NOAA Technical Memorandum NMFS

May 1981

OBSERVATIONS OF ALBACORE (Thunnus alalunga) FISHING OFF CALIFORNIA IN RELATION TO SEA SURFACE TEMPERATURE ISOTHERMS AS MEASURED BY AN AIRBORNE INFRARED RADIOMETER

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NOAA-TM-NMFS-SWFC-11

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

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ABSTRACT. During airborne infrared sea surface temperature surveys, in cooperation with the U. S. Coast Guard and the U. S. Navy off the United States west coast, the location of albacore, Thunnus alalunga (Bonnaterre), fishing relative to sea surface temperature was recorded. An association was found between albacore fishing and certain sea surface temperatures and discontinuities in temperature. Sea surface temperatures where albacore fishing was observed off southern California were 17.8° to 18.9°C (64.0° to 63.0°F); and off central California were 15.6° to 17.2°C (60.0° to 63.0°F) and these temperature ranges are in general agreement with optimum fishing temperatures reported by other authors. On two occasions when the specific objective was to survey temperatures about the commercial albacore fleet, fishing was being conducted immediately west of a temperature discontinuity.

Further studies using the near-instantaneous airborne infrared sea surface and sub-surface survey techniques for temperature, in association with measurements of other physical and biological parameters, aided by satellite data, should be conducted. This would establish the true relation of isotherm patterns to the location and movement of the albacore fishing area for the ultimate development of reliable, tactical information for the fishing fleet and a better understanding of the factors determining the migration patterns of albacore.

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INTRODUCTION

It has been known for over 60 years that a general relation exists between certain ranges of sea surface temperature and the areas of productive fishing for albacore, Thunnus alalunga (Bonnaterre) off the eastern Pacific coast. Thompson (1917) used minimum nighttime air temperatures at sites near the ocean in southern California as an indication of sea surface temperature, and claimed a relation of higher air temperature to a larger catch. Later, Clemens (1961) in an analysis of catch temperatures for 1.3 million albacore sampled off California from 1954 through 1958 reported a catch temperature range of 13.9° to 25°C (57° to 77°F); that 90% of the fish were taken from water having surface temperatures of 15.6° to 19.4°C (60° to 67°F); and best fishing was in the temperature range of 15.6° to 18.3°C (60° to 65°F).

Optimum catch temperatures for albacore are usually lower in the northern latitudes than in the southern latitudes. Powell, Alverson and Livingston (1952) reported that catch temperatures for 1,011 albacore caught by a research vessel in the oceanic areas off Oregon and Washington ranged from 12.2° to 16.7°C (54° to 62°F), with the greatest frequency of catch being made at 15.0°C (59°F). Alverson (1961) reported that research vessel troll catches of albacore were highest off Oregon and Washington when temperatures ranged between 14.4° to 16.1°C (58° to 61°F).

Observations by fishermen on the association of albacore to the coastal sea surface temperatures off California have been referred to by Godsil (1949) and Clemens (1961). They reported that changes in surface temperature are often used by albacore fishermen as indicators of productive areas and that the optimum fishing zone for albacore appears to be the marginal areas where green coastal and blue oceanic (California Current) waters meet. Productive areas were reported by Clemens (1961) to be offshore along the margin of the upwelling area extending from near Point Conception to the Columbia River. Few albacore were reported being taken nearshore in the cold, upwelled water, and catches were reduced farther offshore. Fishermen also reported that albacore frequently abound offshore along edges of cold "tongues" or "fingers" of water, along margins of currents and eddies, and in what appear to be large areas or "pools" of water in the 15.6° to 18.3°C (60.0° to 65.0°F) range well offshore and isolated at its boundary by either warmer or cooler water. Albacore in these "pools" appear to be cut off from the main migration, as these "pools" become smaller, the fish become concentrated, and fishermen sometimes find these areas productive.

Though considerable information is available on albacore catch temperatures and general descriptions of temperature changes which appear to have affected the catch, the relation of albacore fishing to sea surface and near surface temperature, water color, and the occurrence of biological life, particularly forage species, and their changes over a short time scale within a restricted geographical fishing area is poorly understood. Pearcy's (1973) study of the Oregon coast showed that during some airborne infrared surveys, areas having albacore catches were related to temperature patterns and the Columbia River plume in water of 14^{o} to $16.5^{o}C$ (57.2^{o} to $61.6^{o}F$); however, in other surveys a relation of albacore catch to temperature patterns was not evident.

To provide better understanding of large-scale temperature changes in the eastern Pacific and their relation to the albacore fishery, sea surface isotherm charts are issued bi-weekly as an albacore fishing aid during the fishing season by the National Marine Fisheries Service (Johnson, Flittner, and Cline, 1965). These charts, developed from ship observation data, cover a large area of the eastern Pacific and show 2 week average tempratures by 1^{o} latitude by longitude areas. However, these isotherm charts are not sufficiently detailed to permit determination of sea surface temperature patterns in localized albacore fishing areas on a real-time basis.

The correlation of sea surface temperatures with coastal albacore fishing would probably be greatest in areas having a large temperature gradient, or a large change in sea surface temperature in a short geographical distance. Sea surface temperature gradients off the west coast are not large when compared to those for other areas such as the northwest Atlantic's Gulf Stream. However, the major coastal upwelling zone from near Cape Blanco, Oregon to Point Conception, California has along its boundary with the California Current gradients of up to $2.2^{o}C$ ($4.0^{o}F$), and this area provides the best opportunity for comparative studies of coastal albacore distribution and temperature patterns. During airborne infrared temperature surveys (Squire, 1971) the largest gradient changes were observed along the central California coast, and it is in this area that most comparative observations of albacore fishing to temperature patterns were made.

Information on the location of "thermal fronts", when they can be observed by the National Weather Service satellite off the west coast, is being issued to interested albacore fishermen during the fishing season as part of NOAA's Sea Grant Advisory Program (Gorman, 1976). Since this technique involves viewing the sea surface through the total earth's atmosphere, viewing conditions from space requires a clear airpath. Under "clear" viewing conditions, temperature errors can be expected due to changes in marine layer thickness and density. Unfortunately, the California coastal waters are frequently covered with low stratus for extended periods of time during the summer and fall albacore fishing season, making viewing difficult from satellites. Correction factors for sea surface tmperatures to ground truth determined for satellite data during tests by Stevenson and Miller (1974) over the eastern tropical Pacific, report an average difference of $1.5^{o}C$ ($2.7^{o}F$).

METHODS

Sea surface temperature can be determined rapidly and in detail by use of an airborne infrared radiometer, and this technique has been used with success in Australia to assist the southern bluefin tuna (Thunnus thynnus maccoyii) fishing fleet (Hynd, 1968). In the coastal eastern Pacific, the locations of albacore fishing vessels in relation to sea surface temperature have been observed since 1963 during similar airborne temperature surveys, and these observations are presented for the purpose of gaining a better understanding of the relation of sea surface temperature within a restricted geographical area to the distribution of albacore as represented by the physical location of albacore fishing.

In August 1963, the Tiburon Fisheries Laboratory began monthly synoptic sea surface temperature surveys using an airborne infrared radiometer over continental shelf areas off Washington, Oregon, and California (Figure 1), in cooperation with the U. S. Coast Guard. Airborne surveys were conducted at an elevation of 152.4 meters (500 feet) to allow operation during periods of low stratus, although many flights required rescheduling due to ceilings less than 152.4 meters (500 feet). Comparisons between the airborne radiometer and a surface ground truth observation showed an average difference of $0.20^{o}C$ ($0.35^{o}F$), and a range of $-1.1^{o}C$ ($-1.9^{o}F$) to $+0.6^{o}C$ ($+1.2^{o}F$), and a standard deviation of $0.4^{o}C$ ($0.6^{o}F$). Results of the sea surface temperature surveys were issued monthly in isotherm-chart form and a summary report describing the technique and the results for 1963-1968 was issued by the U. S. Coast Guard (Squire, 1971). Flight tracks of these surveys during the summer and early fall occasionally enter the eastern edge of the normally productive albacore fishing area, and during the months of September and October 1963, August 1964, August and November 1965, and October 1966, the flights passed over or near concentrations of albacore fishing vessels. Inspection of logbook data for the albacore fleet indicated catches were being made in the areas where albacore boats were observed fishing. The number of vessels and their locations were noted and later plotted on isotherm charts (Figures 2-7). The actual catch by the albacore fleet on each day observed is unknown. However, since there is communication between vessels, and the albacore fleet attempts to orient itself to locations where fishing is productive, it is assumed that locations of vessels were good indicators of fishable concentrations of albacore.

To explore further the relation of albacore fishing to temperature, special surveys were conducted on September 11, 1970 and September 16, 1972. These surveys of geographical areas having concentrations of albacore fishing vessels were conducted in cooperation with the U. S. Navy and U. S. Coast Guard, respectively (Figures 8-9).

RESULTS AND DISCUSSION

In the central survey area (Figures 2-6), Figures 2, 3 and 4 show locations of fishing vessels in relation to the warmer offshore isotherms of between 15.6° (60.0°F) and 17.2°C (63.0°F) which tend to parallel the coast. Off Bodega Bay (Figure 5) fishing observed in October 1963 was associated with a lobe of water greater than 16.7°C (62.0°F) surrounded on three sides by water of a slightly lower temperature. During the August 1965 survey near Monterey (Figure 6) fishing was associated with a sharp temperature gradient on the southern segment of a large warm gyre of water greater than 17.2°C (63.0°F) and was centered in water about 16.7°C (62.0°F).

Off southern California in August 1964 (Figure 7) both sport and commercial vessels fishing for albacore were observed. This albacore fleet was observed fishing in water having a surface temperature of about 18.3°C (65.0°F) and were oriented along this isotherm northwestward to the limit of vision.

On September 11, 1970 (Figure 8) albacore fishing was concentrated approximately 80 nautical miles west of Point Sur, California, and a total of 80 boats were reported to be involved. A survey of this fleet concentration was arranged through the cooperation of the U. S. Naval Air Station, Moffett Field, California. During a routine offshore patrol, the surface water temperature in an area about the fishing fleet was surveyed. The center of the fleet operation was near 36°25'N latitude by 123°40'W longitude, and most of the boats were operating in an area about 8 nautical miles by 10 nautical miles, oriented in a north-south direction. The fleet center was in a temperature area between the 16.7°C (62.0°F) and 17.2°C (63.0°F) isotherms. Temperature inshore or on the east side dropped to 15.6°C (60.0°F) within about 3-1/4 nautical miles, and a sharp temperature gradient or front was evident in the northeast portion of the survey area, with inshore temperatures down to 14.4°C (58.0°F) range. To the west of the fleet about 4 miles the temperature increased to 17.8°C (64.0°F).

On September 16, 1972, during surveys in cooperation with the U. S. Coast Guard Air Station, San Francisco, California, near the NOAA/NMFS research vessel David Starr Jordan, in an area northwest of Monterey Bay, California, the commercial albacore fleet was again surveyed. About 29 boats were observed in the area and are shown in Figure 9 in their position relative to sea surface isotherms. A temperature gradient or front of 2.2°C (4.0°F) ranging from near 13.3° (56.0°F) to 15.6°C (60.0°F) was evident between shore and the center of the fishing fleet which was fishing in water of 15.6° (60.0°F) to 16.1°C (61.0°F).

From observations recorded during these surveys, it is obvious that the fleet is not always oriented relative to specific temperature isotherms. Off central California the fishery when inshore appears to be associated with slightly cooler temperatures of 15.5° (60.0°F) to 16.1°C (61.0°F) to the west and further offshore where temperatures of 16.7° (62.0°F) to 17.2°C (63.0°F) were observed in the fishing area. The location of fishing operations immediately west of areas having a rapid increase in temperature was observed on two occasions. Areas of albacore fishing may be more related to areas having a rapid change in thermal structure than to a specific isotherm.

Current synoptic thermal front and sea surface temperature charts provide fishermen with general overview of two enviromental parameters which may indicate an infinite number of locations for albacore fishing in relation to thermal fronts or a specific temperature. Whether or not albacore can be caught in these locations is not known, nor is it known what the true relation there is between the relative importance of a "strong" or "weak" front and albacore fishing. In the airborne infrared examples given in previous figures, albacore fishing is many times found to be associated with a temperature change, but not of the magnitude of a temperature "front."

There is a need to determine the true relation of surface and near surface temperature and temperature fronts and other physical and biological parameters to albacore fishing and how they may affect the movement of the fishery. Otherwise we will continue to see the proliferation of synoptic survey material on physical phenomena generated from new measuring vehicles such as satellites that attempt to aid a fishery but the synoptic material has no proven correlation with the behavior of the fish and the fishery.

To determine if a significant correlation exists between isotherm patterns and the geographical occurrence of fishing (and the catch of albacore) over a time period, surveys should be conducted using airborne, surface and subsurface measurement techniques. Surveys in cooperation with the fleet, of fishing areas and the ocean area about them for temperature and biological observations at short time intervals should be of value in observing movements of albacore and the associated fishing fleet in relations to changes in the sea surface and near subsurface temperature patterns, water color, or biological activity. These near surface measurable parameters in conjunction with satellite data could provide a comprehensive analysis of the fishing area. If a relation between movement of albacore and changes in surface and sub-surface isotherm patterns and other biological observations could be firmly established, airborne surveys combined with satellite data may provide a better knowledge of physical and biological parameters related to albacore migration, and possibly a method of real-time prediction of short-term migration within the general area of fishing, a service which would be of tactical value to the albacore fishing fleet.

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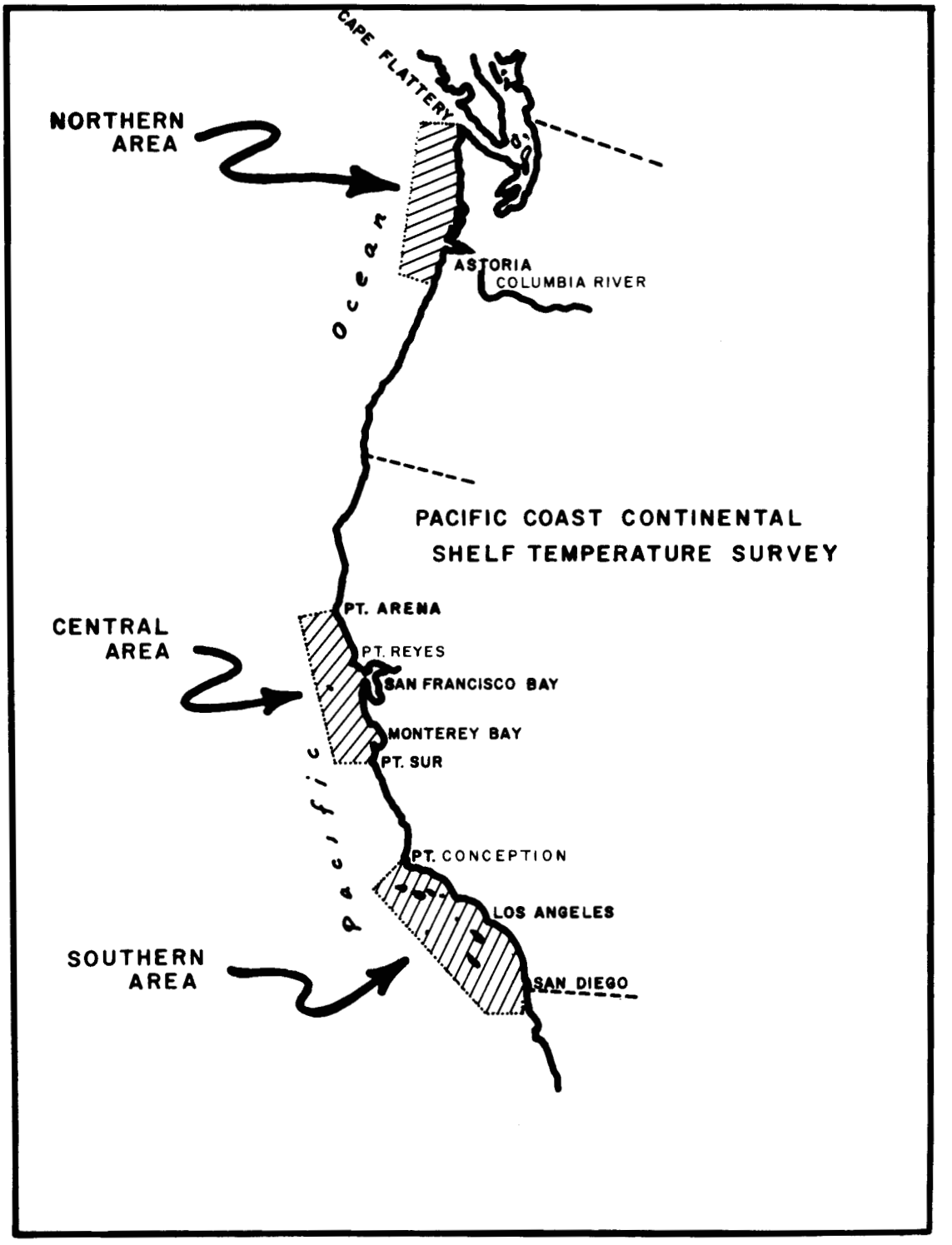

Figure 1. Areas covered by monthly airborne sea surface temperature surveys.

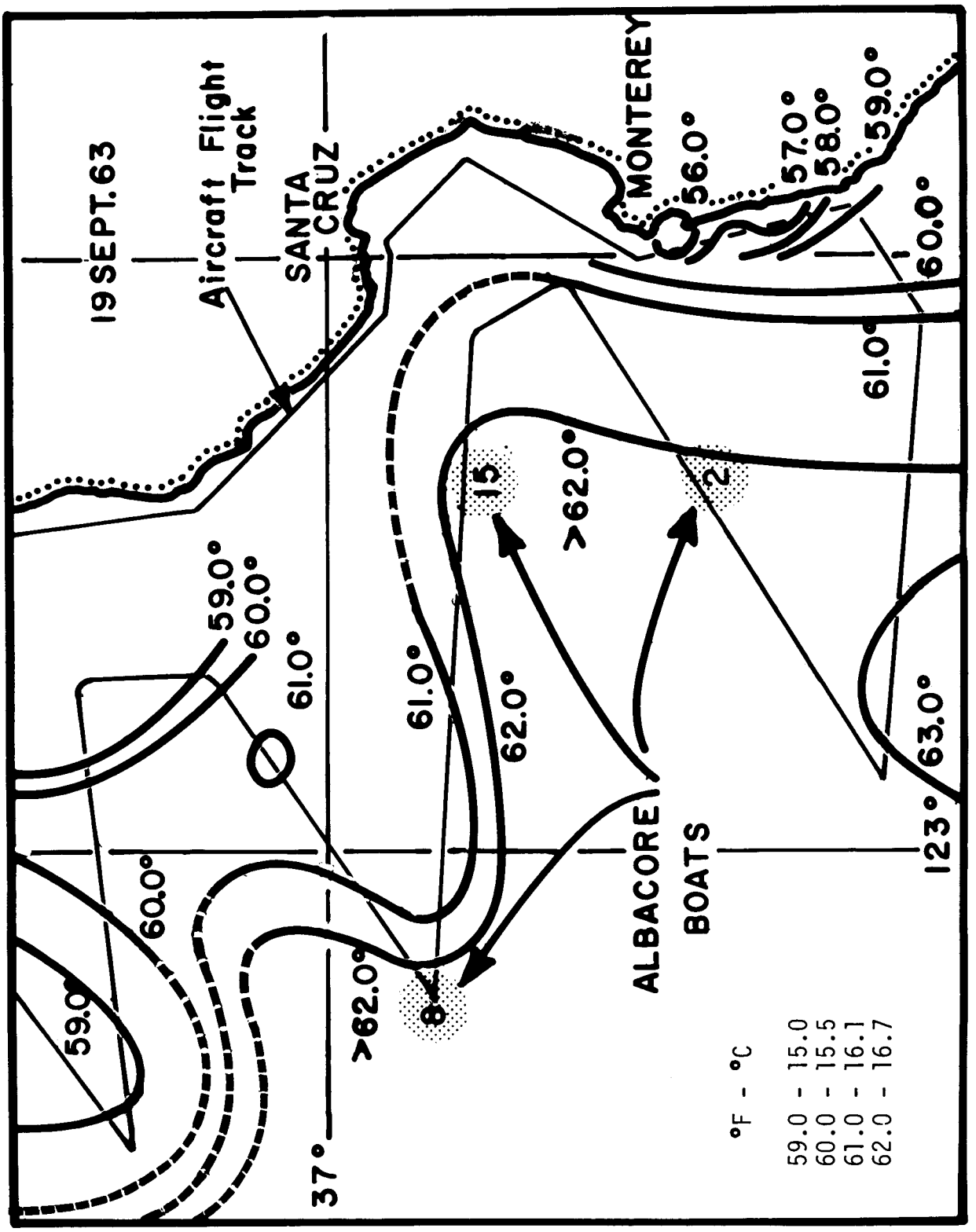

Figure 2. Locations and numbers of albacore fishing boats, and isotherm patterns off Monterey Bay, September 19, 1963.

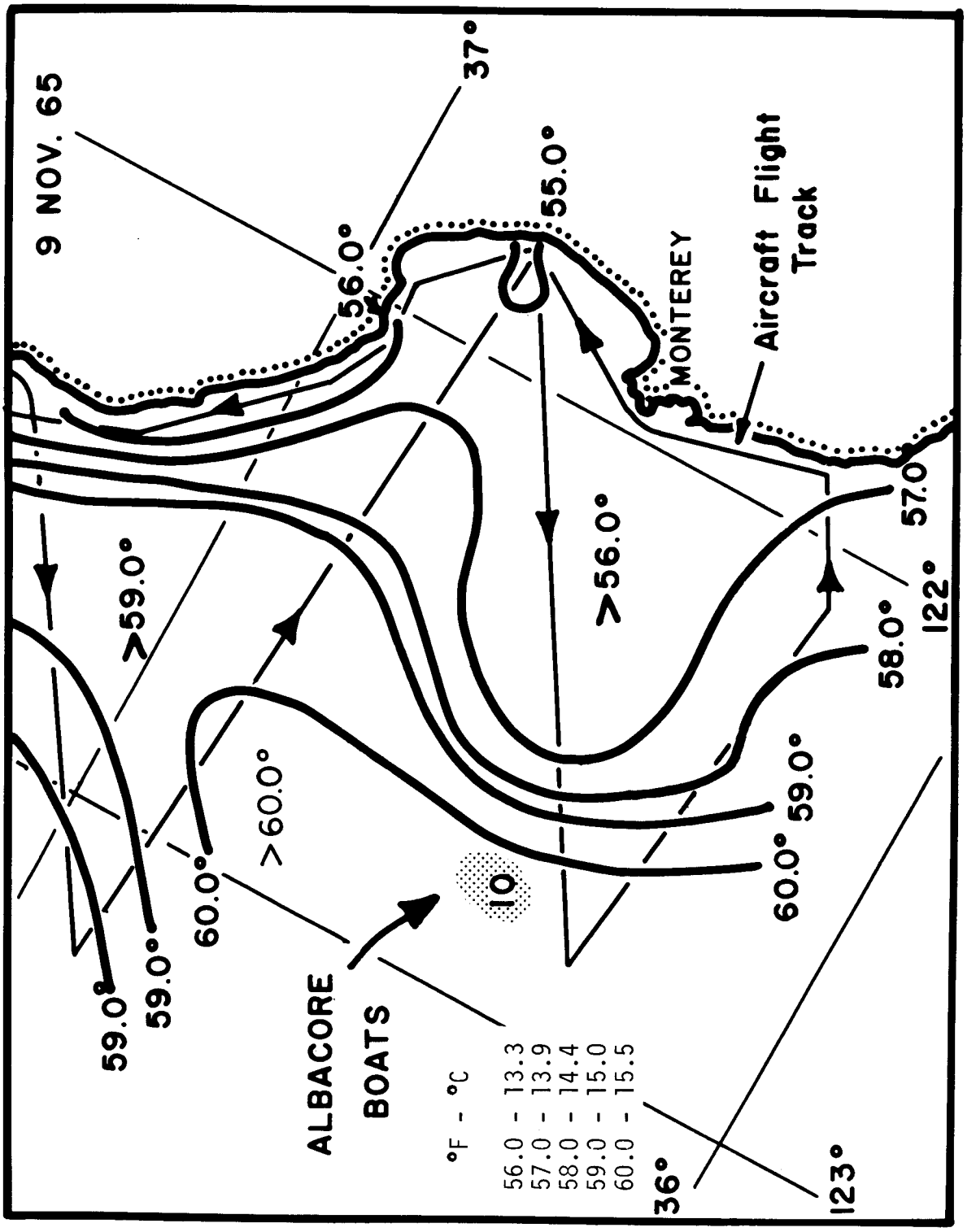

Figure 3. Locations and numbers of albacore fishing boats, and isotherm patterns off Monterey Bay, November 9, 1963.

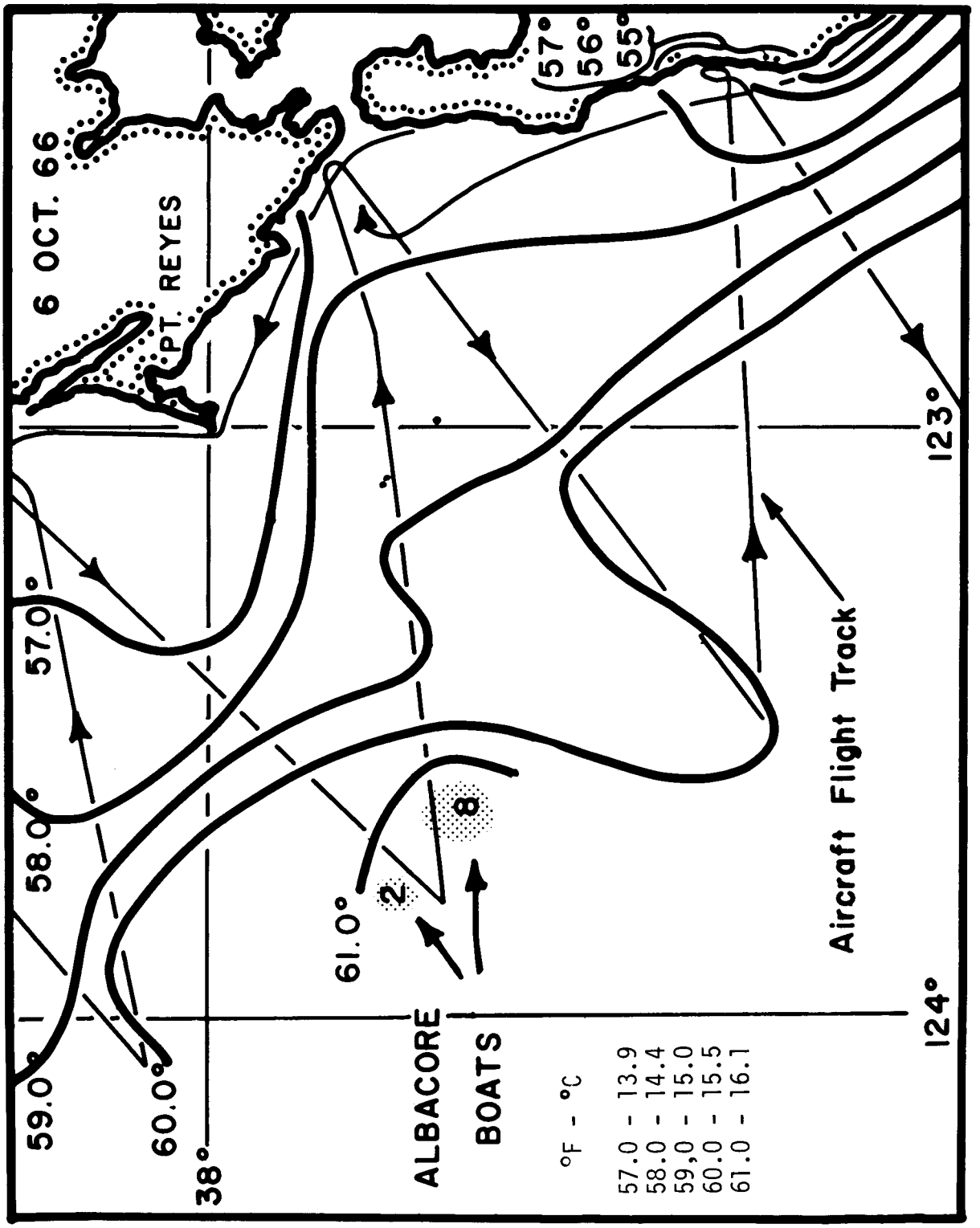

Figure 4. Locations and numbers of albacore fishing boats, and isotherm patterns of San Francisco, October 6, 1966.

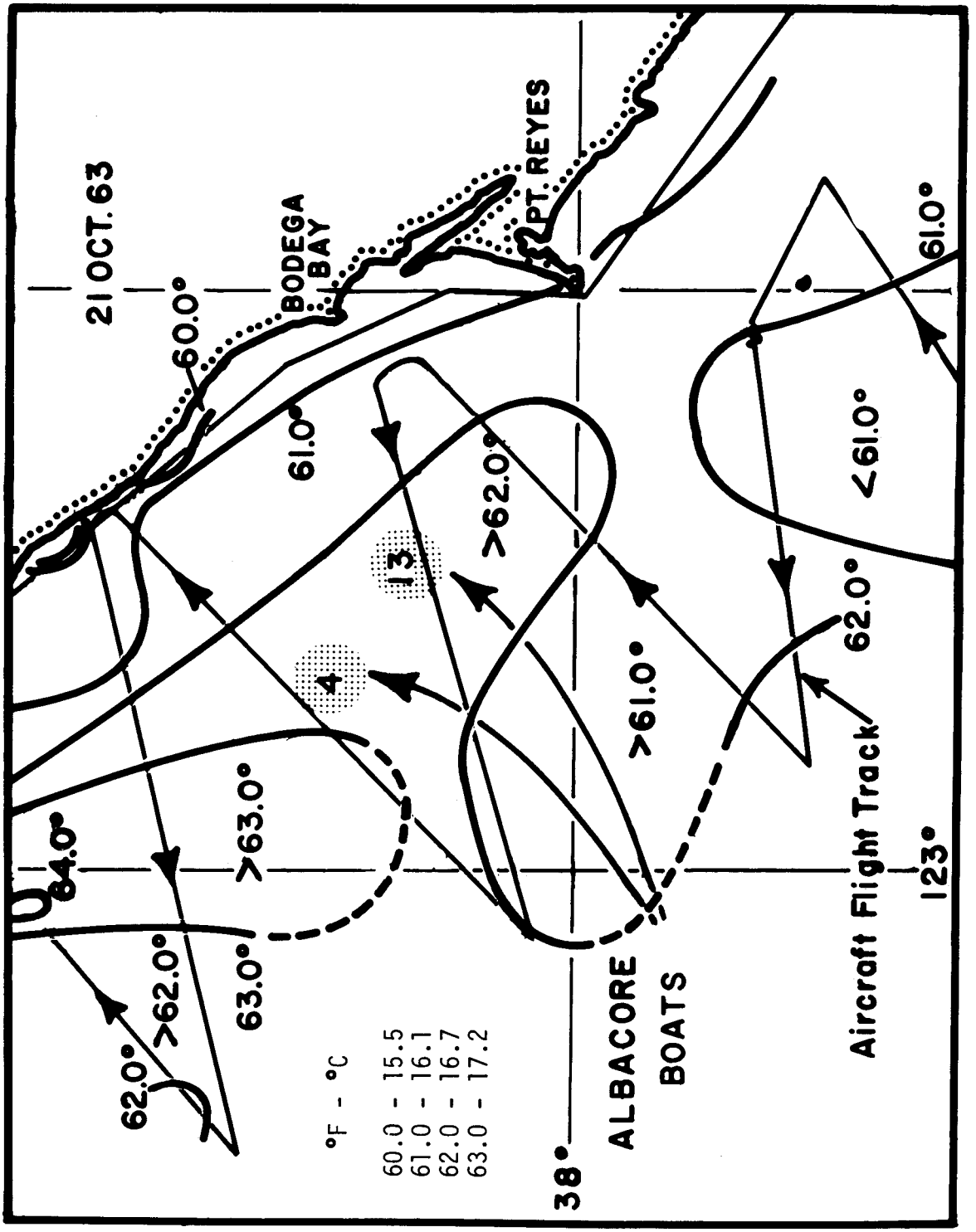

Figure 5. Locations and numbers of albacore fishing boats, and isotherm patterns off Bodega Bay, October 21, 1963.

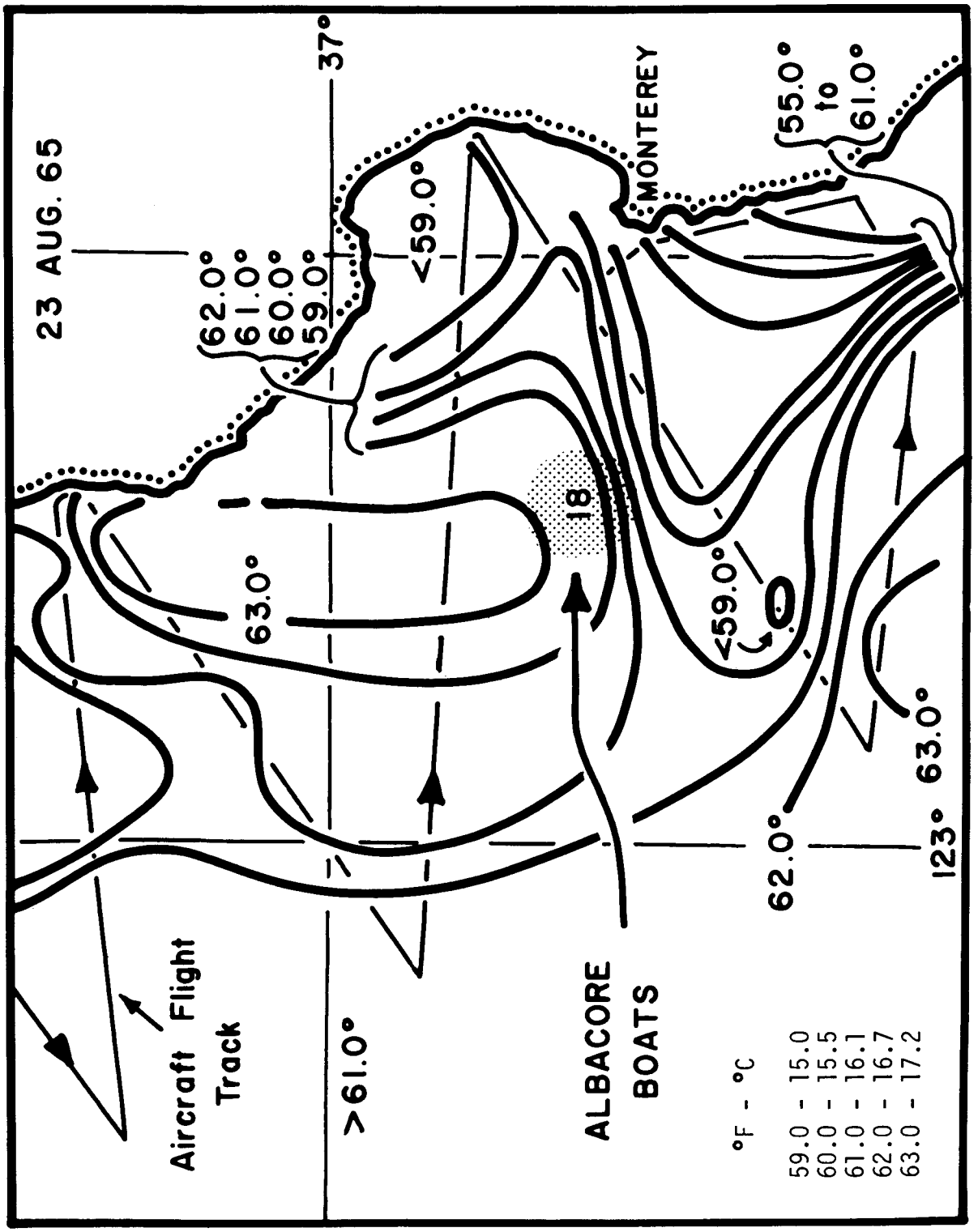

Figure 6. Locations and numbers of albacore fishing boats, and isotherm patterns off Monterey Bay, April 23, 1965.

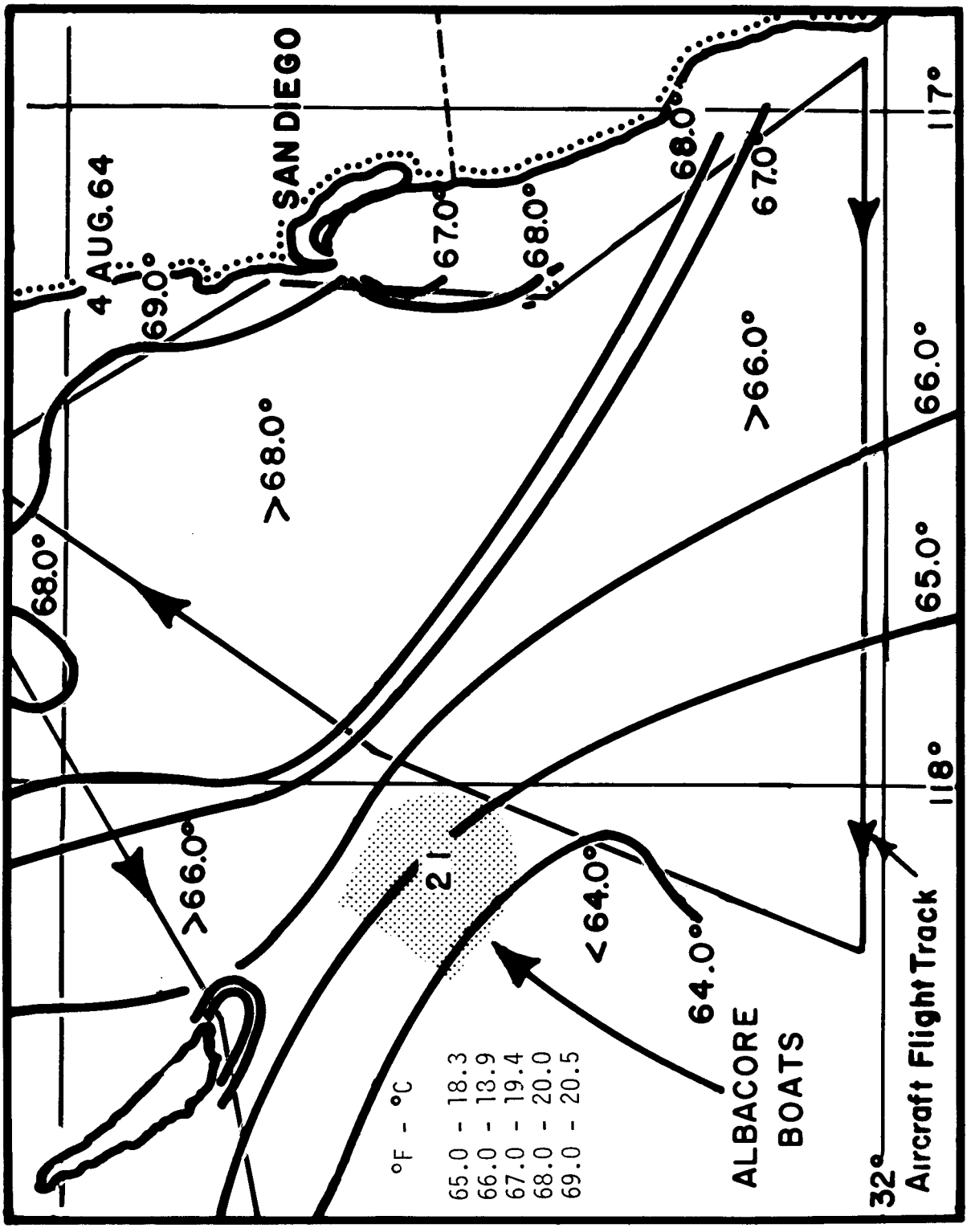

Figure 7. Locations and numbers of albacore fishing boats, and isotherm patterns off San Diego, August 4, 1964.

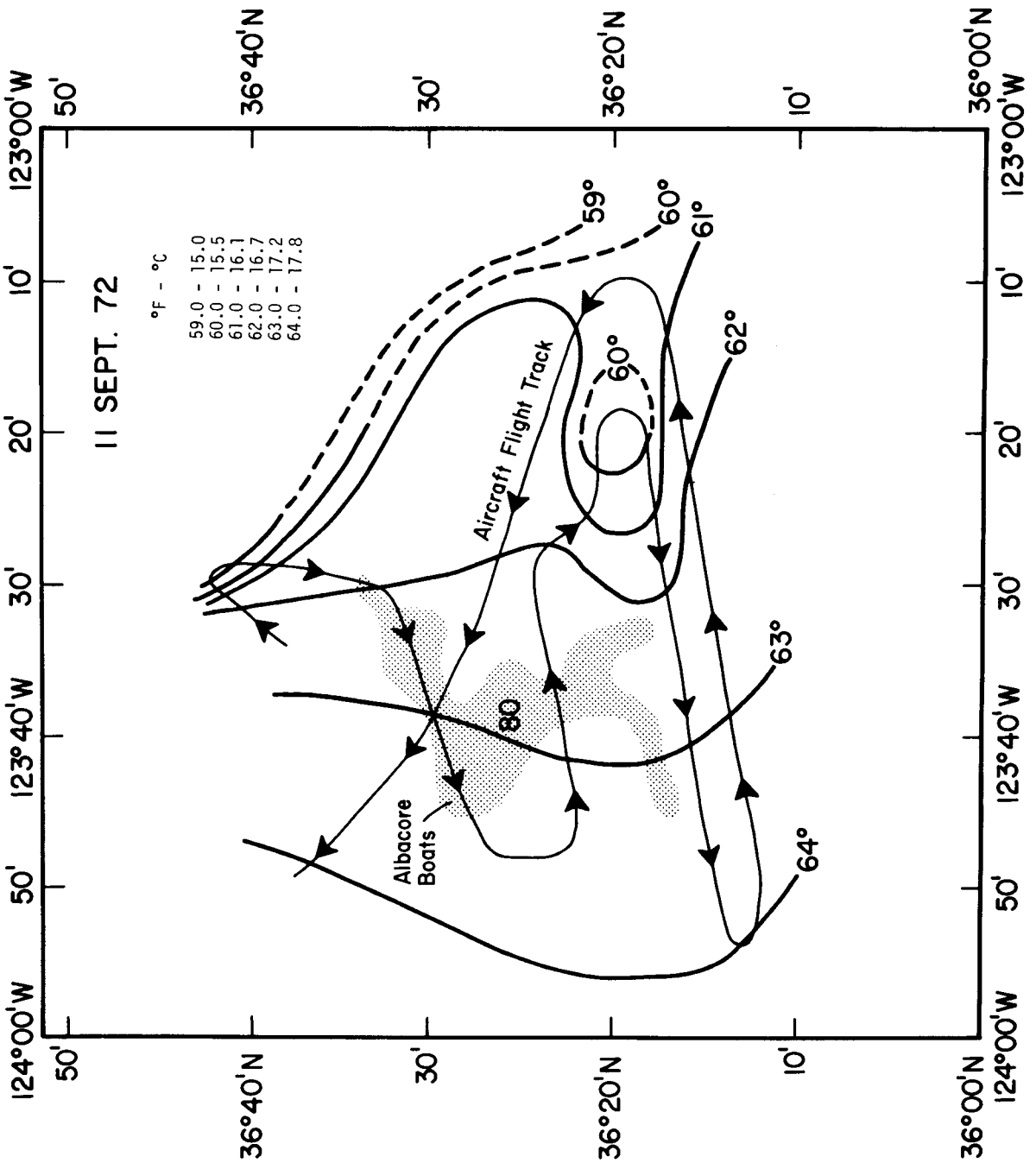

Figure 8. Area of albacore fishing boats, survey flight track and isotherm patterns observed west of Pt. Sur, September 11, 1972.

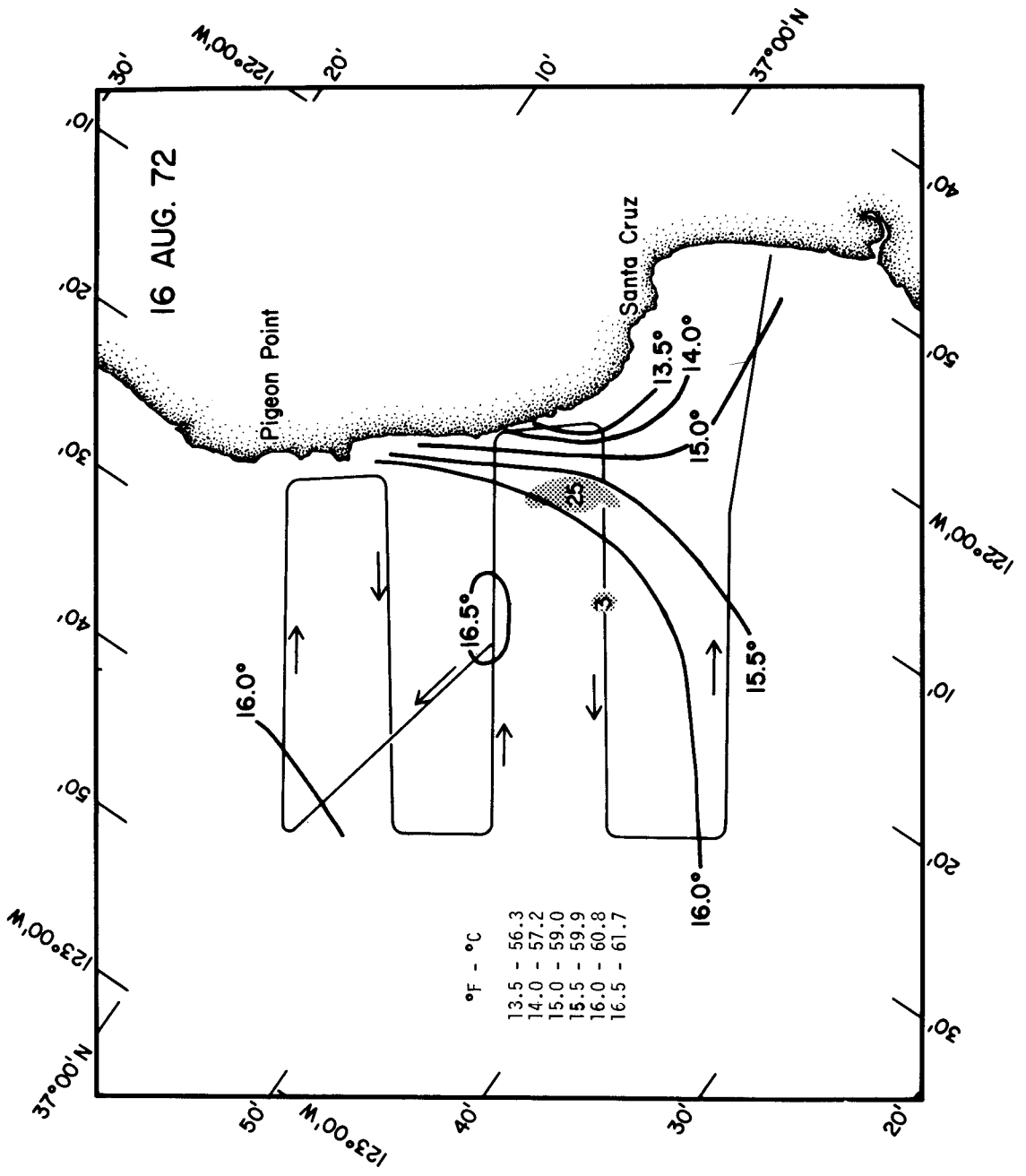

Figure 9. Locations and numbers of albacore fishing boats, and isotherm patterns off Santa Cruz, August 16, 1972.