REMOTE SENSING AND THE PELAGIC FISHERIES ENVIRONMENT OFF OREGON

by

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INTRODUCTION

Remote-sensing oceanography at Oregon State University is part of a multidisciplinary research program (1) to learn more about nearshore oceanographic processes and how they affect the production of marine life and the availability of albacore tuna and (2) to provide fishermen with information in near real-time that will be useful in scouting for albacore concentrations.

Participants in this broad project are listed below:

I. Remote Sensing Aircraft

NASA - Convair 240A, Lockheed P-3, RB-57
U.S. Coast Guard - HU-16
U.S. Air Force - HU-16
University of Michigan - C-47

II. Oceanographic Vessels

Oregon State University - YAQUINA, CAYUSE
Fish Commission of Oregon - SUNRISE
Bureau of Commercial Fisheries - DAVID STARR JORDAN, JOHN N. COBB
Albacore boats with bathythermographs

III. Commercial Albacore Boats

IV. Albacore Advisory Service - "Albacore Central"

OSU Sea Grant's Marine Advisory Program
Fishery - Oceanography Center, La Jolla, California
Pacific Northwest Bell Telephone Company

METHODS

Sea surface temperature was measured on all flights at an altitude of 500 or 1000 feet with a Barnes PRT-5 radiation thermometer filtered to 8.0-13.5 microns and equipped with a 2° field-of-view. The PRT-5 output was continuously recorded on a strip chart with resolution of 0.1°C.

The PRT-5 was calibrated against a thin aluminum plate, covered on one side with Parson's Black Paint, and encased within styrofoam to reduce transient thermal gradients. Plate temperature was measured directly behind the spot viewed with the PRT-5 using a thermistor bonded on the plate with silicone grease. PRT-5 and thermistor measurements between 5°C and 18°C agreed within 0.1°C.

PRT-5 data were corrected for atmospheric absorption and for infrared radiation reflected from the sea surface using the method described by Saunders (1967). The apparent temperatures of the sea surface viewed normal to the surface and at an angle of 60° from the normal were recorded and the difference between these two readings was applied as a correction. This correction assumes that: (1) doubling the path length doubles the effect of atmospheric absorption; (2) infrared radiation reflected from the surface at 60° is approximately double that reflected normally; and (3) the sea surface temperature does not change significantly over the distance (approximately 500 yards) perpendicular to flight track, or along the flight track between measurements. We attempted to make these calibrations in areas where no thermal gradient existed. When the before and after readings normal to sea surface differed, the calibration was not used.

The validity of these assumptions was checked by taking simultaneous measurements with PRT-5 radiometers from an aircraft at 1,000 feet altitude and from a ship. In the two successful "ground-truth" experiments the PRT-5 reading from the ship (corrected to a black plate) agreed within 0.1°C of the PRT-5 reading from the aircraft (calibrated with a black plate and corrected with 60° calibration values).

Based on these experiments, and the results reported by Saunders (1967), we feel that infrared radiometers can measure the sea surface temperature to 0.1°C in the immediate vicinity of a 60° calibration and to 0.2°C over a relatively extensive flight pattern, provided sufficient 60° calibrations are made to ensure that changes in conditions are taken into account.

Standard bucket temperatures during the two successful ground-truth experiments were within 0.5°C of the infrared measurements of sea surface temperature. The IR measurements are of the microsurface temperature; hence, the two methods do not necessarily measure the same phenomenon.

The scanner used on the C-47 in 1969 included a wide angle, uncalibrated scanner: .40-.44μ, .46-.48μ, .52-.62μ, .62-.66μ, .66-.72μ, .80-1.0μ, and 8.0-12.5μ, and narrow field of view calibrated scanner: 8.0-13.5μ (high gain and low gain) and 4.5-5.5μ. An altitude of 500 or 1000 feet was maintained, except where high altitude scanner coverage was obtained on several flights. A TRW Ocean Color Spectrometer and an L-band microwave radiometer were used on NASA's P-3 in 1970.

High altitude (60,000 ft) multispectral photography was obtained from NASA's RB-57 on May 21, 1969 and July 16, 1969. The July flight consisted of six flight tracks parallel to the coast each 10 miles apart. The following camera/film-filters were used: four Hasselblad cameras with Kodak 3400 film and either Nos. 58,25-A, 2E + 38 or 65A filters; Zeiss camera with Kodak infrared SO-117 film and a 15G filter, and an RC-8 camera with Ektachrome 2448 film. Measurements of optical densities in the blue (.41-.47μ) and green (.54-.58μ) regions of the spectrum were made of water color using the Ektachrome transparencies.

Besides obtaining ground-truth for remote sensing flights, surface ships were engaged in studies on physical, chemical and biological processes and properties related to pelagic fisheries. Several commercial albacore boats were outfitted with expendable or mechanical bathythermographs (BT's) so that data on thermal structure could be obtained along the fish catch. The U.S. Navy Fleet Numerical Weather Facility, Monterey, California provided expendable bathythermograph (XBT) probes and Sippican Corporation loaned us two XBT launchers for this project.

Data from aircraft and vessels were communicated to "Albacore Central" on the OSU campus, combined with information from the Fishery-Oceanography Center (BCF) La Jolla and the Weather Bureau, and broadcasted twice daily by the Astoria Marine Operator (Pacific Northwest Bell) to the albacore fleet. Most of the information on sea surface temperature for these radio broadcasts were obtained from the aircraft overflights. Another Albacore Central product for the fishermen was the weekly bulletin which included a sea surface temperature chart. These were distributed to canneries and fishing ports along the coast of Oregon (Panshin, 1970).

The fishermen were important participants in the project. Besides being "consumers" of data on ocean conditions, they had a vital role in providing data on albacore catches. Over 400 albacore logbooks were distributed to fishermen from San Diego, California to Seattle, Washington. They were asked to record detailed information on catches several times a day so that catches could later be correlated with small-scale oceanographic features.

The results to date are all preliminary. The catch data from the multispectral scanner, the spectrometer, and microwave are on tape and are also being analyzed.

RESULTS

Two oceanographic phenomena dominate Oregon waters during the summer: coastal upwelling and the Columbia River plume. Both are detectable by gradients of surface temperature and by water color, hence are amenable to remote sensing. Both of these large-scale processes are extremely dynamic and produce rapid changes. Repeated synoptic surveys by remote sensing therefore are an ideal way to study temporal changes associated with these events.

During the summer cold water upwells along the coast as a result of northerly wind stress and the rotation of the earth. This cold water is rich in nutrients and results in high biological productivity. A common pattern of upwelling is reflected by the sea surface temperatures shown in Fig. 1. Cool water is found along the coast, and warm water is found offshore. Isotherms are almost parallel to the coast off northern Oregon but diverge farther offshore along the southern coast where the strongest winds and coldest temperatures often occur. Thermal fronts, large changes of temperature over small distances, were often associated with areas of active upwelling.

Changes in water color were also found in upwelling areas, and abrupt color changes sometimes coincide with thermal fronts. In general, inshore waters were green because of the large standing stocks of phytoplankton. Offshore waters were blue or blue-green in color. These trends were revealed by plotting blue:green ratios from either the scanner data or from densitometric measurements of the high altitude color photography. Within small areas, however, this trend for an increasing blue:green ratio with distance offshore may be reversed. Sometimes blue-green water was found near shore, presumably in newly upwelled water. Farther offshore water color changed to green and then brown, perhaps followed by a rapid change (front) to blue-green again. These changes are probably related to the production and stratification of phytoplankton as pulses of upwelled water move offshore.

The Columbia River, the second largest river in the United States, injects huge quantities of fresh water into the ocean off Oregon. Unlike coastal streams, peak runoff occurs in the spring and early summer. These waters also respond to local wind stress and usually flow to the southwest as a plume of low-salinity water during the summer. Because plume waters are fresher and lighter, they form a thin layer over the denser ocean waters. Hence the radiant heat they absorb is constrained near the surface where heating takes place more rapidly than outside the plume where mixed-layer depths are greater. As a result, plume waters can be distinguished by their temperatures, especially during the early summer (Fig. 2). At this time high surface temperatures correlate well with low salinities.

The plume also affects water color and has been detected by pronounced reflectance of longer wave lengths in both multispectral photograph and scanner imagery (Pearcy and Mueller, 1970). We have also observed interesting "wave-like" patterns near the mouth of the Columbia River in our high altitude photography. The separation between individual wave "crests", which appeared essentially motionless over a 10-minute period, was 70-100 m. Bands of green and brown water were observed during a low-altitude flight in this same region on another date. We suspect that these patterns were caused by convergence-divergence cells that may be accentuated in the region of sharp density discontinuities around the plume.

ALBACORE TUNA

Albacore, Thunnus alalunga, are fast swimming oceanic tuna that migrate into nearshore waters off the west coast of North America during the summer. The distribution of albacore in the northeastern Pacific is known to be influenced by sea temperatures. Clemens (1961) and Flittner (1961) reported that albacore abundance was greatest where sea surface temperatures were between 15° and 20°C in California waters. In the Pacific Northwest, where yearly fluctuations in landing are extreme, highest catch rates occurred between 14° and 17°C (Alverson, 1961; Johnson, 1962). Although sea surface temperatures are an important determinant in the migration and zoogeography of albacore, fishing within the "preferred" range does not insure good catches, or even the presence of albacore. Hence the best correlation is a negative one: low catches are found outside the preferred thermal range.

Panshin (1970; 1971) plotted the catches of troll-caught albacore against sea surface temperature for the months of the 1969 season off Oregon. He found that the average temperature decreased from 16.9°C in July to 16.5°C in August and 15.7°C in September. Thus the average temperature was not constant but decreased by about one degree Celsius from early season to late season. We interpret this change as follows. In July when albacore migrate into Oregon waters, they are associated with the warmest waters available, i.e., waters of the Columbia River plume where heating takes place rapidly (Fig. 3). Later in the summer maximum temperatures in the region are higher and the area of warm water (14-17°C) expands. However, large catches of albacore are frequently made farther inshore, in waters adjacent to areas of upwelling. Consequently the disparity between average temperature of catches and the maximum water temperature available tends to be greater in August than July.

In 1970, the troll albacore fishing off Oregon was excellent late in July but then rapidly declined to low catches in August, traditionally the month of maximum catches. Figures 4 and 5 show sea surface temperatures for July 29 and 30 as measured by infrared radiometry. Albacore catches were large, averaging about 400 fish/boat/day during calm sea conditions on July 28. The sea temperatures recorded on our IR flight on July 29 (Fig. 4) also reflected the absence of northerly winds: water temperatures were warm, even the inshore zone where cold water usually occurs. Warmest water (18.0°C) was found nearshore in a pool of plume water. The albacore fleet was localized in 15.5-16.0°C blue-green water off the Columbia River.

Figure 5 shows that by the next day, July 30, winds had increased to velocities over 10 knots from the north, inducing upwelling and resulting in the immediate return of cold water near the coast. Moreover, the warmest water offshore was 16.5°C compared to 18.0°C on the previous day. Thus, within a day, rapid changes in both absolute temperatures and the temperature pattern were associated with a change of winds. On July 30, the albacore fleet was still localized off the mouth of the Columbia River, but now closer to shore.

After July 29 albacore catches declined and never recovered during the 1970 troll season off Oregon. The decline occurred despite the presence of favorable surface water temperatures for albacore. Temperatures of 14 to 17°C were common throughout August as in other "good" albacore years. Therefore factors other than sea surface temperature have an important influence on albacore availability.

CONCLUSIONS

1) Albacore fishermen presently use sea surface temperature, water color, and fronts to assist them in locating albacore. These features can be detected by remote sensing. Remote sensing is especially useful because large areas can be surveyed in short periods of time and near-synoptic maps can be constructed. Moreover some of these data can be made available to fishermen in near real-time. This is an important consideration for fisheries in coastal and upwelling regions where oceanographic conditions change rapidly, particularly for highly motile fishes like tuna.

2) Factors other than sea surface temperature are obviously important within the "preferred" temperature range of albacore. Sea surface temperature may be correlative with other more basic oceanographic features, but these more salient factors are yet to be identified.

3) Lastly we need a better understanding of the biology and behavior of albacore and other commercially important species. This was clearly emphasized by the demise of the 1970 troll season off Oregon which was unpredicted and has yet to be explained.

ACKNOWLEDGMENTS

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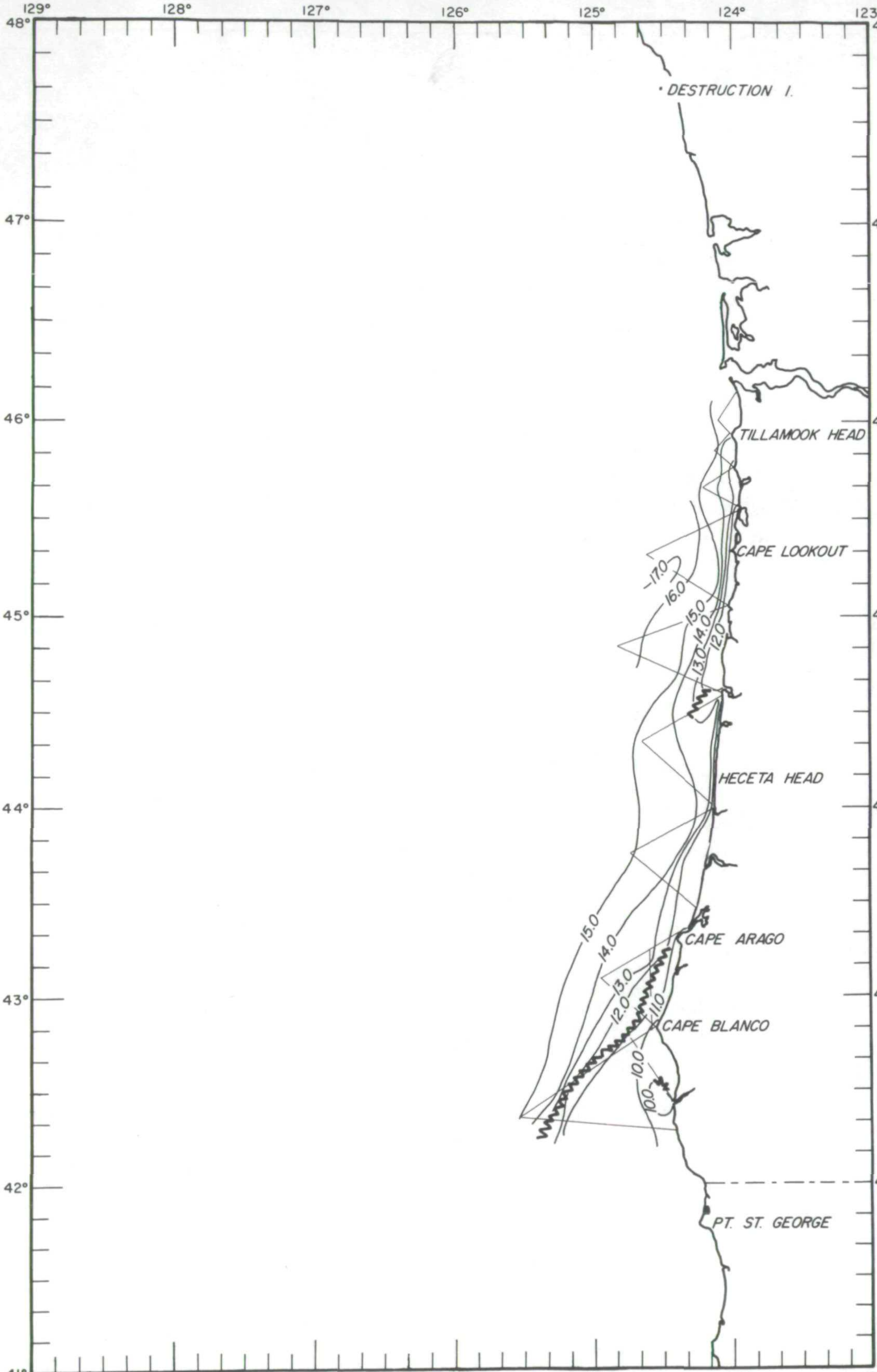

Figure 1. Sea Surface Temperature from Airborne PRT-5 radiometer survey. NASA Manned Spacecraft Center CONVAIR 240A on 12 August 1969. ʌʌʌʌʌ - thermal front.

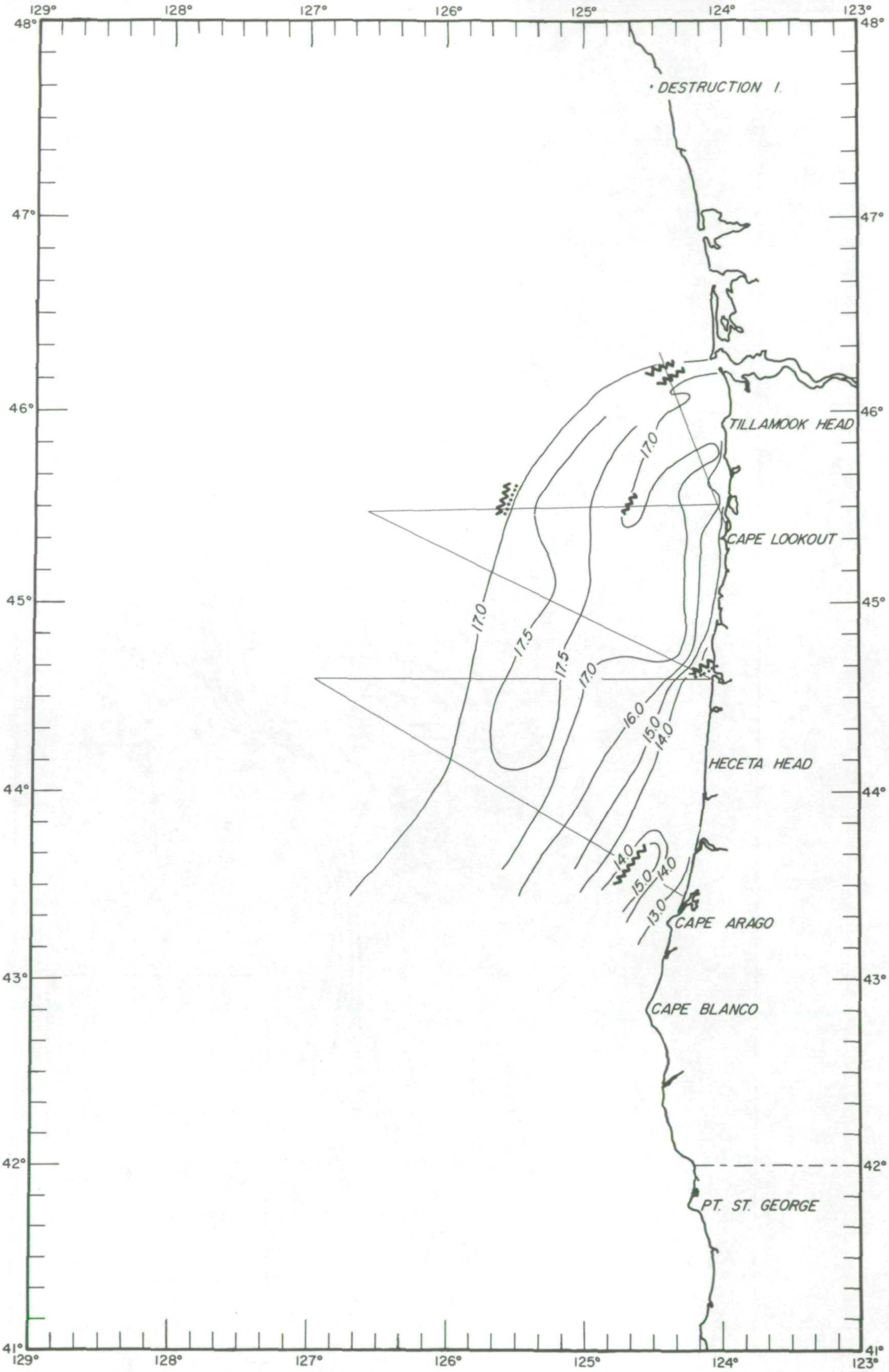

Figure 2. Sea Surface Temperature from Airborne PRT-5 radiometer survey. University of Michigan C-47 on 13 July 1969. ~~~~ - thermal front, •••••• - color front.

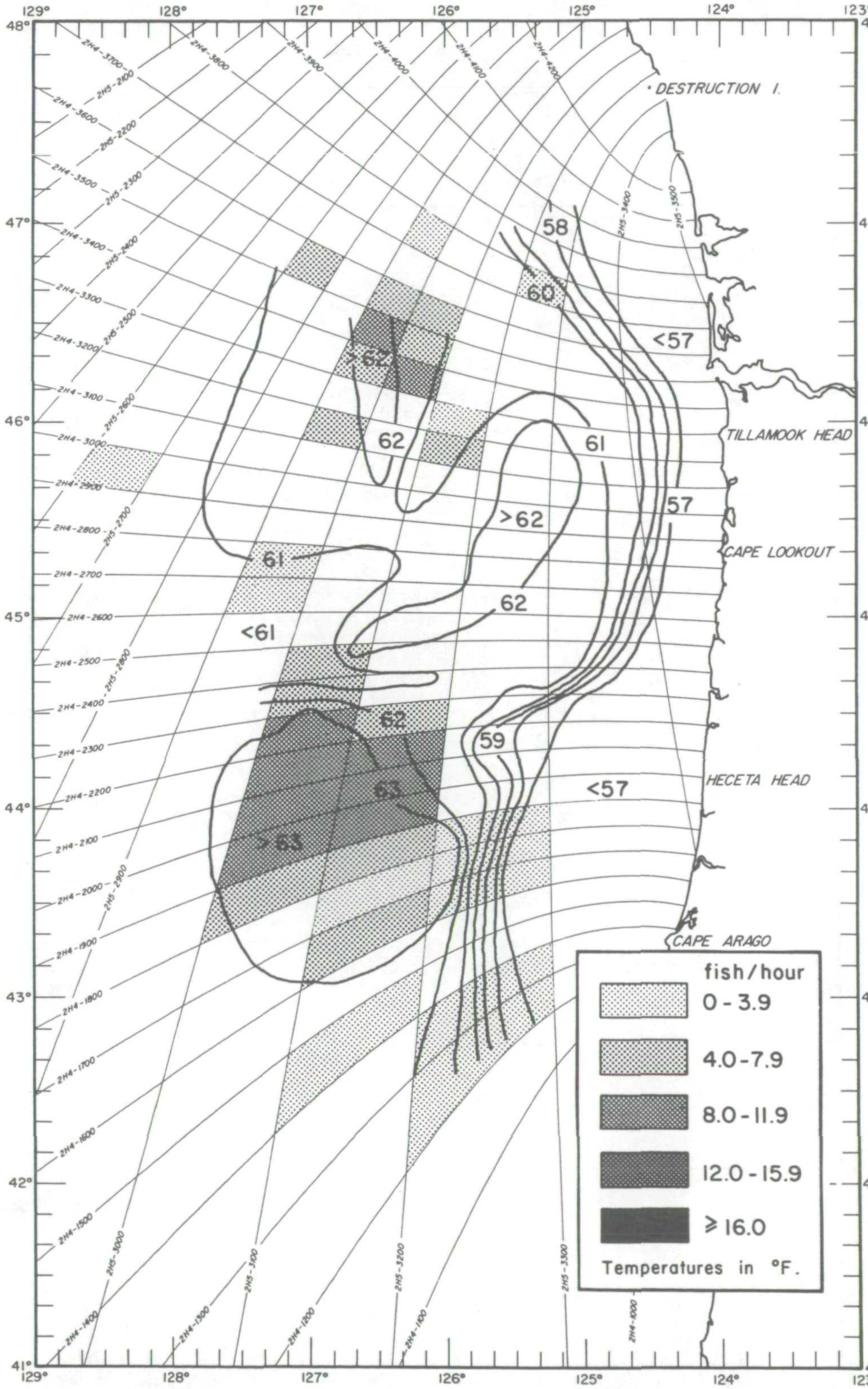

Figure 3. Catches of albacore tuna by Loran blocks and sea surface temperature, 17-23 July 1969. Note that the highest catches are associated with the warmest water.

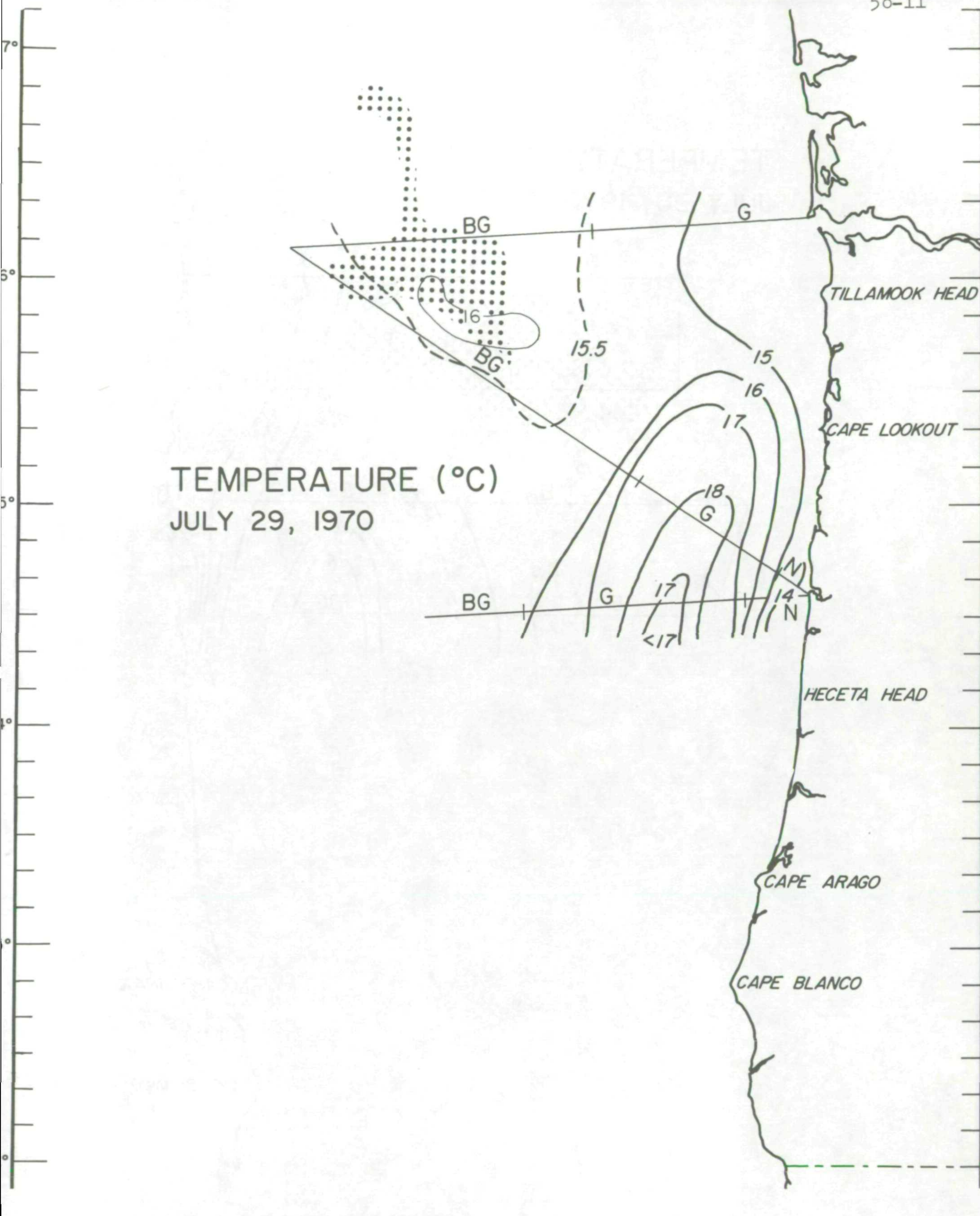

Figure 4. Sea Surface Temperature from Airborne PRT-5 radiometer survey. U.S. Air Force (304th ARRS) HU-16 on 29 July 1970. Visual observations of water color: N = brown, G = green, BG = blue-green. Dotted area designates location of albacore boats.

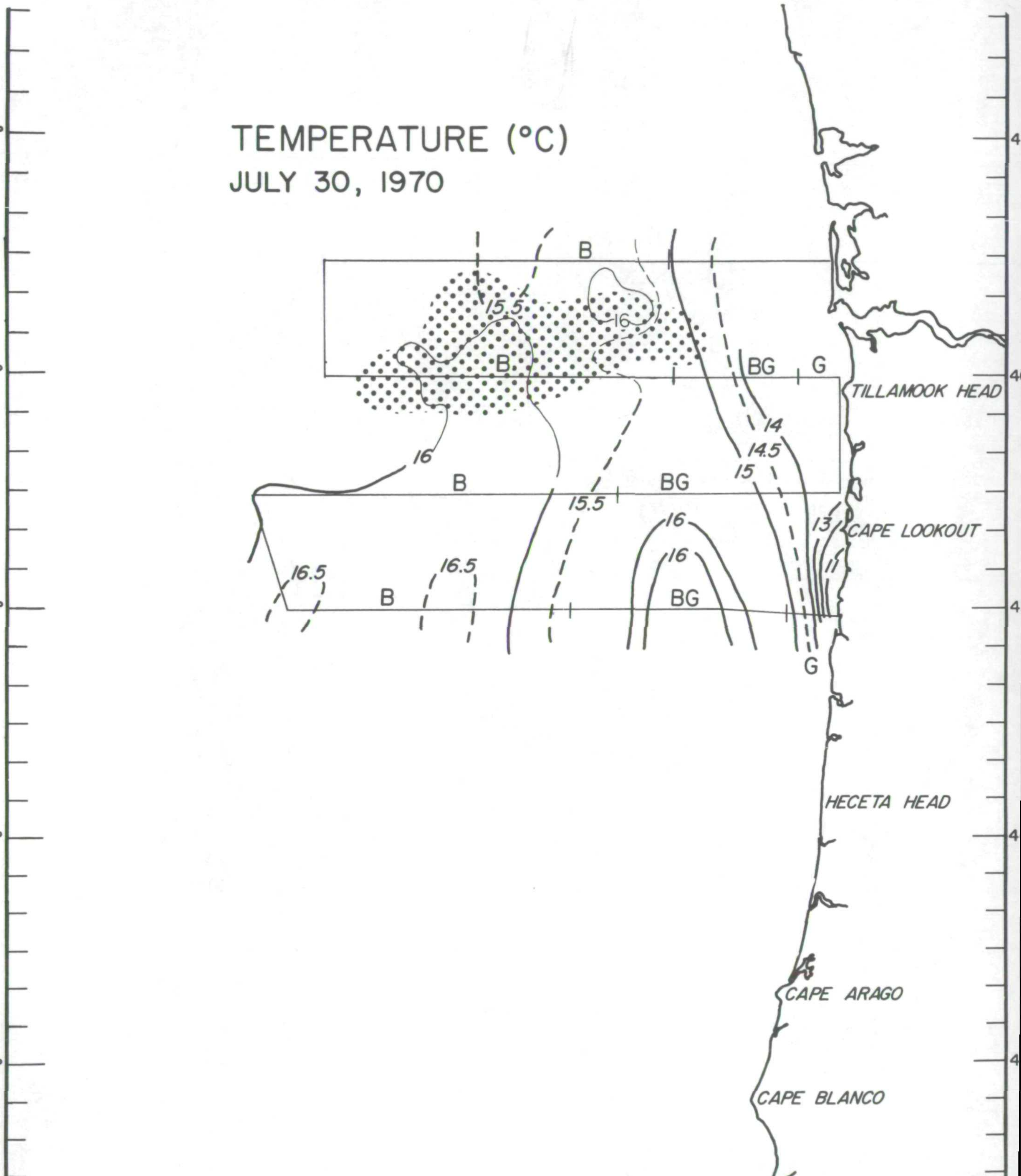

Figure 5. Sea Surface Temperature fron Airborne PRT-5 radiometer survey. U.S. Coast Guard, Port Angeles HU-16 on 30 July 1970. Visual observations of water color: G = green, BG = blue-green, B = blue. Dotted area designates location of albacore boats.