THE NEEDS OF FISHING FLEET OPERATORS IN TERMS OF MARINE ECOLOGY, FISH DETECTION, COMMUNICATIONS, METEOROLOGY AND NAVIGATIONAL AIDS

According to information gathered by the Food and Agriculture Organization of the United Nations, 1970 world production of fish and shellfish amounted to 69.3 million metric tons. Examination of historical records of world fish catches shows that the catch has increased steadily each year for the part 30 years. For example, total world catch in millions of metric tons of marine fish, crustaceans, mollusks, and other aquatic animals was about 18.0 in 1948, 27.5 in 1958, and 55.0 in 1968.

A number of estimates have been made of how much food the ocean can produce on a sustained basis. These estimates have been based on extrapolation of present trends and success in areas now heavily exploited to regions of the ocean yet unexploited and on energy flow through the marine food web. The former approach appears to give estimates much below those of the latter, however, the processes governing ocean productivity are imperfectly understood and much further study is needed to refine estimates now being made. Nevertheless, the present consensus among fishery scientists is that the production from the sea can be increased significantly, perhaps by a factor of 3 to 5 times that now being produced. It is expected that the greatest increases in catch will come largely from the pelagic plankton-eating fishes.

The ultimate amount of food that is harvested from the world oceans on a sustained basis will depend on proper management of the world fishing resources and improved fishery technology, notably an increase in efficiency of fishing operations through improvement of present methods and development of new and economical harvesting techniques.

Remote sensing from satellites holds great potential for assisting man in the rational utilization and increased production of ocean fisheries. Remote sensing from satellites may improve the performance of the fishing industry by increasing the fishery product output through increasing the exploitation of presently underutilized or unutilized species and by reducing costs on existing fisheries. There would appear to be two general ways in which an expanded system of satellite observations may assist fishing operations. The most dramatic would be the location of fish concentrations by the use of satellites. However, this is beyond the present state of the art and does not appear likely that satellites will be able to directly detect large near-surface schools in the near future. Probably the most important benefits that satellite observations may provide to commercial fishing are the observation and recording of environmental phenomena that are related to the abundance and distribution of fish stocks and the improvement of marine weather and sea conditions forecasting.

Fishermen have need for information concerning the distribution of sea surface temperature and ocean color and the location of oceanic boundaries. In addition timely, accurate forecasts of marine weather and sea conditions are important for fishing operations. A brief description of how selected satellite measurements are used or can be used in fisheries is given in the following section.

Sea Surface Temperature

Sea surface temperature is one of the more important oceanographic measurements employed in fisheries oceanography research and in fish scouting operations. Fishes and other marine life have preferred temperature ranges, and temperature usually sets the limits of distribution of marine organisms. The optimum temperature range for distribution and fishing of tuna species is given in Figure 1. In addition, sea surface temperature is fundamentally related to many ocean processes which play important roles in determining the distribution and abundance of marine food and sport fishes. Knowledge of sea surface temperature over large areas is important in the detection and monitoring of ocean currents, water mass boundaries, upwelling zones, and certain air-sea interaction processes which influence the heat-balance of the ocean-atmosphere system.

Sea surface temperature measurements, along with marine meteorological observations, are made by merchant ships, fishing vessels, research vessels, and military vessels. The observations are radioed ashore in real-time and the data are disseminated to users over special teletype circuits. While this is a good and important scheme for obtaining sea surface temperature information, the distribution of the observations is mainly along shipping lanes and there are large ocean areas which are devoid of observations. Often these areas of scarce data are important fishing grounds, such as the eastern tropical Pacific.

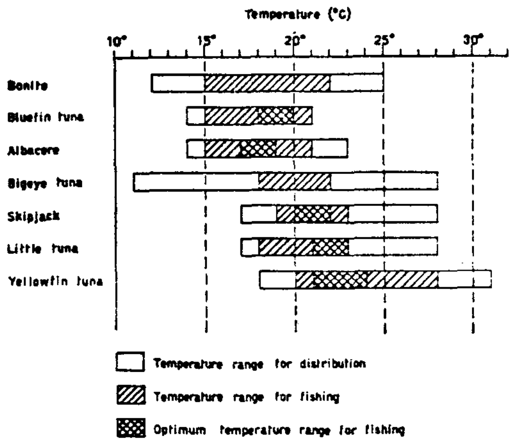

Figure 1. Temperature range for distribution and fishing of tuna species (from Hela, I. and T. Laevastu, 1970. Fisheries Oceanography. Fishing News (Books) Ltd.).

The eastern tropical Pacific is an important fishing region for tunas, billfishes, and other fishes. For example, the annual U.S. tuna catch in 1971 from this region amounted to about 205,000 tons with an ex-vessel value of about 82 million U.S. dollars. Japan, and several Latin American countries also have valuable tuna and other fisheries in the eastern tropical Pacific.

Information concerning the distribution of sea surface temperature, especially delineations of regions of sharp temperature gradient which are called sea surface temperature "fronts", is of great assistance to fishermen in locating potentially good areas of fishing in the eastern tropical Pacific. Ocean temperature information is also needed for long range fishery planning, and population models require ocean temperatures for predicting the location and availability of the tunas in the eastern tropical Pacific. Also detailed sea surface temperature data over the spawning grounds in the central Pacific are essential in estimating the recruitment of future tuna stocks into the fishing grounds.

A plot of the number of sea surface temperature observations received from surface vessels during a 1-week period from the eastern tropical Pacific between 30° N to 5° S and the American coast and 140° W, and a contour plot of the data are shown in Figures 2 and 3, respectively. It is readily apparent that the number of reports is limited, observations are confined mainly to the shipping lanes, and there are large areas where no observations are available. Also, because the data coverage is so sparse, it is not possible to locate the presence of local sea surface temperature "fronts."

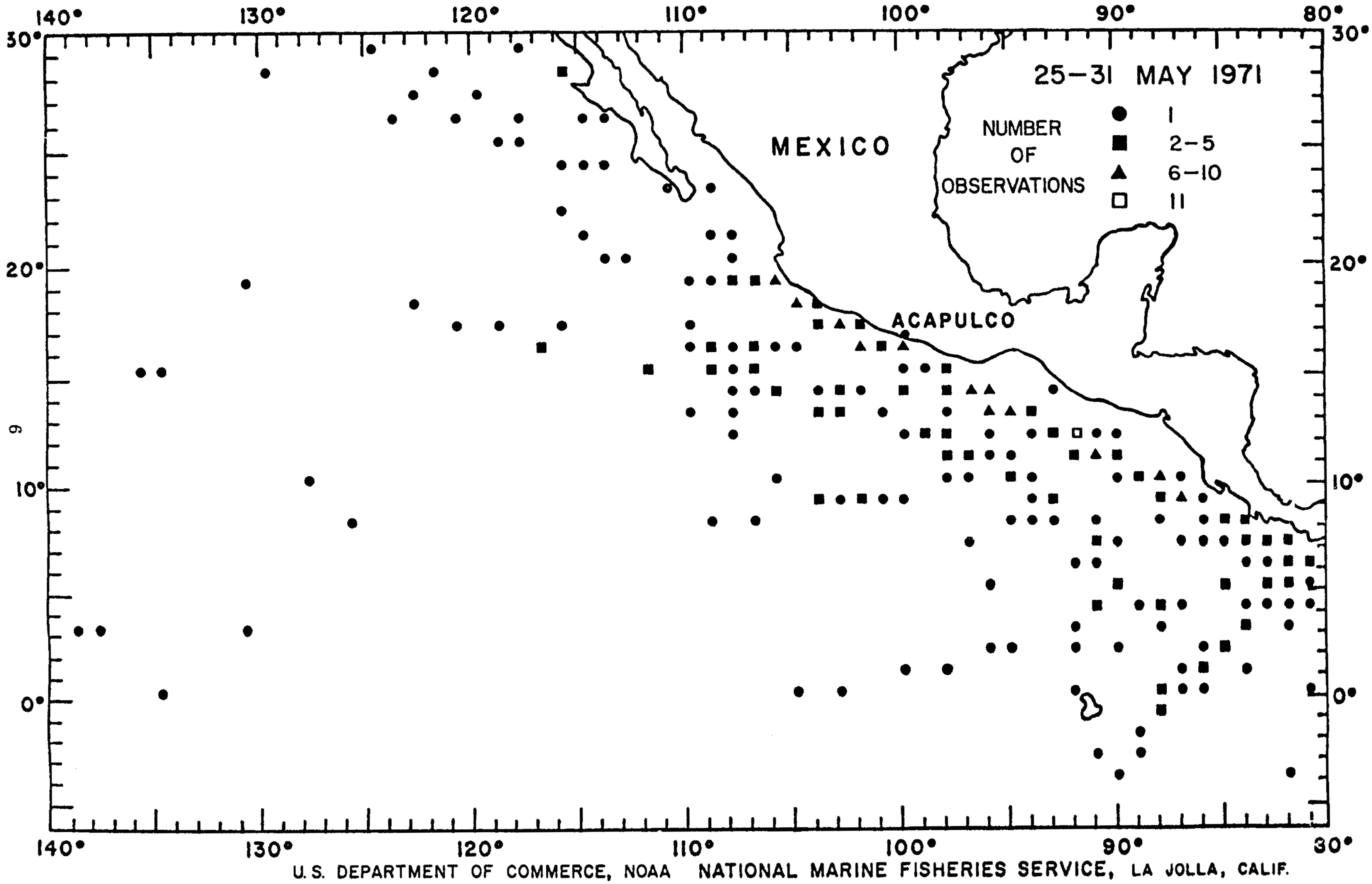

Figure 2. Number of ship reports received from eastern tropical Pacific during May 25-31, 1971.

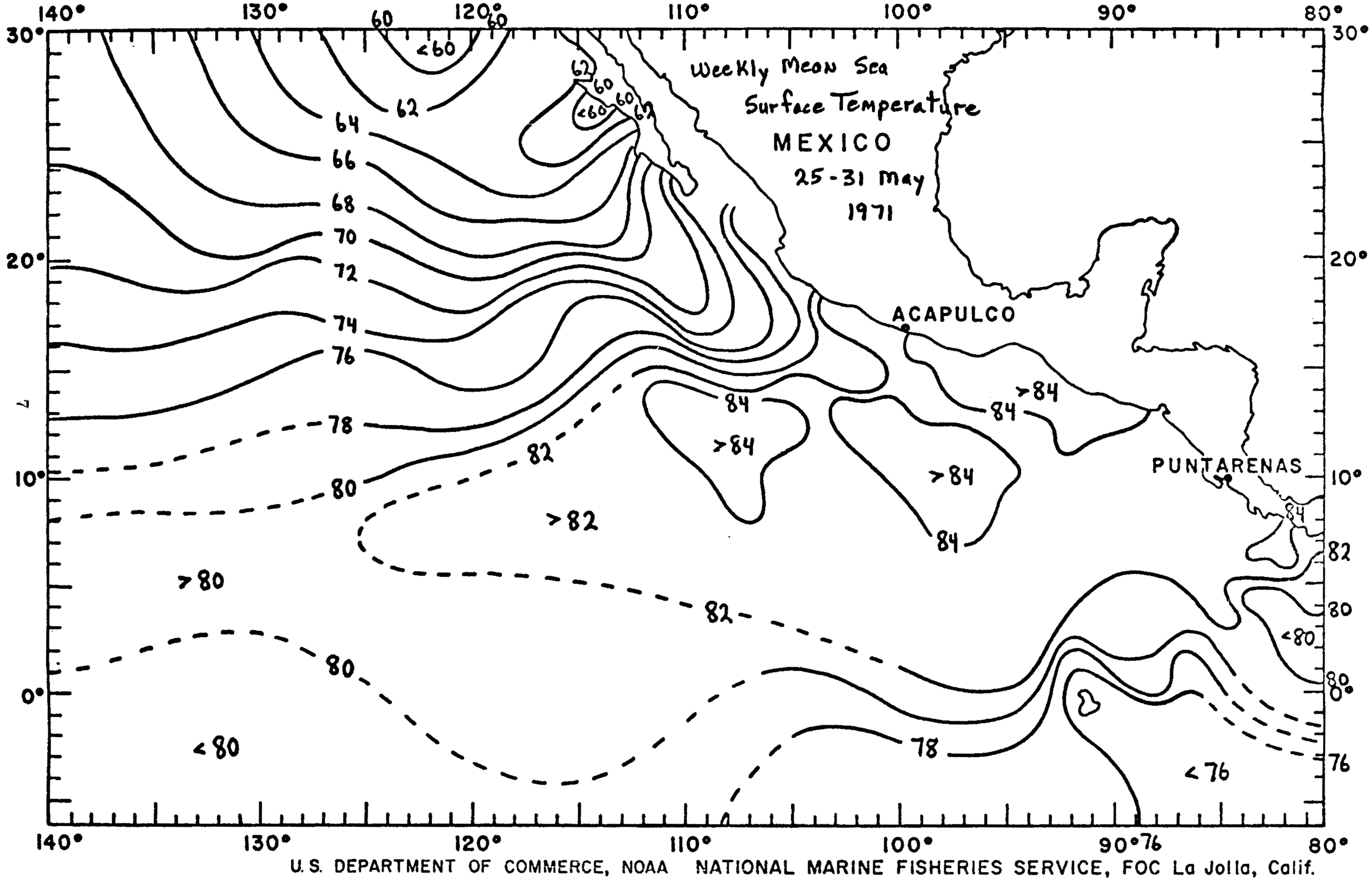

Figure 3. Distribution of sea surface temperature in eastern tropical Pacific, May 25-31, 1971.

A satellite equipped with the proper sensor may provide an ideal means of monitoring and filling in the gaps of data in the distribution of sea surface temperature in the eastern tropical Pacific and other ocean areas. With the ability of a polar-orbiting satellite to repeatedly map the entire globe in 12-hour intervals, remote-sensing of sea surface temperature from satellites could provide valuable synoptic data to evaluate short-term variations in the distribution of sea surface temperature and locate the presence of sea surface temperature "fronts."

Several satellites have been equipped with radiometers for making sea surface temperature measurements using infrared techniques and under certain conditions good results have been obtained. A chart showing the distribution of sea surface temperature based on measurements received from infrared sensors aboard NOAA-1 is shown in Figure 4. The measurements shown in Figure 4 are about 8° C above those reported by ships that were in the area at the same time the observations were made by the satellite. The higher satellite temperatures are due to radiometer calibration techniques. The chart has extremely useful applications to fisheries because it shows small-scale sea surface temperature frontal structure and by having some prior knowledge about the temperature range and distribution in the region and a few ship reports, numbers could be assigned to the isotherms that would be more representative of the absolute temperatures.

There are limitations to infrared measurements of sea surface temperature from satellites. The infrared radiance method involves the assumption of a homogeneous,

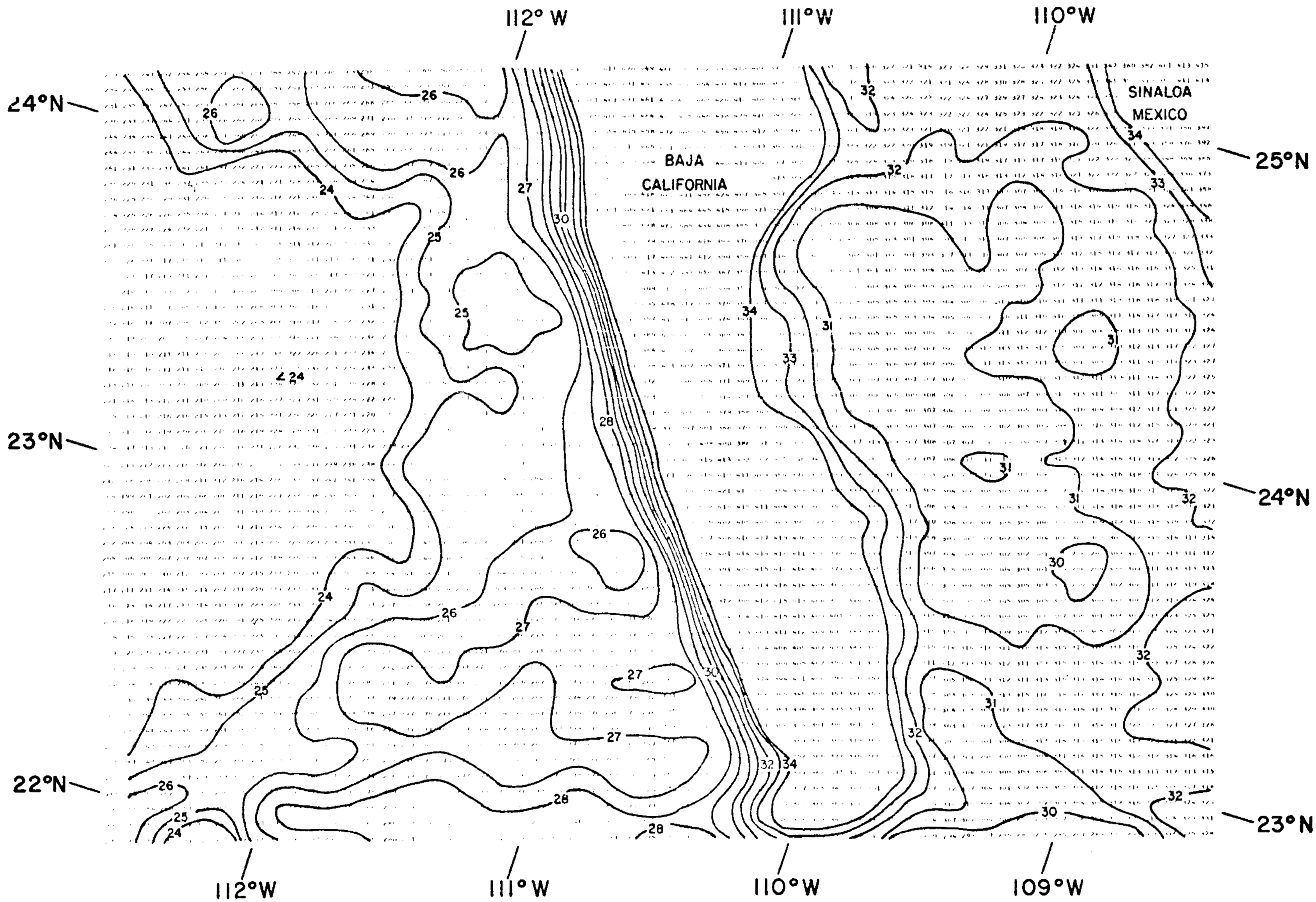

Figure 4. DRIR map of surface temperature (°C) for NOAA 1 (scanning radiometer No. 2) on May 6, 1971.

non-transparent target that fills the radiometer field of view. This means that severe contamination of the radiation measurements is introduced by clouds and that this method of measuring sea surface temperature is limited to cloudless areas. In order to determine whether clouds contaminate the radiation measurements, simultaneous cloud photographs from the same satellite are necessary for proper interpretation of the radiation data. In addition because of atmospheric attenuation due to water vapor, which is non-uniformly distributed in space and time in the atmosphere, proper corrections must be applied to satellite radiance measurements in order to derive correct sea surface temperatures.

In spite of limitations, the information concerning the distribution of sea surface temperature derived from infrared measurements made from satellites can be very useful to fisheries. However, the total potential of sea surface temperature measurements from satellites will not be realized by fisheries until sensors are developed which will give all-weather measurements. This will enable sea surface temperature measurements to be made from satellites in regions of upwelling, where most of the world's most important fishing areas are located, and other cloud-covered areas which are important fishing grounds.

The development of microwave radiometry for remote measurements of sea surface temperature and other applications is underway. Experiments using airborne microwave sensors are yielding encouraging results and indicate that an all-weather capability of measuring sea surface temperature from space platforms may be possible in the near future.

Ocean Color

It appears quite probable that spectral measurements of backscattered light from the ocean surface will be made by satellites in the near future and provide information on ocean color. The ability to measure ocean color with high accuracy on a global basis by satellites may provide a new and useful tool for locating areas of high biological productivity in the world ocean and lead to the discovery of exploitable fishing grounds.

Ocean color can be used to delineate water masses, to trace currents, and to determine the amounts of chlorophyll, pollutants, and other important materials in the ocean. In addition ocean water color is also used by fishermen in planning fishing strategy and in deciding where to fish. For example, some Japanese tuna fishermen use water color measuring kits to find water of optimum color before setting their lines. Salmon and albacore tuna fishermen fishing in Pacific waters off the coast of North America often will use color "fronts" as one of the indicators of an area of potentially good fishing and many fishermen have reported that high catches are often made in the vicinity of ocean color "fronts." Water color, as an indicator of coastal currents may also assist in the determination of migration paths of shrimps in the Gulf of Mexico and may be useful in predicting their abundance and distribution. An oceanographic analysis of a photograph taken during the GEMINI flight series determined that the shrimp catch in the Gulf of Mexico was highest in turbid water.

Since chlorophyll is associated with living plants, spectral measurements of chlorophyll concentration may be used as an index of the amount of phytoplankton present in ocean water. Phytoplankton - microscopic, floating plants - form the base of the marine food chain and regions of high phytoplankton abundance can support large populations of herbivores and of successive links in the food chain, including those which are of economic importance to man. Thus, chlorophyll may be used to indicate the presence of potentially productive areas. Remote spectral measurements of the proper wavelengths for estimating chlorophyll concentration have been successful from low flying aircraft and have shown that increasing amounts of chlorophyll are associated with a relative decrease in the blue portion of the spectrum and an increase in the green. The absorption spectrum of a variety of marine phytoplankton is shown in Figure 5.

Investigation is underway to extend the airborne instrumentation and technique for measuring chlorophyll to satellite application. Providing certain atmospheric interference can be eliminated, or identified and allowed for, spectrometric procedures from satellites for estimating chlorophyll concentration appears probable.

Detection of Oceanic Boundaries

The detection of boundaries between water masses, currents, and other oceanic discontinuities could have important applications to marine fisheries. The migration routes followed by some pelagic fishes are thought to be related to oceanographic boundaries. High biological productivity is often associated with

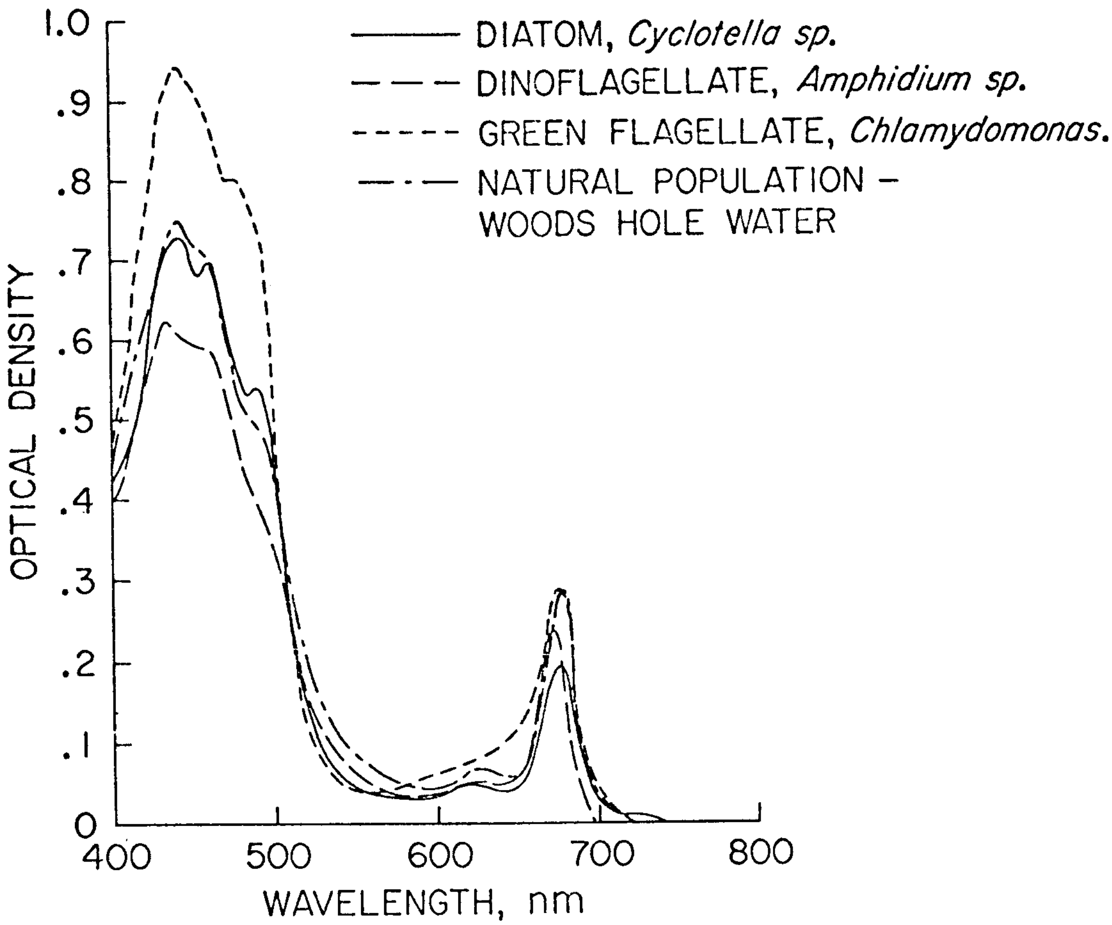

Figure 5. Absorption spectra of a variety of marine phytoplankton (from Yentsch, C. S., 1959. The influence of phytoplankton pigments on the colour of sea water. Deep-Sea Research 1: 1-9).

some types of oceanic boundaries, resulting in good feeding conditions for fishes. Thus, areas of good fishing are often found in the vicinity of oceanic boundaries and fishermen spend much looking for them as a place to fish. In addition, certain marine organisms, including some fishes, are limited to specific water masses and the delineation of the water mass makes it possible to predict the distribution of species confined to it.

Studies have shown that present satellite photography can provide information useful in detecting pronounced oceanic discontinuities, essentially from contrasting sea surface temperature conditions. The location of boundaries can be inferred visually from photographic results from satellites by characteristic modifications of existing cloud patterns as caused by differential sea surface temperature patterns and the concurrently induced local vertical circulations in the lower atmosphere. However, this method is not highly accurate because the ocean boundary and the cloud boundary do not always coincide, and may be displaced several kilometers from each other. The method has been successful in delineating the general location of boundaries of several major ocean currents including the Gulf Stream, the Brazil and Falkland Current boundary, the boundary between the Oyashio and Kuroshio Currents and the western boundary of the Agulhas Current.

Assuming successful sensor development for satellite application, the simultaneous measurement of sea surface temperature and ocean color may be used to locate oceanic boundaries on a global scale in the future. Simultaneous measurement of these two properties from airborne sensors has been successfully used to delineate oceanic boundaries.

Meteorological Aids

Weather conditions are extremely important to the safety and efficiency of fishing operations and timely accurate weather forecasts are extremely important to fishermen. Video photographs received from cameras pointed toward the earth aboard orbiting and geostationary satellites are proving to be of great assistance to meteorologists in making weather predictions. This has been especially true in those instances where photographs from satellites are being used as an aid in making marine weather forecasts for fishermen. For example, at the National Marine Fisheries Service, Southwest Fisheries Center in La Jolla, California, an Automatic Picture Transmission (APT) satellite receiving system is being used to monitor conditions over the fishing grounds in the eastern tropical Pacific. The fishing grounds extend westward from the principal shipping lanes along Central America, and the APT satellite coverage makes it possible to infer, more accurately, weather and sea conditions in areas where surface observations are sparce. The APT satellite photographs are extremely useful in locating areas of bad weather along the Inter-tropical Convergence Zone and elsewhere, and in tracking the movements of tropical storms and hurricanes. Also, when combined with surface ship observations, the APT satellite photographs are of great assistance in identifying areas of good weather and probable improved fishing conditions.

Based on the analysis of APT satellite photographs and surface observations from merchant and fishing vessels, two charts (Figures 6 and 7) containing oceanographic and weather information tailored to fishermen's needs are being transmitted daily via radio facsimile broadcast to vessels on the fishing grounds in

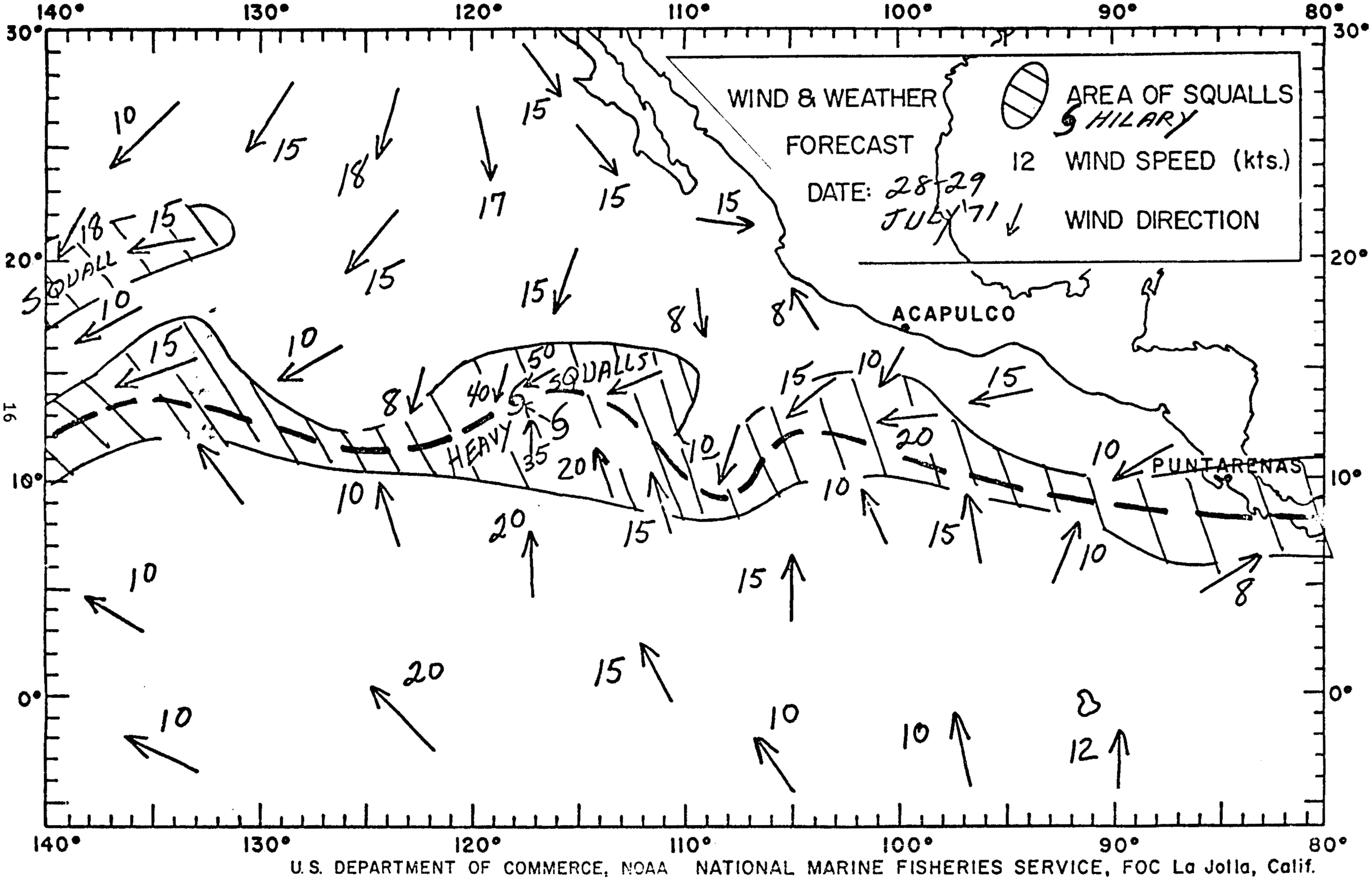

Figure 6. Wind and weather forecast chart.

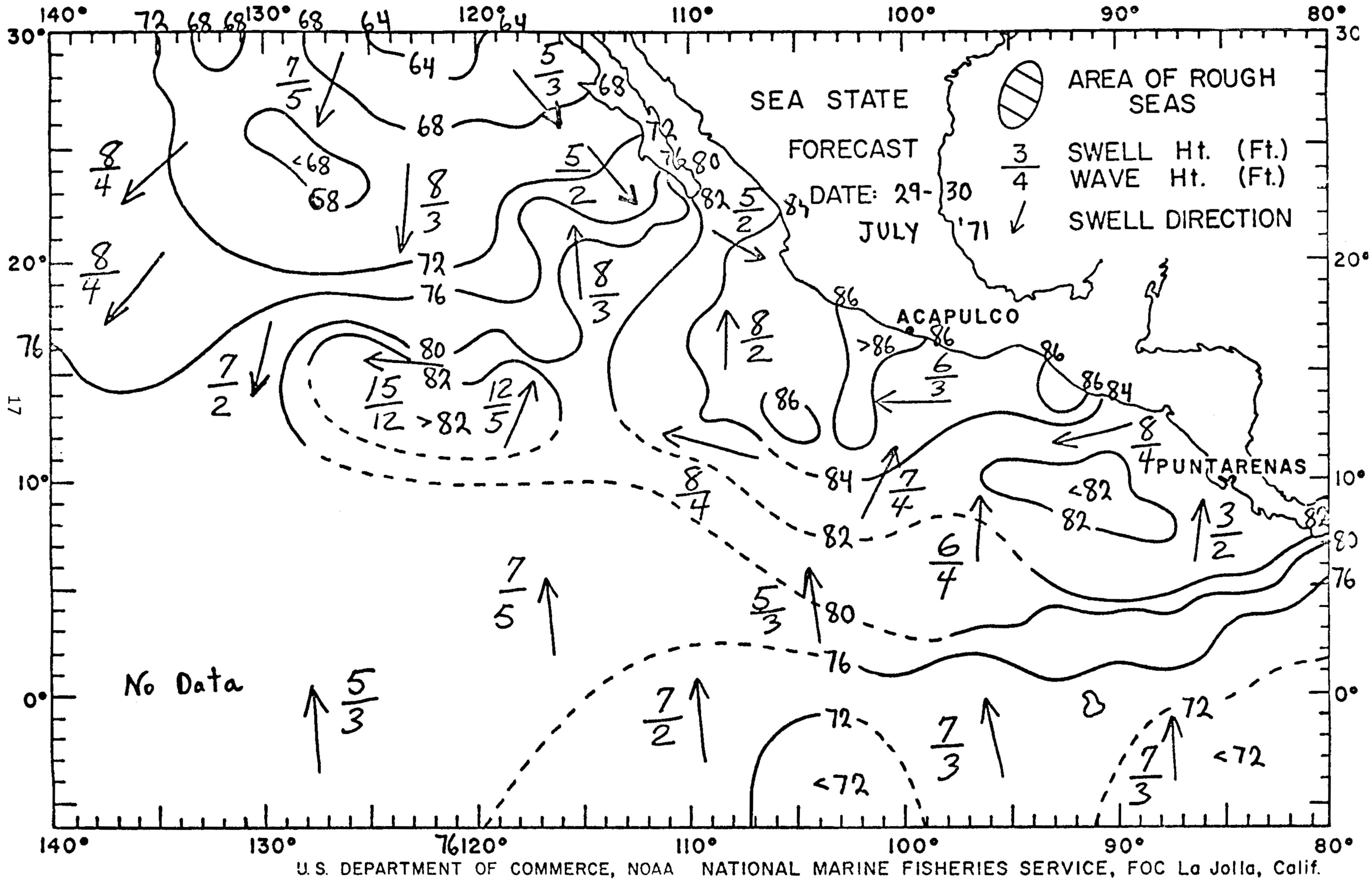

Figure 7. Sea state forecast and sea surface temperature chart.

the eastern tropical Pacific. Sea state information including swell direction and height, wind-wave height and, once each week, a 7-day sea surface temperature analysis, is given on one chart. A second chart provides information on direction and speed of surface winds, location and direction of movement of tropical storms, location of areas of squalls and other inclement weather conditions, and location of the Intertropical Convergence Zone. Within the very near future a weekly analysis of thermocline depth and summaries of catch information will be included on the charts. Eventually the location of ocean surface temperature fronts indicated by infrared temperature measurements made by orbiting satellites and received by the APT installation at the Southwest Fisheries Center will be added to the charts.

The fishery-advisory service to tropical Pacific tuna fishermen is being performed on an experimental basis as a means of obtaining valuable environmental data from fishing vessels and to provide fishermen with information which may assist them in making tactical fishing decisions. Fishermen are provided radio facsimile recording equipment for copying the charts with the agreement that they radio ashore environmental data. The environmental data collected by fishermen are used in the preparation of the fishery-advisory charts and in research concerning the development of fishery-forecasting techniques and methods for tropical tunas currently underway at the Southwest Fisheries Center.

Navigation and Locating Electronically Equipped Objects

Methods of navigation used by fishermen range from visual using the human eye unaided or aided by instruments such as telescopes and sextants to highly sophisticated electronic navigation systems such as Loran and Omega. To my knowledge no U.S. fishing vessels are equipped with satellite navigation equipment and it is unlikely that U.S. fishing vessels will use satellite navigation equipment in the near future because of high cost, complexity of operation, and difficulty of obtaining service in small ports.

There is a great potential in fisheries research to use satellites for locating electronically equipped objects and communication of information to shore. This use of satellites could extend and improve geographic coverage of data and make it possible to obtain data, particularly below the surface, on a real-time or synoptic basis. It could also be used to track movements of fishes and other marine animals, and improve our understanding of their migration patterns.

Summary

Remote sensing from satellite technology as applied to fisheries and fisheries-oceanography is an emerging technique. Nevertheless, the degree to which satellite remote sensing may assist is becoming more positive. Measurement of sea surface temperature from orbiting satellites with infrared radiometry has been demonstrated and the development of an all-weather thermal capability using microwave radiometry is expected to provide basic scientific data for the benefit of fisheries. Measurement of ocean color and sea state on a global scale by satellites appears feasible. In addition it appears possible to monitor ocean currents and boundaries and areas of upwelling from earth orbiting satellites.

One of the greatest potential applications of remote sensing from satellites to fisheries would be the simultaneous determination of sea surface temperature and ocean color. Synoptic measurements of temperature and chlorophyll could provide valuable information for locating potential areas of good fishing. For example, fishery-oceanography studies off the Pacific coast of Baja California have shown that tunas there feed almost exclusively on pelagic red crabs, Pleuroncodes planipes. The red crabs are herbivores and are most abundant in and adjacent to areas of localized upwelling where phytoplankton abundance is highest. Thus remote sensing of chlorophyll could provide an indirect assessment of the distribution and abundance of potential tuna forage and sea surface temperature measurements could be used to locate which of the forage-rich waters are of optimum temperature for tuna. Correlations between fish population and water color and temperature have also been found in the region of the Columbia River plume off the Pacific Northwest coast of the U. S. Color measurements in conjunction with temperature measurements could also be used to delineate water mass boundaries and currents.

A strong point should be made, however, if the information acquired by sensors aboard satellites is to be usefully applied to fisheries, each data acquisition (sensor) package will require unique data management and analyses techniques and equipment to convert the information to usable forms. Likewise an effective communication network will be required to transmit the information to users.

May 19, 1972