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Fishery Engineering Advancements: A 5-Year SEFC Progress Report

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ABSTRACT–The Southeast Fisheries Center of the National Marine Fisheries Service, NOAA, formally established the Technology Division in 1973 to apply and monitor technological advancements, and to develop new methods and increase the accuracy and efficiency of old methods for assessment and utilization of living marine resources.

Two groups comprise the Technology Division: Harvesting Technology and the Fisheries Engineering Laboratory. A summary of activities undertaken by the Division is contained in this report. These activities are Satellite Application, Remote Sensing, Sampling and Analysis Systems, Harvesting Technology and Conservation Engineering, Data Management, and Planning and Systems Analysis.

INTRODUCTION

Man's increasingly diversified use of the oceans, coupled with the complexity and vastness of marine ecosystems, dictates the need for technological advancements to accelerate the collecting, processing, and managing of resource assessment information required to make intelligent fisheries management decisions. Therefore, the Southeast Fisheries Center (SEFC) of the National Marine Fisheries Service (NMFS), NOAA, established a Fisheries Engineering Program in 1971 to provide the emphasis necessary to fulfill these needs.

In 1973, an SEFC reorganization established the Technology Division, composed of existing engineering elements located at the Fisheries Engineering Laboratory (FEL), Bay Saint Louis, Miss., and the Pascagoula Fisheries Laboratory, Pascagoula, Miss. This document is a compilation of the various projects undertaken by these elements over the past 5 years.

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Missions and Objectives

NMFS has a well-established program of biological sampling and research; however, sufficient engineering capability has not always been available to apply engineering talents and principles to fishery problems when technology was found to be a major constraint to achieving NMFS goals. The mission of the Technology Division is to satisfy the technological needs of the other SEFC Divisions; promote technological advancements in fisheries management and utilization; and apply engineering expertise to fishery problems when technology is found to be a major constraint to achieving NMFS goals. The mission is being implemented through three organizational objectives: 1) Development of sampling, monitoring, and tracking systems to increase data return, coverage, and accuracy; 2) development of fishing gear and tactics to efficiently harvest latent and underutilized fishery resources, conserve nontarget species, and reduce damage to marine habitats; and 3) development of data management systems and techniques for efficient data storage, retrieval, display, and analysis.

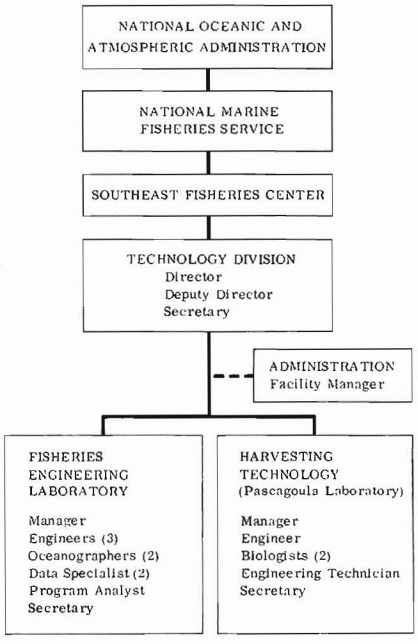
Organizational Structure

The organizational structure of the Technology Division (Fig. 1) consists of four elements: Management, administration, FEL, and Harvesting Technology. Management establishes policies, procedures, and new program areas, and maintains liaison with SEFC, other NMFS organizational elements, and other agencies. Administration includes functions such as facility management, personnel, and purchasing. The FEL is responsible for aerospace remote sensing applications, systems analysis, and data management functions. Harvesting Technology deals with underwater remote sensing, conservation engineering, and harvesting systems. Both elements are active in technology transfer to, and applications engineering for, affected user groups.

Management Concept

A project engineer is assigned to each discrete element of work. It is his responsibility to conduct that effort in a semiautonomous manner drawing on associates with special skills as required.

Figure 1.—Technology Division organizational structure.



Managers oversee and coordinate all activities. Periodic program reviews and regular staff meetings are used to keep management apprised.

Interagency Involvement

Most of the Technology Division is located at NASA's National Space Technology Laboratory (NSTL), Bay Saint Louis, Miss. The objective of NSTL is the application of technology in space and environmental sciences. These applications are stimulated by the catalytic effect of a multiagency operation sharing, interchanging, and utilizing individual research developments to enhance the entire NSTL technical and scientific community. Agencies colocated at NSTL include elements of NASA, NOAA, and EPA; the Departments of Interior, Transportation, and Defense; and Mississippi and Louisiana State governments and universities.

Work Breakdown

Activities have been categorized into the following work elements: Satellite Applications, Remote Sensing, Sampling and Analysis Systems, Harvesting Technology and Conservation Engineering, Data Management, and Planning and Systems Analysis. Each is discussed briefly in the following sections. One other element—Technology Transfer and Engineering Applications--provides an effective means to enable the transfer of appropriate technology to interested user groups. As such, this element is the vehicle for disseminating results of all the other work elements.

SATELLITE APPLICATIONS

Existing satellite-supported sensor systems, available for fishery applications, lack sufficient resolution for direct fish detection. However, the use of satellite sensors to measure selected oceanographic parameters and then use these measurements to predict the distribution and abundance of a fish species appears to be feasible (Vanselous and Kemmerer[1]). Two satellite investigations demonstrating this feasibility, the ERTS-1 Menhaden Investigation and the Skylab Gamefish Investigation, have been conducted by FEL. A third—the LANDSAT Menhaden and Thread Herring Investigation—is currently being conducted.

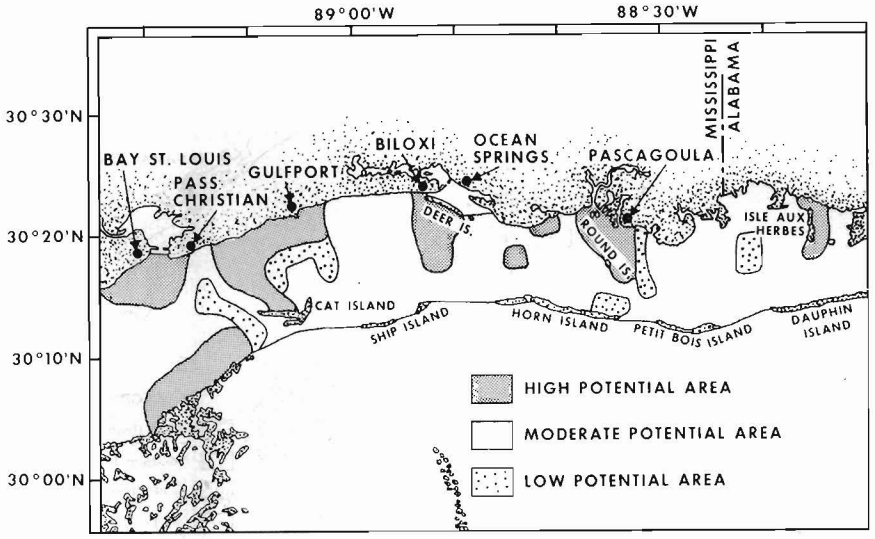


Figure 2.—Predictions for menhaden distribution in the Mississippi Sound on 7 August 1972. (Kemmerer et al., 1974.)

ERTS-1 Menhaden Investigation

The primary objective of the ERTS-1 Menhaden Investigation was to establish the feasibility of using satellite imagery for determining the abundance and distribution of adult menhaden, *Brevoortia patronus*, in the Mississippi Sound. The investigation began in July 1972 and lasted 18 months. Experimental rationale was to convert data obtained by ERTS-1 and aircraft-supported sensors into oceanographic data, derive statistically valid correlations between these data and the distribution and abundance of menhaden, and then determine if the relationships had meaning for commercial fishing operations and resource management.

Participating with NMFS in the experiment were the National Aeronautics and Space Administration (NASA) Earth Resources Laboratory and the National Fish Meal and Oil Association (NFMOA) through its contractor, EarthSat Corporation. NASA's role was to infer a series of oceanographic measurements from remotely sensed data; the NMFS responsibility was to convert these data into fish distribution and abundance information; and the NFMOA function was to develop utilization criteria for the fish distribution and abundance information.

The feasibility of using satellite-supported sensors to predict fish distribution was demonstrated (Kemmerer et al., 1974). ERTS-1 Multispectral Scanner imagery contained density levels which correlated with menhaden distribution. Further, these density levels correlated significantly with sea-truth measurements of Secchi disc transparency and water depth, two parameters which correlated significantly with menhaden distribution. Additionally, surface salinity, Forel-Ule color and chlorophyll-*a* content correlated with menhaden distribution.

A regression model was constructed to predict menhaden distribution in high, moderate, and low-potential categories, reflecting the probability of finding fish at certain points within the study area (Fig. 2). The model was devised empirically using sea-truth measurements of salinity, turbidity, water color, and water depth. These parameters, except depth, can be measured remotely; thus, the model appears to provide a potential tool for using satellite data for enhancing the harvest and management of menhaden.

[1] Vanselous, T. M., and A. J. Kemmerer. An overview of remote sensing applications to fisheries related problems. Proc. Symp. Util. Remote Sensing Data Southeast. U.S. Am. Soc. Photogramm., Athens, Ga., Jan. 1975, 12 p. Unpubl. rep.

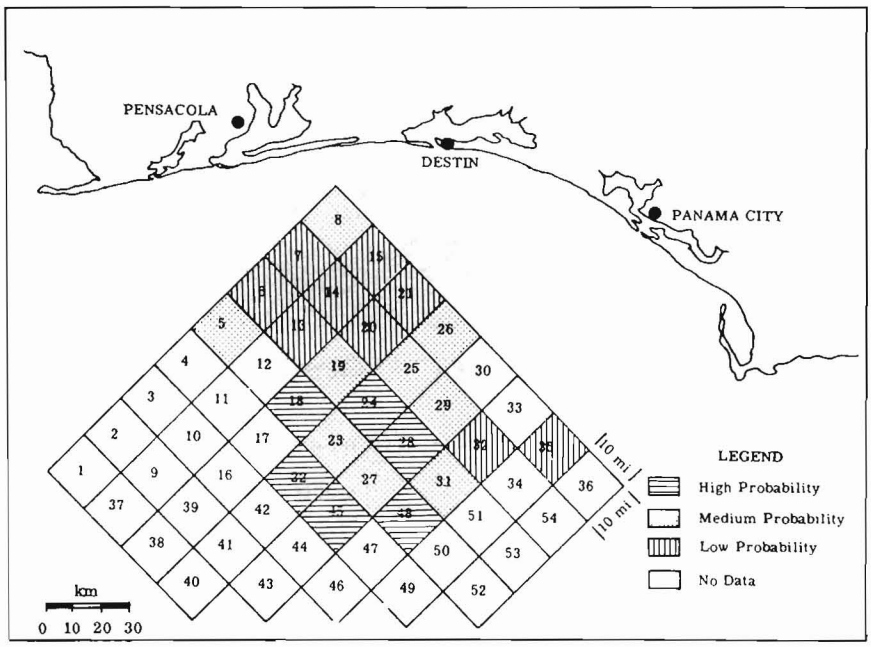


Figure 3.—Prediction results of 4 August data for white marlin. (Savastano et al., see footnote 2.)

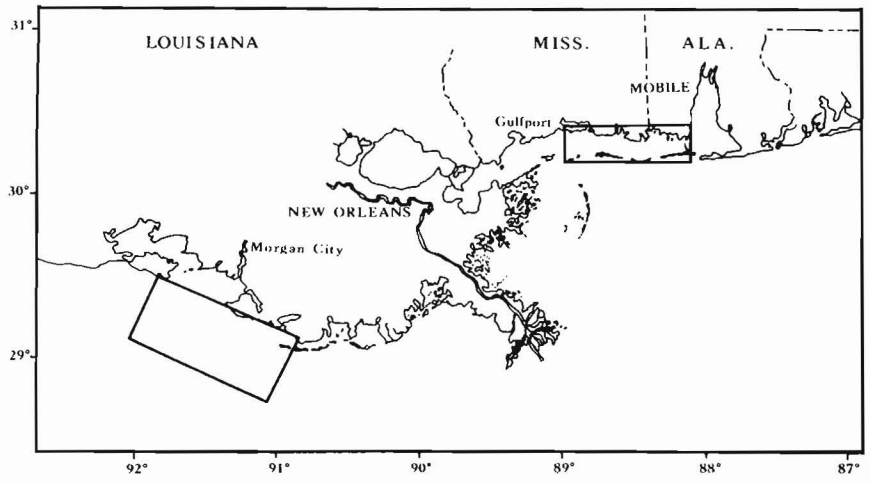


Figure 4.—LANDSAT Menhaden and Thread Herring Investigation test areas.

Skylab-3 Gamefish Investigation

A Skylab-3 experiment was initiated in April 1973 to establish the feasibility of utilizing remotely sensed data acquired from aircraft and satellite platforms to assess and monitor the distribution of oceanic gamefish. The test area was off Florida between Pensacola and Panama City in the northern Gulf of Mexico.

Gulf coast sportfishing clubs, NASA, and NMFS participated in the experiment. The experimental rationale was to establish correlations between selected oceanographic parameters measured remotely, and the fishing success experienced by participating anglers over a 2-day period. Several species known to be in the test area were initially selected as targets for the sportfishermen; however, analytical emphasis was given to white marlin, *Tetrapturus albidus,* because they provided the largest proportion of the sportsmen's catch.

The distribution of white marlin was demonstrated to be significantly correlated with chlorophyll-*a*, sea surface temperature, turbidity, and water density (Savastano et al.[2]). A predictive model for white marlin was developed (Fig. 3) based on these parameters which demonstrated a potential for increasing the probability of gamefishing success.

LANDSAT Menhaden and Thread Herring Investigation

As a logical progression to the previous experiments, a LANDSAT Menhaden and Thread Herring Investigation was initiated in April 1975. Its experimental design is based on the rationale used in the preceding investigations. The primary goal is to verify and refine the relationships of certain coastal and environmental parameters, observable from aerospace platforms, to the availability and distribution of Gulf menhaden. A secondary objective is to establish similar relationships for a potential commercial fish—thread herring, *Opisthonema oglinum*. As in the ERTS-1 Menhaden Investigation, primary participants are NMFS, NASA, and NFMOA.

Two test sites were selected (Fig. 4)—one in the Mississippi Sound and one south of Morgan City, La. The Mississippi Sound was the site of the previous ERTS-1 experiment, which left some questions unanswered. It was not clear whether density differences in satellite imagery, which correlated with fish distribution, represented turbidity or depth relationships. Additionally, sea-truth data appeared at times to be contaminated by maneuvering fishing vessels that produced plumes of turbidity, thereby possibly affecting the analyses. The second site, south of Morgan City, supports sizeable populations of both menhaden and thread herring and is an area of transition between estuarine and oceanic hydrologic zones.

Field operations were completed in September 1975. Primary data acquisition platforms included fishing vessels (with and without scientific observers aboard), oceanographic vessels, spotter aircraft, NASA low- and medium-altitude aircraft, and photographic aircraft. LANDSAT-1 and -2 provided satellite coverage of the test areas. Most sea-truth data have been formatted and stored on magnetic tape. Data analyses and conclusions are scheduled to be completed in early 1977.

[2]Savastano, K. J., E. J. Pastula, Jr., E. G. Woods, and K. J. Faller. Preliminary results of fisheries investigation associated with Skylab-3. Ninth Int. Symp. Remote Sensing Environ., Environ. Res. Inst. Mich., Apr. 1974, 30 p. Unpubl. rep.

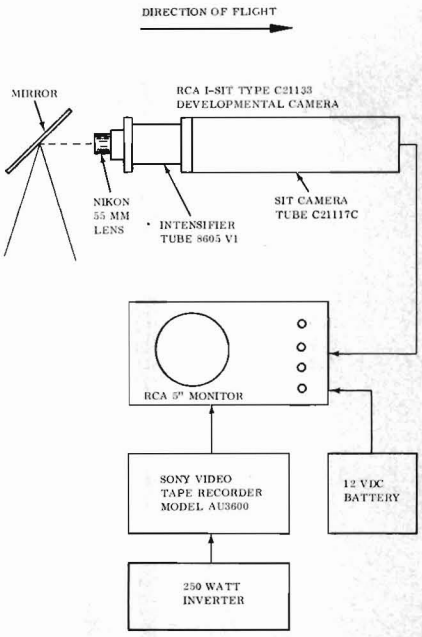


Figure 5.—Low-light-level television system block diagram. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

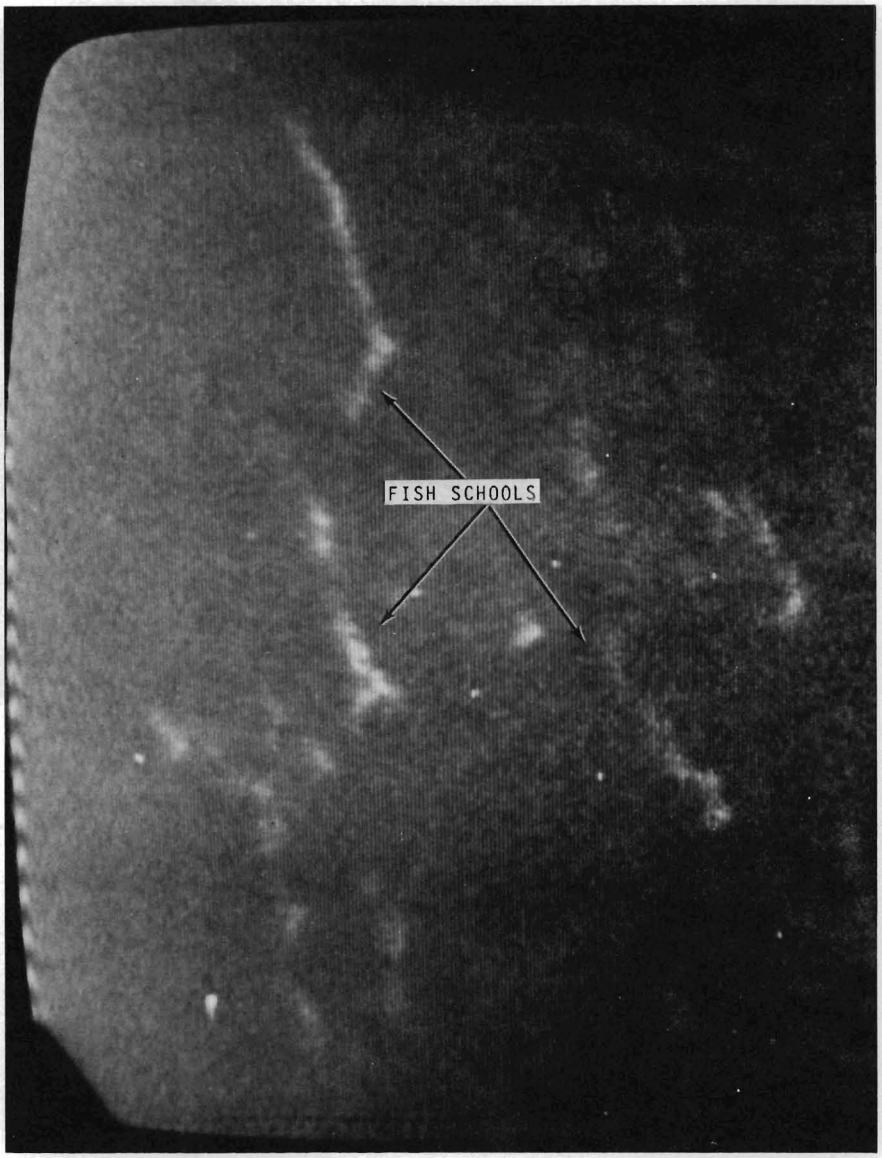


Figure 6.—Low-light-level television system video data showing schools of menhaden from 914.4 meters (3,000 feet).

Brazilian Shrimp Investigation

In support of the U.S.-Brazil Agreement of 9 May 1972 a preliminary study was implemented to ascertain if a relationship existed between the distribution of shrimp and a relatively constant high-turbidity zone along the northeast coast of South America. Using LANDSAT imagery, the study showed that the shrimp grounds could be divided into general regions of primary and secondary turbidity. The stratification of the turbidity patterns was found to be similar to the distribution of the shrimp fishery located off the coasts of Guyana, Surinam, and French Guiana. The four species of shrimp found in the area are distributed in distinct bands generally parallel to the coastline. Not only were the bands of shrimp distribution similar in orientation and shape to the primary and secondary turbidity region, but also the entire shrimp fishery was located within the general seaward limits of the turbidity region. A more comprehensive study has been proposed to further delineate the shrimp/turbidity relationship.

REMOTE SENSING

The objective of this program is to develop remote sensing systems to efficiently locate, identify, and quantify living marine resources. Two approaches are being investigated—airborne remote sensors, and surface and subsurface sensing systems. Airborne sensors are limited to the detection of epipelagic fishes and surface oceanographic phenomena which may influence pelagic and demersal species. Surface and subsurface sensors can provide valuable information about mid-water and benthic fishes and crustaceans, and related environmental parameters.

Low-Light-Level Television

The phenomenon of bioluminescence and the development of tactical night vision devices for the military in Vietnam led to an investigation of the applicability of low-light sensors for detection of fish schools. A number of system components have been tested and evaluated. The system currently used (Fig. 5) consists of a television camera fitted with an intensifier tube that amplifies light approximately 120,000 times, a 12.7-cm (5-inch) television monitor, a video tape recorder, and a power source. The system is used from aircraft operating at night during dark-of-the-moon periods. It detects and amplifies the bioluminescence caused by fish agitating dinoflagellates (very small plankton) in the water. The effect is a faint glow surrounding each fish and, in turn, the fish school. This glow can be easily observed with the low-light-level television (Fig. 6).

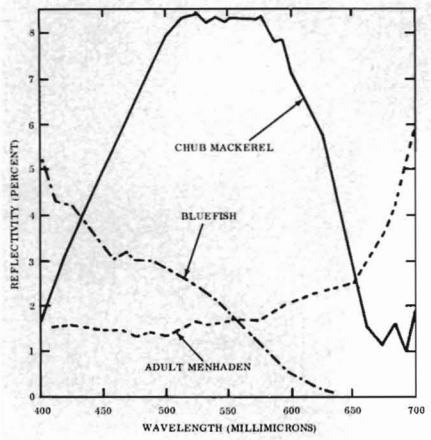


Figure 7.—Spectral signatures of three species of pelagic fishes.

The system has been used in a developmental mode to survey saury, *Cololabis saira,* northern anchovy, *Engraulis mordax,* and euphasiid shrimp schools in the Pacific Northwest; menhaden, *Brevoortia patronus,* and thread herring, *Opisthonema oglinum,* in the northern Gulf of Mexico; Atlantic herring, *Clupea harengus harengus,* off the northern coast of Scotland; bluefin tuna, *Thunnus thynnus,* off the New England and Florida coasts; and pilchard, *Sardinops ocellata,* off the coast of South Africa.

Aerial Photography

Aerial photography is probably used more than any other remote sensing technique for direct detection of selected species of fish and marine mammals. A standard aerial mapping camera equipped with a 22.9-cm (9-inch) film format, and 15.2-cm (6-inch) or 30.5-cm (12-inch) focal length lens is commonly used.

Many pelagic species exhibit unique spectral signatures which can be used to assist in the photographic identification and discrimination of fish against the light-absorbing water background. Bluefish, *Pomatomus saltatrix,* reflect highly in the blue portion of the spectrum (400-500 mμ), chub mackerel, *Scomber japonicus,* in the yellow-green portion (500-600 mμ), and menhaden, *Brevoortia* sp, in the red portion (600-700 mμ) (Fig. 7). Enhancement of these color differences through proper selection of film and filters produce contrasting fish school images (Fig. 8).

Figure 8.—Photographic imagery showing Atlantic bluefin tuna.

Laser

Airborne laser systems (Fig. 9) are being investigated as a possible future method of fish assessment. They have the potential of

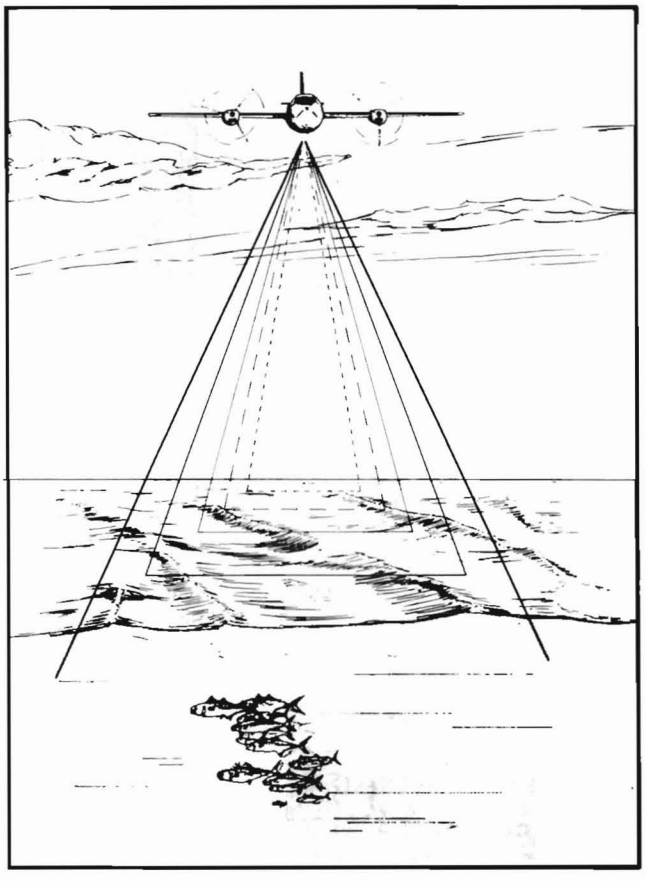


Figure 9.—Laser system survey pattern. (Woods, E. G. Recent developments in remote sensing technology for marine resource detection and monitoring. 62nd Statutory Meeting. International Council for the Exploration of the Sea, Copenhagen, Denmark, Sep.-Oct. 1974, 12 p. Unpubl. rep.)

being used during day and night, and acquiring data from significant depths. Nominal objectives of the developmental effort are detection, identification, and quantification of fish schools at various depths in the water column.

Application of laser technology to fish detection has received little attention to date, probably because laser systems were not sufficiently developed for airborne operations. Recent developments in laser technology, however, have increased the probability of developing a suitable laser survey system. A feasibility study was initiated in 1973 as the first step in laser application. Objectives of the study were to determine the feasibility of using lasers for detecting fish, and to generate a model defining the physical characteristics of laser light as it penetrates the water column, strikes a target, and returns to a suitable detector. Murphree et al. (1974) reported that the air-sea interface would permit entry of sufficient signal and return of meaningful fisheries information. This conclusion was based on perpendicular signal penetration. The effect of laser scanning and noise in the resulting signal are being investigated in a follow-on study.

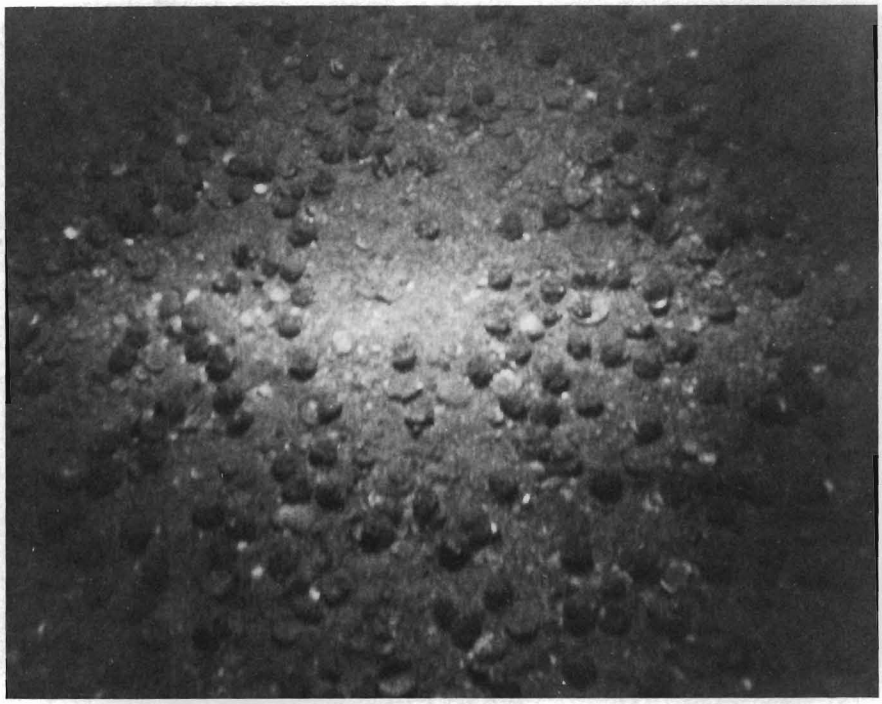


Figure 10.—Dense calico scallop concentration photographed by RUFAS I.

Spectrometer

Spectrometer investigations were initiated in 1968 to establish the feasibility of using various portions of the visible light spectrum for locating and identifying epipelagic fishes. Spectral systems were expected to record color and intensity of the reflection of the sun's rays off fish schools. These data were counted on to yield information on the location, identification, and biomass of epipelagic fish schools.

Initial tests were conducted in a laboratory environment where anesthetized fish were placed in a spectrometer's field of view and the spectral signatures recorded. Other tests used live fish schools impounded in nets below an offshore platform near Panama City, Fla., and in a tank system developed by FEL. Airborne tests were also conducted in the northern Gulf of Mexico and off the coast of southern California in conjunction with sea-truth fishing operations.

Analyses of test data revealed that while many fish exhibited unique spectral signatures, these signatures were virtually impossible to measure with available spectrometers under field conditions. The light reflected from the fish was so rapidly attenuated by the water that the spectrometer was unable to record significant spectral differences between the fish schools and their water environment.

Remote Underwater Fisheries Assessment System

The Remote Underwater Fisheries Assessment System (RUFAS) consists of a towed submerged platform equipped with lights, television and photographic cameras, and acoustic transducers (Seidel, 1970). It is flown several feet above the ocean floor by scientists aboard a research vessel using acoustical signals and television images to regulate flight. The system has been upgraded and used extensively by the NMFS Brunswick and Miami laboratories off the southeast coast of the United States for photographic surveys of calico scallop, *Argopecten gibbus*, beds (Fig. 10).

The first RUFAS system was so well received by marine investigators that an improved system, RUFAS II, was developed as a joint venture between Sea Grant and NMFS/SEFC. The principal differences are in design depth (400 fathoms compared with the 50-fathom depth limitation of RUFAS I), and an automatic flight control capability. RUFAS II can be programmed to fly at a constant height above the ocean floor, whereas RUFAS I has to be manually flown.

Hydroacoustics

The NMFS must develop an operational acoustic system for detection and quantification of fishery resources to meet the operational requirements unique to southeastern U.S. fishing conditions. Under contract to NMFS, the MIT Charles Stark Draper Laboratory developed a mathematical model which was assumed to provide unbiased estimates of the number of reflecting targets (fish) in an acoustical echo signal. An experimental program was initiated to test the model (Gandy, 1973) in a large water-filled tank with arrays of plastic-ball targets (Fig. 11). The experiments, however, did not validate the acoustic model. Subsequently, another mathematical model was developed that provided accurate estimates of target density based on the experimental data (Stevenson, 1974). Further testing will be required, however, before this model can be employed in an operational acoustic system.

In another application of acoustic

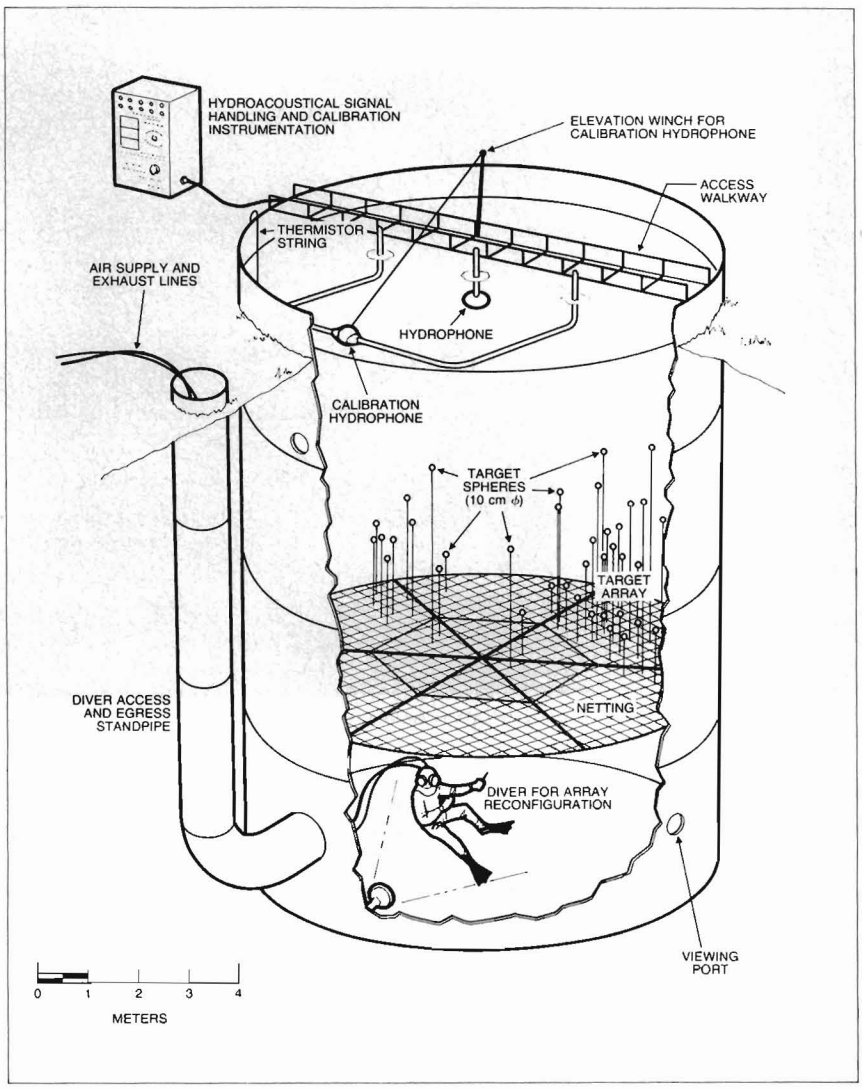


Figure 11.—Test configuration for testing hydroacoustics mathematical model. (Stevenson, E. A., and W. S. Shepard. Theory for hydroacoustic multiple target scattering assessment with experimental verification. Acoust. Soc. Am., San Franc., Calif., Nov. 1974. Unpubl. rep.)

technology, an imaging device (Shadowgraph), loaned by the Naval Coastal Systems Laboratory, was tested to determine its application to fishery resource assessment problems, and for locating and identifying underwater fishing obstructions. The experimental approach was to deploy the underwater acoustic imaging device and RUFAS over identical targets. Using the optical imagery from RUFAS as a standard, the acoustical image could then be analyzed for resolution and sensitivity.

The acoustic imaging device appeared to obtain adequate bottom profile and underwater obstruction data. The effectiveness of the system as a resource assessment tool was not definitively established. Further testing is planned.

SAMPLING AND ANALYSIS SYSTEMS

Sampling activities, especially in an assessment or exploration mode, require an understanding of the efficiency of the sampling device and the environmental conditions of the area being sampled to develop reliable evaluations of the resulting catch. Furthermore, the tedious process of manually analyzing the biological samples cannot keep pace with the demand for the resulting data. Studies have been undertaken to apply modeling techniques and advanced technology to ultimately provide better analytical results.

Net Systems Studies

A bongo net was selected to serve as a basis for the development of a theoretical approach to the understanding of plankton sampling systems. The object of the study was to mathematically describe the performance of different net systems. The approach considered system dynamics, hydrodynamic forces, sound and pressure fields, and consisted of mathematical and empirical studies. Preliminary studies resulted in a series of design improvements which were forwarded to the NMFS Marine Resources Monitoring, Assessment, and Prediction (MARMAP) Office.

Preliminary engineering studies also were completed on the development of a high-speed nektonic neuston sampler designed for minimum specimen damage. Numerous net configurations were considered, and a small boat hull capable of being towed to one side of a ship's wake at speeds up to 15 knots was proposed (Fig. 12). The proposed system consists of an opening on the forward undersurface which would divert water into a chamber shaped to accommodate a spray trajectory. The top of the boat's midsection was designed in the form of a dome, also conforming to a spray trajectory, to lead the spray into the mouth of a net. The net would retain the plankton while exit tubes in the stern emptied the boat in the manner of a self-bailing cockpit.

Both projects demonstrated a potential application to problems related to fisheries research. In each case, however, fiscal constraints caused further efforts to be held in abeyance. If completed, the plankton sampling system study would have produced: improved data leading to an understanding of the physical and biological processes of plankton sampling; minimization of data uncertainties and correlation of data from different systems; and optimization of conventional designs and determination of their limitations. Development of the high-speed neuston sampling system would have resulted in an increased availability of samples to facilitate more emphasis on studies related to the neuston component.

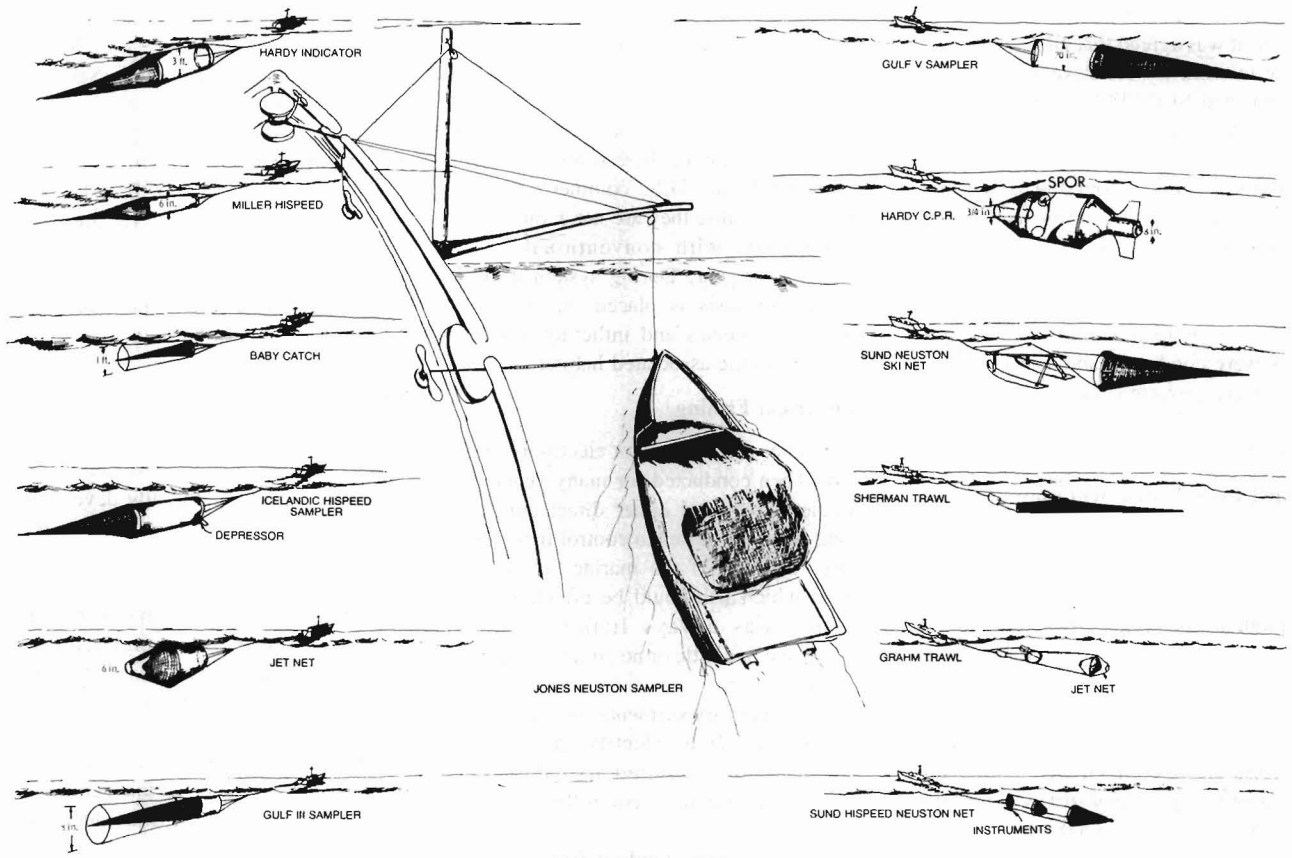


Figure 12.—Neuston sampling system net configurations.

Electric Shrimp Trawl Resource Assessment Survey System

The electric shrimp trawl is the first trawling system with an accurately defined catch rate. This catch rate was determined through statistical modeling based on carefully controlled laboratory experiments and field tests. Animal behavior information in response to an electrical field, together with the effects of physical parameters such as water temperature, salinity, bottom type, electrical field strength, and towing speed, were variables in the model.

It has been shown that throughout a nighttime fishing period, most shrimp are burrowed (Wickham and Minkler, 1975). Therefore, accurate resource assessment information cannot be obtained by standard trawls because the number of burrowed shrimp at any particular time is unknown.

With a defined catch efficiency, catch results are directly relatable to resource abundance during daytime shrimping. During nighttime hours, the catch increase produced by the electric shrimp trawl, compared to a standard trawl, represents the number of shrimp still burrowed. By comparing the catch of a standard trawl and increased catch of an electric trawl, the catch rate for the electric shrimp trawl at night is defined in terms of actual resource abundance encountered by the trawl.

Automatic Fish Scale Reading System

The feasibility of developing an automated system for aging fish scales was investigated. Currently, most scales are manually read by determining the relative distances between microscopic ridges (circuli) on the scales. The spacing between the circuli corresponds to the growth rate of the fish. When growth is minimal, the circuli tend to grow close together forming annuli; the number of annuli on a scale represents the age of the fish.

Two study contracts were awarded for alternative aging devices. The first was for the evaluation of an automatic image analysis system. This system, which converted circuli and annuli to gray-scale densities for comparative analysis, did not approach the 75-percent repetitive factor achieved by manual processes. The second contract was for the application of a recording optical spectrum analyzer—a diffraction pattern sampling technique. This system appeared to have potential and the recommended future action was to pursue this approach.

Automatic Plankton Sorting System

Thousands of plankton samples are collected annually by NMFS investigations, and manually sorted, counted, and identified. The purpose was to develop a method to expedite the process. At the same time the Northeast Fisheries Center (NEFC) was

working toward a similar goal. After consultation, it was agreed that NEFC would continue to work toward developing a sorting system and SEFC/FEL would concentrate on the development of an automatic transport method which would move sorted plankton through a counting system.

An evaluation of current and potential systems was conducted. A hydraulic transport system was developed based on a system used by the Fisheries Research Board, Nanaimo, British Columbia. Numerous tests were conducted and two minor problems were corrected. The system was shipped to the MARMAP Field Office in November 1973.

Trawl Door Instrumentation

The development of an environmental sensor for use in conjunction with trawl surveys for bottomfish is being investigated through a cooperative program with the Naval Underwater Systems Center, Newport, R.I. The concept is to design a self-contained miniaturized sensor package for attachment to trawl doors. The system will measure and record salinity, temperature, and depth over a 3-day survey period without servicing. Data from the sensors will be used to develop bioenvironmental correlations which can aid significantly in establishing future survey designs and in enhancing understanding of marine ecology.

HARVESTING TECHNOLOGY AND CONSERVATION ENGINEERING

This program has two primary goals: 1) increased levels of harvest by U.S. fishermen; and 2) conservation of nontarget resources which are damaged subsequent to other harvesting activities. Of major interest is the development of systems to harvest unutilized resources in the southeast region. Presently, many of these resources are unavailable to the U.S. commercial fishing industry because they are not economically harvestable with conventional fishing methods or gear. During system development, emphasis is placed on conserving nontarget species and inflicting minimum damage to the associated habitat.

Electrical Fishing

Studies of the effect of electricity on fish have been conducted for many years. Past studies have used either direct current or long-duration pulses to control fish. Therefore, the area of the marine environment from which fish could be effectively harvested was always limited, and the technique had little or no commercial application.

Laboratory experiments were conducted (Klima, 1972) to identify the electrical characteristics required to induce electrotaxis as a means of controlling and leading fishes. A modified electric generator was used to produce pulsed direct current in the form of capacitor discharges at rates of 5-75 per second. An index of optimal responses was obtained for selected species (Table 1).

Based upon the results of the fish behavior study, an electrical pulse generator system was designed for both commercial and resource assessment applications. A 120 kilowatt pulse generator was constructed and installed aboard the FRV *Oregon II* for in situ field tests (Seidel and Klima, 1974). Fish were attracted to the electrode array and their responses to various combinations of electrical fields and pulse rates were evaluated. Based on these tests, the system was modified and an updated version is now installed on the FRV *Oregon II* to provide a capability to lead and control pelagic fishes to facilitate rapid, efficient capture and harvest.

Table 1.—Effective combinations of voltage (per 10 cm) and pulse rate (per second) for inducing electrotaxis in the species studied and the approximate amperes (per square meter) (Klima, 1972).

Species	Volts	Pulses	Amperes	Fish length (mm) Range	Average
Coastal pelagics					
Scaled sardine	1.5	15-55	62.5	100-145	118
	3.0	8-28	86.5	100-145	118
Spanish sardine	1.5	35-45	43.3	85-180	130
	3.0	15	86.5	85-180	130
Round herring	3.0	25-45	86.5	80-150	104
Silver anchovy	3.0	35-45	98.3	85-110	96
Butterfish	1.5	35	41.3	80-100	118
	3.0	45	86.5	80-160	118
Chub mackerel	1.5	15	53.8	125-240	180
Bumper	1.5	15	57.0	135-230	173
Rough scad	1.5	15-25	42.3	120-145	133
Thread herring	1.5	15	62.5	80-185	146
Round scad	1.5	15	43.3	90-170	148
Bottom fish					
Spot	1.5	15-35	43.3	90-250	120
Longspine porgy	1.5	25-35	43.3	100-160	128

Electric Shrimp Trawl System

The electric shrimp trawl system can potentially increase shrimp production in excess of 100 percent. Initially developed to expand shrimping to daylight hours, it was determined that the system would also significantly increase the nighttime harvest of shrimp. Studies have shown that the majority of shrimp are burrowed even at night and therefore are unavailable to conventional trawls (Wickham and Minkler, 1975).

Electrical response characteristics were established to properly stimulate shrimp from the bottom in such a manner that they could be harvested by a trawl during daylight and nighttime hours. A pulse generator and associated hardware were designed, utilizing the shrimp response requirements, and a complete electrical system was built for a shrimp trawl. The system was tested to demonstrate the feasibility of a commercial electric shrimp trawl system and, based on the results, a commercial unit is presently under development for the shrimp industry by two different companies.

The electric shrimp trawl also can be used to provide accessibility to new shrimp grounds. Areas now unavailable to standard shrimp gear, because of bottom roughness, can be opened for sampling or harvesting through modifications of this system.

Shrimp Separator Trawl

Estimates place the amount of groundfish destroyed during commercial shrimping operations at between 1 and 4 billion pounds of fish annually. This represents a significant loss to both the pet food and human food groundfish fisheries. A shrimp separator trawl is being developed with a design goal of reducing the capture and subsequent destruction of groundfish by 90 percent. Preliminary studies indicate that these goals are

feasible and, if attained, a significant conservation of the groundfish resource will have been achieved.

Research of other separator trawl designs determined they were unsuited for use in the Gulf of Mexico, although fish portions were reduced by 50-60 percent. Therefore a new net design was formulated based on direct diver observation of shrimp and fish behavior during trawling operations. A prototype separator trawl was designed and constructed, using results obtained from laboratory studies and three preliminary cruises (Fig. 13). Test results of the prototype were encouraging: sponges and crabs were eliminated; fish portions were reduced; and shrimp loss was miantained at 10-15 percent of normal. This system will be further developed and tested to optimize its selectivity for commercial use.

Nightlighting for Attraction and Control

Extensive behavioral studies formed the basis for the development of techniques to concentrate fish at night with lights. Subjective observations indicated that fish could be attracted by a wide range of lamps and light intensities (Wickham, 1971). Conclusions were that a single high-wattage point-source lamp created the most controllable aggregations, and underwater lamps were more efficient than surface lamps.

Lighting attraction and control methods were first evaluated for commercial application using coastal pelagic fish harvested in the Florida baitfish fishery. A single light used in conjunction with a conventional purse seine yielded approximately 1,814 kg (4,000 pounds) of fish in 3 hours. Multiple lights, properly spaced, acted as independent attraction points and it was demonstrated that fish attracted to one light could be led by sequentially illuminating the series of lights. A single moving light also proved successful in leading fish (Wickham, 1973).

Artificial Structures As Attractors

The Gulf of Mexico coastal pelagic resource is generally not found in large concentrated schools. Normally, numerous small schools are found scattered throughout an area. Artificial structures were found to be effective in attracting and holding these fish in increased numbers for harvest.

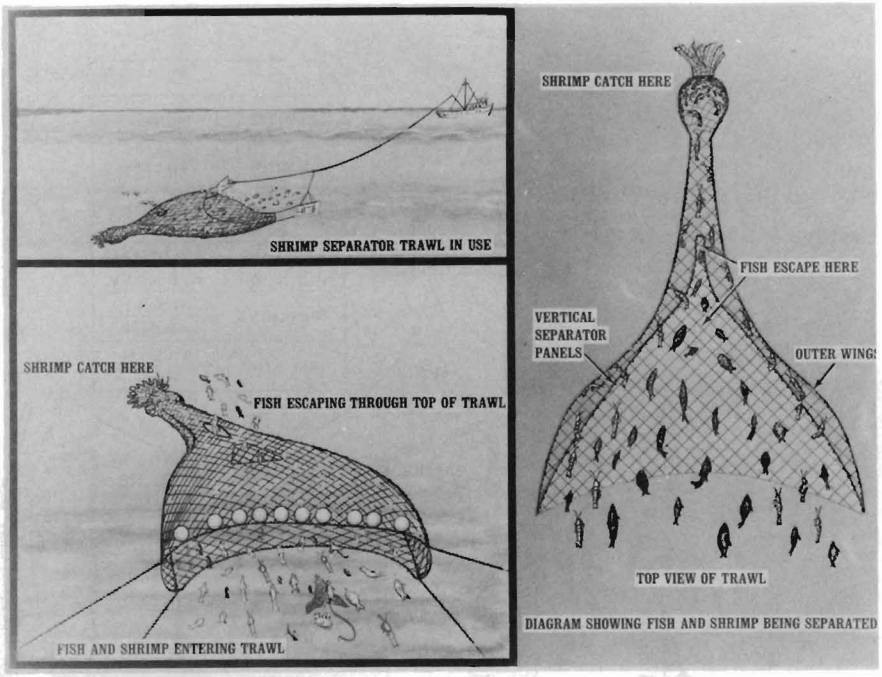


Figure 13.—Separator trawl concept.

Attraction structures were evaluated through a contract to a Florida commercial fishing company. Purse seine sets were made around the artificial structures to determine the rate and effectiveness of the structures for concentrating commercial numbers and species of fish. The information obtained from this study showed that coastal pelagic fish could be concentrated in numbers greater than those in which they are normally found (Klima and Wickham, 1971).

The structures were also evaluated as a technique to improve or enhance the catch of sportfishermen (Wickham et al., 1973). Through a joint study with the NMFS Game and Sportfish Laboratory in Panama City, Fla., it was demonstrated that the artificial structures could significantly improve the strike and catch rate of sportfish in an area. As a result, several structures have been made by State and Federal agencies to further evaluate the potential of this technique.

DATA MANAGEMENT

Expanded survey programs, covering vast oceanic areas and intensively studying discrete areas, will produce massive quantities of environmental and biological data. The full value of these data cannot be realized, however, without comprehensive processing and display systems nor can their full significance be economically attained without automated analysis systems. Traditionally, data processing has been generally directed toward presenting information about discrete areas without correlation with other areas and without looking at vast areal coverage. The objective of this program is to develop systems capable of integrating vast amounts of information while maintaining a capability for discrete analyses.

Data Logger System

This study was initiated to develop a portable data acquisition system capable of automated shipboard data recording of ship performance and configuration, and oceanographic, meteorological, and biological parameters (Fig. 14). The design concept was to develop an analog system, with a quick-look capability, in modular units. Off-line computer programs were developed to provide summary data for each station in general plot and tabulation formats.

Each hardware unit was designed to be packaged in nearly self-sufficient operating enclosures called "cubicles". Individual components within each cubicle were also modular allowing a partial mix of two or

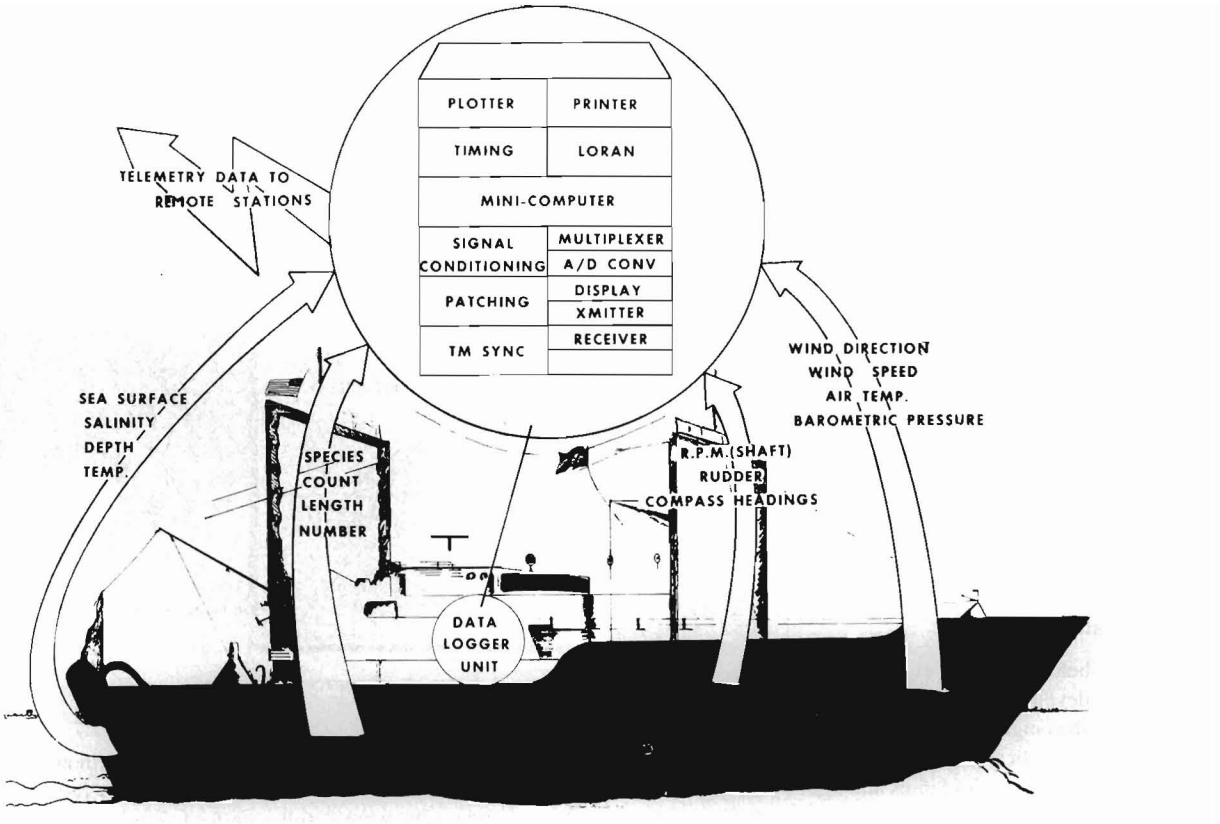


Figure 14.—Parameters measured by the data logger system.

more systems in a single cubicle. A prototype system was fabricated and installed aboard the FRV *Albatross IV*.

Information Management System

A Center-wide system is being developed which consists of software that facilitates organization, storage, retrieval, and updating of large amounts of data. The system will use a simple user language to allow flexible data file structuring and maintenance, and virtually unlimited information retrieval selectivity. Random access data storage and retrieval techniques will allow access to data without sequential searches and will eliminate storage of filler or other irrelevant characters.

The Information Management System will use data management techniques developed to satisfy LANDSAT and other satellite-related requirements (Fig. 15). The system can be generally divided into three main segments. The first (unit conversion and reformatting) is being developed to reformat all incoming digital data for input to the Information Storage and Retrieval System (ISRS). The ISRS will enable users to selectively retrieve pertinent information subsets from the compressed file, print the information, or store it on magnetic tape for use in analytical routines.

The last segment will consist of software elements for data display and analysis. These elements will include statistical and mathematical routines, and graphical displays (by incorporating the Atlas Display System) such as land-mass plots with contours and symbols, histogram plots, and X-Y plots. The goal is to use a central computer facility with connecting terminals at other NMFS laboratories.

Atlas Display System

An atlas display system was developed to display biological and environmental data as a function of time and location. The goal was to establish a data management tool to study the interactions of these variables, and to provide a real-time assessment and management display device for studying and managing marine resources.

The first step was to develop plotting routines consistent with available plotter requirements. Software was developed to plot, contour, and display the variables, to accept inputs of discrete functions and to display composite frames of data. In addition, a system to display integrated data in an annotated form was developed.

The first major application of this system concentrated on the dispersal mechanisms of the transport and distribution of phyllosomes (lobster larvae). Using surface current velocities and drift-bottle data, film sequences were constructed showing phyllosome drift paths based on assumptions of starting points and time of the year.

Exploratory Fishing Data Base

A groundfish resource assessment data management and display system was developed. This software package provides a

master file and update capability for all groundfish exploratory survey data, which currently consists of approximately 400,000 observations. The master file can be displayed spacially to provide a symbolic representation of species distributions, catch rates, and sampling stations. Also, the display software has the capability of displaying the 5-, 20-, and 50-fathom depth contours on the same catch-rate plot. A current master data file is maintained at the FEL for this project.

Utilizing a subset of the above data, a North Carolina coastal summary atlas was prepared. Software was developed to normalize and plot the North Carolina data by species showing distribution and catch rates spacially in conjunction with the coastal land mass. Approximately 130 different plots were prepared utilizing a Stromberg Carlson SC4020 microfilm plotter[3]. The plots represented approximately 11,300 observations of the distribution and availability of selected species taken by various gear.

In support of a Food and Agriculture Organization project, exploratory fishing data were processed and displayed for the southeast region. The project included computations of groundfish and crustacean biomass estimates, and distribution and catch-rate plots (including land-mass outlines). Computation of catch rates for estimating the efficiency of trawl configurations, ultimately for biomass calculations, were also provided. Subsequently, distribution plots using other exploratory fishing data were provided for the Campeche/Yucatan area.

Preparation of a shrimp atlas has been initiated for the Atlantic Coast from North Carolina to Florida. Software was developed to interrogate the file for the purpose of counting sampling stations (records) by region, shrimp species (white, pink, and brown), and month. Further counts were made to determine the number of stations in each subset having measurements of depth, temperature, and weight, and number of shrimp. The same procedure was followed for each state, by season and species. A second computer program was developed to sort species data by region, season, time of day, and sampling device. Catch rates were normalized to a 12.2-m (40-foot) shrimp trawl and a 1-hour sampling period.

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

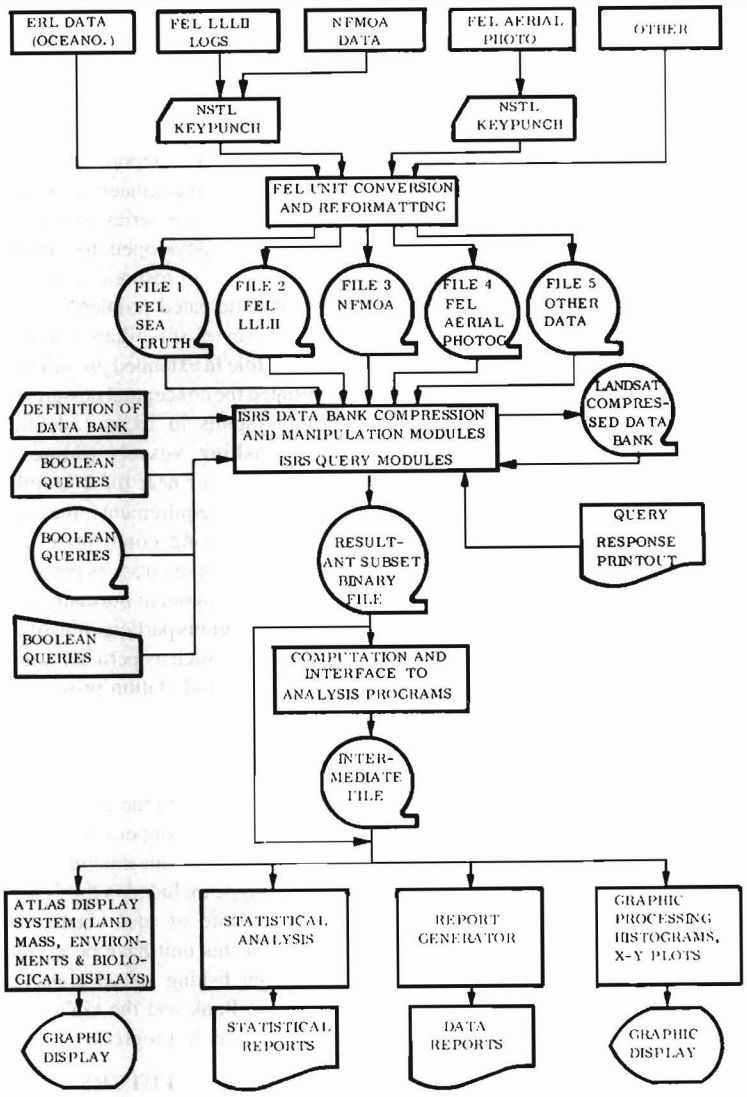


Figure 15.—LANDSAT data management software system.

Law Enforcement Data System

A data storage and retrieval system has been developed for the NMFS Southeast Regional Law Enforcement Office in New Orleans. The system has the capability to add, change, and delete data associated with a master surveillance file. It also has the capability for outputting up to 14 different tabulations of the data with each tabulation emphasizing a different aspect of the data. Current plans call for adding several refinements to the system including the capability to display the location and time sequence of fishing violations utilizing the atlas display system.

PLANNING AND SYSTEMS ANALYSIS

Planning and systems analysis are decision-making processes which result in bringing into focus the objectives of a project and the methods of attainment. Emphasis can be placed on one of two primary aspects: the fact-finding process of planning or the decision-making process. The two aspects are inseparable since sound management decisions can be accomplished only after an evaluation of all the related factors has been concluded. These principles have been applied to activities being

conducted at FEL, and in several instances to other NMFS functions.

Regional Recreational Fishing Program

A Marine Recreational Fishing Program Development Plan was prepared at the Southeast Fisheries Regional Office in 1975. FEL provided systems engineering and planning support to insure total integration of all the elements inherent to marine recreational fisheries management in the southeast. The plan is intended to solidify and provide impetus to research and monitoring and assessment activities related to marine recreational fishes in the southeast.

Cruise Track Optimization

An automated system is being developed for cruise track and station selection as a function of survey objectives. This system is expected to significantly reduce the amount of effort currently being expended in selecting survey stations and the order in which they are sampled. The system will be flexible enough to compensate for delays and other unforeseen contingencies during survey operations.

During a literature search at the onset of the project, a software system already developed for optimizing salesmen's routes was identified as having direct applicability. In its fisheries survey application, an augmented random number generator was added to select survey stations within predefined survey areas and then to optimize the cruise track between stations. The system has been compiled on the Univac 1108 and tests are being conducted to demonstrate its operational capability.

Extended Jurisdiction Fisheries Management

The United States has assumed jurisdiction over fisheries resources out to 200 nautical miles. Inherent in this extension is responsibility for the protection and utilization of these resources. Significant effort will be required to develop the body of knowledge and systems necessary to support this action.

The NMFS established an office to plan the activities required to support extended jurisdiction. FEL supports this office by providing systems engineering and planning support. Initially, a series of management displays were developed to enhance the planning ability to respond to required actions and anticipated problems.

Fishing vessel surveillance will play an important role in extended jurisdiction. FEL has initiated the conceptual design of remote sensing systems to locate, identify, and monitor fishing vessels (domestic and foreign) within or near the 200-mile limit. To meet initial requirements, the concept of a system involving cooperative and noncooperative components was proposed. The cooperative component normally would require conscientious participation of a fishing vessel captain, such as periodic radio transmissions to a land station providing information on location, activity, and catch.

The noncooperative component essentially would serve to validate the information received through the cooperative component. One noncooperative component being considered is an imaging radar unit, such as the type included in the Sea Satellite (SEASAT) suite of instruments. Preliminary tests of this unit have been conducted over foreign fishing vessel concentrations off Georges Bank and the Gulf of Alaska. Data analysis is in progress.

THE FUTURE

Technology is advancing at an unprecedented rate and the potential applications to fisheries problems are limitless. Techniques such as lasers, high-resolution color television, and hydroacoustics will be investigated more thoroughly. The advent of the SEASAT will provide the first opportunity to use data acquired by satellite systems designed specifically for oceanographic purposes. Data management techniques will be expanded and improved to provide more comprehensive, workable data bases to process and analyze massive quantities of integrated data. Harvesting systems will be developed and improved to facilitate harvests of latent resources and selectively harvest target species. However, the key to the future lies in the successful transfer of new techniques to user groups and the recognition by users that the new techniques can successfully replace the old standards.

ACKNOWLEDGMENT

This document is based upon the efforts and output of the entire Technology Division staff—past and present. Through their combined expertise, significant accomplishments can be reported and continued success predicted.

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