

1957: THE YEAR OF WARM WATER AND SOUTHERN FISH OFF CALIFORNIA COAST

ABSTRACT

A preliminary report on oceanographic conditions and the pelagic fisheries of California during 1957 prepared for the Marine Research Committee by the agencies participating in the California Cooperative Oceanic Fisheries Investigations (CCOFI)^{1/}. The year 1957 was unusual compared with the last several years. The question seems to be whether 1957 is unusual or perhaps the only "normal" year in the past 10. Oceanographic and biological data are presented and discussed.

BACKGROUND

By now it is common knowledge that climatically 1957 has been an extraordinary year. This condition seems to have been Pacific-wide: Hawaii had its first recorded hurricane; the Peruvian coast was afflicted with the fish-killing El Nino; the ice went out at Pt. Barrow at the earliest time in history; on the western edge of the Pacific, the tropical rainy season lasted almost six weeks beyond its usual term.

This widespread variation in the weather has manifested itself dramatically on a local scale. At La Jolla, for example, the temperature of the sea surface reached the highest averages during July, August, and September 1957 it had achieved in 26 years. Southern California has had one of its rainiest autumns in several years. By mid-December, for example, the weather station at Lindbergh Field, San Diego, had recorded 3.57 inches, against a normal (the mean from 1920 to 1950) to that date of 2.48 inches. Throughout the summer reports came in of the appearance in quantity of fishes that in recent years had been caught only as stragglers: by the end of September, the party boats had landed 2,805 dolphinfish against a previous high of 15 in 1947.

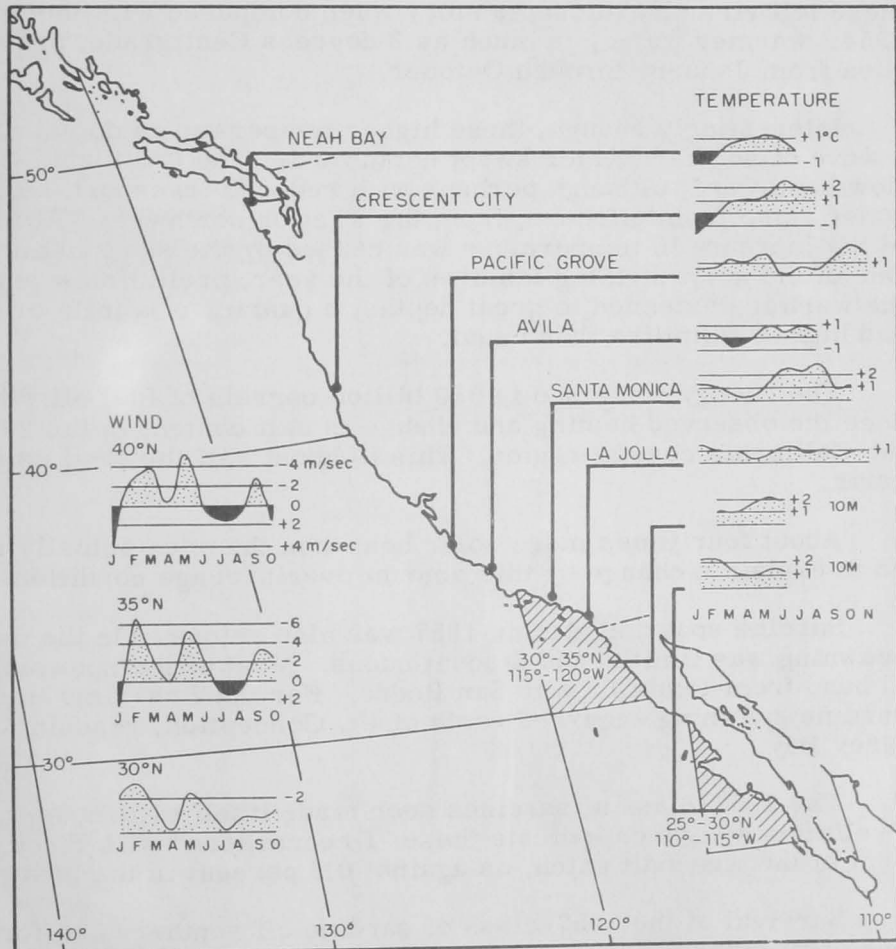


Fig. 1 - Temperature and wind anomalies at shore stations, 1957 compared to the 1949-56 period. Wind anomalies show variations in the northerly component of the geostrophic winds (computed from pressure charts). A negative anomaly means that the northerly component was weakened. Positive temperature anomalies indicate warmer water.

^{1/}California Academy of Sciences; California Department of Fish and Game; Stanford University, Hopkins Marine Station; U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, South Pacific Fishery Investigations, University of California, Scripps Institution of Oceanography.

To the agencies conducting research under the California Cooperative Oceanic Fisheries Investigations, the year 1957 presents both an opportunity and a challenge. In previous years, large amounts of data were collected on the ocean and the fisheries, so that it has been possible to describe in considerable detail what has happened to oceanographic conditions since 1949. This material will now offer an invaluable basis of comparison with a year which differs strikingly from those immediately preceding but which may have been similar to others in the past for which not so large an amount of data exists. Thus, 1957 may offer an opportunity to explain both the immediate past and perhaps throw further light on the years of the thriving sardine fishery.

Some of the oceanographic data for 1957 are still being processed, but results already available for publication are striking. (Processing of the remaining 1957 data has been given priority over other processing.) Shore temperatures (which have proven to be useful clues to conditions offshore) have been higher than at any time throughout the 1949-56 period. The winds in 1957 had less of a northerly component than at any time during this period.

Sea surface temperatures for the entire CCOFI area are available for 1957 and these tell virtually the same story when compared with those for the period 1949 to 1954: warmer water, as much as 3 degrees Centigrade, prevailed over most of the area from January through October.

Interestingly enough, these higher temperatures do not necessarily mean that a wave of southern water swept northward. The California Current continued to flow southward, although perhaps with reduced transport. Most probably the warm water came from offshore, from the west or northwest. At most, only a small part of the increase in temperature was caused by the sun's heating in the CCOFI region. One of the most striking features of the year, preliminary analysis shows, is that the warming extended to great depths, a quarter of a mile or so. This warm water had higher salinities than usual.

The energy contained in 560 billion barrels of fuel oil would be required to produce the observed heating and change in salt content in the 200,000 square miles of the California coastal region. This is about half the total estimated oil reserves on earth.

About four times more solar heat than the area actually received would be needed to explain a change by this amount over average conditions.

Sardine spawning during 1957 was also unique. On the usual offshore grounds, spawning was limited and discontinuous. Most of the spawning took place in a coastal band from Punta Baja to San Pedro. For the first time in several years, some sardine spawning occurred north of Pt. Conception, reaching at least as far as Monterey Bay.

The 1957-class of sardines soon made itself evident in the live-bait fishery. Preliminary figures indicate these "firecrackers" will account for at least 6.0 percent of the live-bait catch, as against 0.3 percent in the best previous year.

Survival of the 1957-class of sardine off southern California has undoubtedly been better than in recent years. It is possible that the 1957-class will prove to be large. Judgment should be reserved, however, since these juveniles may have been overavailable during the year because of their inshore origin, and been oversampled.

The plankton collections so far examined reveal no striking changes from previous years, a fact of importance so far as the South Pacific Fishery Investigations are concerned, implying as it does that the distribution of these creatures may not be determined by surface temperatures.

The plankton collections do point toward a successful 1957-class of jack mackerel. An unusual abundance of larger jack mackerel larvae appeared in the collections.

So far as the fisheries are concerned, the most startling information for 1957 comes from the sport fishery. The year will unquestionably be the best for southern California anglers since party-boat records were re-established in 1947. Yellowtail have been caught off all southern California sport-fishing ports and in large

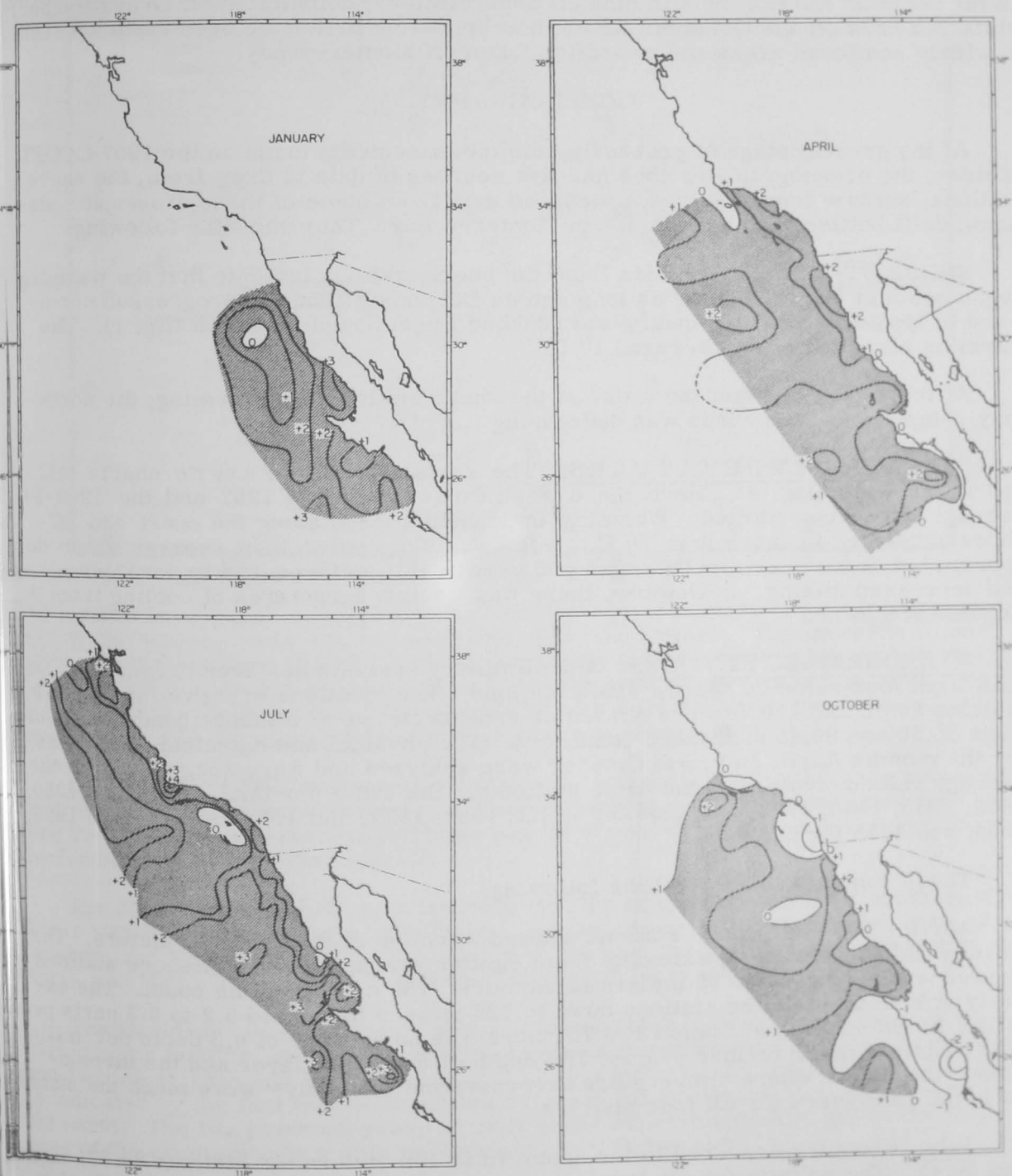


Fig. 2 - Differences between sea surface temperatures in 1957 and in earlier period. Upper left, January 1957 compared with 1949-55 average. Upper right, April 1957 compared with 1949-54 average. Lower left, July 1957 compared with 1949-54 average. Lower right, October 1957 compared with 1949-54 average. Differences are expressed in degrees Centigrade. Shading indicates warming.

numbers south of Port Hueneme, and the barracuda catch has also increased greatly over the past several years. More bonito and yellowtail have been taken by party boat anglers than in any year previously recorded.

Equally as remarkable as this upsurge in landings of game fish by sportsmen is the fact that many species have been taken much farther north than in recent years. White sea bass have been taken off the Golden Gate, for example; skipjack tuna, dolphinfish, and bonito were taken 30 to 80 miles off the Farallon Islands and as far north as Eureka; bluefin tuna off Cape Flattery; dolphinfish off Grays Harbor; white sea bass off the Columbia River; marlin and sailfish have been reported seen in widely scattered areas and swordfish taken off Monterey Bay.

OCEANOGRAPHY

At the present stage of processing the measurements made on the 1957 CCOFI cruises, the oceanographers have had five sources of data to draw from, the shore stations, surface temperatures, processed data from some of the hydrographic stations, drift bottles, and the cruises in Monterey Bay. They show the following:

SHORE STATIONS: The data from the shore stations indicate that the warming began south of Port Hueneme as long ago as December 1956. It progressed northward to Monterey Bay in January and reached Puget Sound in March (fig. 1). The warming along the coast averaged 1° C.

At the same time that the water at the shore stations was warming, the northerly component of the winds was decreasing (fig. 1).

SURFACE TEMPERATURES: The surface temperature charts tell the same story (fig. 2). Here the differences between 1957 and the 1949-54 average have been plotted. Warming in various places along the coast and offshore amounted to more than 3° C. A few spots of cooler than average water do appear, but these were small in size and presumably were caused by local upwelling and decreased mixing. In October, there was a fairly large area of cooling from Pt. Eugenia southward.

HYDROGRAPHIC STATIONS: A preliminary analysis has been prepared of the data from four selected hydrographic stations. The locations are given in figure 3. Stations 80.90 and 100.70 were chosen as representative of offshore conditions, Stations 80.60 and 90.45 of inshore conditions. The physical and chemical properties for the months April, July, and October were analyzed and were compared with the average values obtained at the same stations in the same months in the years 1950, 1952, 1953, 1954, 1955, and 1956 for April; 1950, 1952, and 1953 for July; and 1952, 1954, and 1955 for October.

These comparisons reveal the following:

April: The two inshore stations showed warming in the upper 50 meters. The salinity did not change significantly from earlier years. The two offshore stations showed warming down to 75 meters in the north, 150 meters in the south. The salinity at both these latter stations down to 125 meters increased 0.2 to 0.3 parts per mille. At 200 meters at Station 100.70, there was an average of 0.3 parts per mille less salinity than in former years. The depth of the mixed layer and the thermocline--the region where temperature decreases most rapidly--were much the same as in the past years for all four stations.

July: Warming occurred in the upper 75 to 100 meters for Stations 80.60, 80.90, and 90.45. The salinity for the two inshore stations was little changed. At Station 80.90, offshore, the salinity increased an average of 0.35 parts per mille from the

surface to 100 meters, and 0.15 parts per mille from 100 to 150 meters. At 200 meters the salinity decreased over the other years by an average of 0.01 parts per mille. The oxygen values at Station 80.90 at 200 meters was much higher than usual, 4.0 milliliters per liter. The depth of the mixed layer was the same as in past years.

October: By October a very noticeable change had occurred from Pt. Conception to Pt. Eugenia. The temperatures at the four stations increased as deep as 400 meters with Station 80.90 having the largest increase. At 50 meters, the depth of the mixed layer, the temperature was over 2° C. higher than the average, and at

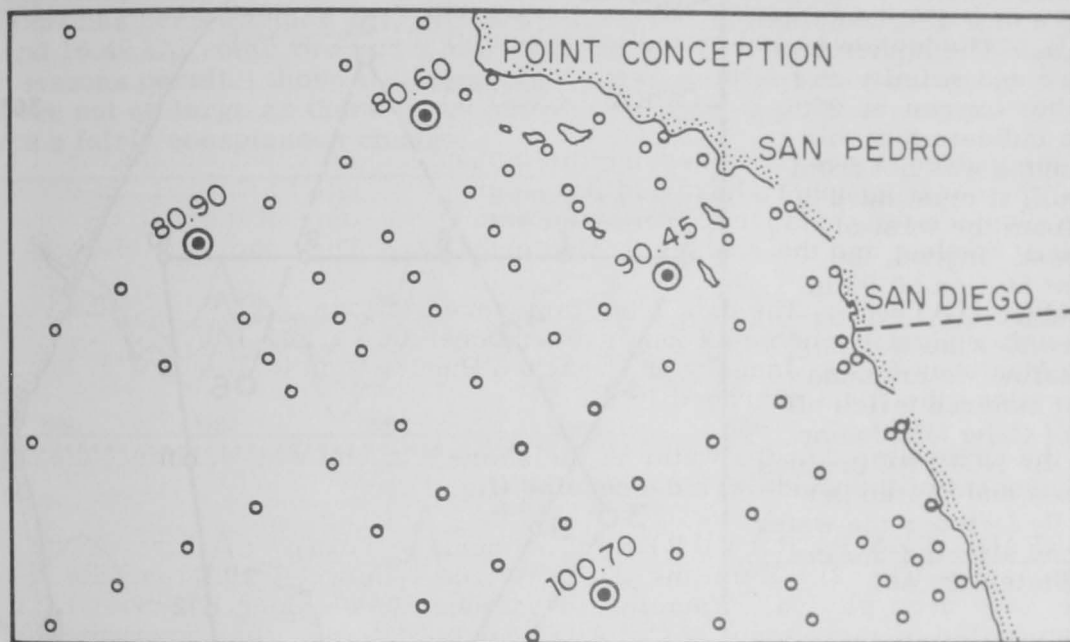


Fig. 3 - Location of four hydrographic stations for which 1957 data have been analyzed.

150 meters it was 1.8° C. higher. The salinity also increased for all stations except 90.45, where it was slightly less than in former years. The increase in salinity was the greatest at Station 80.90, averaging 0.4 parts per mille to 125 meters. Again at this station the salinity was less at 200 meters, by an average of 0.2 parts per mille. The oxygen value at Station 80.90 was 4.6 milliliters per liter. The mixed layer was the same as in previous years at all stations.

DRIFT BOTTLES: At present, clues to the currents during the year come only from the drift-bottle experiments, as the hydrographic data must be processed before the standard current computations can be made. Other clues will come from the further analysis of the plankton.

The drift-bottle experiments indicate that the eddy often found off southern California was in existence during November and December 1956, and during June, July, October, and November 1957. The eddy was not observed during February, March, April, and May. There are no data for January, August, and September.

The Davidson countercurrent, which sweeps along the central California coast during some months, usually in the winter, was apparently active during November and December 1956 and February, March, July, October, and November 1957. This is indicated by the fact that drift bottles released off Pt. Conception were found to the north. The two previous years of drift-bottle experiments had shown the presence of the countercurrent only in November and December.

Though warming began in the south and shifted northward in time, there is no indication that southern water moved northward. Study of the zooplankton shows no

species from other areas. The northerly winds were greatly reduced in the first part of the year. This may have retarded the normal transport of water along the coast allowing advection of warmer offshore water into the region off southern California and Baja California. The slight increase in salinity at Station 80.90 in April and the larger increase at Station 100.70 indicate that water from farther west than usual was in fact present. By July, Station 80.90 more clearly shows the presence of a different water mass. The higher temperature and salinity and the higher oxygen at 200 meters indicate that this water mass was not from the south; it must have come from the west or northwest. Indeed, the water at Station 80.90 in July and October strongly resembles the warmer, more saline water found several hundred miles offshore of Cape Mendocino during the NORPAC cruises of August and September 1955. By October the water mass had affected the in-shore Station 80.60.

We may summarize our conclusions to date by saying that the water was warmer, the northerly winds reduced, and that the warm water did not seem to come from the south, but at present we do not understand the combination of the oceanographic and meteorological mechanisms by which these changes took place.

CRUISES IN MONTE-REY BAY: Monterey Bay is historically one of California's richest fishing grounds. It is broadly open to the sea, and conditions in the Bay therefore reflect to a large extent the conditions which occur in the offshore waters of central California.

Since 1951 the Hopkins Marine Station of Stanford University has operated for CCOFI what amounts to an oceanographic "weather station" on Monterey Bay, with approximately weekly cruises that sample the water conditions and plankton organisms at several points in the bay (fig. 4). The Department of Fish and Game biolo-

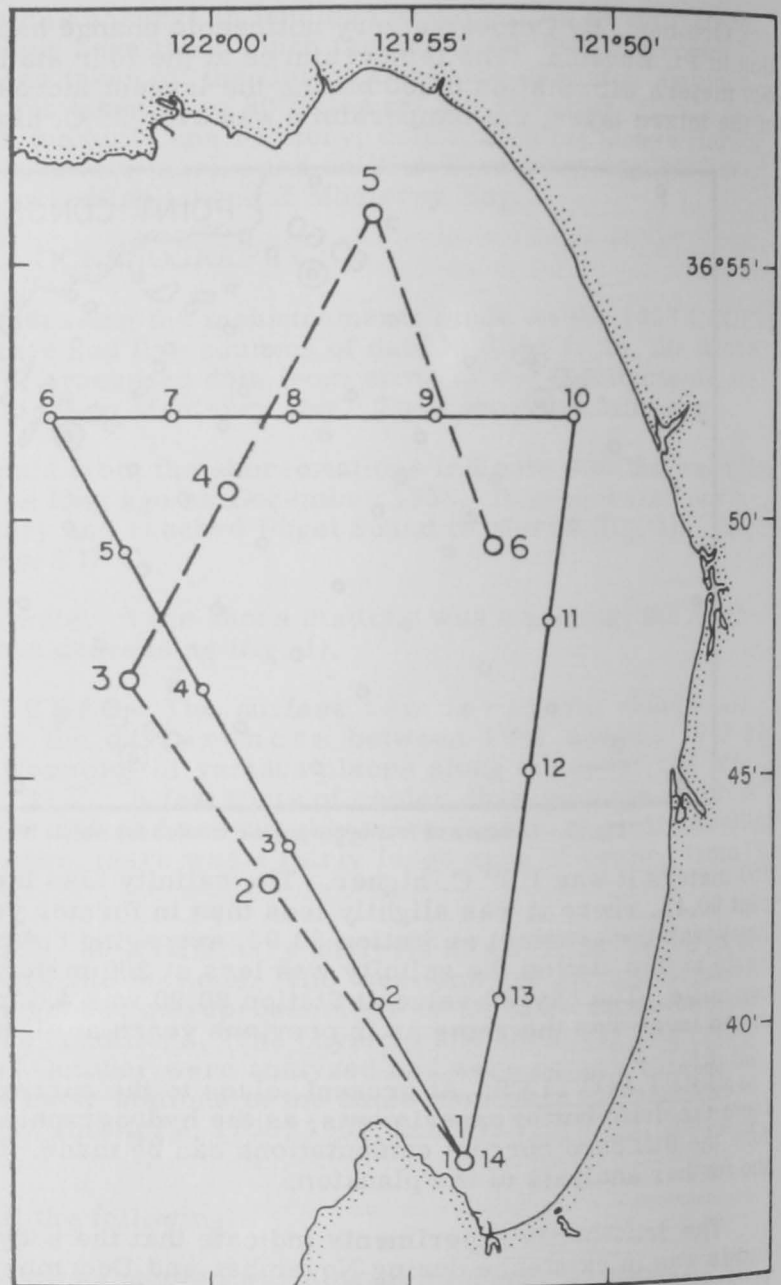


Fig. 4 - Path of regular oceanographic cruises in Monterey Bay. The solid line and small numbers show the cruise pattern and stations occupied at approximately weekly intervals from September 1951 to February 1954. The broken line and large numbers represent the cruise pattern and stations similarly occupied during the period March 1954 through November 1957, and continuing. At each station the vessel records weather and water temperatures, and takes water samples and plankton hauls for analysis.

gists, also located at the Hopkins Marine Station on Monterey Bay, have followed conditions and catches of the fishery in this area, and conducted aerial surveys of pelagic fish schools in the region from San Francisco south to Point Conception.

Warmer Water Conditions: Monterey Bay and the ocean beyond have shown a definite trend toward warmer conditions since 1955. The year 1955 was cold, with surface temperatures rarely rising above 14°C ., even in inshore waters (fig. 5). September and October, nearly always the two warmest months of the year, showed monthly average temperatures on the bay of 13.1°C . The year 1956 was warmer, with September and October average surface temperatures of 14.6 and 14.9°C . The year 1957 has been warmer yet, with September and October monthly averages of 15.7 and 16.4°C ., some two and a half degrees warmer than in 1955. Changes in other seasons parallel those indicated above, though differences in winter temperatures are not as large as those given above. For oceanographic conditions this represents a fairly conspicuous change.

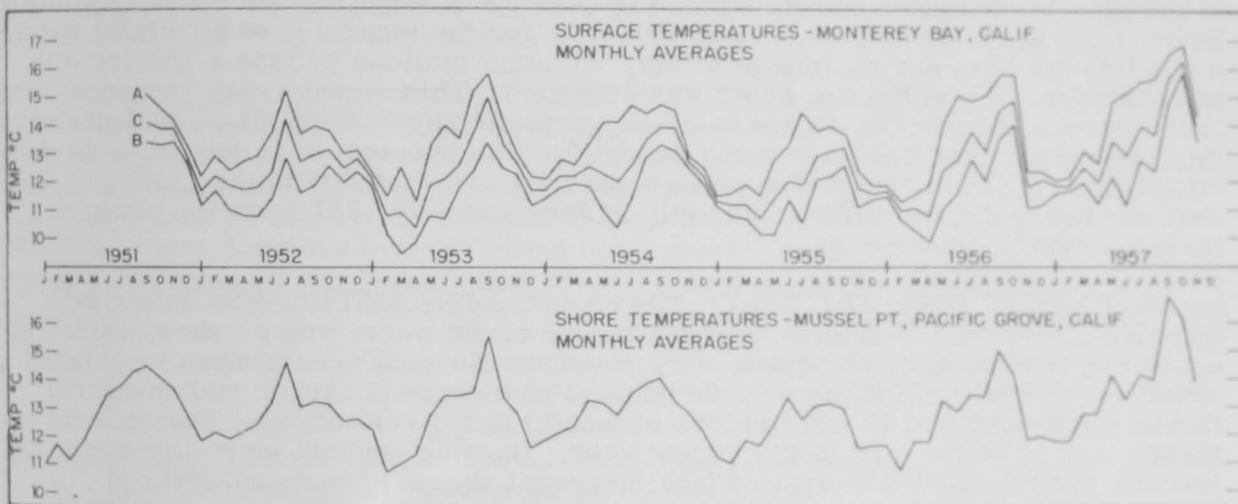


Fig. 5 - (Top) Surface temperatures, Monterey Bay (monthly averages in degrees Centigrade). Curve A--Monthly averages of the highest surface temperature recorded during each weekly cruise. Curve B--Monthly averages of the lowest surface temperature recorded during each weekly cruise. Curve C--Monthly average of all surface temperatures recorded during each weekly cruise. The surface temperatures in Monterey Bay show a characteristic pattern of change through the year. During the fall and winter months there is little temperature variation from place to place in the Bay. Conversely, during the period March through July or August the range of temperatures encountered during any particular cruise is relatively great. This increased temperature range during spring and summer results from a combination of upwelling in the center of the Bay and surface warming in peripheral areas. Cold waters rise in a slow fountain from the Monterey submarine canyon in the center of the Bay, and move toward the shores, gradually warming as they spread. For the cruise patterns used, the range of surface temperatures encountered on a particular day provides a good indirect measure of the amount of upwelling occurring. Curves A and B approach each other rapidly as upwelling ceases. The chart shows a clear shift toward warmer conditions in the surface waters of the Bay since 1955. (Bottom) Shore temperatures, Mussel Point, Pacific Grove (monthly averages in degrees Centigrade). Curve D shows monthly averages of the shore temperatures at the southern end of Monterey Bay, based on daily measurements recorded by Hopkins Marine Station for the Scripps Institution of Oceanography. As do the surface temperatures of the Bay, the shore temperatures show a clear trend toward warmer conditions since 1955. The warmer conditions in 1957 were accompanied by indications of a good spawning of anchovies in the months of May and June, and a light spawning of sardines (the first recorded off Monterey since 1950) in the same period. Young current year-class anchovies and sardines entered the Bay in numbers in September and October.

BIOLOGY

SARDINE SPAWNING: Sardine spawning during 1957 was also unique. On the usual offshore grounds, spawning was limited and discontinuous. Most of the spawning took place in a coastal band from Punta Baja to San Pedro (Station lines 90-107).

For the first time in several years, some sardine spawning occurred to the north of Pt. Conception. Sardine eggs and/or larvae were taken at five stations on lines 67 to 77 in June. Spawning north of Pt. Conception was observed in July, the northernmost locality being off Monterey Bay.

Sardines of the 1957-class were taken in the live-bait fishery and were commonly observed by sardine fishermen fishing out of Port Hueneme. Sardines of the 1957-class have also been reported from north of Pt. Conception at least as far north as Monterey Bay.

Survival of the 1957-class of sardines off southern California has undoubtedly been better than in recent years. It is possible that the 1957-class will prove to be a large one. Judgment should be reserved, however, since these juveniles may have been overavailable owing to their inshore origin, and been oversampled.

PLANKTON COLLECTIONS: A number of plankton samples collected off California during the June and July cruises of 1957 have been examined in order to determine if there was anything unusual about the distribution of plankton organisms during this period. Inasmuch as there had been marked incursions of warm water fish into the area, it was of interest to ascertain whether there were also incursions of the plankton animals associated with tropical or central Pacific water. On this basis, from the plankton, there is no evidence for the incursion of a tropical water mass into the area during June and July. At some stations in June a species with affinities for central Pacific water was collected. This species may approach close to the coast at times, but its presence supports the physico-chemical evidence of an incursion of central Pacific water. Except for this species, the plankton in the area off California was made up of species ordinarily associated with the California Current and hence did not differ materially in June and July 1957 from the plankton of these months in other years.

LARVAE IN JUNE AND JULY: The June and July 1957 plankton collections were also examined to determine if the larvae of the warm water fishes, which were appearing in abundance as adults, were present. No such occurrences were noted. However, an exciting finding was the unusual abundance of larger jack mackerel larvae (between 5 and 10 millimeters in length) in the collections. The survival to these sizes is better than in any recent year. Barring unusual mortality during the juvenile period, the 1957-class of jack mackerel should be a successful one.

THE FISHERY: Despite the earlier starting date (September 1) in 1957, a dispute on price kept the San Pedro sardine fleet idle and as of November 1, 1957, a price settlement had not been reached; consequently, the vessels fishing out of Port Hueneme and Santa Barbara landed almost the entire catch. The sardines appeared to be widely scattered and not very abundant in 1957.

AERIAL SURVEYS: Results of the two first aerial surveys in 1957 showed a decrease of anchovy stocks coastwide, especially in central California; however,

Table 1 - Total Annual Party-Boat Catch of Several Species,
1947 through September 1957

Year	Barracuda	Yellowtail	Bonito	Tuna		Dolphinfish	Angler Days
				Yellowfin	Skipjack		
(Number of Fish)							
1957 ^{1/}	490,075	176,849	186,587	425	6,417	2,805	-
1956	87,603	29,198	61,404	78	13	2	523,063
1955	154,962	36,468	22,409	1	10	0	496,286
1954	282,552	40,872	70,078	0	50	12	532,190
1953	170,550	27,702	6,321	0	279	0	502,146
1952	336,550	59,263	7,649	34	38	2	562,898
1951	269,545	23,721	14,475	56	132	0	556,949
1950	256,367	6,971	2,359	6	31	1	544,264
1949	366,423	17,710	5,372	11	9	0	469,915
1948	384,056	13,028	14,519	18	460	0	407,757
1947	677,449	6,948	36,496	137	698	15	359,436

^{1/}Through September, preliminary report.

there are good indications that the 1957-class should be a strong one, particularly off central California.

It is noteworthy that on Flight 57-2 (May 14-24), a school group of sardines appeared in the area around the Coronados Islands and Pt. Loma. These fish were reported about May 1 by commercial aerial spotters and samples of the live bait collected at San Diego proved them to be nearly all of the 1955-class. Over the past three seasons sardines were not seen on aerial flights until late in June.

BAIT SAMPLING: In 1957 there has been an enormous increase in the percentage of young sardines ("firecrackers") in the live-bait catch. Firm figures are not yet available, but it appears that the "firecrackers" may exceed 6.0 percent (as against 0.3 percent for 1955, the best previous year for which records were taken). Even more significant is the fact that these sardines of the 1957-class have been taken by the live-bait fleet off all sportfishing ports from San Diego north to Morro Bay. In addition, the sardines of the year have been collected from Monterey Bay for the first time in several years.

THE SPORT FISHERY IN 1957: Aside from the obviously better survival of the 1957-class of sardines, there has been in this year of unusually warm waters a phenomenal increase in the catch of many sport fish. The year 1957, unquestionably, will be the best sport-fishing year southern California ocean anglers have enjoyed since party boat records were re-established in 1947. Yellowtail have been caught off all southern California sportfishing ports and in large numbers south of Port

Table 2 - Preliminary List of Other Warm-Water Species Taken in California Waters in 1957

Number Taken in 1957	Common Name	Scientific Name	Years Formerly Reported	Location of Capture in 1957
1	Bullet mackerel	<u>Auxis</u> sp.	1918 1919 1935	Coronado Island
2	Sharpchin flyingfish	<u>Fodiator acutus</u>	1931	Long Beach
1	Tai or Porgy	<u>Calamus brachysomus</u>	1953?	Oceanside
1	Shortnose spearfish	<u>Tetrapturus anguistirostris</u>	(Never previously taken off California)	60-mile bank
1	Spiny trunkfish	<u>Lactoria diaphanus</u>	1932 1933 1949 1/1951	Santa Monica Bay
1	Pilotfish	<u>Naucrates ductor</u>	1928 1936 1945	San Clemente Island
3	Triggerfish	<u>Verrunculus polylepis</u>	1924 1931 1946 1950 1/1951	Santa Monica Bay, Laguna Beach, and San Diego
1	Monterey Spanish mackerel	<u>Scomberomorous concolor</u>	1931 1937 1939 1944 1947 1948 1949 1/1951	Santa Barbara
1	Green jack	<u>Caranx caballus</u>	1858 1924 1945 1953 1/1955	Belmont Shore

1/Probably other years, also.

Hueneme, and the barracuda catch has also increased greatly over the past several years. More bonito and yellowtail have been taken by party boat anglers than in any year previously recorded.

The catch in numbers of several game species from 1947 through September of 1957 are shown in table 1.

Even pier anglers were able to snag small (1957-class) sardines for bait to catch large numbers of bonito and occasional barracuda.

In addition to the good fishing for yellowtail, barracuda, and bonito, party boats also encountered skipjack tuna and dolphinfish in greater amounts than during the past 10 years, and they occasionally landed yellowfin tuna.

Equally remarkable as this upsurge in landings of game fish by sportsmen is the fact that many species have been taken much farther north than in recent years. White sea bass have been taken off the Golden Gate in fair numbers both by sportsmen and by commercial fishermen trolling for salmon. A rather substantial sports fishery for white sea bass began in Monterey Bay. Meanwhile, commercial albacore fishermen were taking skipjack, dolphinfish, and bonito 30 to 80 miles off the Farallon Islands and as far north as Eureka.

Biologists from Oregon and Washington have reported bluefin tuna taken by commercial fishermen off Cape Flattery, skipjack as far north as Cape Blanco, dolphinfish off Grays Harbor, and white sea bass off the Columbia River. Unusually warm sea temperatures have been reported all along the coast by the albacore fishermen in the former offshore albacore fishing areas. Marlin and sailfish have been reported seen in widely scattered areas and swordfish have been taken off Monterey Bay.

In addition to the warm-water species listed in table 2, hammerhead sharks were seen frequently in California waters during 1957 and many were caught. Several green sea turtles were taken, especially by bait haulers in Los Angeles Harbor, and others have been reported sighted as far north as the Farallons.

At Pismo Beach the set of Pismo clams in 1957 was the best to occur at that locality in the past 10 years. This set compares favorably with the best sets since the Department's Annual Pismo Clam census was inaugurated in 1923.

The year 1957 was, indeed, unusual compared with the last several years, and sportfishing seems more nearly like it was in the years prior to World War II. The question seems to be whether 1957 is unusual or perhaps the only "normal" year in the past 10.



DRY FISH SILAGE

A dry fish silage feed which can be sold in paper sacks and which has good keeping quality has been produced in Denmark. H₂SO₄ silage is mixed with drier materials, such as wheat bran, alfalfa meal, etc., the resulting mixtures containing 40 to 50 percent water. Mold growth is prevented by addition of mold inhibitors (Arsberetning fra Fiskeriministeriets Forsegslaboratorium for 1955, Copenhagen, Denmark).