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Monitoring the Ocean Environment

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INTRODUCTION

Atmospheric and oceanographic conditions in the vicinity of the sea surface have historically been monitored by mariners and fishermen. From their observations has come much of our knowledge of the marine climate. Such observations, taken four times daily, recorded in weather logs and transmitted by radio to shore stations still constitute the primary source of information on surface conditions over the world ocean. This information is now supplemented by data from weather satellites which provide a major advance in global monitoring. The value of satellites for surveillance of atmospheric and oceanic conditions will increase greatly as sensor technology and processing techniques evolve.

There exists no systematic monitoring of subsurface conditions that can be considered comparable to surface monitoring. Subsurface temperatures are taken with XBT (expendable bathythermograph) systems installed on U.S. Navy vessels and on selected merchant ships which travel regular routes. Time-series data are provided by ocean station vessels (which are being withdrawn from service), and a few moored buoys and by sea-level stations at coastal and island locations. Sea-level data can give an indication of mean density in the water column in the vicinity of the station. Research vessels take subsurface observations of many kinds, but at times and places pursuant to particular objectives. Such reports must be considered as incidental to routine monitoring systems.

The basic purposes of monitoring the marine environment are to collect synoptic observations adequate for investigation of significant fluctuations in momentum and heat exchange and their effects on atmospheric and oceanic circulation, and on the distribution of relevant properties. Advances in the basic understanding of the ocean-atmosphere system have application to all activities affected by it, including transportation, military operations, harvesting and management of natural resources, recreation, etc. Particular applications may pose differing requirements upon the monitoring system with respect to time and space scales and to the properties monitored, although there are areas of overlap.

For many of these applications the existing monitoring system is considered inadequate.[1] The obvious shortcomings are the lack of surface observations outside normal shipping lanes and the general deficiency of subsurface observations, except along a few chosen tracks. Less obvious perhaps are the difficulties in making direct measurements of many important parameters and the uncertainties inherent in computing heat and momentum flux from existing observations. Not only are the semi-empirical formulas commonly used to compute these fluxes subject to question, but the actual parameter values used in the formulas (cloud amount; wind speed; and sea, air and dew point temperature) are subject to observational error. Nevertheless, in the sociopolitical, economic, and technological framework of today, there is no meaningful alternative to the existing data collection system from ships of opportunity (i.e., vessels whose primary mission is not collection of data) for large-scale monitoring of environmental conditions.

There are, however, many ways in which this system can be modified and supplemented to improve both the distribution and quality of environmental observations. Such augmentation of environmental monitoring will tend to be selective insofar as large-scale monitoring is supported mostly by government agencies, and the determination of where, when, and what to monitor is guided by an agency's objectives or mission.

The U.S. Navy, whose ships and shore stations contribute to the basic system, also supports supplementary monitoring from ships of opportunity to meet its needs for surface and subsurface data from areas not well covered by the basic system. It operates in both a direct mode, maintaining its own liaison with cooperating ships, and also indirectly through cooperation with marine-oriented academic institutions and with other government agencies, including the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

Academic institutions undertake the solution of a broad range of problems formulated to advance understanding of the ocean and atmosphere. They contribute directly to environmental monitoring through the activities of research vessels. They also contribute to the planning and improving of monitoring systems through investigation of space and time scales relevant to significant processes and events, development of instrumentation and methods of measurement suitable for large-scale monitoring, and through organization of observational programs needed to fill gaps in existing systems.

Weather satellites provide full global coverage of weather systems, over

[1]The status of oceanographic monitoring efforts and a specification of needs for expansion are detailed in a recent report entitled "The ocean's role in climate prediction," available from the Ocean Affairs Board of the National Academy of Sciences, Washington, D.C.

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Figure 1.—Environmental data received over National Weather Service teletype circuits are recorded on paper tape, transferred to punched cards, and inspected for quality control. The cards are then used to update environmental data files on disk for computer processing.

periods of about 12 hours, and partial coverage of surface conditions depending on cloud distribution. The National Environmental Satellite Service of NOAA, which operates this system, is primarily concerned with the sensing, reduction, and presentation of data, and has put much effort into analysis and interpretation of satellite data to facilitate user application.

In general, then, agencies and institutions draw selectively from the conglomerate environmental monitoring system according to their requirements and contribute to the total system by implementing subsystems, either on a unilateral or cooperative basis, to bolster weaknesses in particular mission-related areas. The primary purpose of this review is to describe some of the activities at the Southwest Fisheries Center (SWFC) which fall within that context. First, however, we will touch briefly upon a few of the attributes which might be considered desirable in an optimum monitoring system.

THE IDEAL SYSTEM

If sociopolitical, economic, and technological constraints are ignored, we can envisage the establishment of a World Ocean and Atmospheric Agency (WOAA) with effective capability for global monitoring. The WOAA could establish centers for collection, reduction, and analysis of all environmental data. The processed data could be loaded into a real-time data base accessible to user agencies and institutions through a time-sharing network. The real-time data base could be updated at intervals pertinent to the events or conditions being monitored. Data displaced from the real-time data base would be added to an historical data base in order to update time series and long-term means.

User agencies could select, manipulate, and further analyze data from either the real-time or historical data bases and, if appropriate, store results back into the system to be available to other users in the network. For example, generalized weather forecasts prepared by a world or national meteorological center might be retrieved, through the time-sharing network, at some particular service agency's center and tailored to the needs of that agency's constituency.

Consider the application of this conceptually ideal monitoring system toward achievement of efficient harvesting of living marine resources and effective resource management. The environment relates to these objectives in several ways. Thermal conditions, for example, establish the territorial range which particular species inhabit, and therefore delineate the fishing grounds. In temperate and colder zones, thermal conditions may have large seasonal variations which influence migration patterns and therefore delimit the fishing season. Deviations from normal environmental conditions affect the survival (abundance) and migration behavior (availability) of fish. Prognostic information on long-term trends in environmental conditions and on anomalous year-to-year fluctuations could be applied in planning and policy decisions by producers, processors, and resource managers. Analyses and short-term prognoses have application for tactical and operational decisions.

Oceanographic analyses applicable to fishing operations might include surface temperature and salinity, surface currents, location of surface convergence and divergence lines, subsurface thermal and salinity structure, and subsurface current structure.

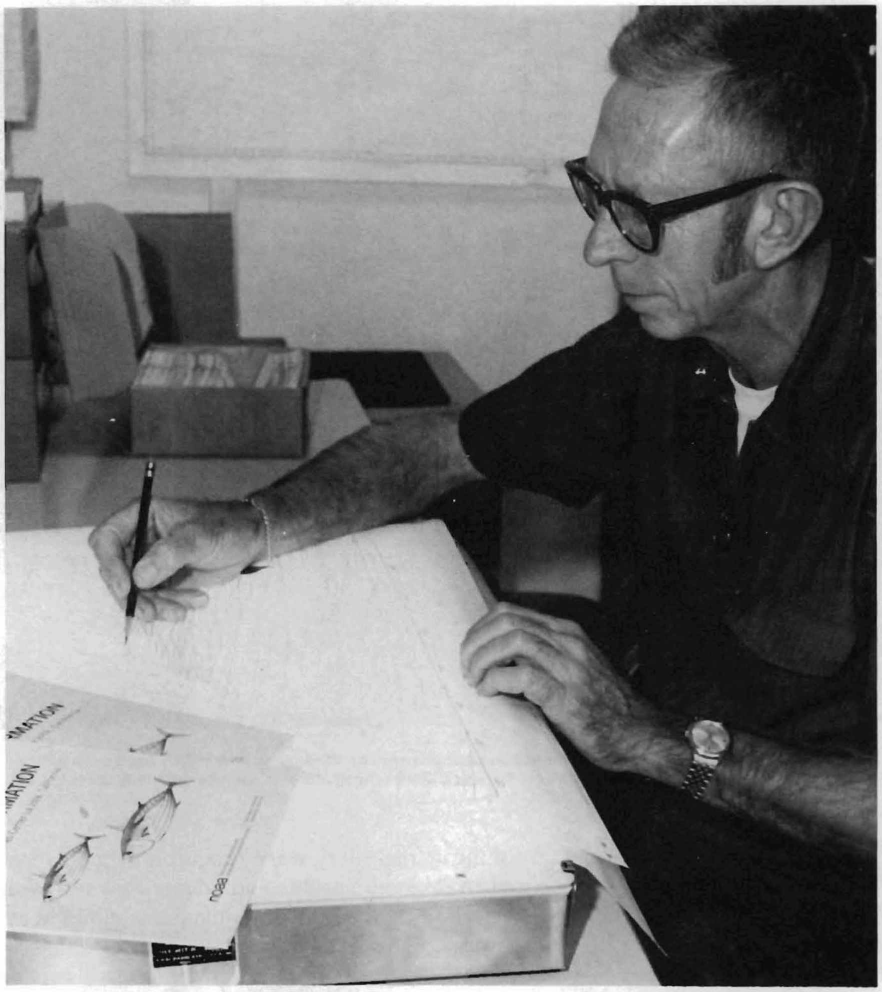

Figure 2.—Sea surface temperature data application are edited, summarized, and plotted by computer. The final analysis of isotherms is drawn by hand. Such maps appear monthly in the publication *Fishing Information*.

For planning and management applications which do not require environmental information on a real-time basis, analyses of oceanic properties could be prepared for time spans associated with significant changes in a fishery during or between seasons. The selection of properties or fields to be analyzed could be based on either established or potential information value. Particular analyses with wide application might be loaded into a special products data-base in the time-sharing network and made available to nonagency users, fishery-related or otherwise.

Environmental research to advance basic understanding of processes and to develop applications could provide feedback into the monitoring system through refinement of the specification of time and space scales for observational networks, the properties to be measured and the observing techniques.

In summary, the principal elements of the idealized environmental information system are:

1) Capability for global monitoring of oceanic and atmospheric properties, circulations, and energy and momentum fluxes on time and space scales commensurate with significant fluctuations and events in the ocean-atmosphere system.

2) Global collection and data reduction and archival facilities in which historical and current environmental data bases would be maintained and made accessible to user agencies and institutions in a time-sharing network.

3) Partitioning of basic analysis and forecast responsibilities among user agencies according to their respective missions or objectives. Adaptation of basic outputs by other agencies to satisfy particular constituency requirements.

4) Global radio and satellite communications capability for coordinated transmission of environmental information products to ships at sea and remote land stations.

5) Provision for an environmental information products file in the time-sharing system for users with requirements for immediate access to the information.

6) Provision for timely preparation and dissemination by mail of time-averaged analysis and other products not in immediate demand.

7) Ongoing research to advance understanding of basic processes in the ocean-atmosphere system, to develop capability to predict anomalous fluctuations and, for fisheries management, to determine the effects on the fisheries of such fluctuations.

ENVIRONMENTAL MONITORING ACTIVITIES AT THE SOUTHWEST FISHERIES CENTER

Three principal activities concerned with contribution to and application of environmental monitoring which have been developed at the Southwest Fisheries Center (SWFC) are: 1) the radio facsimile (FAX) advisory program, 2) the publication of *Fishing Information*, and 3) the expendable bathythermograph (XBT) ship-of-opportunity program.

FAX Program

The FAX program evolved out of the need to supplement the existing environmental monitoring effort in the eastern tropical Pacific. Recognition of this need was stimulated by EASTROPAC, an international cooperative investigation of the eastern tropical Pacific, which was intended to produce information necessary for a more effective use of the marine resources of that area, especially tropical tunas. It was apparent that biological and physical properties alike were subject to significant spatial and temporal variations. It was also apparent that the tropical tuna fishing fleet afforded the best opportunity for obtaining environmental observations in the tuna habitat.

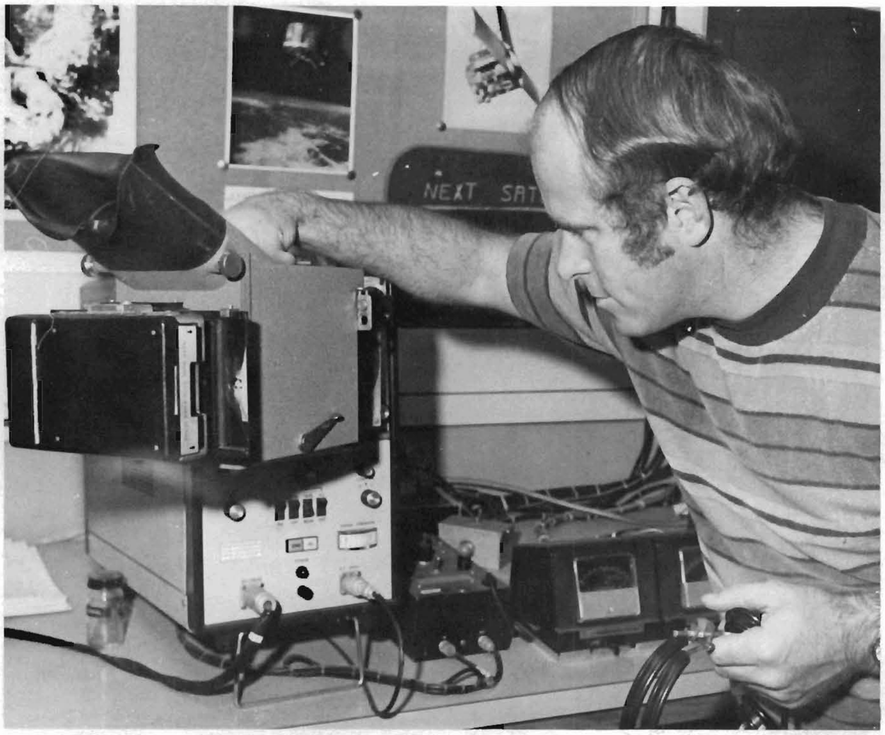

Figure 3.—Observations of cloud cover and weather phenomena transmitted from NOAA weather satellites can be received directly at the Southwest Fisheries Center. Application of satellite data to monitor ocean surface conditions is under development.

The NMFS's need for data from the eastern tropical Pacific was shared by the U.S. Navy's Fleet Numerical Weather Central (FNWC). Environmental data are used by FNWC to prepare analyses and forecasts of oceanic and atmospheric fields in support of U.S. Navy operations. Consequently, FNWC requires this data on a real-time basis.

The NMFS and FNWC recognized their mutual interest in enlisting the cooperation of fishermen for collection and transmission of observational data. They also recognized both an obstacle in securing such cooperation—that being a disinclination of tuna vessel captains to reveal their position on the fishing grounds—and a need to provide the fishermen with some incentive to take and transmit observations. The obstacle was removed through innovation of an encoding scheme for transmitting data messages which assured skippers of confidentiality with respect to their position. The incentive was provided in the form of wind, weather, and sea-state advisory charts, prepared especially for the area of the tropical tuna fishery and transmitted by radio facsimile from NMFS-licensed radio station WWD.

To implement the program, facsimile recorders were procured from government surplus and adapted for use with shipboard communications equipment. These recorders have been installed on more than 55 participating vessels under a reciprocal agreement providing for daily data transmissions from the fishing grounds. In addition, there are approximately 20 vessels in the program with privately owned units. Each vessel is furnished with its own unique encoding chart prepared at FNWC. The decoding keys are locked into the Navy computer, accessible only to the program which processes the observational messages. All participating vessels are expected to take and transmit surface weather observations, including wind speed and direction, weather, cloud cover, barometric pressure, air temperature, sea-surface temperature, swell direction, and wave height. Some 20-25 vessels in the tropical tuna fleet are equipped with XBT systems and report subsurface temperatures in the BATHY message format. The BATHY messages include temperatures and depths at significant points down to 500 meters, extracted from XBT analog traces. Maintenance of the XBT and FAX equipment is performed by SWFC personnel.

In practice, tuna vessels at sea begin transmission of weather and BATHY messages to station WWD each day about midafternoon. The messages are relayed via teletype line to SWFC and accumulated on a magnetic tape loop in the collect and transmit terminal unit of the Navy Environmental Data Network tie-line. At scheduled times, messages accumulated on the magnetic tape are sent over the tie-line to the computer at FNWC, decoded and processed for input to the FNWC operational programs. The decoded messages, along with other reports from the eastern tropical Pacific region, are sent back over the FNWC tie-line to SWFC and also to the NWS forecast office at Redwood City, Calif.

Data originating from tuna vessels, received at SWFC from FNWC, are punched on cards to be added to the environmental data base. Wind and sea-state parameters are extracted from these data and plotted on the current working charts used in preparation of the FAX advisories. Synoptic marine reports from merchant ships received over NWS meteorological teletype circuits also are used for this purpose, along with analyses and forecasts received over the NWS facsimile line and the FNWC tie-line and satellite pictures from NWS facsimile and from the SWFC direct readout system.

The weather advisory charts developed by the FAX program at the SWFC consist of a wind and weather forecast and a sea-state forecast. Prior to August 1974, these charts were transmitted from station WWD daily except Saturday and Sunday at about 4:15 p.m. The format and content of the SWFC FAX charts evolved through feedback from the fishermen. In addition to forecast wind speeds and directions, they depict the configuration of the Inter-Tropical Convergence Zone (ITCZ) and the locations of incipient tropical storms, which tend to develop along it. Such storms can intensify suddenly and pose a hazard to tuna boats which tend to fish in or near the ITCZ, trying to avoid strong prevailing winds outside but also wary of disturbances inside.

The National Weather Service (NWS) became a participant in the program in June 1974. A data line was established from the NWS forecast office, Redwood City, Calif., to radio station

WWD and to the SWFC, La Jolla, Calif., to be used for transmission of wind and weather and sea-state forecast charts prepared by NWS. Initially, the NWS charts were broadcast from WWD to the tuna fleet on weekends, to fill the gap in the SWFC transmissions, and recorded weekdays at the SWFC for evaluation and assessment of compatibility in format and in depiction of significant forecast elements.

Since August 1974, the NWS FAX charts have been broadcast from WWD daily. Surveillance of wind and weather conditions in the eastern tropical Pacific has been continued at SWFC, however, to insure that supplementary verbal advisories are broadcast from station WWD when appropriate, and to respond to direct requests from tuna vessels for information in specific situations.

In addition to the daily wind, weather, and sea state FAX advisories, three charts depicting ocean conditions are prepared at SWFC and transmitted by radio facsimile weekly. These are a sea-surface temperature analysis, a mixed layer depth analysis, and a sea-surface temperature difference chart which compares present conditions with those in the corresponding week of the previous year.

The success of the FAX program depends on continuing participation of a large number of tuna vessel owners and captains. The importance of taking observations, encoding them properly, and transmitting the radio messages must be stressed repeatedly. On the other hand, dialogue with the fishermen is also necessary to modify and adapt the advisory products as nearly as possible to their needs.

The weather logs and XBT records kept aboard the tuna vessels are collected by SWFC personnel when the vessels return to San Diego. Data taken on the fishing grounds but not received through the real-time transmission system are extracted from the logs and added to the environmental data base.

Figure 4.—Facsimile charts sent via land line from the San Francisco Weather Service Forecast Office are received simultaneously at the Southwest Fisheries Center and at radio station WWD, where they are recorded on magnetic tape. Visual inspection is made prior to transmission time for quality control.

Fishing Information

Charts of sea-surface temperature (SST) for the eastern north Pacific were published by the Honolulu Laboratory of NMFS (then the Bureau of Commercial Fisheries, BCF) from 1957 through 1959 in connection with a study of the distribution of north Pacific albacore. Responsibility for preparation of the charts was assumed by the BCF Tuna Forecasting Program, San Diego, Calif. in 1960, in order to provide up-to-date SST information to the tuna fishing industry, governmental fishery agencies, marine scientists, and meteorologists (Johnson, Flittner, and Cline, 1965). This program also undertook the compilation and publication of historical SST data back to 1947, in furtherance of studies on tuna environment (Johnson, 1961; Renner, 1963).

Initially, the SST charts were issued monthly for the region north of lat. 20°N and east of long. 180° and, during the albacore fishing season, semimonthly for the region of lat. 25° to 52°N and east of long. 136°W. Monthly SST plots for 1-degree squares were prepared for the eastern tropical Pacific between lat. 20° N and 20°S. The computation of the monthly and semimonthly mean temperature values, and the plotting of these values on base maps for analyses of the temperature fields, were done by hand. As emphasis shifted to automatic data processing and feedback from users identified additional needs for environmental information, the analyses were extended to include other regions and other properties.

Fishing Information now contains the following monthly charts: a) Sea surface temperature for the eastern north Pacific; b) Sea surface temperature for the western north Pacific; c) Sea surface temperature for the eastern tropical Pacific; d) Deviations from long-term means of a), b), and c); e) Difference between a) and the corresponding SST field one year earlier; f) Sea level pressure and resultant wind (both current month and long-term monthly means) for the eastern north Pacific.

Fishing Information also contains graphs of subsurface temperature structure along ships' routes from Hawaii to U.S. west coast ports, narrative descriptions of the significant features of the charts, and articles on the albacore fishery at the beginning and end of the albacore fishing season.

The semimonthly SST charts are now published year-round as the *Fishing Information* supplement. During the albacore fishing season, they are accompanied by the *Albacore Bulletin* which contains timely information on fishing conditions and on the progress of the fishery.

In addition to the charts listed above, a set of tabulations is produced each month which contains average SST's, air temperatures, dew point temperatures, sea level pressures, cloud amounts, and resultant winds for 5-degree squares. From these monthly averages of observed environmental variables are computed the principal components of heat exchange at the sea surface, including incoming radiation, reflection, back-radiation, evaporation, and sensible heat flux. The tabulations also contain deviations of each of the observed and computed variables from their respective long-term monthly means. These monthly tabulations are not routinely distributed, but are available for on-site use by local users. Also, a preliminary run of the 5-degree averages is made a few days before the end of each month for use by the Long Range Prediction Group of the National Weather Service. Cooperation with other organizations in this way offers potential benefit through progress in understanding and prediction of large-scale environmental fluctuations.

The computation of heat exchange components from monthly averages of observed environmental variables gives relatively gross estimates of heat flux across the sea surface. Although there have been attempts to use such estimates in oceanic heat budget studies, their value for monitoring significant fluctuations has not been fully evaluated. To make the information more widely available, an 11-year series (1961-1971) of total monthly heat exchange has been compiled in chart form for the eastern north Pacific, and published along with monthly mean charts of each of the principal components averaged over the same period (Clark et al., 1974).

The principal source of data for the environmental charts prepared by the SWFC, other than reports from tuna vessels, are the 6-hourly synoptic ship's weather observations transmitted from ships at sea in the International Ship's Meteorological Code and collected by NWS. The system developed by the Tuna Forecasting Program in 1960 for processing the observations employed a computer program which produced printed SST summaries and other parameters at the end of each month. The summary values were hand plotted

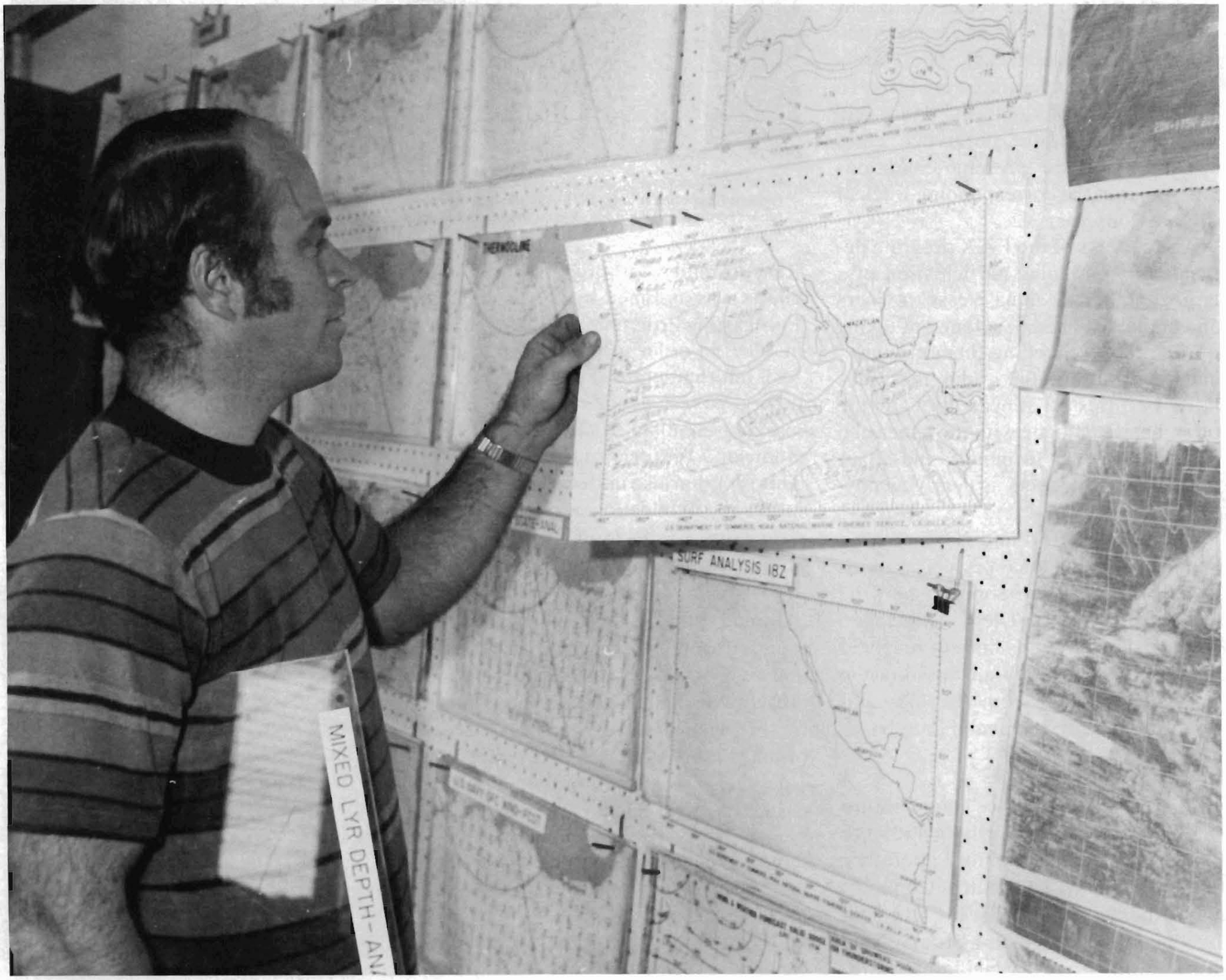

Figure 5.—Advisory charts prepared for radio facsimile transmission are displayed for convenient reference along with environmental charts and satellite pictures received from the National Weather Service, and Fleet Numerical Weather Central.

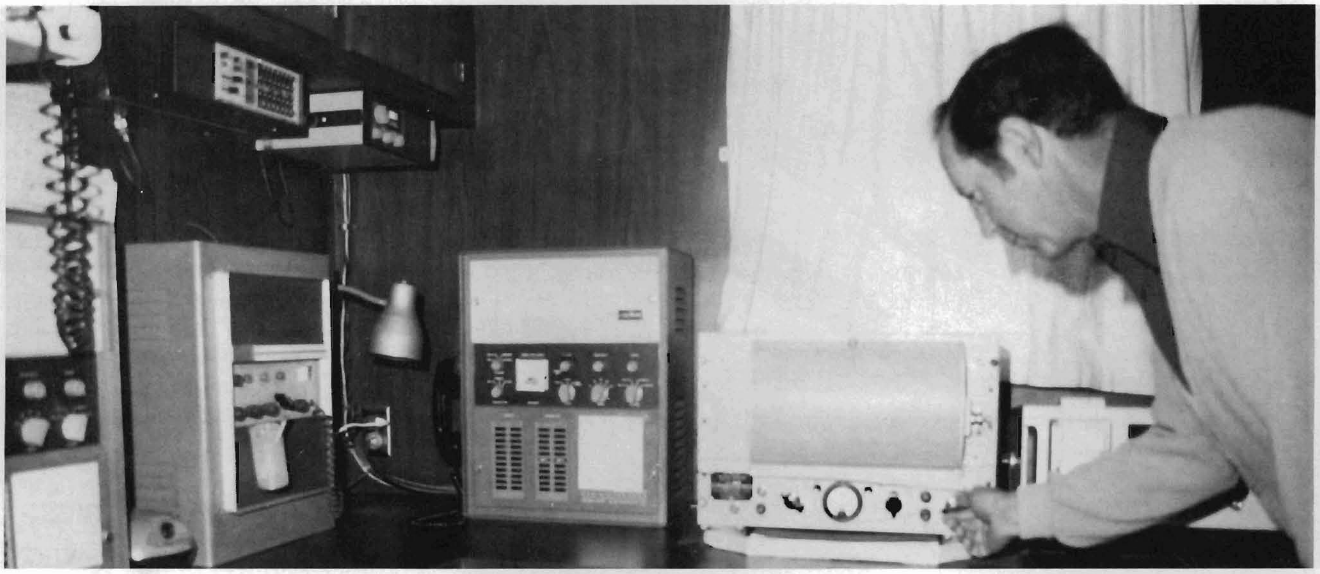

Figure 6.—Weather advisory charts can be received daily by fishing vessels such as this one equipped with radio facsimile recorders. Observational data received from the fishing vessels contribute significantly to the accuracy of the advisories.

and analyzed to prepare the environmental charts for *Fishing Information*. The original observations were saved on punched cards.

Subsequently, programs were added or modified to produce new outputs such as digital plots to replace those formerly done by hand, and special printouts formatted in a geographical grid for convenient reference. The present system provides for frequent update and ready accessibility of both current and past data on disk and magnetic tape files so that operational programs can be run on schedule and special analyses or plots for any time period and any specified region can be run as required.

Ship-of-Opportunity Program

This program was initiated to expedite utilization of a new instrument system (the XBT) capable of augmenting subsurface temperature monitoring and to apply the new system to create time series of subsurface temperature data along well-frequented shipping routes (Saur and Stevens, 1972). Such data are needed for the identification, quantitative description, and understanding of seasonal and nonseasonal changes in the subsurface temperature structure and heat content and of mass transports (through geostrophic estimation of currents) in the upper layers of the tropical and northeast Pacific Ocean. The program activities comprise three phases: 1) Data collection, in which observations of surface salinity and of vertical temperature profiles are made at 120-170 km intervals with expendable bathythermograph instrumentation aboard ships of opportunity; 2) Data processing, in which the observations are digitized, edited, printed for convenient reference, and added to the XBT data base for research; and 3) Data analysis, in which temperature-depth sections are prepared and the observations are analyzed to depict changes in subsurface ocean conditions.

The ship-of-opportunity program started in 1966 with a single ship, the Matson Navigation Company's bulk sugar carrier *Californian*, which made about two trips per month on the San Francisco-Hawaii run. The present program is considerably larger and, in 1974, involved three shipping companies and nine different ships.[2] During that year the program produced 52 sections between San Francisco and Hawaii, 27 sections between Los Angeles and Hawaii, 10 sections between Seattle and Hawaii, 2 sections between Alaska and Hawaii, 4 sections between Tahiti and Hawaii, and 4 sections between Samoa and Hawaii.

The program is conducted jointly with the NMFS Pacific Environmental Group, Monterey, Calif., where the digitization and computer analysis of subsurface temperature structures is performed and through which liaison with cooperating ships is supervised. Responsibility for the data analysis was transferred from SWFC to the Scripps Institution of Oceanography (project NORPAX) at the end of 1974. The program interfaces with FNWC interests in global monitoring of subsurface temperature on a real-time basis and with academic interests in understanding the processes of air-sea interaction and fluctuations in oceanic heat storage. The program receives support from FNWC, in the form of computer time and expendable probes, and from the National Science Foundation and the Office of Naval Research through project funding.

FNWC has supported the installation of XBT systems on merchant, fishing, and research vessels to supplement those on naval ships in order to obtain broad geographical coverage with sampling intervals sufficient to resolve large-scale oceanic features. For definition of mesoscale eddies, which have come under recent investigation by oceanographers and may be important in connection with transient ocean fronts, much finer sampling is required. Such sampling can be carried out from merchant ships only when project observers are aboard. The NMFS program has endeavored to maintain an intermediate sampling interval sufficient to identify transition zone characteristics between water masses and to reveal significant fluctuations along repeated tracks.

[2]Matson Navigation Company, Chevron Shipping Company, and Pacific Far East Line. Mention of trade names, commercial products, or firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

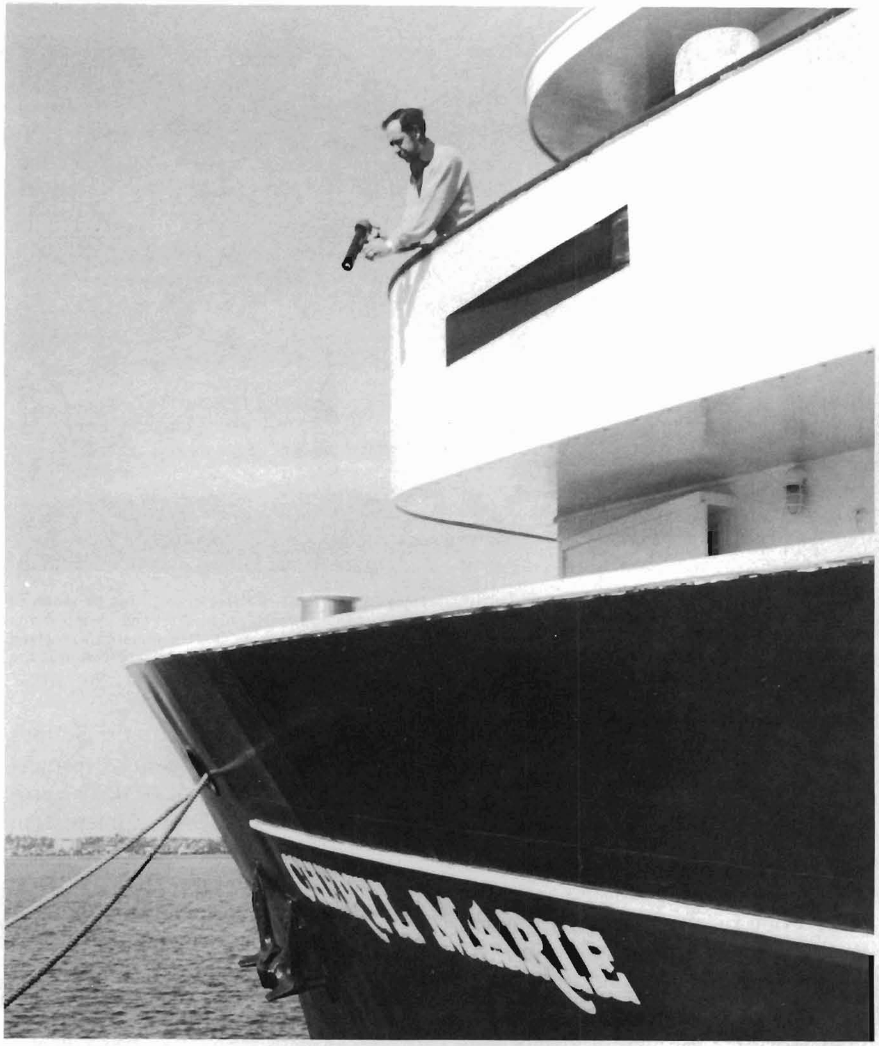

Figure 7.—Some fishing vessels are equipped with expendable bathythermograph systems. Temperature-sensing probes, released from a hand-held launcher, send data back to the vessel through fine conductor wires as they descend through the water.

Ancillary Information Sources

In establishing capability for monitoring environmental conditions of concern to fisheries, SWFC has become an acquisition center for real-time environmental information in a variety of forms. Analyses and forecasts of subsurface, surface, and upper air conditions are received daily over the FNWC tie-line and plotted as charts on CalComp plotters. A similar array of products is received over the NWS facsimile circuit. The NWS circuit also carries gridded satellite pictures from polar-orbiting and geostationary weather satellites. These pictures are particularly useful in determining the location and configuration of the ITCZ and in following the development of tropical storms. SWFC also can receive pictures transmitted directly from the polar-orbiting satellites on nearby orbits which occur twice each day. The satellite pictures, oceanographic and meteorological analyses, and forecast charts are displayed on the chart board in the environmental data room for convenient reference by environmental analysts, other SWFC staff, and visitors. The daily proximity of current environmental charts helps the analyst become attuned to the time and space scales of real-time events and develop insights which can lead to new approaches in the investigation of the ocean-atmosphere system.

Weather satellites have great potential for ocean monitoring, and the National Environmental Satellite Service has spent considerable effort in the interpretation of data from scanning radiometer infrared sensors to determine sea-surface temperatures. Although significant problems exist, one of the foremost being cloud contamination, this effort appears certain to lead to useful application, and growing consideration has been give to ways of incorporating this information into the routine SST analyses. The SWFC has cooperated with the Inter-American Tropical Tuna Commission, through use of the direct readout satellite receiving system, in studies to evaluate the feasibility of using data from scanning radiometer sensors aboard NOAA satellites to discern oceanic fronts and to apply satellite data to problems of fishery oceanography (Stevenson and Miller, 1974).

APPLICATION TO FISHERIES

The purposes underlying SWFC's involvement in environmental monitoring, through the programs described in the preceding section, are to contribute to the development of the real-time fishery prediction capability and effective resource management. A fishery prediction and management system should accomplish two basic functions: 1) Help maintain the fishery at a level of abundance consistent with optimum yield and recoverability from adverse environmental conditions or excessive fishing pressure; and 2) Increase the efficiency of harvesting, through prediction of distribution and availability, in order to maintain a viable fishery that can deliver fishery products to the consumer at an economical and competitive price. By strengthening the total environmental monitoring effort in areas which are important to fisheries, the potential benefit of research in relationships between the environment and fisheries is enhanced.

Environmental data taken by tropical tuna fishermen on the fishing grounds in the eastern tropical Pacific during 1971-1974, as a direct result of the FAX program, are shown in Table 1. These data are being utilized in ongoing research on the relationship between environmental parameters and fishing success.

The FAX program contributes to the efficiency of harvesting by meeting the needs of tropical tuna fishermen for information on weather and ocean conditions. Interviews with 22 skippers and navigators were conducted between December 1973 and March 1974 to obtain the fishermen's evaluation of the

Table 1.—Summary of marine observations, 1971-1974.

Year	Weather	BATHY	Total observations	Boats
Collected by radio station WWD				
1971	[1]844	684	1,528	3-25
1972	2,150	498	2,648	39-53
1973	2,579	570	3,149	55-57
1974	2,178	408	2,586	61-63
Total	7,751	2,160	9,911	
Collected from weather and BATHY logs				
1971	—[2]	886	—[2]	3-25
1972	2,610	665	3,275	39-53
1973	5,167	1,160	6,237	55-57
[3]1974	3,265	616	3,881	61-63
Total	11,042	3,327	14,369	

[1]WWD did not collect weather observations on a regular basis until September of 1971.
[2]Weather observations from fishing vessels were integrated into the monthly deck of synoptic observations and not separately accounted for.
[3]1974 figures are based on projections pending receipt of all of the 1974 data.

FAX products. Nearly all of those interviewed indicated that they copied the FAX charts every day, if possible, and listened to the verbal advisories broadcast on weekends when severe wind or weather conditions were expected.

The information regarded as most valuable is the location and expected movements of chubascos (tropical storms) and of extreme wind conditions such as occur in the Gulf of Tehuantepec. Sea and swell advisories and the sea surface temperature charts were rated next in value for aid in deciding when and where to fish. The mixed layer depth charts are being copied by most of the vessels, judging from the sample response, but were given a high value rating in only a few cases. These charts represent an effort to furnish environmental information to the fisherman on a provisional basis and thereby enlist his participation in developing the potential application of such information to fishing strategy. The charts also form a time series depicting weekly changes in oceanographic features, which may induce short-term variations in fish behavior and distribution.

The FAX program also provides a service to the albacore fishery through weekly transmission of sea surface temperature charts covering the albacore fishing grounds. This activity contributes to the joint research effort of the SWFC Albacore Research Investigation and the American Fishermen's Research Foundation (AFRF). These charts are copied by about a dozen vessels equipped with FAX recorders by AFRF. As with the tropical charts, they provide the fisherman with environmental information applicable to fishing strategy, and also support the work of the albacore investigations in modeling the albacore fishery.

The series of monthly and semimonthly charts of sea surface temperature and other environmental fields, published in *Fishing Information* and its *Supplement*, go back as far as 1960. They are sent to a distribution list of some 1,196 individuals, organizations, institutions, and agencies, some of whom receive copies for further distribution. In order to assess the impact and utilization of these charts, recipients were asked to fill out and return a brief questionnaire distributed with the November 1973 issue. A total of 575 questionnaires were returned. They reveal the following breakdown by user classification:

User classification	Percent of total returns
Commercial fishermen	38
Processors and distributors	3
Sport fishermen	9
Fishery managers	10
Marine scientists	16
Teachers	10
Other	14

The last category includes meteorologists, military oceanographers, marine suppliers, librarians, trade journal publishers, and others. The survey revealed that the charts are used primarily for fishing strategy by commercial and sport fishermen, for planning by processors, for fishery research by fishery managers, and for environmental research and teaching by marine scientists, meteorologists, and educators. The survey indicated greatest interest in the SST charts for the eastern north Pacific; however, all of the environmental charts received favorable response.

Overall, the response to the questionnaire affirms that the program is accomplishing its original objectives. It benefits the industry by providing useful environmental information and contributes to potential advances in fishery prediction by benefiting environmental and fishery research. It should be noted that the preparation and distribution of environmental charts by this program is a unique undertaking, and to some degree, provides the only generally available source of quasi-current information on abnormal conditions, such as El Niño occurrences. The SWFC receives numerous inquiries during such anomalous events concerning the status and tendency of environmental conditions.

Although much work has been done on the relation of fish to environmental conditions, the problem has hardly been scratched. An intensive and long-range research effort must be sustained to determine the specific extent and nature of environmental control on the distribution, survival, and behavior of fish. A similar effort must be made to understand the forces that produce environmental fluctuations which may have significant effects on a population. Such efforts must be supported by a comprehensive monitoring of the ocean-atmosphere environment and by reliable assessments of sizes and locations of populations. Only when adequate descriptions of relevant environmental fields are available along with adequate descriptions of fish stock distribution, can the knowledge of environmental processes and of behavioral responses to such processes be applied effectively in a fishery prediction system to control the fishery.

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