Remote Sensing and the Pelagic Fisheries Environment off Oregon

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INTRODUCTION

One of the biggest advantages of remote sensing is that large areas of the earth's surface can be surveyed in short periods of time, providing near-synoptic "pictures." Repeated surveys of one area, like time-lapse photography, can be interpreted as a movie to illustrate the dynamics of detectable features. These attributes of remote sensing from aircraft or spacecraft are especially important in coastal and upwelling regions of the oceans, where oceanographic conditions change rapidly. The world's largest fisheries are also located in these dynamic areas.

In general, oceanographic variables, measured by remote (or non-remote) sensors can be used in two ways to increase the efficiency of exploited fisheries. They differ in the time lag between collection and use of data, but both endeavor to predict fish concentrations in time and space.

First, measured variables such as temperature can be compared with fish catches in hopes of discovering good correlations between ocean factors and the distribution of species so that scientists can provide fishermen with new indicators or methods for locating fish stocks. This approach, in my opinion, has not been especially fruitful in the past. One reason is the difficulty in obtaining environmental data and catch statistics from the same area at the same time and on the same geographical scale.

Obtaining catch data from fishermen and correlating them with oceanographic data takes time. One reason for this is that remote sensing data are extensive and are often recorded on magnetic tapes. Therefore, correlation studies seldom have application during the same fishing season the data were collected.

Even if a positive relationship exists between high catches and an oceanographic feature, predicting availability may be based on the assumption that this feature is relatively static and will persist for days or weeks. In coastal waters influenced by upwelling, however, temperature and oceanographic features fluctuate rapidly and are difficult to predict (Lane, 1965).

These considerations argue for the second approach: to disseminate information in realtime: i.e., make it rapidly available to fishermen so they can use it to plan their day-to-day fishing tactics. In this way, the fisherman relies on his past experience to interpret data. Timely information is vital to improved scouting for motile pelagic species whose distributions change constantly in a dynamic medium.

Both of these approaches have been used in our research at Oregon State University during 1969 and 1970. Our objectives were (1) to learn more about the ocean conditions off Oregon during the summer and how they affect the albacore tuna catches and the productivity of the pelagic food chain, and (2) to provide albacore fishermen with information in near realtime that could be used in scouting for fish.

The research constituted a broad and multidisciplinary program. It included four interdependent components:

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 Group
Fishery - Oceanography Center, La Jolla, California
U.S. Weather Service
Pacific Northwest Bell Telephone

Remote sensing aircraft used infrared radiometers (Barnes PRT-5) on all low level (500 or 1000 ft. altitude) flights. The calibration techniques of Saunders (1967) were used. A multispectral scanner was used on University of Michigan's C-47, a TRW Ocean Color Spectrometer and on L-band microwave radiometer on NASA's P-3, and high altitude (60,000 ft) multispectral photography from the RB-57.

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 with fish catch. The U.S.

Navy Fleet Numerical Weather Facility, Monterey, California provided 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 both 1969 and 1970 are still being processed. The data obtained from the multispectral scanner, the spectrometer, and microwave are on tape and also being analyzed.

Upwelling and Columbia River Plume

Remote sensing overflights were ideal for semi-synoptic surveys of coastal upwelling and the Columbia River plume. These two features greatly influence the pelagic environment off Oregon during the summer, and both are detectable by anomalies in sea surface temperature and water color. Sequential flights helped to reveal the dynamic nature of both of these features: patterns of sea surface temperature, for example, changed on a daily basis indicating the fluctuating nature of this region (Pearcy and Mueller, 1970).

Upwelling was evidenced by cold water (and sometimes fog) along the coast, coldest temperatures usually occurring off southern Oregon. Thermal fronts, where the temperature changed markedly, were frequently found between cold water and warmer offshore water.

The Columbia River plume was often observed as a tongue of warm water. The Columbia River is the second largest river in the United States and discharges an average of 7300 m^3/second into the Pacific Ocean. Unlike coastal streams that have peak runoff in the winter, the Columbia has a large runoff in the early summer from snow melt in the mountains. In the ocean, the effluent responds to prevailing winds and usually flows to the southwest in the summer. Because the low salinity plume water is separated from the denser ocean water by a strong pynocline near the surface and because of its large load of particulate matter, the plume waters are heated more rapidly than surrounding waters with a deeper mixed layer. Therefore plume waters are distinguishable by warm surface temperature early in the summer (Owen, 1968).

Changes of water color were sometimes associated with both upwelling and the plume. Multispectral scanner data and microdensitometry of high altitude Ektachrome transparencies indicated a general increase in the blue/green ratio with distance offshore. This trend could be reversed in localized regions, however, with the blue/green ratio decreasing offshore in areas of recently upwelled water along the coast.

Sea Surface Temperatures - 1970

Some sea surface temperature maps derived from airborne infrared radiometry (Figs. 1-3) illustrate some of the important oceanographic features found off Oregon during the summer. The map for July 22 (Fig. 1) shows the influence of upwelling, with coldest surface temperatures (< 11°C) along the coast. Warm water (> 16°C) is pooled offshore and localized in a small area near the mouth of the Columbia River. For several days preceding this flight winds blew from the north at velocities greater than 10 knots. Upwelling was intense and mixing of Columbia River water with cool upwelled water destroyed the continuity of the Columbia River plume.

A week later on July 29 (Fig. 2) there is little evidence of upwelling. Surface temperatures inshore were > 14°C and offshore were up to 18°C, both warmer than on July 22. This condition was attributable to the light winds, which were predominately from the southwest, the lack of strong upwelling, and the continued heating of surface and plume waters. Water colors visually observed from the aircraft are noted. Warmest waters, probably in the plume, were green. Blue-green water predominated offshore, and brownish water was noted near the coast. Brown water is produced when dense phytoplankton blooms occur near the surface, a condition sometimes observed in nearshore waters after northerly winds and upwelling subside. Presumably a shallow mixed layer is produced in the nutrient-rich upwelled water allowing rapid growth of phytoplankton near the surface.

On July 30, one day later, another flight was made over the same area (Fig. 3). A comparison of Figs. 2 and 3 reveals how much sea surface temperatures can change in one day. Northerly winds of 10 knots or more commenced on the afternoon of July 29 and their effect is indicated by lower inshore temperatures from upwelling (< 12°C). Warmest temperatures offshore are 16.5°C instead of 18°C on July 29. Note also that brown water was not seen on this flight, after the onset of strong northerly winds.

The CAYUSE made observations on temperature and salinity in the area of these overflights between July 27 and August 2. The maps of surface temperatures obtained by ship and by aircraft were similar: both showed a bilobed pattern with two regions of warm water (as in Figs. 2 and 3). The pattern of surface salinity was also bilobed, the areas of low salinity corresponding to areas of high temperature. This inverse relationship between temperature and salinity has been noted before during early summer, and Evans (unpublished M.S.) reported that the core of low salinity usually lies inshore of the core of warmest water.

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; unpublished M.S.) 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 as albacore migrate into Oregon waters, they are closely associated with the warmest waters available near the axis of the Columbia River plume where heating takes place rapidly. 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 most albacore troll boats that turned in log sheets moved northeast during July parallel to the axis of the Columbia River plume. High catches (averaging about 400 fish per boat per day) were recorded on July 22 and July 28, when the fleet was concentrated 90-120 miles off the mouth of the Columbia River. High catches were made along the seaward edge of the plume on July 22 (Fig. 1) and within the cooler, offshore lobe of the plume on July 28 and 29 (Fig. 2). These areas were intermediate in surface temperature, usually 15-16°C. Low catches were made in the warm (> 16°C) plume waters found close inshore (Fig. 2).

July 29 was the last day that good albacore catches were reported by troll boats off Oregon in 1970. Thereafter catches declined rapidly until the end of July, and the troll fishery off Oregon never resumed. This demise of the 1970 troll season was not related to any drastic change of ocean conditions reflected by sea surface temperatures. The surface temperatures during and after the decline were approximately the same as those in other good fishing years.

Some Conclusions

(1) The factors presently used by fishermen to locate albacore are surface features amenable to remote sensing. A Sea Grant questionnaire returned by 163 albacore fishermen showed that sea surface temperature, location of fleet, water color and fronts, in that order, are the most often used.

Large areas of the ocean can be surveyed by means of remote sensing. Therefore maps of sea surface temperature can be constructed. We found that our ships, on the other hand, provided too little data in a day's steaming for areal mapping.

(2) Within the "preferred" or "optimal" temperature range of the albacore, factors other than temperature obviously affect distribution and availability. This conclusion is supported by the changing relationship between catches and sea surface temperature during the progression of the 1969 fishing season and by the collapse of the 1970 troll season in Oregon despite the presence of favorable water temperatures.

The lack of obvious correlations between absolute surface temperatures and catch rates does not necessarily mean the absence of important relationships. The pattern of surface temperatures may reflect important circulation and subsurface features. We need more information on how surface features are related to ocean processes.

(3) Fronts are sometimes areas of high albacore and tuna catches (Hynd, 1969; Blackburn, 1964). According to Powell et al. (1952) good albacore water is often in the blue oceanic water bordering the cooler green coastal water. Given a suitable range of water temperatures, fronts may be areas where fish aggregate and where chances of success are increased. But as Hynd (1969) found, catches may also be high in absence of fronts. Temperature fronts off Oregon are usually near upwelling areas along the coast. Salmon are found in these frontal areas but usually temperatures are too cold for albacore, even on the oceanic side. Offshore fronts in "tuna water" may be areas of higher than average albacore abundance, perhaps because of the abundance of forage animals. We found that offshore color fronts were less common than those occurring around upwelling zones.

(4) The instruments we used to measure the spectral quality of surface waters did not have outputs that could be interpreted in realtime, so the data were of little value in assisting the fleet in day-to-day operations. Visibility from the aircraft was also poor and continuous visual observations were difficult. A simple, rugged photometer that measures blue and green upwelled light from the sea surface and records the ratio as an output on a strip chart recorder, simultaneously with measurement of infrared temperatures, would be very useful. Such color and temperature information used in combination would enable better discrimination of water types and ocean features, and data could be made available to fishermen on a near-realtime basis.

(5) Lastly, the distribution of albacore, or any species, is affected by a multitude of environmental factors which change in importance with season, time of day, and location, physiological state and age of fish, etc. The 1970 season was a lesson in humility for us. The drastic change in albacore availability was not predicted, nor has it been explained. The absence of obvious changes of ocean conditions that correlate with the decline of catches emphasizes how little we know about the behavior of albacore. In order to use environmental data to effectively predict distributions of migratory fishes we must also increase our understanding of their biology.

Acknowledgments

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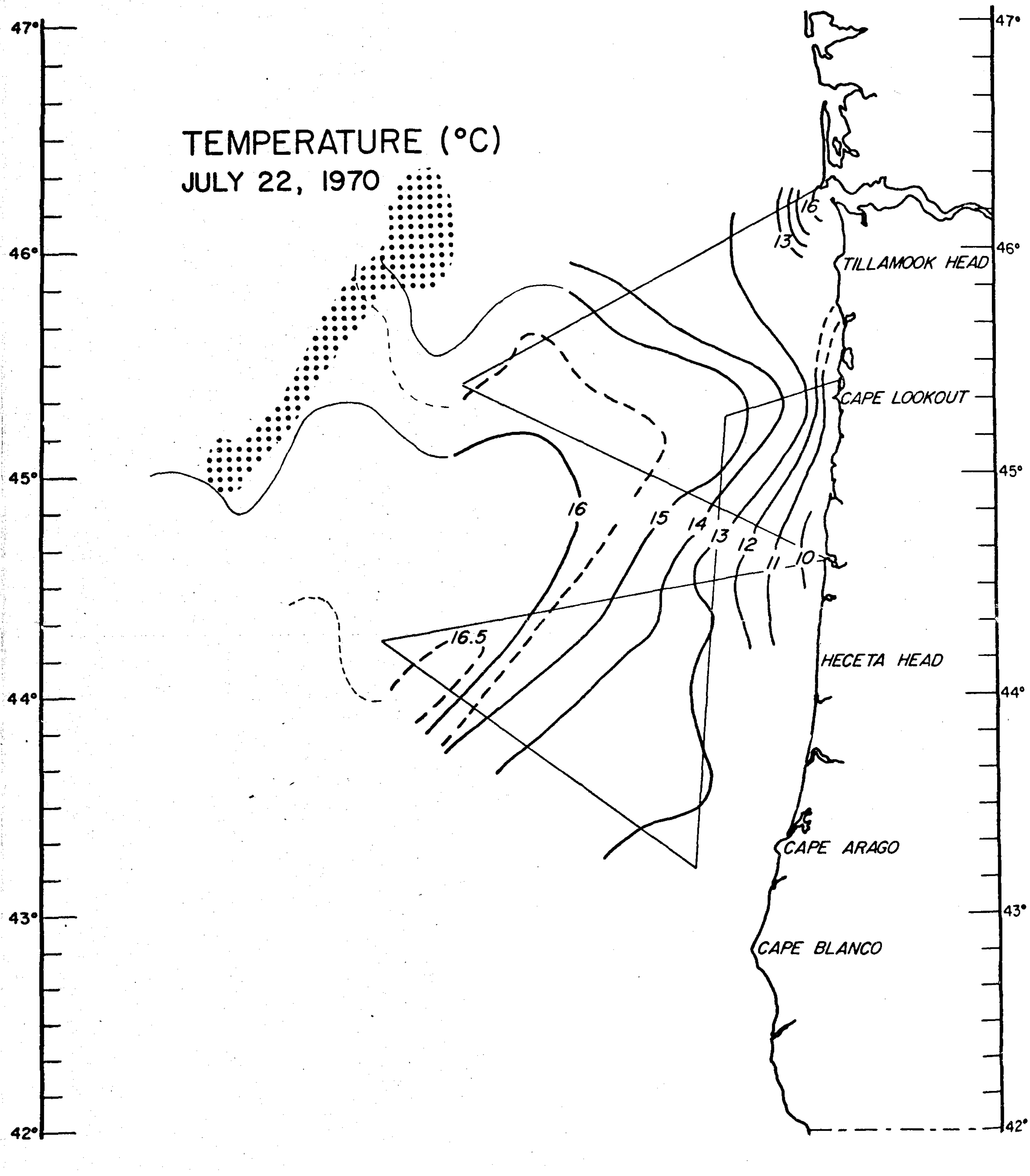
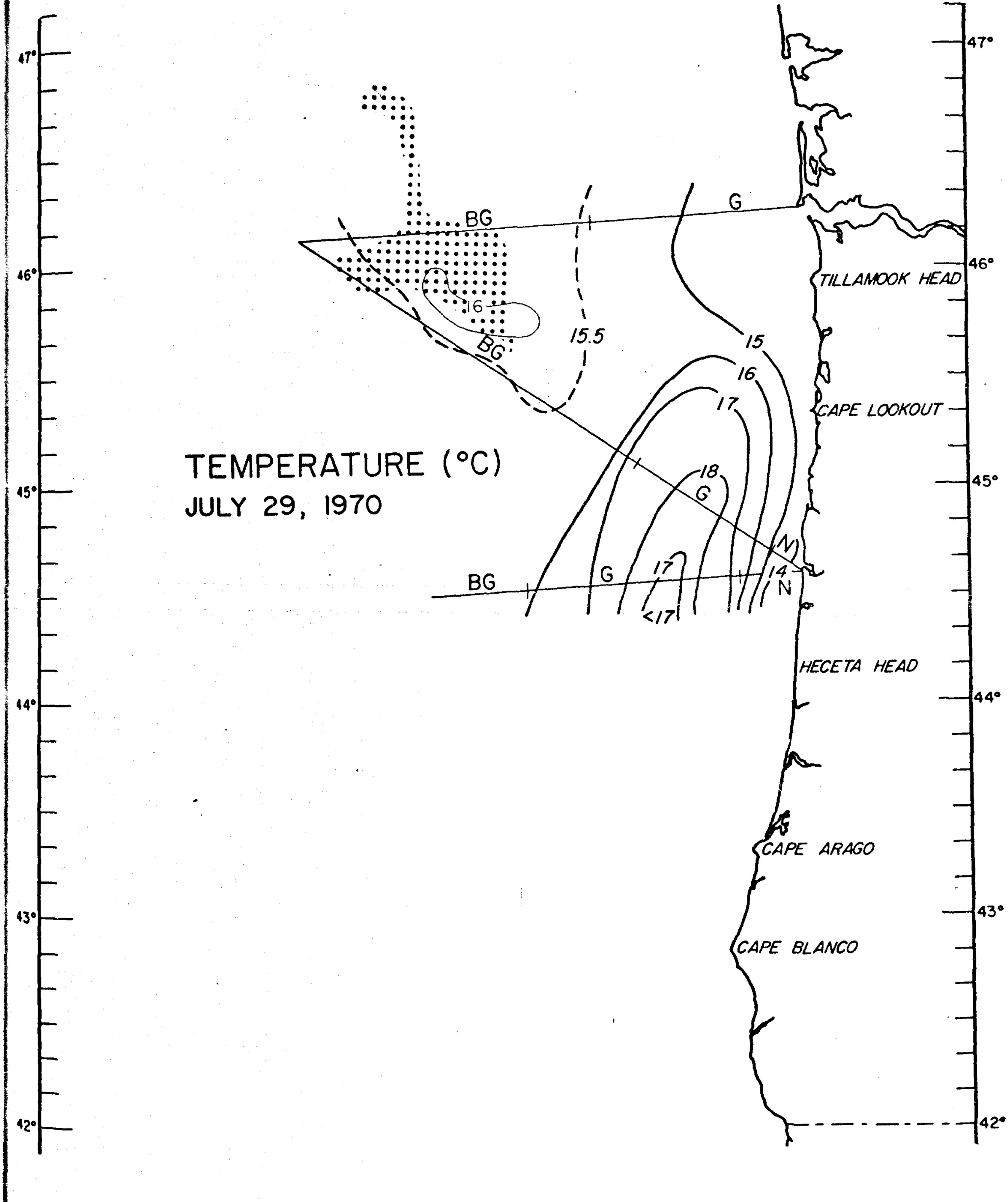
FIGURE CAPTIONS

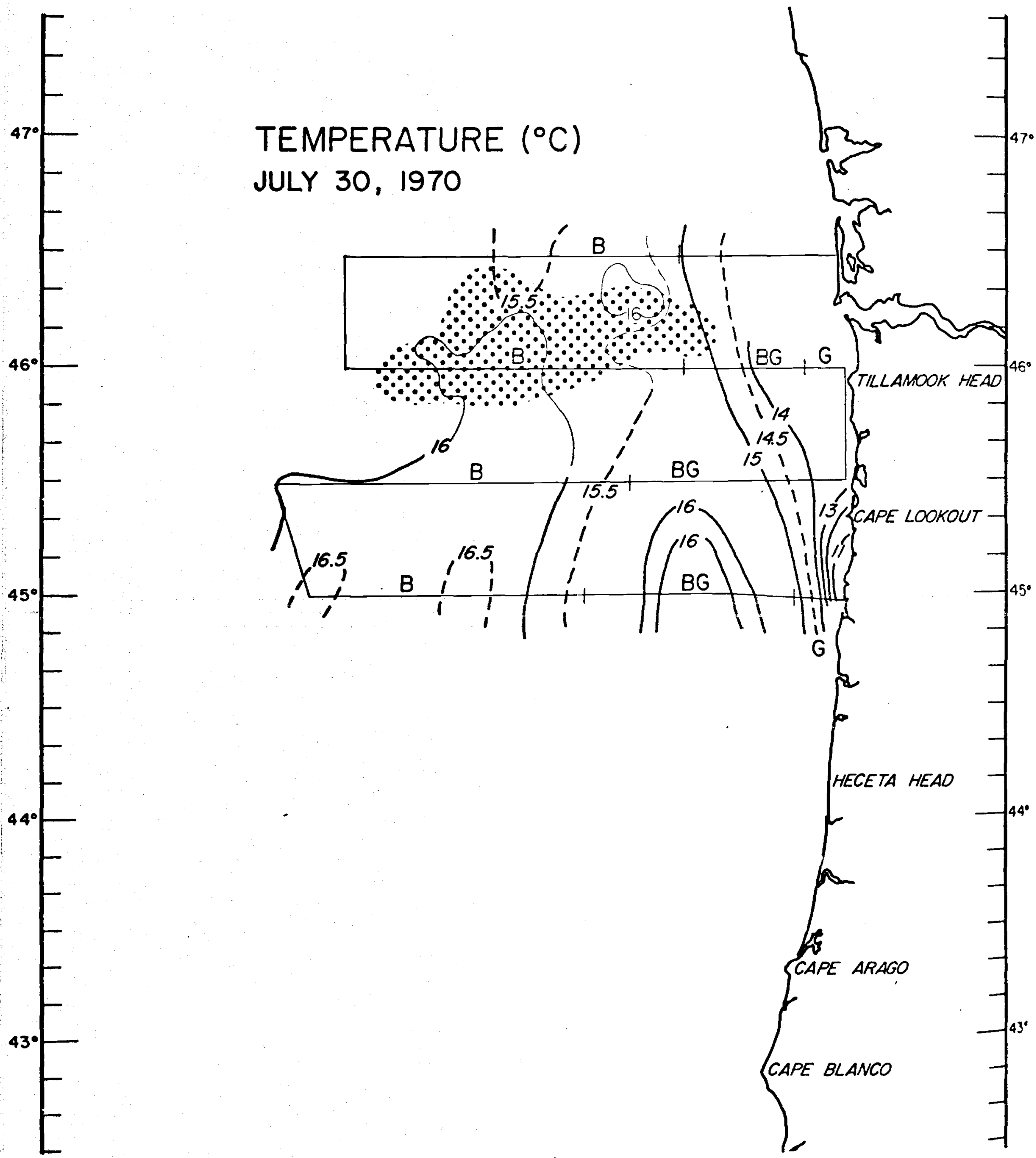
Figure 1. Sea surface temperatures, July 22, 1970, obtained mainly by by infrared radiometry. The flight lines of the U.S. Air Force's HU-16 are indicated by the straight lines. Albacore boats were located in the dotted area; surface temperatures in this area were obtained from the boats.

Figure 2. Sea surface temperatures, July 29, 1970, obtained by infrared radiometry. The flight track of the U.S. Air Force's HU-16 is indicated by the straight lines, the location of albacore boats by the dotted area, and visual observation of water color by G (green), BG (blue-green) and N (brown).

Figure 3. Sea surface temperatures, July 30, 1970, obtained by infrared radiometry. The flight track of the U.S. Coast Guard's HU-16 is shown by the straight lines, the location of the albacore boats by the dotted area, and visual observations of water color by G (green), BG (blue-green),and B (blue).


TEMPERATURE (°C)
JULY 22, 1970
47°
46°
45°
44°
43°
42°
TILLAMOOK HEAD
CAPE LOOKOUT
HECETA HEAD
CAPE ARAGO
CAPE BLANCO
16
13
16
15
14
13
12
11
10
16.5


TEMPERATURE (°C)
JULY 29, 1970
47°
46°
45°
44°
43°
42°
BG
G
16
15.5
15
16
17
18
N
14
<17
TILLAMOOK HEAD
CAPE LOOKOUT
HECETA HEAD
CAPE ARAGO
CAPE BLANCO


TEMPERATURE (°C)
JULY 30, 1970
47°
46°
45°
44°
43°
B
15.5
16
BG
G
14
14.5
15
16
B
BG
15.5
16
16
13
11
16.5
16.5
B
BG
G
TILLAMOOK HEAD
CAPE LOOKOUT
HECETA HEAD
CAPE ARAGO
CAPE BLANCO