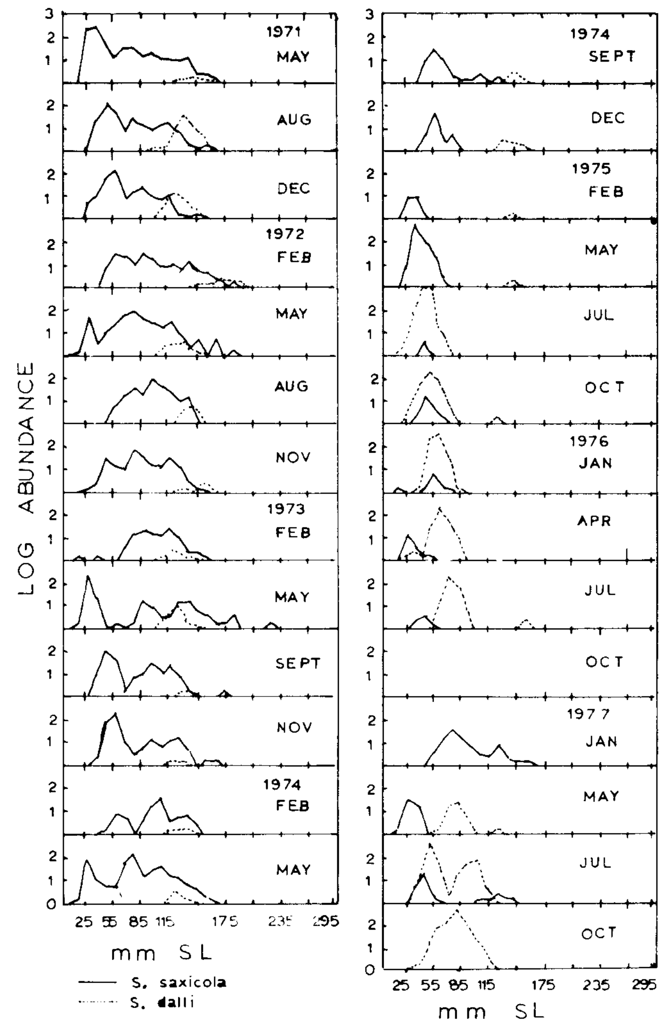

Figure 4. Length-frequency histograms for *Sebastes saxicola* and *Sebastes dalli* from 27 consecutive quarterly trawl surveys, May 1971 through October 1977. Note appearance of 25-to-35 mm standard length *S. saxicola* each spring and appearances of young *S. dalli* in the summers of 1975 and 1977. Neither species was collected in October 1976.

1974, and 1976). The three episodes of very transparent water lasted approximately six months and in each case were followed by a rapid decline in transparency (winter-spring 1973, 1975, and 1977). During four of the summers (1969, 1970, 1972, and 1974), warming was accompanied by increased turbidity but not during 1971, 1973, and 1976 when summer warming was accompanied by clearing water.

Comparison of these physical events with the trawl data indicates that increasing catches of young fish were associated with episodes of cool or cooling water and decreasing clarity, whereas clear periods were generally associated with low catches. An exception during the 8-year period was the turbid-water spring of 1976, which also followed one of the warmest winters of the survey period.

There are several possible explanations for the higher catches of young fish during or just following periods of increased turbidity. The fish may be better able to see and avoid the trawl gear in clear water than in turbid water. Alternatively, the turbid water may simply be what it is—a useful indicator of high plankton activity, which includes larval and postlarval fish and their food—and thus may be marking those periods when young fish successfully arrive on the coastal shelf and when enough food exists to support their survival and growth during their first few months of life.

Juvenile Rockfish: Example of Multispecies Recruitment

In general the comparisons made above indicate that the variations in occurrence of juvenile coastal fishes is related to oceanographic episodes, which can occur at other than annual intervals. Moreover, there seem to be general patterns that are not totally obliterated by examining all species as a unit. The patterns and their relation to oceanographic conditions are applicable to recruitment of single species or species-groups and are described in the following example.

Sebastes saxicola and *S. dalli* have been the most prominent rockfish in these catches, yet they rarely occurred together in high numbers. For example, during the period 1971-75, juvenile *S. saxicola* catches averaged 41 fish/haul; in 1976 and 1977 the catches decreased 20 fold to 0.8 fish/haul. In contrast, juvenile *S. dalli* catches averaged 1.7 fish/haul during the period 1971-74, 79 fish/haul in 1975, and 55 fish/haul during the two-year period 1976-77.

Examination of length frequencies of both fish during this 7-year period revealed the patterns and events leading up to these shifts. As shown in Figure 4, both *S. saxicola* and *S. dalli* were present in the survey area in May 1971, but only *S. saxicola* was represented by recently recruited young (35-45 mm SL). This "year-class" appeared to survive and grow well during the next several years; *S. saxicola* recruited again in the spring of 1972, 1973, 1974, and 1975, again in the absence of *S. dalli*. There was also what appeared to be a progressive loss of larger "age groups" of *S. saxicola* during 1973-75. In July of 1975, the pattern established over the previous five years was obliterated when a large number of juvenile *S. dalli* invaded the survey area. This "1975" year class of *S. dalli* survived and grew (slower than *S. saxicola*). A few *S. saxicola* appeared once again in the spring of 1976. Neither species were caught in the early fall of 1976. By the next winter several age groups of *S saxicola* returned to the survey area and then [illegible] appeared during the remainder of 1977. Finally, in the spring of 1977 there appeared to be moderately successful recruitment of both *S. saxicola* and *S. dalli*, plus a return of older age groups of both species. In summary then, what appeared to be a stable, repeatable, and predictable pattern of recruitment of one species (*S. saxicola*) over a 4-year period was rather quickly obliterated in 1975 and resulted in a rather unpredictable alternation of species from 1975 through 1977.

One pattern was not obliterated by these changes, however. A second scan of the data in Figure 4 reveals that, whichever species was present, both contributed to strong "combined" year classes (1971, 1973, 1975, and 1977). As noted above and in Figure 3, spring conditions during these years were marked by more rapid cooling and increased turbidity than in the adjacent even-numbered years.

CONCLUSIONS

Many investigators have considered otter trawling useful in assessing the general composition of nearshore bottomfish assemblages but not useful for further quantitative or statistical assessments of bottomfish populations. In contrast, I believe the present data confirms that standardized procedures applied over a long period of time can provide insight into some of the factors that may be regulating the composition and production of nearshore fish assemblages. Certainly these data can be subjected to a more rigorous statistical analysis but in their present form do lead me to several important speculations. For example, the apparent match between recruitment episodes and physical changes suggests that oceanographic conditions are at least as important as any nearshore processes in determining the abundance of bottomfish on the mainland shelf. The patterns of the two rockfish species, moreover, suggest that once post-larval recruitment has occurred there may be important episodes of competition among the young fish. Finally, long-term sampling reaps a series of benefits as sampling continues—e.g. the first few surveys will document the principal species and something about their general abundance; several years are required to establish seasonal norms; finally, nearly all species can be encountered with 5 to 6 years of sampling, and the chance of encountering an episodic change in the major composition of the fauna increases. The effort required depends on the questions under consideration.

More detailed comparisons of these and related data on upwelling, storms, and rainfall are in progress. Meanwhile, I recommend that this or a similar survey continue so that long-term trends in nearshore fish populations will be established for at least one site on the coast of southern California.

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