

BENTHIC OCEANOGRAPHY AND THE DISTRIBUTION OF BOTTOM FISH OFF LOS ANGELES*

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ABSTRACT

Changes in bottom water isotherms of the coastal shelf appear to have a direct effect on the abundance and diversity of demersal fishes and invertebrates. These changes are also highly correlated with near-bottom dissolved oxygen concentrations. In addition, resident fauna of the shelf can experience warmer water in winter than in summer. These effects are probably caused by incursion of offshore basin waters onto the coastal shelf following development of the thermocline. Recognition of these events may aid in clarifying and defining (a) shelf community structure, (b) our concept of the terms "near-shore" and "off-shore", and (c) monitoring and survey programs adequate for separating natural from man-induced effects.

INTRODUCTION

The nearshore coastal zone off southern California is a productive yet distinct and diverse environment between the land and the open sea. Because of a wide variety of commercial, recreational, and scientific interests, we know a great deal about the intertidal and shallow subtidal environments (to about 40 m) but very little about the vast remainder of the continental shelf (which is from 40 to 200 m deep), the slope, or the basins (3 to 15 km offshore). Yet these large areas now receive the bulk of domestic wastes discharged into the coastal waters off southern California.

Our familiarity with the organisms that inhabit the area between the intertidal zone and the eastern edge of the California Current is increasing as a result of numerous trawl and benthic surveys. We know, for example, that the populations of the coastal self are diverse, that their distribution is uneven—often related to depth—and that they are affected by waste discharge (Southern California Coastal Water Research Project, 1973). Benthic fish and invertebrate populations are colorful and active. There appear to be large populations of shrimp, flatfish, and rockfish at middepths on the coastal shelf; hake, grenadiers, and sablefish live along the edge of the continental shelf, and a variety of midwater fishes occupy the waters overlying the basins.

We do not yet have an understanding of the physical, chemical, and biological factors that control the distribution and abundance of offshore coastal

fish and invertebrate populations. These populations may be affected by the composition of the benthic sediments and the availability of food organisms as well as by the temperature and dissolved oxygen content of the waters, both of which decrease with depth. In fact, temperature has often been used elsewhere as a predictive tool in coastal fisheries (Laevastu and Hela, 1970). Unfortunately, there have been few local coastal surveys in which fish, sediments, and bottom water quality were studied simultaneously. For example, oxygen and temperature in coastal waters are monitored frequently, but not often in conjunction with trawl surveys and rarely near the bottom at depths beyond 50 m. Contamination of marine sediments by metals and hydrocarbons also is monitored intensively, but only in cases of severe contamination can these measurements be related to anomalous fish distributions (Southern California Coastal Water Research Project, 1973). Thus, the data from many monitoring programs are inadequate to describe the major environmental factors regulating the distribution of coastal marine fish and macroinvertebrate populations.

METHODS

During the past year, several kinds of programs were initiated by the Coastal Water Research Project and other agencies to better describe the physical characteristics of the coastal benthic environment. Whenever possible, we have taken hydrographic samples at the surface, at middepth, and 1 to 2 m from the bottom at each trawl station during quarterly or biannual surveys off Dana Point and Palos Verdes, and in San Pedro and Santa Monica Bays. To provide additional depth and regional perspectives, the Project conducted a 3 day synoptic survey in September 1973 (Mearns and Greene, 1974). In this survey, water samples were analyzed for temperature and dissolved oxygen content and, in some cases, pH and salinity. This information supplemented the basic catch statistics we obtained from standardized trawl hauls (2 to 2.5 knots, 10 minutes on the bottom, using otter trawls with 25 ft headropes).

The Project also conducted two special cruises in January and June 1974 to examine temperature, dissolved oxygen, salinity, pH, and coliform gradients in a portion of the Santa Monica Basin (to depths of 900 m) adjacent to the coastal shelf. These data were

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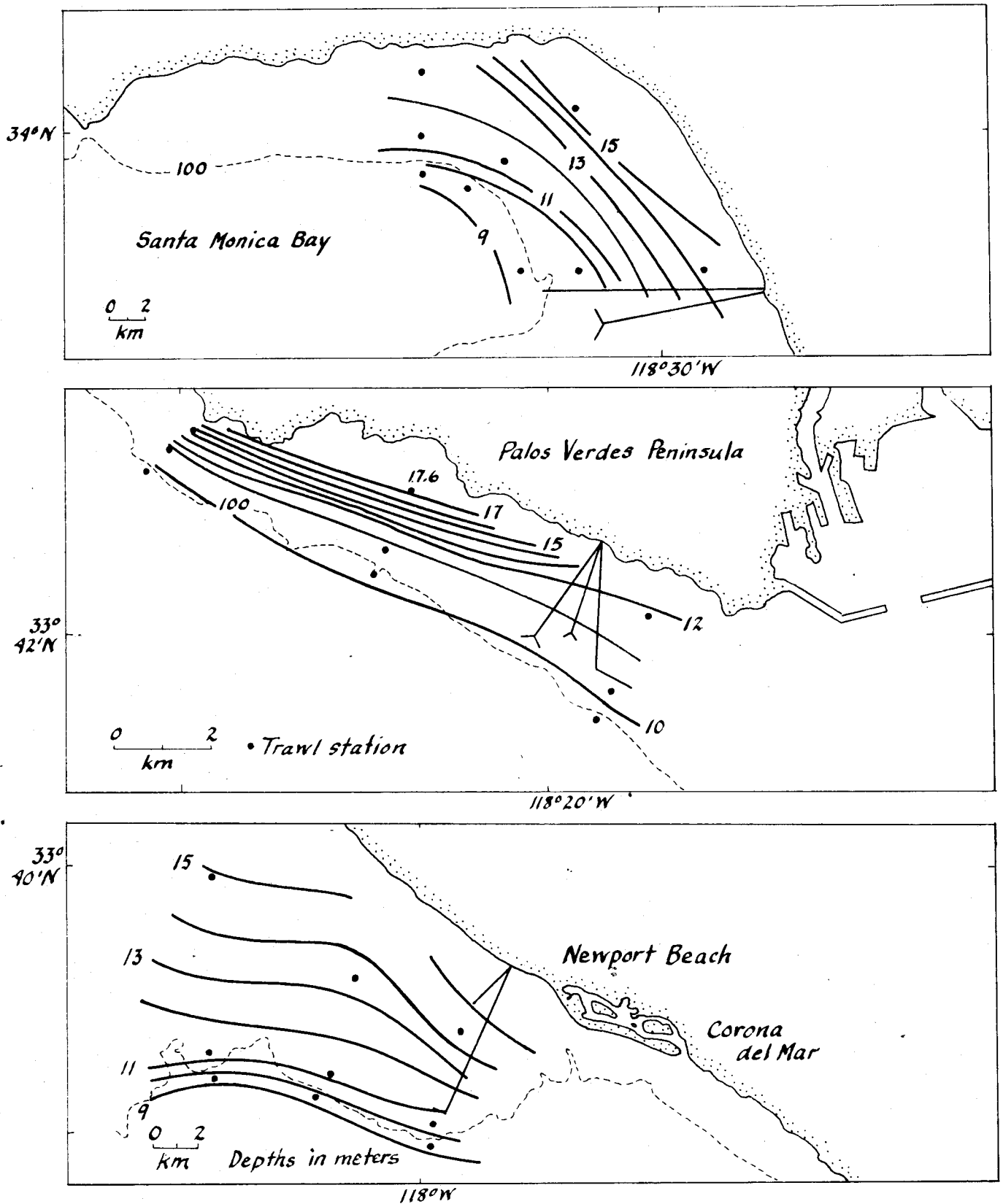


FIGURE 1. Bottom water isotherms ($^{\circ}C$) in three coastal shelf areas of southern California, 24-26 September 1973 (From Mearns and Greene, 1974). Major municipal wastewater outfalls are shown.

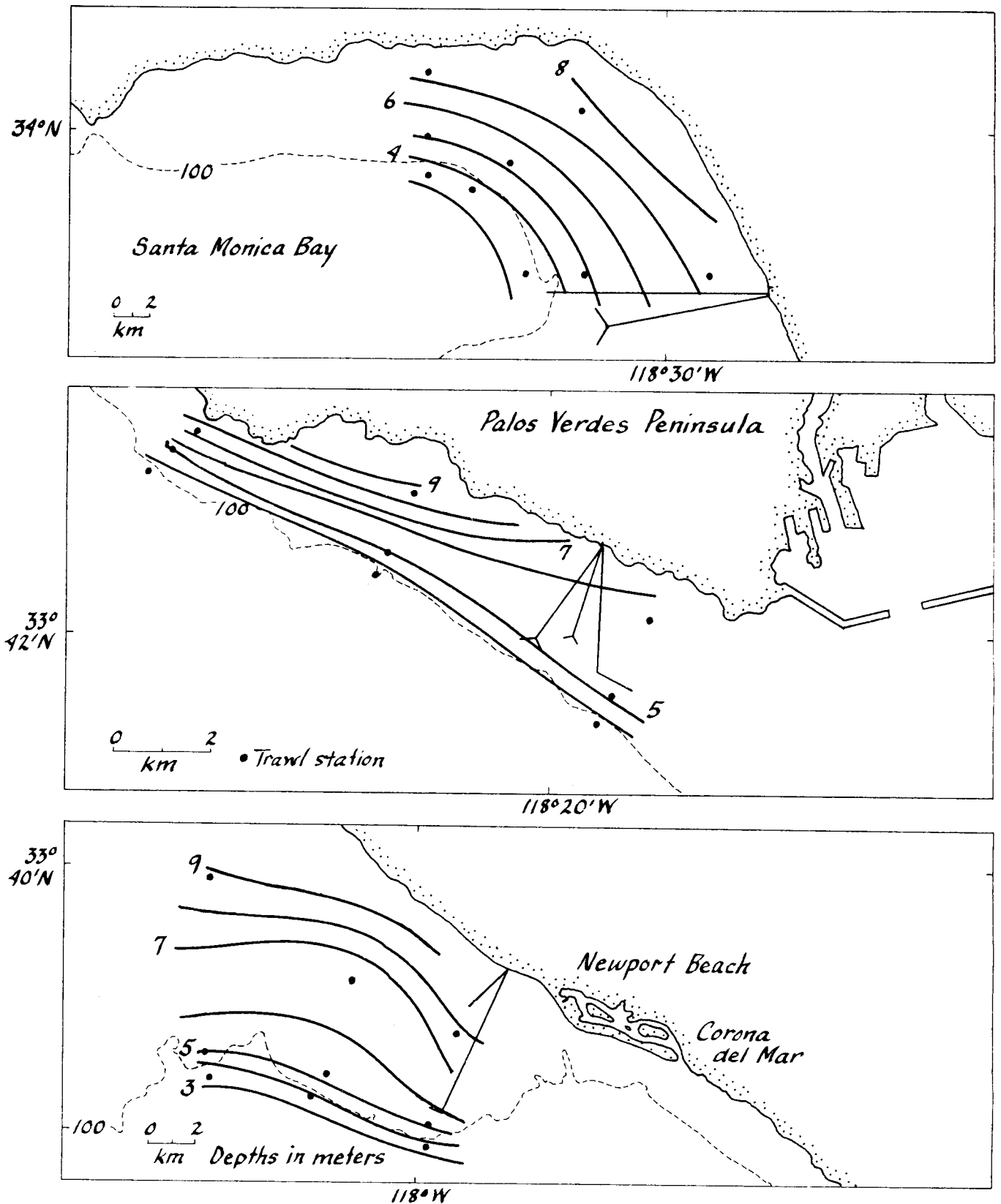


FIGURE 2. Bottom water dissolved oxygen isopleths (mg/l) in three coastal shelf areas of southern California, 24 to 26 September 1973 (From Mearns and Greene, 1974).

compared to those taken inshore at similar depths to observe the possible effects of offshore subsurface water activity on the coastal shelf waters at similar depths (Mearns and Smith, 1975). We have also examined oceanographic data from ongoing monitoring surveys to verify what appeared to be major changes in surface, midwater, and bottom-water isotherms and dissolved oxygen isopleths.

The data from these surveys were then compared to information on demersal fish and other benthic organisms. We plotted bottom water temperature and dissolved oxygen by depth and season. These data were compared to similar summaries of catch statistics (median catch and biomass, diversity and number of species per unit effort) and other survey attributes such as species and site clusters as

described in the project's 3 year report (1973) and more recently by Allen and by Greene and Sarason (Southern California Coastal Water Research Project, 1974). The analyses were designed to reveal general patterns rather than specific details.

RESULTS

Bottom water contours of temperature and oxygen in Santa Monica Bay, off Palos Verdes, and in San Pedro Bay during September 1973 (Figures 1 and 2) were determined when all three regions were surveyed by identical physical and biological survey methods (Mearns and Greene, 1974). Striking gradients of decreasing values were observed as we proceeded offshore in all three areas. Inshore (26 m), demersal and benthic biota were exposed to temperatures ranging from 15° to 18°C and oxygen values ranging from 6 to 9 mg/l. Offshore (170 m), the benthos was exposed to temperatures ranging from 9° to 11°C and oxygen concentrations ranging from 3.5 to 5.5 mg/l. In each area, the ocean outfalls were discharging into relatively cool (10° to 11°C), low oxygen (4 to 6 mg/l) water, and anomalously low oxygen distributions were related to temperature more than to proximity to the discharges. The variability of temperature and oxygen within a given depth interval was surprisingly low (Figure 3).

The trawl catch data taken in conjunction with these measurements showed rather striking relationships with depth, temperature, and dissolved oxygen (Figure 3). From 27 to 62 m, fish biomass, abundance, number of species, average size of fish, and diversity increased with depth and with decreasing temperature and dissolved oxygen. Beyond 62 m, we found no major increases in biomass, number of species, abundance, or diversity, but the average size of fish increased; temperature and oxygen decreased at much lower rates in this area than inshore. No samples were taken beyond 150 m.

The data we have at present are sporadic, and thus our interpretation is equally limited. For example, visual avoidance of gear by fishes may be a factor contributing to the low catches inshore in the daytime, and on-bottom sampling time in deep waters may be longer than that in shallow water because of the increased scope ratios (John Stephens, Occidental College, Los Angeles, pers. comm.). However, the general trends in the biological curves (i.e., the maximum values at midshelf depths) do correspond to other biological features such as maximum benthic biomass, or potential food (Southern California Coastal Water Research Project, 1973). Similar relationships have been observed in other surveys in which different gear were used. In Santa Monica Bay during the spring of 1972, peak values occurred at somewhat shallower depths—25 and 50 m (Mearns, Allen, and Sherwood, 1974); in the winter and summer of 1960, peak values

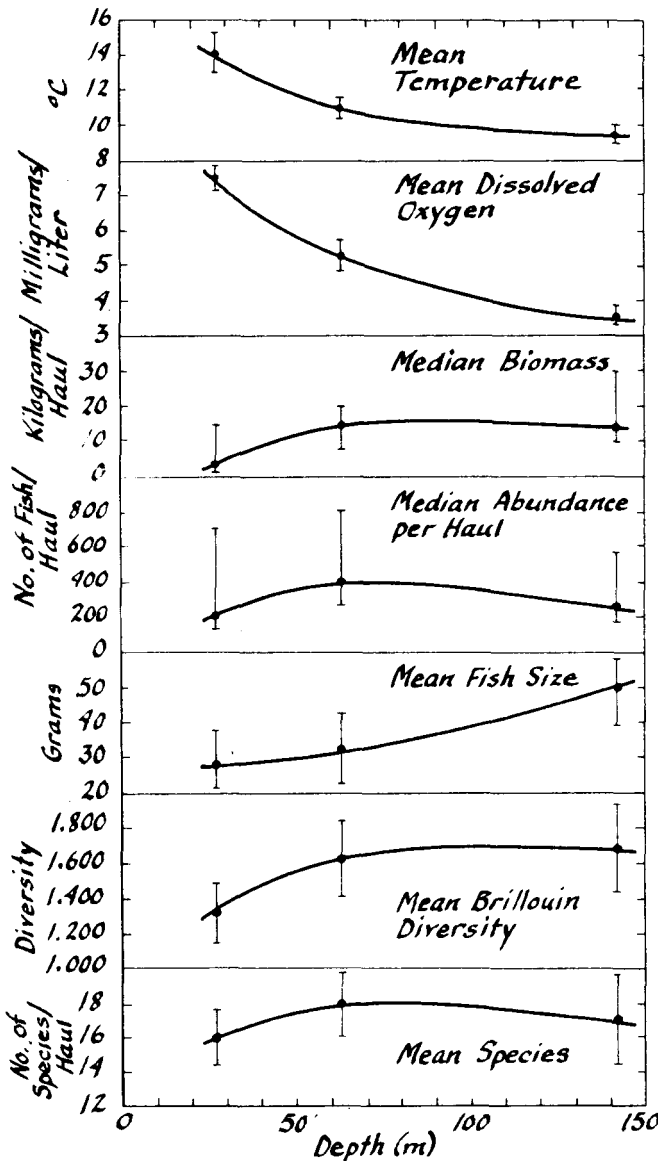


FIGURE 3. Mean (± 2 SE_x) or median (± 95 percent confidence limits) values for seven variables measured in three coastal shelf areas of southern California, 24 to 26 September 1973.

occurred at different depths between 37 and 140 m (Southern California Coastal Water Research Project, 1973). Overall, the data suggest that benthic fish are responding, to some extent, to temperature, oxygen, or other depth-related factors such as light and food availability.

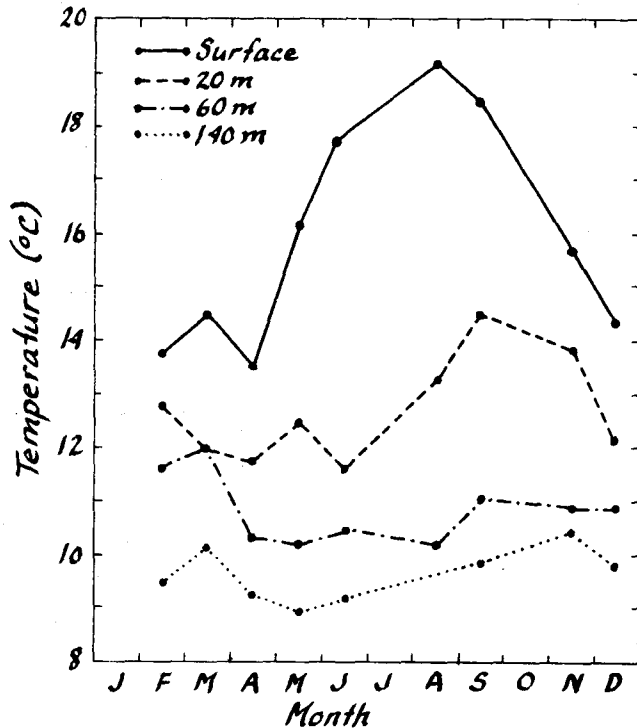


FIGURE 4. The 1972 and 1973 temperatures of surface waters and near-bottom waters at 20, 60, and 140 m on the coastal shelf of Los Angeles and Orange Counties.

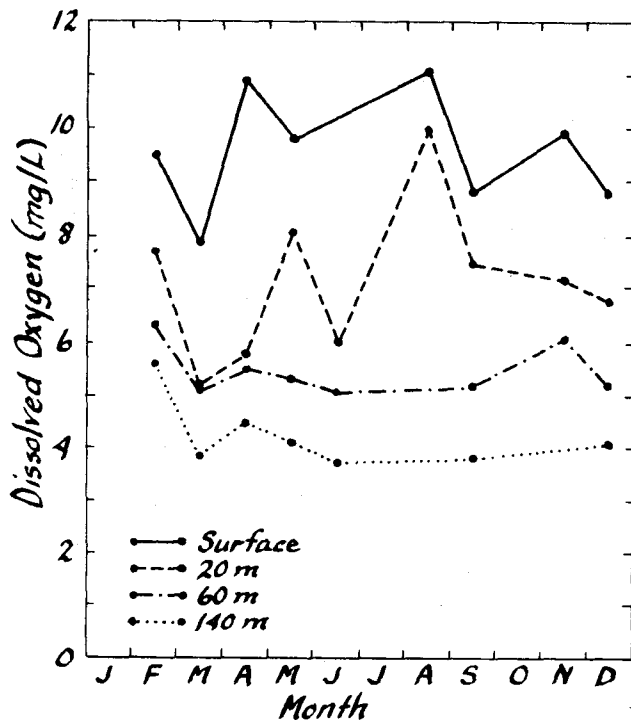


FIGURE 5. Annual change in temperature and dissolved oxygen values of surface and near-bottom waters on the coastal shelf of Los Angeles and Orange Counties, 1972-73.

Although much biological and environmental data remains to be analyzed and correlated, we have summarized information on seasonal changes in benthic water characteristics for various depths on the coastal shelf to observe for divergent benthic exposure patterns. A compilation of annual surface and bottom water changes in temperature and dissolved oxygen at several depths is of interest. While surface temperatures (Figure 4) display a typical pattern of warming in the spring and summer and cooling in the fall and early winter, deeper waters do not. In fact, below a depth of 25 to 60 m, the benthic waters are cooler in summer than in winter. Both the absolute temperatures and the temperature range at each depth generally decrease with depth. Annual temperature ranges (ΔT) rapidly decrease between the surface and about 25 m and then decrease more slowly below this depth (Figure 5).

Dissolved oxygen concentrations show similar patterns beyond the 20 m isobath (Figures 5 and 6). In fact, changes in bottom water dissolved oxygen are directly correlated with temperature changes (Figure 7), particularly in waters below 25 m.

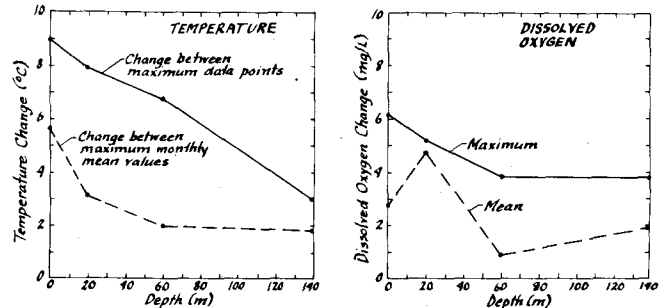


FIGURE 6. The 1972 and 1973 dissolved oxygen content of surface waters and near-bottom waters at 20, 60, and 140 m on the coastal shelf of Los Angeles and Orange Counties.

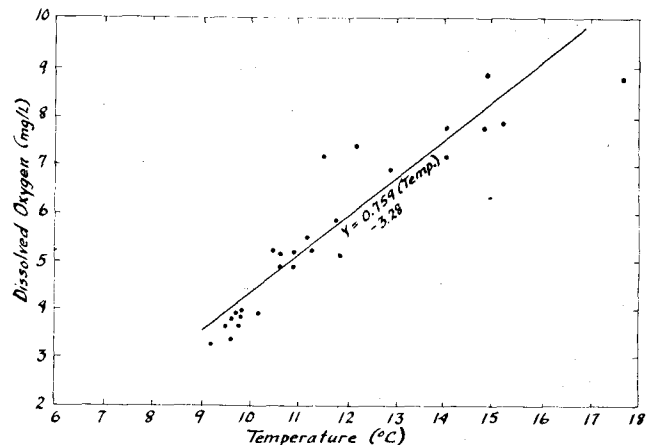


FIGURE 7. Bottom water temperature vs. dissolved oxygen in three coastal shelf areas of southern California, 24 to 26 September 1973. Linear correlation, $r = 0.934$ ($p < 0.001$).

Relationships Between Coastal Shelf and Offshore Basin Waters

Additional data suggest that the characteristics of the water masses near the bottom of the coastal shelf change gradually, with little perturbation, as one moves from the shore over the shelf and into the cold, low oxygen water of the adjacent basins. Profiles of temperature and oxygen at stations in Santa Monica Bay sampled during January and June

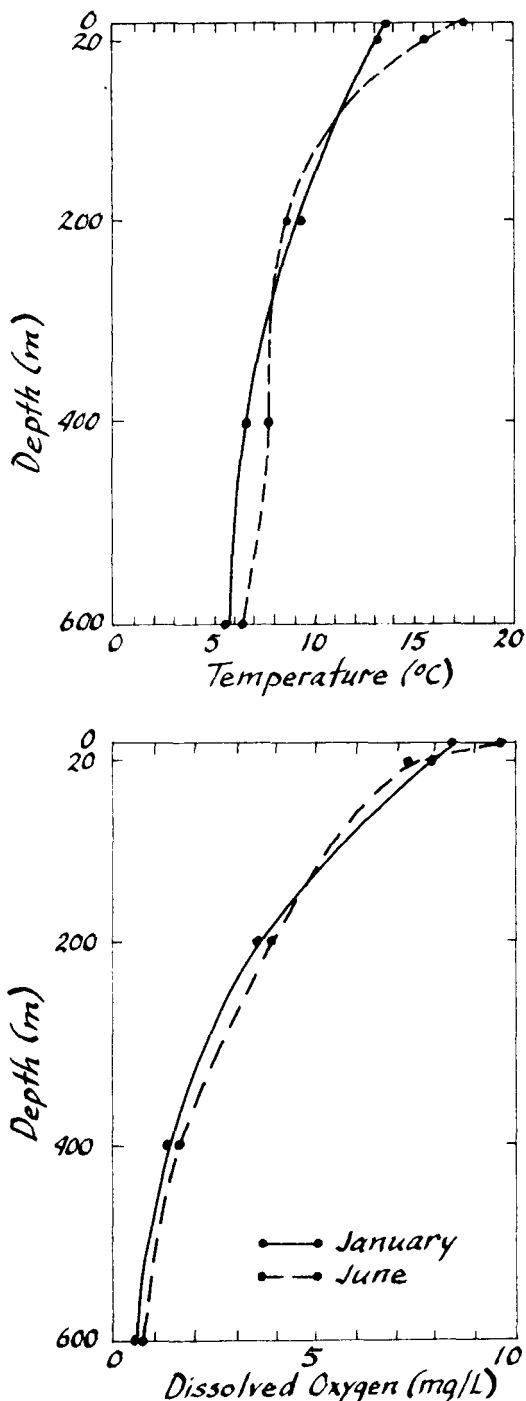


FIGURE 8. Temperature and dissolved oxygen in the northeastern portion of Santa Monica Basin, January and June 1974.

1974 indicate that below 300 m, there seems to be little change in temperature or oxygen from summer to winter (Figure 8). But during the same time period, the waters between 20 and 200 m appear to undergo cooling and decrease in oxygen content (similar trends, which suggest upwelling, have been noted offshore; Dr. Paul Smith, National Marine Fisheries Service, La Jolla, pers. comm.). In the 1974 survey, we observed that a seasonal thermocline, with warm, well oxygenated water, had formed above 20 m, thus inhibiting vertical movement or mixing of the waters.

Implications of the Characteristics of the Subsurface Waters of the Coastal Shelf

A recognition of the major environmental gradients in temperature and other basic characteristics of the bottom waters of the coastal shelf may simplify our understanding of the constituents of the nearshore biota and the interplay of the faunal units characteristic of local coastal areas. The seasonal thermocline has long been recognized as a feature allowing the development of the fauna most characteristic of southern California. But even at its maximum development of 20 to 50 m, the thermocline intersects only a portion—30 to 50%—of the coastal shelf occupied by marine populations and used by man. The waters below this layer may have quite different physical attributes than those in the inshore zone or above the slope and basins. Likewise, the depths at which isotherms fluctuate the most (e.g., inshore, at 10 to 40 m) may have biological attributes of their own. There may be a number of zones on the coastal shelf (e.g., between 10 and 150 m) that are defined by temperature alone, and anomalies in the depths of these zones can be expected near submarine canyons or other unique topographic features. A typical pattern of isotherms forms during or following the development of the thermocline in summer (Figure 9). Of particular importance is that, although much of the coastal shelf (Area C on Figure 9) may be unaffected by the seasonal thermocline (but greatly influenced by the

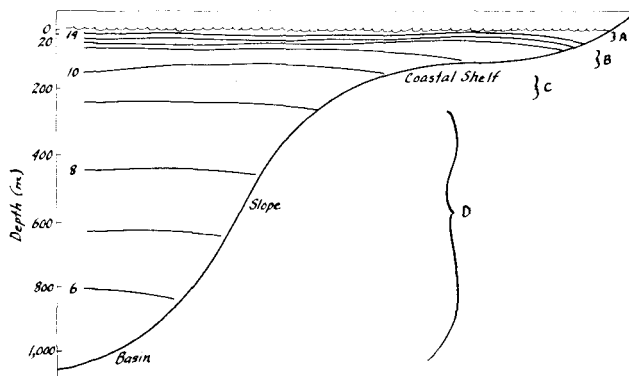


FIGURE 9. Section of the coastal shelf of southern California showing four possible environmental zones defined by temperature (°C).

basin waters), there may be an area inshore (Area B) that is subject to rather rapid temperature increases and decreases, depending on currents and on the rate of development of the thermocline and its strength. Offshore of the shelf edge (Area D), temperature and oxygen fluctuations are minor.

These patterns are somewhat consistent with the general faunal changes and faunal zonation on the coastal shelf, such as the recurrent group associations of benthic fishes described by the Project (1973). In addition, demersal and benthic fauna inshore of 20 m generally show major seasonal changes in abundance and species composition associated with temperatures. Our analyses, which are still in progress, suggest that there is an abrupt compositional change between 20 and 60 m, particularly in the demersal fish and shrimp fauna. From 60 to 20 m, there are additional but more gradual faunal changes in populations of shrimp, flatfishes, poachers, and rockfishes.

Bottom water dynamics may explain changes in the distribution of many coastal fishes, such as the inshore congregations of bottom fishes observed in Santa Monica Bay between January and June 1960 (Southern California Coastal Water Research Project, 1973; based on a reanalysis of data reported by Carlisle, 1969). An incursion of offshore bottom water (e.g., water from 60 to 200 m) into an inshore (5 to 20 m) trawl survey area could substantially change the nature of the demersal and benthic fauna and its abundance at one or more sites. Likewise, such events can successfully deliver larvae of demersal and benthic animals to different localities, depending on the bottom topography, the weakness of the thermocline, or the movements of bottom water stimulated by entrainment at large outfall sites.

Finally, year-to-year differences in the dynamics of nearshore and surface waters and those of bottom waters may partially account for longer term, apparently unrelated changes in nearshore and demersal fish populations. For example, Carlisle (1969) showed data on average annual surface and bottom water temperatures and on sport and trawl monitoring catch statistics in Santa Monica Bay. Reexamination of these plots suggests an inverse relation between surface and bottom water temperatures and between sport catches (primarily

predatory fishes from the water column) and trawl catches (primarily benthic and small forage fishes).

Continued simultaneous monitoring of benthic and demersal biota and the variables of bottom (or even near-bottom) waters such as temperature and dissolved oxygen should help refine our understanding of the coastal shelf and aid in distinguishing natural biological anomalies from those induced by man's use of the shelf. Adjustments of ongoing coastal monitoring programs and coordination with programs of larger scope, such as CalCOFI, should greatly enhance this effort.

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