

NOAA Technical Report NMFS SSRF-720

**Sea Surface Temperature  
Distributions Obtained  
Off San Diego, California,  
Using an Airborne  
Infrared Radiometer**

James L. Squire, Jr.

March 1978



U.S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service

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Juanita M. Kreps, Secretary

**National Oceanic and Atmospheric Administration**

Richard A. Frank, Administrator

**National Marine Fisheries Service**

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# Sea Surface Temperature Distributions Obtained Off San Diego, California, Using an Airborne Infrared Radiometer

JAMES L. SQUIRE, JR.<sup>1</sup>

## ABSTRACT

Sea surface temperature surveys were conducted weekly off San Diego, Calif., using an airborne infrared radiometer during the months of April through October 1972-74. A total of 90 surveys were made over the 320-mile flight track. The analog chart record of temperature was keyed to a "ground truth" temperature measurement and read to determine 1 min average temperatures which were plotted on the flight track and 1°F (0.56°C) isotherms were contoured from the data. The trend of sea surface temperatures during the 3-yr period showed warmer temperatures in 1972, which was an "El Niño" year, cooler in 1973, warmer than 1973 in 1974, but not as warm as 1972. In early July 1974, an anomalous warming period occurred and highest average temperatures of 73°F (22.7°C) were recorded in 19 July 1974. Lowest average temperature of 54°F (12.2°C) was recorded on 2 April 1973.

The 1972-74 survey temperatures taken over the "ground truth" calibration site were compared with a time series of temperature observations taken during the same months from 1963 to 1968. The average temperature during 1963-68 was 63.4°F (17.4°C) and for 1972-74, 64.1°F (17.8°C), a difference of less than 1°F (0.56°C). Average monthly temperature differences, 1963-68 compared with 1972-74, shows April the same, warmer 2°F (1.12°C) for May, 3°F (1.68°C) for June, 1°F (0.56°C) for July, same for August, 1°F (0.56°C) less for September, and 2°F (1.12°C) less for October.

## INTRODUCTION

Synoptic sea surface temperature surveys with an airborne infrared radiometer were first conducted off the Pacific coast in August 1963 over the coastal waters of Washington, Oregon, and California by the National Marine Fisheries Service's (NMFS) Tiburon Fisheries Laboratory at Tiburon, Calif. Surveys over three areas were conducted in cooperation with the U.S. Coast Guard, and these surveys are being continued as part of the U.S. Coast Guard oceanographic program. The first 5 yr of surveys (1963-68) were reviewed by the author (Squire 1971). The objective of the coastal program was to increase the general knowledge about the nearshore temperature structure, to define areas of nearshore upwelling, and to develop temperature data that may be useful in relating the distribution and relative abundance of major coastal species of fishes to sea surface temperature and its changes.

The initial surveys, conducted monthly, were broad in geographical scope and in time. The data have been useful in computing average catch temperatures for salmon off central California, and for a number of pelagic species common to southern California waters (Squire unpubl. manuscr.). However, this broad-based survey did not cover some of the more important coastal fishing areas in

sufficient detail and at short enough time intervals to permit the determination of the relation of changes in catch composition and catch rates to short-term temperature fluctuations.

To determine short-term temperature effects, an area having a heavy amount of fishing effort and catch was selected for detailed study. This area covered the southern California coastal waters from near Del Mar, Calif., to south of the United States-Mexico border, and to about 22.3 km (12 n.mi.) offshore. The area, known by the project name of "San Diego Test Area" encompasses the major sportfishing grounds off La Jolla, Point Loma, and about the Coronado Islands off Mexico.

The airborne temperature surveys used a "ladder-type" search pattern, modified to accommodate navigational aids. These surveys were flown once each week, 1 April through 31 October during 1972 to 1974. A total of 90 surveys was made, each requiring about 2 h to complete.

## OPERATIONAL PROCEDURES

The airborne sea surface temperature sensing unit used in the study was a Barnes research radiometer (PRT-5) modified with a special lens filter system to restrict the viewing range in the infrared spectrum to 10.5 to 12.5  $\mu$ m. This spectral range approximates the infrared range that is used in the ITOS (NOAA, National Environmental Satellite Service) series weather satellite.

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The PRT-5 was piloted by the author in a NMFS twin-engine aircraft over the survey flight track (Fig. 1) at elevations between 152 and 304 m (500 and 1,000 ft). Low stratus bases at 243 and 304 m (800 to 1,000 ft) common to the coastal areas were encountered on most flights during the 3-yr period. On numerous occasions, flights were rescheduled due to very low stratus or fog conditions. Only on rare occasions was there an absence of haze or low stratus, middle and high clouds, the type of conditions that would allow direct comparison of satellite data with the low altitude temperature surveys.

Calibration measurements, or "ground truth," were obtained from surface sources for each flight either from observations taken at the end of the Scripps Institution of Oceanography pier, La Jolla, Calif., or from the U.S. Naval Undersea Center's (NUC) oceanographic tower located approximately 2.8 km (1½ n.mi.) off Mission Beach, San Diego, Calif. Most comparative observations were taken over the oceanographic tower as it is located offshore, and the temperature of surrounding surface waters are relatively stable when compared with those near the outer surf zone at Scripps pier. Simultaneous sea surface temperature observations were made with either a surface bucket thermometer off Scripps pier, or a surface thermistor temperature reading from the NUC oceanographic tower. To obtain a comparative reading, the aircraft was flown over the pier or tower at an elevation of about 45.7 m (150 ft). At the moment the aircraft passed over the pier or tower, the radiative surface of the structures, being much warmer than the sea surface, would produce a response from the infrared detector to make a synchronous mark on the temperature analog recorder chart. The analog recorder chart was driven at a speed of 2.54 cm (1 in) per minute.

The temperature analog chart was keyed to the "ground truth" temperature measurement, and the chart was read to determine a 1-min average temperature, with a slide rule averaging readout device developed by the author (Squire 1971). The 1-min temperature averages were plotted on the flight track, and 1°F (0.56°C) isotherms were contoured from the data. The weekly isotherm charts were given limited distribution to a list of interested fishing and scientific organizations and their personnel.

Isotherm charts are shown in the Appendix for all surveys in 1972, 1973, and 1974 (1972, Figs. 1-28; 1973, Figs. 29-61; 1974, Figs. 62-90). For conversion of °F to °C see comparative temperature data on each figure.

## RESULTS

Isotherm charts were developed for each of the 90 survey flights. Distribution of survey flight effort by month for the 3-yr period is as follows:

| <i>Month</i> | <i>Flights</i> |
|--------------|----------------|
| April        | 12             |
| May          | 13             |
| June         | 10             |

|           |    |
|-----------|----|
| July      | 15 |
| August    | 14 |
| September | 12 |
| October   | 14 |

June has the least number (10) of flights during the survey period, reflecting the problems of conducting aerial surveys during a period when persistent low stratus is most present over the coastal waters off San Diego.

The general trend of sea surface temperature during the 3-yr period showed that 1973 was cooler than 1972, which was an "El Niño" year with above-normal warming along the west coast of North and South America (Miller and Laurs 1975). Temperatures in 1974 were warmer than those observed in 1973, but not as warm as those experienced in 1972. However, in 1974, an anomalous warming period occurred in early July off southern California, and the highest temperatures were recorded at that time. Examples of isotherm patterns observed during surveys having the lowest average temperature (2 April 1973) and the highest average temperature (19 July 1974) are shown in the Appendix, Figures 31 and 76.

Semimonthly isotherm charts of the northeastern Pacific, developed from ship data, are issued by the NMFS Southwest Fisheries Center. To develop data for comparative purposes, weekly temperatures were then averaged by semimonthly periods for each month, 1 through 15 days and 16 through 30/31 days, for the 3 yr of data from temperatures observed at locations along the survey flight track, as shown in Figure 1. Isotherm charts in 1°F with °C equivalents drawn to these semimonthly data are presented in Figures 2 to 15.

The only time series of infrared sea surface temperature data available for comparison with the 1972 to 1974 data off San Diego is the 1963-68 data resulting from the cooperative program with the U.S. Coast Guard. During these surveys, ground truth calibration checks were also made over the NUC oceanographic tower. Comparing 1963-68 monthly average temperatures (to the nearest whole °F) for the area off Mission Beach (NUC tower area) with those observed in the same location during the 1972-74 surveys, we note an average difference of less than 1°F (0.56°C). The average temperature for 1963-68 was 63.4°F (17.4°C) and for 1972-74 was 64.1°F (17.8°C). Average monthly temperatures rounded to the nearest °F for the 3-yr period were observed (Table 1) to be the same for April, warmer 2°F (1.12°C) for May, 3°F (1.68°C) for June, 1°F (0.56°C) for July, the same for August, 1°F (0.56°C) less for September, and 2°F (1.12°C) less for October.

A general description of sea surface temperature patterns that would be typical of those usually observed off San Diego during the weekly surveys is as follows: Temperatures that are greater than any other locations in the survey area are usually found north offshore and to the northwest of La Jolla. From off La Jolla Point to Pacific Beach and continuing southwest and offshore to the southwest is an area of upwelling with generally lower temperatures than those to the north. Evidences of this

**Table 1.—Comparative temperatures—U.S. Naval Undersea Oceanographic Tower for airborne infrared sea surface temperature surveys, 1963-68/1972-74.**

| Month     | 1972-74<br>monthly mean<br>temperature |      | 1963-68<br>monthly mean<br>temperature |      |
|-----------|--|------|--|------|
|           | °C                                     | °F   | °C                                     | °F   |
| April     | 14.6                                   | 58.2 | 14.4                                   | 58.0 |
| May       | 16.8                                   | 62.3 | 15.6                                   | 60.0 |
| June      | 18.4                                   | 65.3 | 16.7                                   | 62.0 |
| July      | 19.7                                   | 67.4 | 18.9                                   | 66.0 |
| August    | 20.0                                   | 68.0 | 20.0                                   | 68.0 |
| September | 17.3                                   | 63.3 | 18.3                                   | 65.0 |
| October   | 17.3                                   | 63.3 | 18.3                                   | 65.0 |

upwelling area was also observed when a temperature decline, sometimes sharp, was frequently present west of Mission Beach and the NUC tower when proceeding toward the coast. The kelp bed area west of Point Loma appears to be slightly warmer than the area to the north off Mission Beach. Near the area south of Point Loma and about the San Diego harbor entrance channel, a significant drop in temperature is usually observed, this resulting from upwelling near the south end of the Point. Temperatures tend to remain lower than those found west of the Point Loma peninsula and they remain lower to the southeast of Point Loma, off the Coronado Strand, and increase slightly off Imperial Beach. Immediately south of the International Border of Mexico is frequently

found the northern edge of an extensive coastal upwelling zone. The effects of this upwelling increase to the south and extend further offshore. Warmer temperatures than those found near the coast of Mexico are encountered offshore about the Coronado Islands, and temperatures in this area are more typical of those found offshore in the northern portion of the survey area.

### ACKNOWLEDGMENTS

The interest and cooperation of E. C. LeFond, Dale Good, Paul Hansen, and the staff associated with the NUC oceanographic tower in making sea surface calibration observations is appreciated. To a number of personnel from the Southwest Fisheries Center, NMFS, NOAA, and to Clyde Melendy of the National Weather Service, NOAA, who took time from their activities to assist in the airborne surveys, I express my appreciation.

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1971. Measurements of sea surface temperature on the eastern Pacific continental shelf using airborne infrared radiometry, August 1963-July 1968. *U.S. Coast Guard Oceanogr. Rep.* 47 (CG373-47), 229 p.



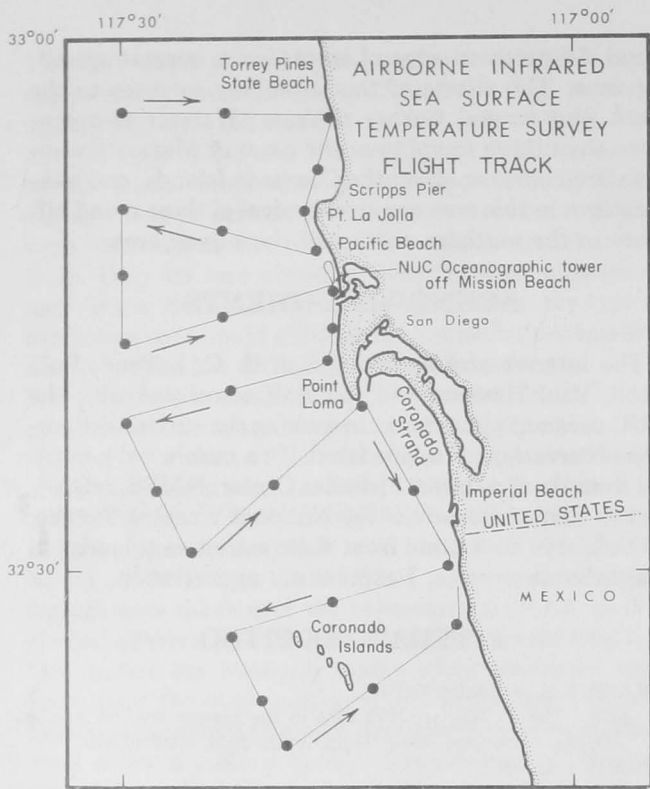


Figure 1.—Survey flight track pattern flown during the 3-yr study. Dots indicate points where temperatures were taken for the development of biweekly average isotherm charts.

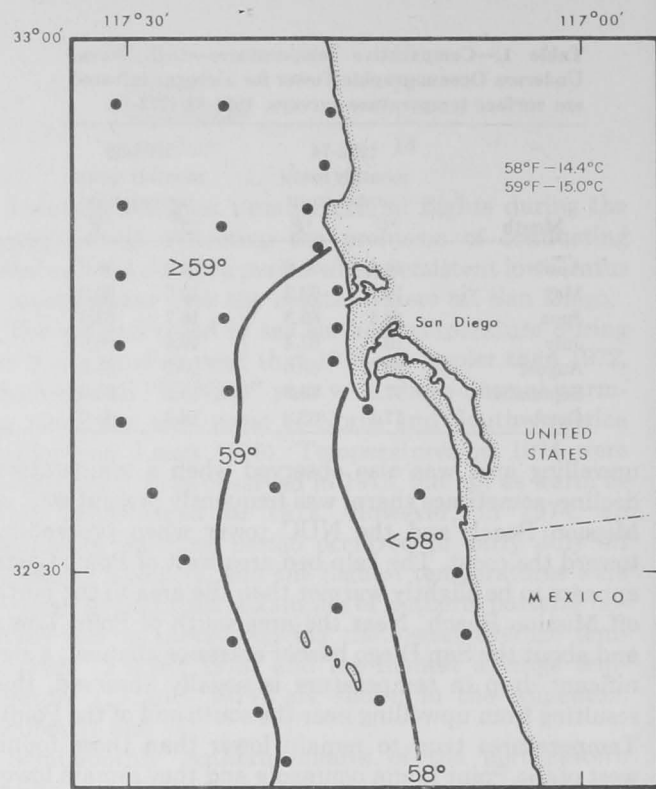


Figure 3.—Average isotherm patterns observed off San Diego in  $^\circ\text{F}$  with  $^\circ\text{C}$  equivalents for the 3-yr period, 16 to 30 April 1972-74.

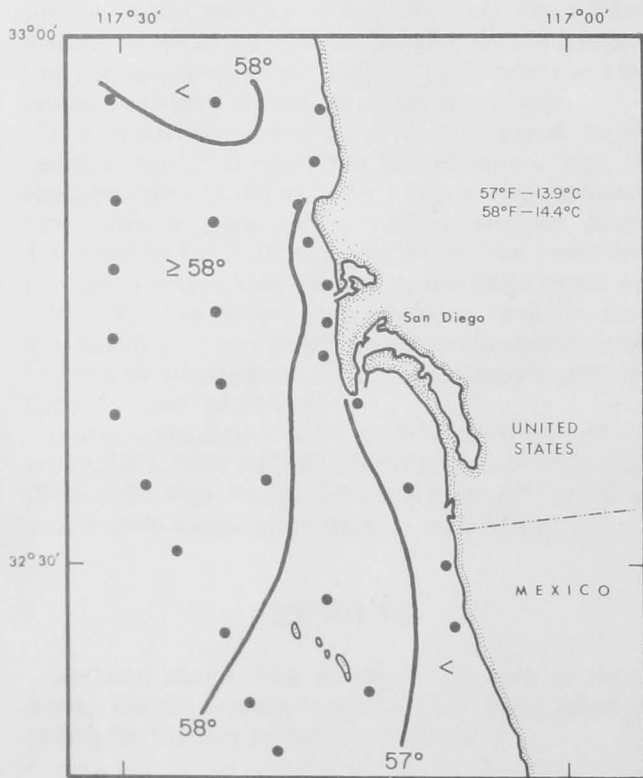


Figure 2.—Average isotherm patterns observed off San Diego in  $^\circ\text{F}$  with  $^\circ\text{C}$  equivalents for the 3-yr period, 1 to 15 April 1972-74.

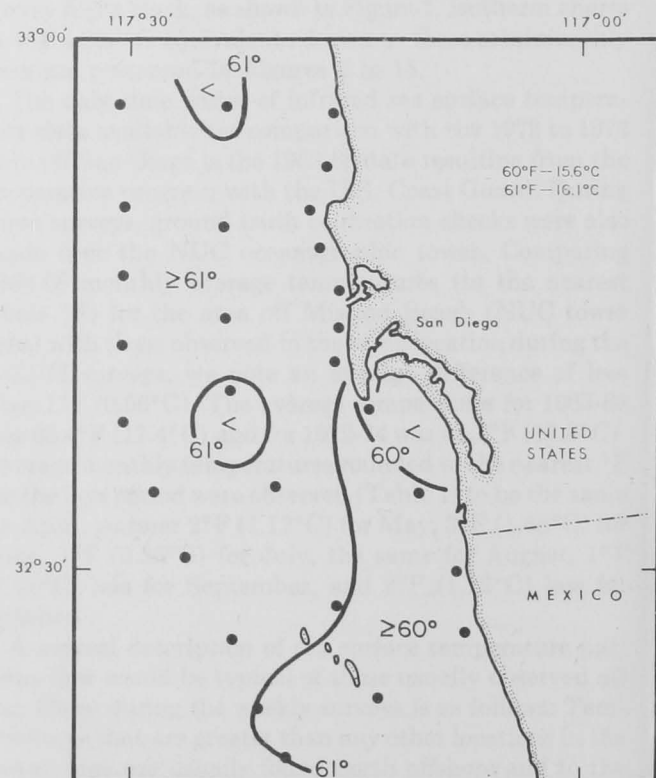


Figure 4.—Average isotherm patterns observed off San Diego in  $^\circ\text{F}$  with  $^\circ\text{C}$  equivalents for the 3-yr period, 1 to 15 May 1972-74.

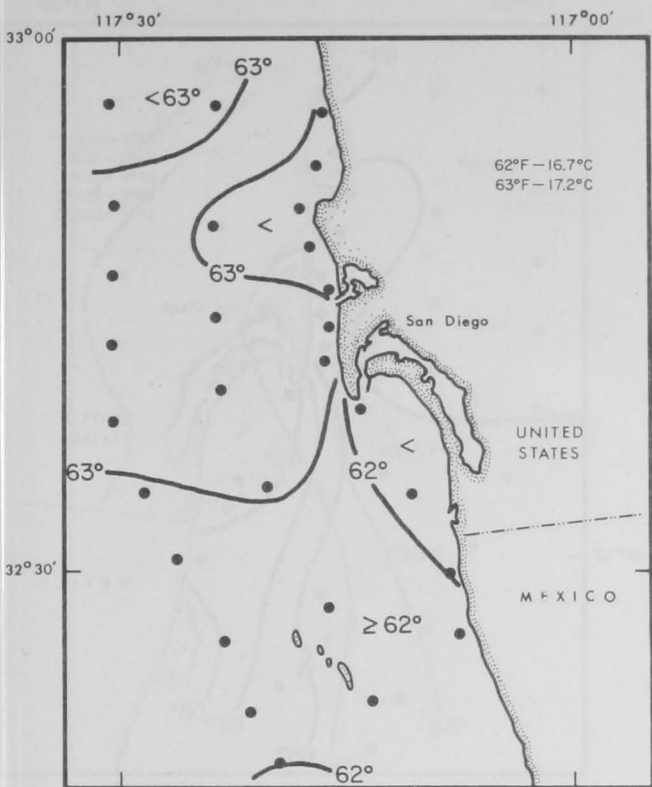


Figure 5.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 16 to 31 May 1972-74.

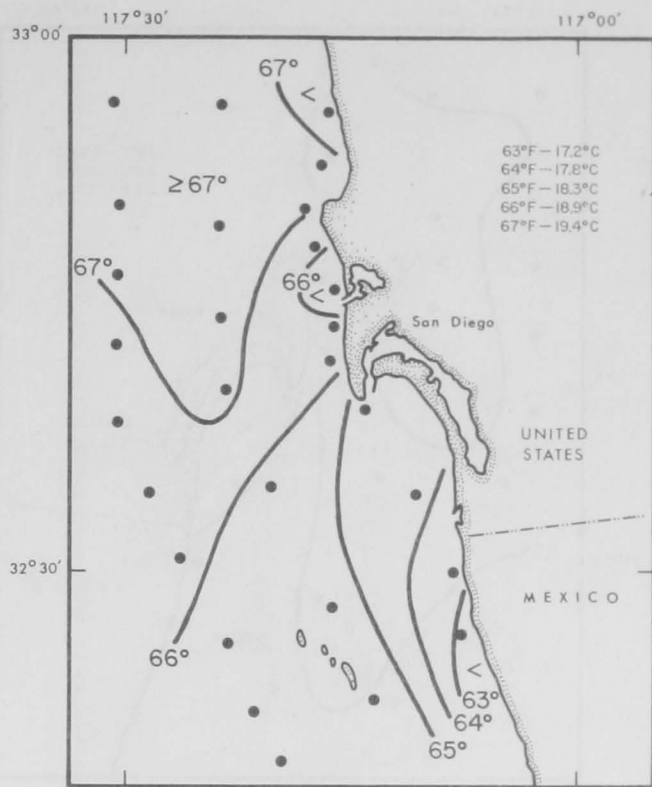


Figure 7.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 16 to 30 June 1972-74.

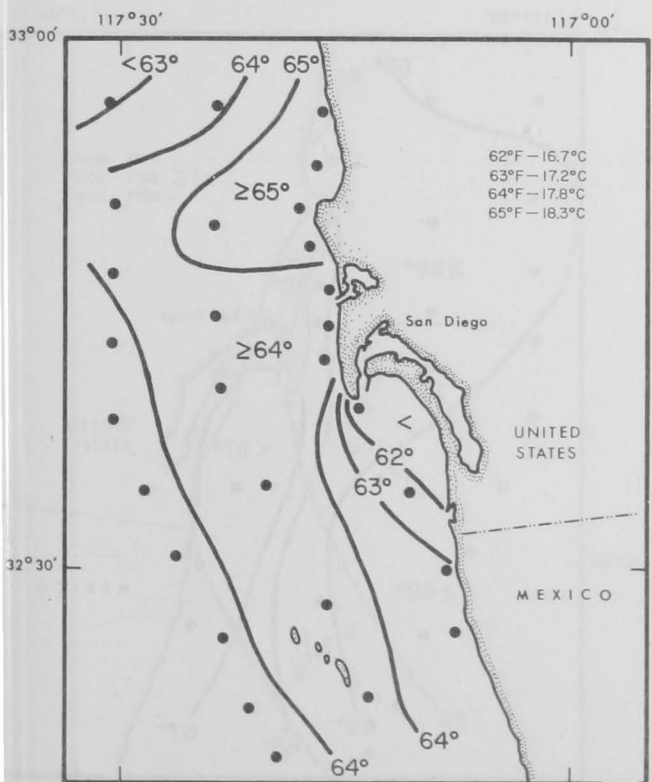


Figure 6.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 1 to 15 June 1972-74.

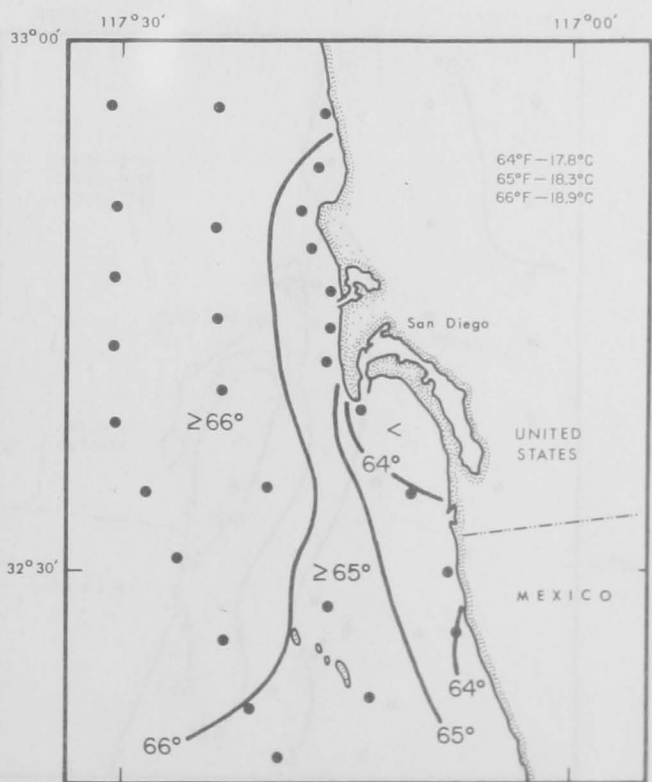


Figure 8.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 1 to 15 July 1972-74.

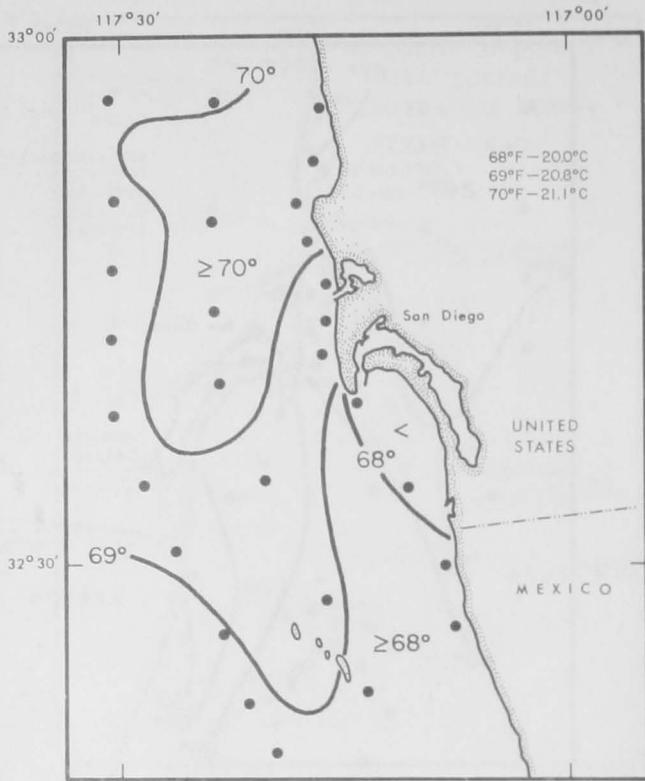


Figure 9.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 16 to 31 July 1972-74.

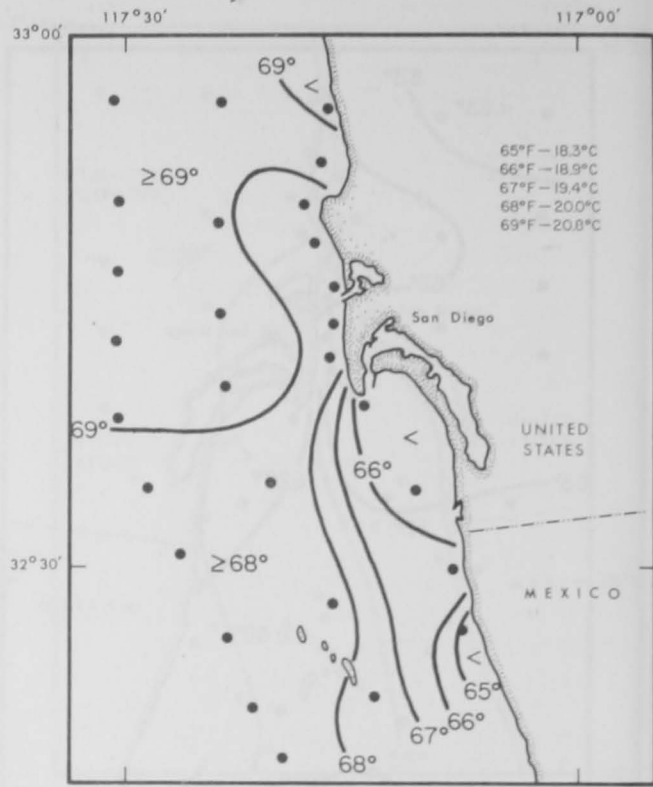


Figure 11.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 16 to 31 August 1972-74.

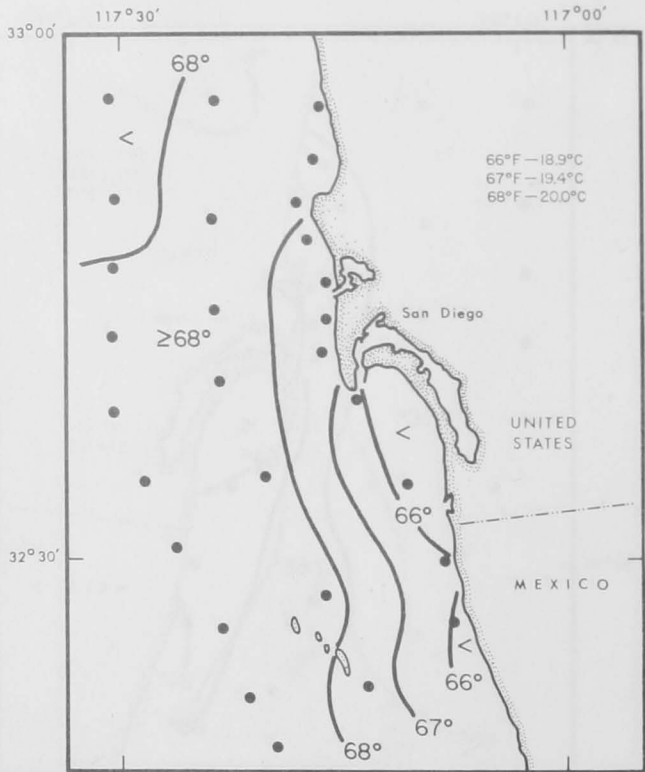


Figure 10.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 1 to 15 August 1972-74.

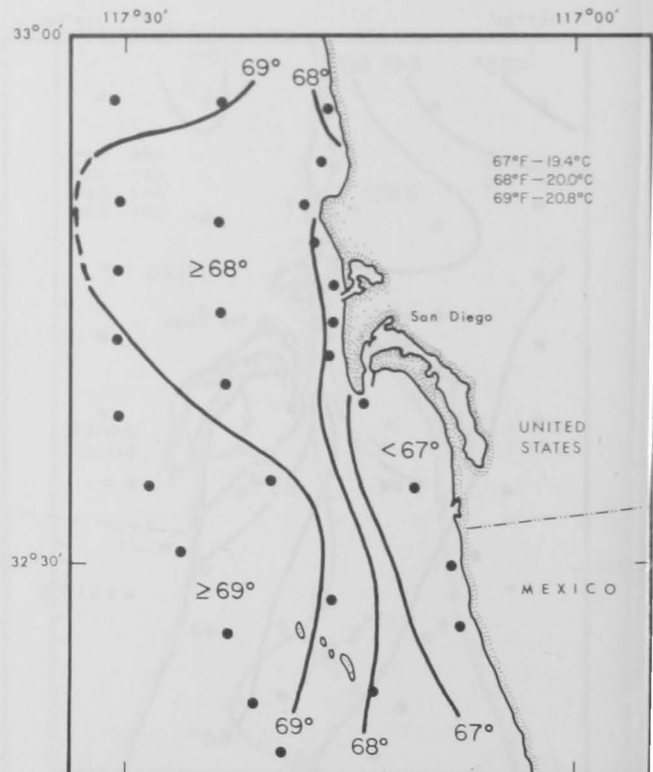


Figure 12.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 1 to 15 September 1972-74.

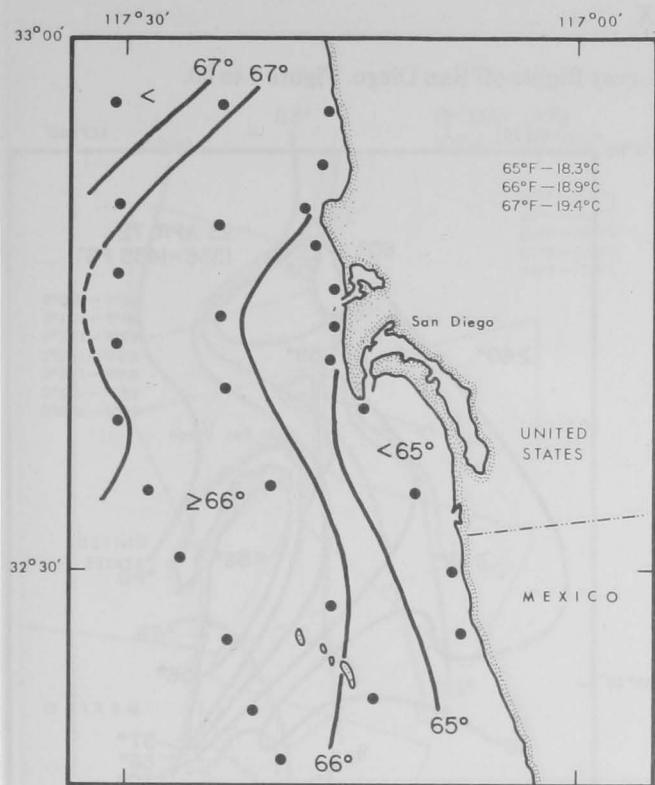


Figure 13.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 16 to 30 September 1972-74.

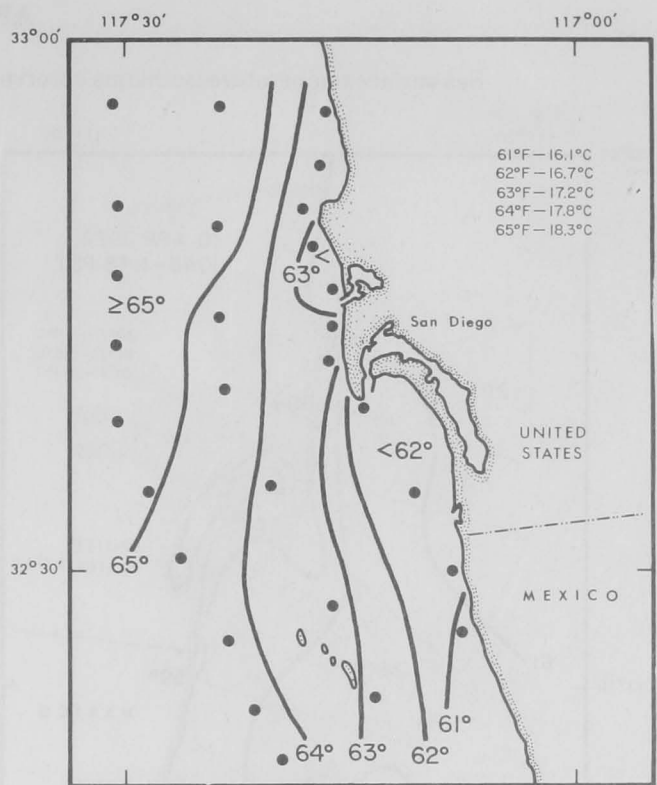


Figure 15.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 16 to 31 October 1972-74.

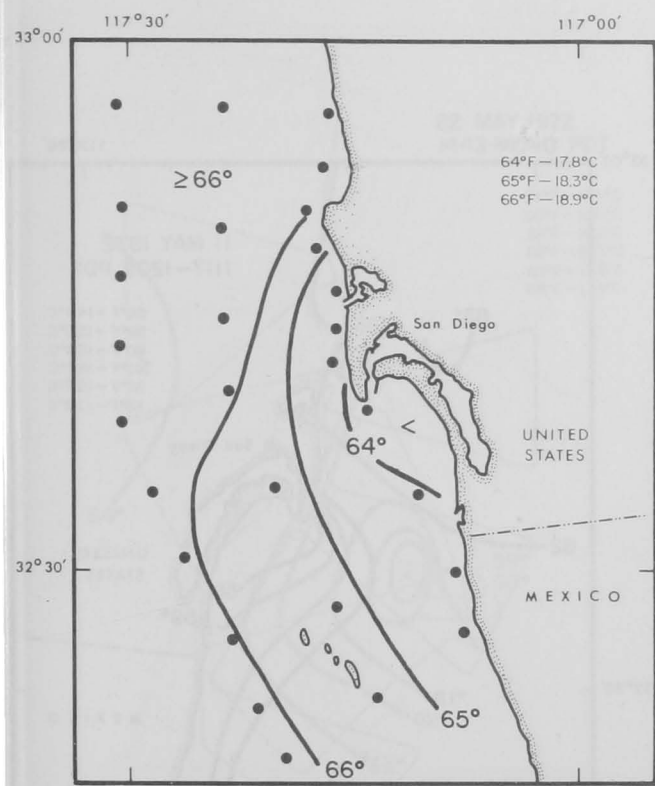


Figure 14.—Average isotherm patterns observed off San Diego in °F with °C equivalents for the 3-yr period, 1 to 15 October 1972-74.

# APPENDIX

Sea surface temperature isotherms observed during survey flights off San Diego. Figure 1 to 90.

