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VARIATIONS IN COASTAL PHYSICAL VARIATIONS IN COASTAL PHYSICAL CONDITIONS, 1969-78

Changes in ocean "climate" affect nearshore coastal marine life more than is generally appreciated. For example, small but widespread changes in ocean temperature or slight shifts in major ocean currents can cause major changes in survival of the young of economically important coastal fishes. The purpose of this report is to summarize information on physical and biological events occurring in southern California coastal waters during the past 10 years, from 1969 through 1978. The results of this investigation indicate that, during the past decade, coastal waters have become significantly warmer and clearer, and intensity of upwelling and visibility have undergone several 2-year cycles. Some fishes, such as the Pacific mackerel (*Scomber japonicus*) increased greatly in abundance during the decade; the abundances of others, such as the northern anchovy (*Engraulis mordax*) decreased during the latter years of the decade. The middle years (1972-76) were marked by a series of biological invasions, in which "red-tide" phytoplankton, squid, jellyfish, and pelagic red crabs moved into the coastal waters in unusually large numbers. Finally, the data from more than a decade of monitoring with otter trawls indicated that year-to-year and long-term changes in abundance of bottom fish are strongly correlated with changing ocean conditions.

OCEANOGRAPHIC EPISODES AND TRENDS

A deviation from the normal seasonal cycle of warming and cooling of coastal waters is often an indication that major changes are taking place in offshore waters. If the temperature deviation is observed at widely separated areas, the offshore phenomena are probably region wide.

For years, data on sea surface temperatures and water clarity (as measured by Secchi disk readings) have been collected weekly by the City of Los Angeles from 20 stations located throughout Santa Monica Bay. The same type of data has been collected off Scripps Pier in La Jolla by Scripps Institution of Oceanography for a much longer time period. When we compared the two sets of data for the past 10 years, we found generally good agreement. Monthly mean summer temperatures in Santa Monica Bay were an average of 0.5 to 1°C lower than those off La Jolla, and winter means were about the same in the two areas. Thus, it appears that measured variations in physical oceanographic conditions in Santa Monica Bay were the result of changes occurring in the southern California region as a whole.

Data on temperature and water clarity from the Santa Monica Bay stations, on rainfall levels at Los Angeles Civic Center, and on upwelling intensity[1] were summarized for the period from January 1969 through December 1978 (Figures 1 and 2). An analysis of yearly and monthly averages for these data reveals several significant events and trends.

Temperature

Sea surface temperature during the latter part of the last decade was higher than that during the decade, as a whole. Average temperature, calculated on an annual basis, from 1969 through 1978 was 16.3°C. During the last 3 years of that period, the average temperature was 17.1°C (Figure 1) The higher annual temperatures appeared to result from un-usually warm winter conditions. At least one of the warm-water winters was associated with a period of abnormally high surface temperatures throughout the Northeast Pacific (Lasker 1978).

Water Clarity

Water clarity in Santa Monica Bay was greater (12.0 meters, Secchi disk depth) during the last 3 years of the decade than during the first 3 years (9.5 meters; Figure 1). In 1972, 1974, and 1976, there were episodes of poor water clarity (Secchi disk readings of 5 to 7 meters) during the summer followed by almost 6 months of extremely clear water (readings averaging 14 meters; Figure 2). Such dramatic changes were not evident in 1971, 1973, and 1975, although--on an annual basis--water clarity improved successively in these years (Figure 1).

Clear water is believed to be poor in nutrients and may mark periods during which young plankton-feeding fishes are unable to obtain sufficient amounts of food.

Rainfall

There have been significant year-to-year differences in rainfall in the southern California coastal region during the past 10 years (Figure 1). There were heavy winter rains in 1969 (36 cm, or about 14 inches, in January at Los Angeles Civic Center; Figure 2). Rainfall was low in 1971, 1972, 1975, 1976, and 1977 and high in 1978. Thus, local coastal waters received larger amounts of runoff and rain-fall at the beginning and end of the past decade than during the intermediate years.

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1. Calculated from Santa Monica Bay wind measurements by Dr. A. Bakun, National Marine Fisheries Service, Monterey, Calif., personal communication; see also Bakun 1975.

Upwelling

Upwelling of deep, nutrient-rich ocean water occurs naturally along the southern California coast. Considerable year-to-year and seasonal variations have occurred in Santa Monica Bay during the past 10 years (Figures 1 and 2). The annual average over the past 22 years, 1956-78, was approximately 128 metric tons of water Upwelling per second per 100 linear meters of coastline. Upwelling amounts in 1969, 1971, 1973, and 1975 were 5 to 15 metric tons/sec/100 meters (or 4 to 12 percent) above the 22-year average. In contrast, Upwelling amounts in 1970, 1972, 1976, and 1978 were 16 to 33 metric tons/sec/100 meters (or 13 to 26 percent) below the average. Upwelling was generally strongest in the spring months and decreased in the fall in association with increase in water clarity (Figure 2). Episodes of downwell-ing, during which offshore water moves onshore, were evi-dent in the fall and winter periods of 1975-76 and 1976-77. Overall, upwelling intensity has been somewhat below the 22-year average during the past 10 years.

BIOLGICAL EPISODES AND TRENDS

Major coastal biological events may be triggered by shifts in ocean water masses or region-wide changes in water temperature and clarity. Changes in the size of fish and in-vertebrate populations, mass strandings of various marine animals on local beaches, and algal blooms resulting in "red tides" are events occurring over the past 10 years that may reflect wide-scale changes in offshore conditions.

The biological data we have examined came from Project surveys as well as several other sources. Information on commercial and sportfish landings, as well as events such as blooms, invasions, and strandings of marine organisms, is compiled by the National Marine Fisheries Service and the California Department of Fish and Game. In evaluating the condition of nearshore demersal fish populations we have examined the otter trawl data collected by Orange County Sanitation Districts in their quarterly monitoring program; we also referred to the original data from the 1957-63 trawl survey of Santa Monica Bay conducted by Carlisle (1969). Summaries of various aspects of the biological data from these sources are presented in Figures 1 and 2 and discussed in the following sections.

Nearshore Demersal Fishes

There have been significant changes in the abundance of nearshore demersal fishes over the past 10 years. Off Orange County, otter trawl catches were large in 1971 and 1975 (Figures 1 and 2). Small specimens, less than or equal to 60 mm, standard length (SL), made up a significant part of the catches in these two years. Small specimens were also relatively abundant in 1973 and

1977. Much of the variation in catch size was the result of fluctuations in the number of juvenile rockfishes (*Sebastes* spp.), which were most abundant'in 1971, 1973, 1975, and 1977 (Figure 2). Shifts in the most dominant rockfish species also occurred during the 10-year period. From 1971 to spring 1975, the stripetail rockfish (*Sebastes saxicola*) dominated catches; from July 1975 through January 1979, the calico rockfish (*S. dalli*) was most abundant. Occasional deep-water otter trawl samples taken during the latter period revealed that the stripetail rockfish was still abundant at the edge of the mainland shelf even though its numbers had decreased in shallower waters (Mearns 1977, 1978).

A comparison of sea surface water temperatures and trawl catch data from surveys of the area off Orange County (1969-78) and Santa Monica Bay (1957-63) is presented in Figure 3. Because of differences in the efficiencies of the trawl procedures used in each area (Mearns and Stubbs 1974; Mearns and Greene 1974), values for catch per unit effort from the two surveys could not be directly compared. There-fore, the grand mean catch per unit effort was calculated for each survey, and the amount by which each yearly mean deviated from the grand mean for that survey was determined. The deviations were then plotted against annual average sea surface temperatures in Santa Monica Bay; the latter values are, for the year 1969-77, means of monthly average values and, for the years 1958-62, annual averages given by Carlisle (1969; the 1963 average was estimated from data in Jones 1971). As shown in Figure 3, catches were much higher in the "cool-water" years (15 to 16°C) than in the "warm-water" years (17 to 18°C). This relationship suggests that nearshore benthic fishes are affected by changing ocean con-ditions and provides an explanation for catch variations en-countered in these monitoring programs.

Fisheries

Data on catches of several commercially important fish species are summarized in Figure 1. Landings of northern anchovy in California coastal waters increased from 60 to 140 thousand metric tons between 1969 and 1975. However, landings of this species decreased between 1976 and 1978. In contrast, landings of Pacific mackerel began to increase in 1977, and more Pacific mackerel were caught in 1978 than during the previous 9 years combined. The largest catch of swordfish (*Xiphias gladius*) on record—nearly one million metric tons—also occurred in 1978.

Landings of sable fish (*Anoplopoma fimbria*) from southern California increased from less than 10 metric tons in 1969 to over 2,000 metric tons in 1978. However, this increase was the result of a southward expansion of a trap fishery into offshore bottom waters rather than a variation in the size of the populations.

Blooms, Strandings, and Unusual Occurrences

In July and August 1971, a major red tide, the most intense since 1964, was present in southern California coastal waters. The tide was the result of dinoflagellate blooms and may have been responsible for small, isolated fish kills. In the fall of that year, large numbers of salps were noted in coastal waters by various monitoring groups. An in June 1972, large numbers of *Pleuroncoides planipes* (pelagic red crabs or "tuna shrimp") were stranded on beaches from Morro Bay to San Diego. They were also present in deep water off-shore, and appeared in trawl catches and in the stomachs of many trawl-caught fishes. Previous invasions of pelagic red crabs were in 1941, 1957-58, 1959 and 1960 (Radovich 1961).

In 1974, there was another extensive red tide, during which large numbers of jellyfish (Pelagia sp.) appeared in coastal waters. In the summer of the following year, *Dosidiscus gigas* (the jumbo squid) was abundant in nearshore waters, and some beach strandings of these organisms were reported. Later in 1975, bluefin tuna (*Thunnus thynnus*) were reported in Santa Monica Bay and were fished commercial- ly until January 1976.

In spring 1976, large numbers of jellyfish were re-ported, and jumbo squid washed ashore. The squid, which were 1 meter in length, were observed to be preying on anchovy and grunion (*Leuresthes tenuis*).

No notable red tides, biological invasions, or mass strandings were noted in 1977 and 1978.

Other Biological Events

There have been other noteworthy biological events that may or may not be completely related to changing oceanographic conditions. Giant kelp (*Macrocystis pyrifera*) were observed to be reproducing off Palos Verdes in 1973. This followed a period of several years in which culture programs had been conducted by various groups. From 1973 to 1977, the kelp canopy grew to 34 hectares (Mearns et al. 1977); by October 1978, the canopy covered 120 hectares.[2]

Prior to the summer of 1973, *Listriolobus pelodes*, a large echuiroid worm, was rare on the mainland shelf south of Ventura. Between February and July 1973, the number of *L. pelodes* increased significantly, particularly near deep-water outfalls. By 1978, this species was less abundant than it had been in the period from 1973 to 1977. The populations were so large off Palos Verdes that we think they may have aerated formerly anaerobic bottom sediments. These sediments once again became anaerobic over large areas in 1978.

During the summer and fall of 1978, *Patiria miniata* and several other species of starfish exhibited signs of a de- generative disease. The condition

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2. K. Wilson, California Department of Fish and Game, personal communication.

affected specimens in shallow waters in Mission Bay near San Diego, off Palos Verdes, and at Catalina Island, was related to warm-water conditions, and may have been the result of an infectious disease.

DISCUSSION

The Project's studies of relationships between large-scale oceanographic phenomena and biological conditions in near-shore waters have only recently been initiated. The principal findings to date are that the abundances of young rock-fish appear to vary with seasonal and year-to-year variations in temperature and water clarity (Mearns 1977, 1978) and that the abundance of trawl-caught fishes in general changes in association with changes in sea surface temperature.

Similar studies are being conducted by other individuals and organizations. Much of the current research in coastal fisheries is directed at determining the ways in which fish populations respond to changing oceanographic conditions (Lasker 1978). In recent work, Parrish (1977) found that recruitment of Pacific mackerel varies with year-to-year variation in a set of oceanographic conditions, including summer/fall upwelling and water temperature changes. Other studies have produced evidence of strong relationships between water clarity (and depth of light penetration) and phytoplankton abundance and water temperature and nutrient content (Epply et al. 1978). More recently, change in the depth of rapid nitrogen increase has been found to be related to kelp production.[3]

It is important that physical and biological oceanographic conditions continue to be recorded and reported in a systematic fashion because such information can indeed ex-plain much of the variation encountered in nearshore coastal ecosystems. The Project plans to continue its studies of such relationships by further analyzing historical data and comparing results with those of other researchers.

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3. Dr. Richard Epply, Institute of Marine Resources, University of California, San Diego, personal communication.

on biological events. Joe Nagano (Hyperion Treatment Plant, City of Los Angeles) and Michael Heinz and Ann Martin (Orange County Sanitation Districts) provided data on trawl catches, ocean temperatures, and Secchi depth readings.

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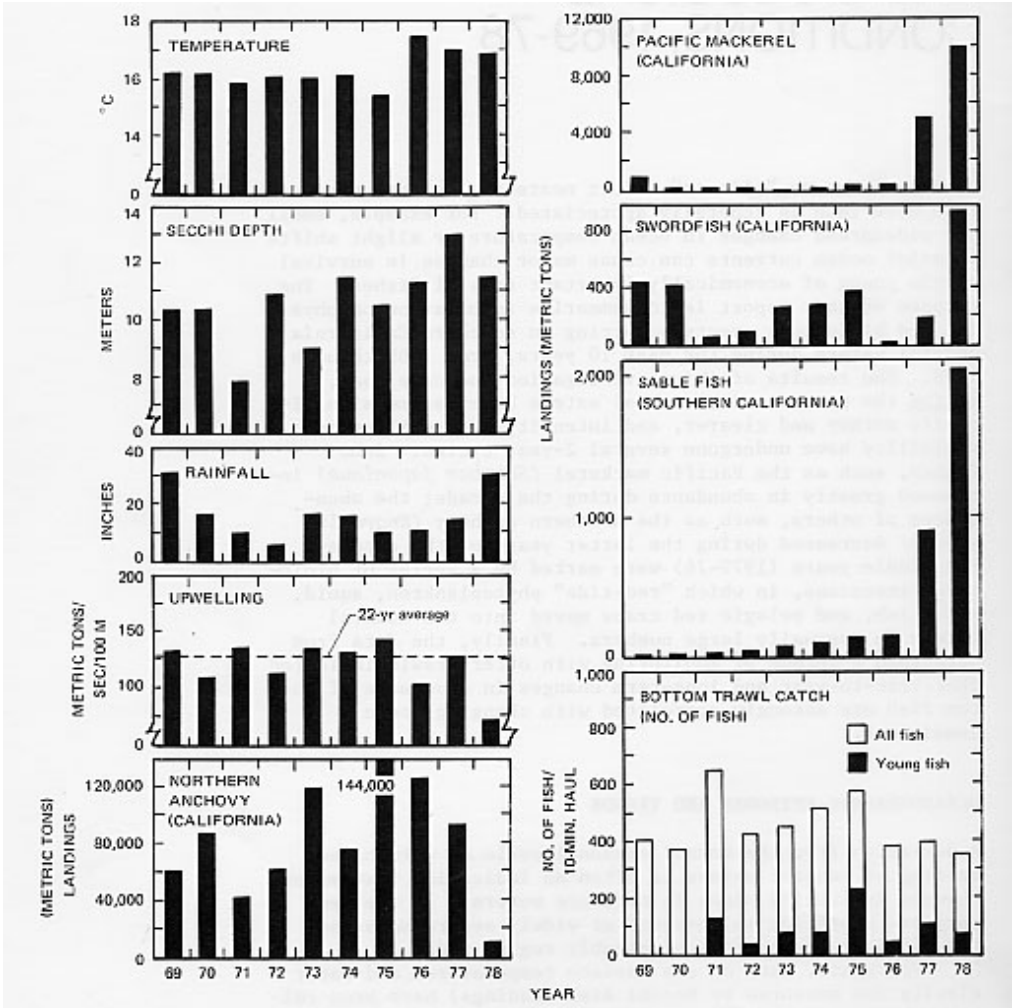

Figure 1. Physical and biological oceanographic conditions off southern California, 1969-78. Values are annual averages.

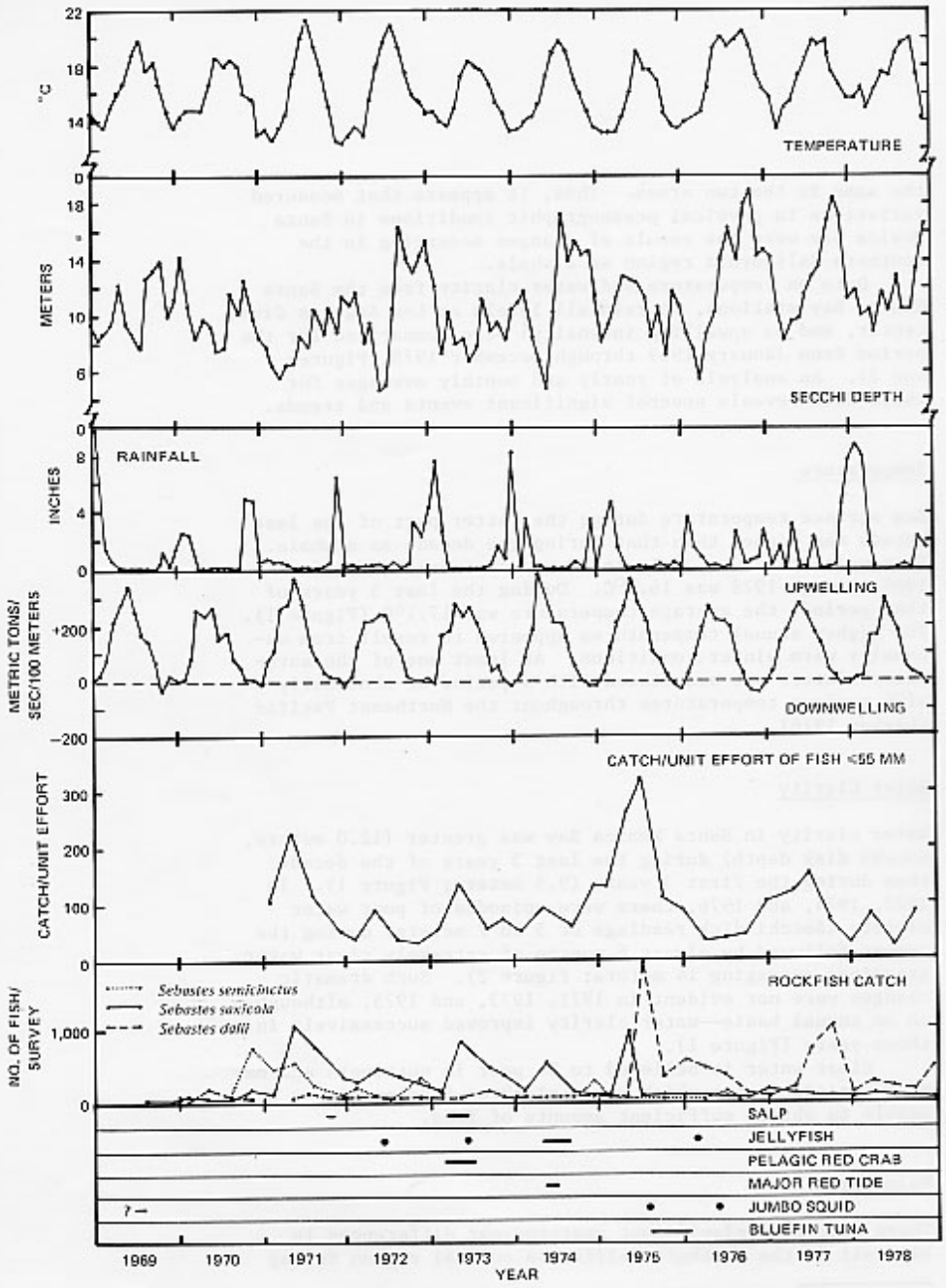

Figure 2. Variations in six physical and biological characteristics of local coastal waters, January 1969 through December 1978. The durations of invasions by six organisms are also shown.

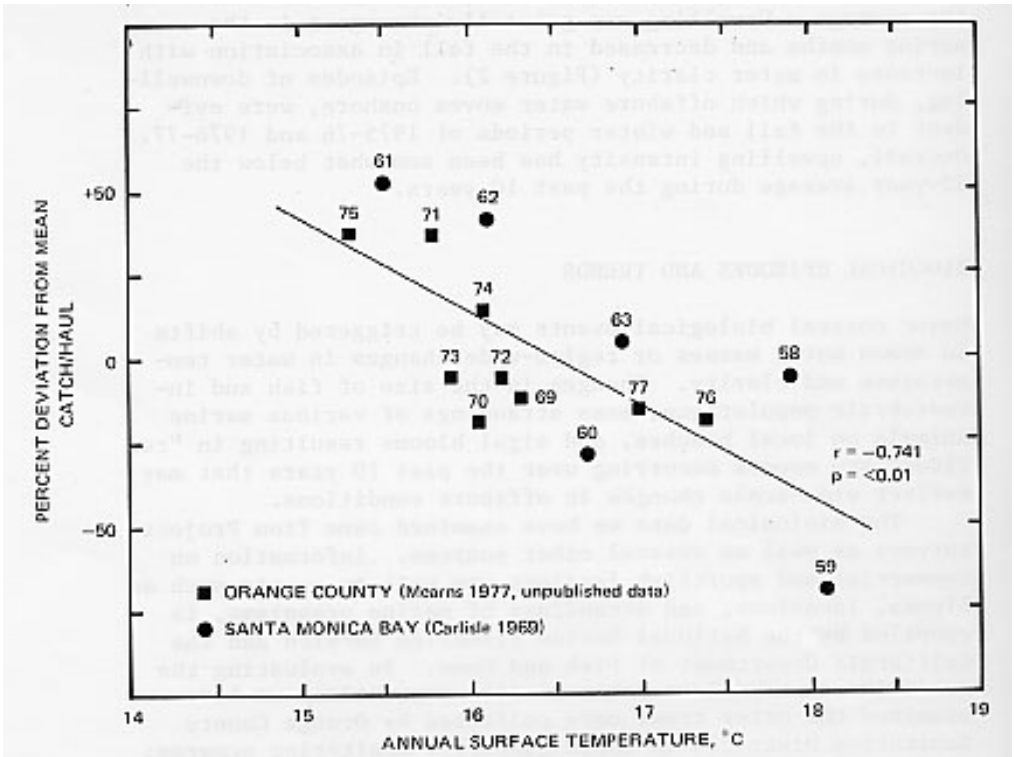

Figure 3. Relationship between annual average catch per unit effort of trawl-caught fishes and annual average sea surface temperatures in southern California, 1958-63 and 1969-78.