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INVESTIGATION USING DATA FROM ERTS-1 TO DEVELOP AND IMPLEMENT

UTILIZATION OF LIVING MARINE RESOURCES

W. H. Stevenson and E. J. Pastula, Jr.
National Oceanic & Atmospheric Administration
National Marine Fisheries Service
Fisheries Engineering Laboratory
Mississippi Test Facility
Bay Saint Louis, Mississippi 39520

December 1973
FINAL REPORT

Principal Investigator: William H. Stevenson
Project No: 240
GSFC. I.D. No.: CO 321
Contract No: S-70246-AG

Prepared for

GODDARD SPACE FLIGHT CENTER

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16. Abstract This 15-month ERTS-1 investigation produced correlations between satellite, aircraft, menhaden fisheries, and environmental sea truth data from the Mississippi Sound. Selected oceanographic, meteorological, and biological parameters were used as indirect indicators of the menhaden resource. Synoptic and near real-time sea truth, fishery, satellite imagery, aircraft acquired multispectral, photo and thermal IR information were acquired as data inputs. Computer programs were developed to manipulate these data according to user requirements. Preliminary results indicate a correlation between backscattered light with chlorophyll concentration and water transparency in turbid waters. Eight empirical menhaden distribution models were constructed from combinations of four fisheries-significant oceanographic parameters: water depth, transparency, color and surface salinity. The models demonstrated their potential for management utilization in areas of resource assessment, prediction and monitoring.

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PREFACE

The primary objective of this 15-month study was to demonstrate the feasibility of using ERTS-1 data to determine the availability and distribution of Gulf menhaden, Brevoortia patronus within the Mississippi Sound and adjacent waters. Secondary objectives were: 1) determine the effectiveness and reliability of ERTS and aircraft remotely sensed data to provide fisheries significant coastal environmental information, and 2) ascertain the utility of these data for improving resource harvesting and management. Selected oceanographic, meteorological, and biological parameters were used as indirect indicators of the resource. Synoptic and near real-time sea truth, fishery sampling and weather data, as well as satellite imagery, aircraft acquired photo, multispectral, and thermal IR information, were acquired as data inputs. Computer programs were developed and implemented to manipulate these data according to various user/participant requirements. The experiment produced correlations between satellite, aircraft, fisheries, and environmental sea truth data. Eight empirical regression menhaden distribution prediction models were constructed from combinations of four fisheries-significant oceanographic parameters: water depth, transparency, color, and surface salinity. In addition, the significant correlation between chlorophyll a and menhaden distribution could not be substantiated because of insufficient data. The models, although not precise, demonstrate their potential as a tool for providing menhaden distribution information on a real-time basis. In addition, preliminary results indicate a correlation between backscattered light with chlorophyll concentration and water transparency in turbid waters. Experiment results are being used to facilitate development of minimum levels of effort required to obtain data for resource distribution studies, and to provide insight into areas of investigation applicable to the utilization of remote sensing as a management means of resource assessment, surveying and monitoring.

ACKNOWLEDGEMENTS

The Principal Investigator gratefully acknowledges the cooperation and assistance of the many people who participated in this project. It is not possible to recognize each individual in this report, but those who made a major contribution to the project and deserve special recognition are: The co-investigators Mr. E. J. Pastula, Jr., of NMFS/FEL, Dr. A. J. Kemmerer and Mr. J. A. Benigno of NMFS/SEFC, Dr. B. Atwell of NASA/ERL, and Dr. A. Marmelstein of Earth Satellite Corporation. Sincere appreciation is also expressed to Mr. E. L. Tilton of NASA/ERL for his cooperation and support; Mr. K. J. Savastano of NMFS/FEL for his programming assistance in many of the analyses; Mr. J. W. Weldon of NASA/ERL for his contribution on remote measurement of water color, and the MTF support personnel of the General Electric Company and Lockheed Electronics, Inc.

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SECTION 1

INTRODUCTION

1.1 REPORT HISTORY

This report is the seventh and final effort in a series under NASA/ERTS-1 Project No. 240, GSFC ID CO 321, Contract No. S-70246-AG. The document constitutes a Type III, or Final, Report covering the entire investigative period from 1 July 1972 through 4 October 1972. Type I Progress Reports were submitted in September and December 1972 (1,2) as well as during the months of June and September of 1973 (3,4). A combined Type I/Type II Report, entitled "Interim Report" was submitted in June 1973 (5), and the second Type II Report was forwarded in July 1973 (6).

A comprehensive listing of these and other reports, as well as published papers, which have been generated as a result of this project, are included in the References and Bibliography.

1.2 PROJECT OVERVIEW

Application of aircraft and satellite remote sensing systems to the problems confronting the fishing nations of the world is undergoing intensive development. The evolution of sensing systems to acquire information about the world's oceans has outrun current understanding of the basic processes involved in fisheries identification, utilization, and management. This is due to rapid expansion of remote sensing technical capabilities in several countries over the past ten years.

In seeking ways to utilize this advanced technology to the benefit of humankind, some very broad hypothesis have been postulated, particularly in the application of remote sensing to fisheries. These assumptions were:

- Satellite-acquired data can be directly applied to fishing operations.
- Oceanographic information can be directly used by fishermen in their daily activities.
- The cause and effect relationships between the ocean environment and fish stocks are understood to the point of technical application.

A project plan (7) incorporating four major components was drafted and implemented to test these hypotheses, and to accomplish the study objectives. The four components were: Utilization, Living Marine Resource, Oceanography and Aerospace. Each component was related to one or more of the objectives, and all components were integrated to achieve overall goals. Project life was estimated to be 17 months: one month start-up, 12 months dedicated to operations and the last four months devoted to a quick-look data analysis and report preparation. We anticipate that spin-off use of the data will continue for approximately five years.

During the operational phase, three types of mobile platforms were simultaneously utilized to acquire oceanographic, fishery and relevant meteorological data within, and surrounding, the study area. These platforms were satellites, aircraft and surface vessels (Figure 1). Satellite data originated from both the Earth Resources Technology Satellite (ERTS-1) and the NOAA-2 Improved TIROS Operational Satellite, formerly ITOS-D.

Medium and low altitude aircraft flew over the test site along predefined flight paths, with the flights underflying and coinciding with selected orbital passes of ERTS-1. Sensor systems aboard each aircraft provided data similar to that obtained by the satellite sensors. The aircraft sensors also provided supplemental information not obtained by ERTS sensors.

Sea surface vessels occupied oceanographic and fishery stations within the test site during the satellite and aircraft overpasses for the purpose of acquiring simultaneous sea truth data. Sea truth oceanographic data acquisition methods consisted of in-situ measurements and water sample collections for shore-based laboratory analysis. The latter was analyzed for both chlorophyll and other constituents not readily measurable with in-situ techniques and devices. Personnel aboard research and commercial surface vessels acquired data on the adult menhaden stock within the test site, along with associated oceanographic information.

Meteorological information was obtained from land stations to supply weather and specific atmospheric information necessary for annotation and correction of satellite and aircraft acquired data. Pertinent data, directly and/or indirectly related to the project, was reduced and analyzed for possible correlations to meet the objectives.

The project was implemented by elements of three basic organizations: The National Oceanic and Atmospheric Administration (NOAA), The National Aeronautics and Space Administration (NASA), and The National Fish Meal and Oil Association (NFMOA). Organizational responsibilities were coordinated by the Principal Investigator through Co-Investigators. An active interchange of information and techniques was encouraged and methods implemented to provide maximum benefit to all project participants.

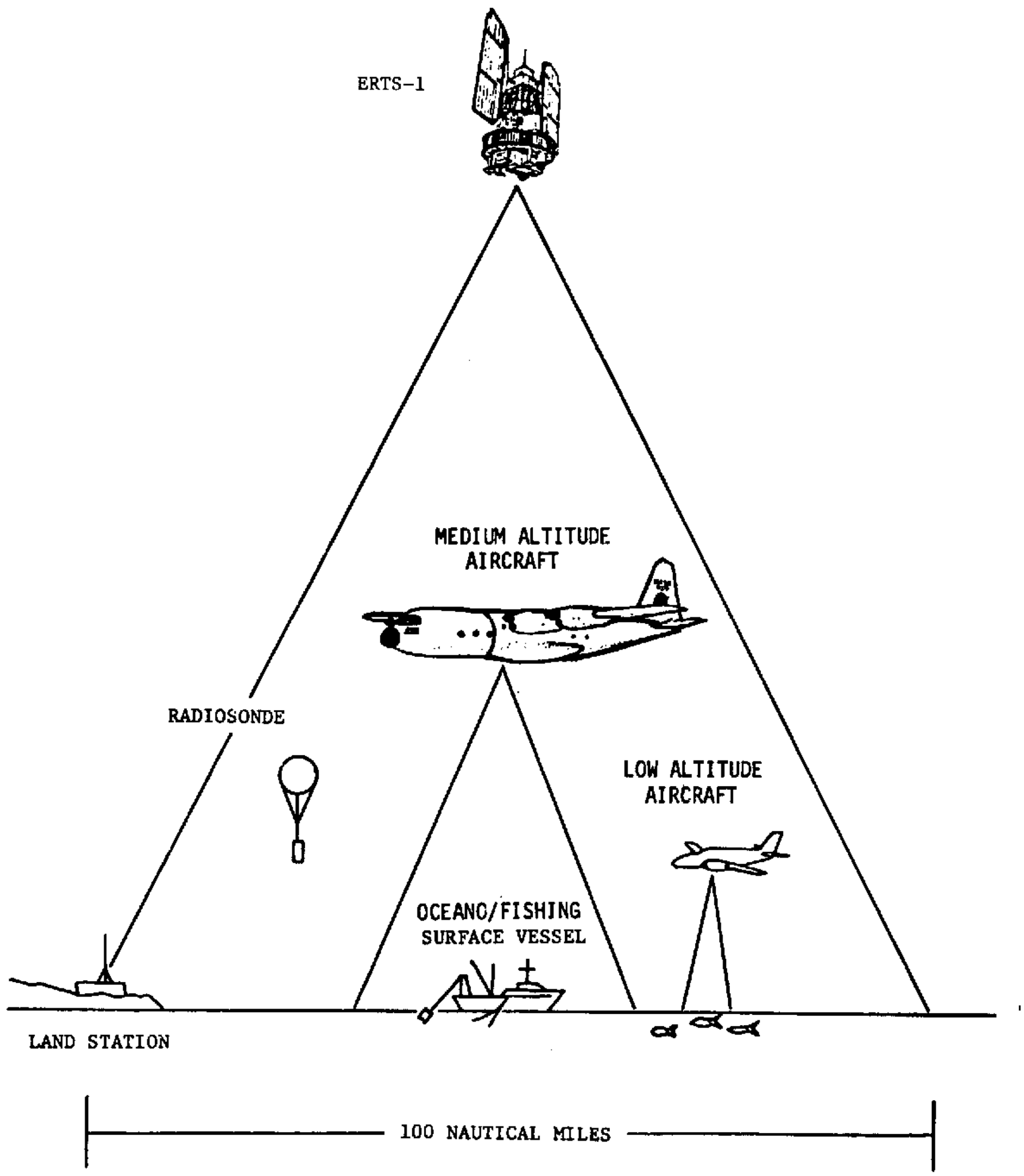


Figure 1. Field Operations Overview. (S-70246-AG)

1.3 OBJECTIVES

The primary objective of this ERTS-1 study was to establish the feasibility of utilizing satellite imagery to determine the availability and distribution of the adult menhaden Brevoortia patronus (figure 2), a living marine resource inhabiting N.E. Gulf of Mexico waters. This objective has been achieved through a series of correlations between satellite/aircraft imagery and surface truth information related to the marine environment and the resource, and between this resource and the fishery as presently prosecuted.

Secondary objectives were as follows:

- Determine the effectiveness and reliability of aircraft and ERTS-1 sensor data to provide fisheries significant coastal oceanographic data.

- Ascertain the usefulness of remotely acquired oceanographic, environmental and resource information for improving the harvest and management of the menhaden resource.

1.4 BENEFITS

This study has produced correlations between satellite and aircraft acquired data, and sea truth fisheries and environmental information. These correlations have aided in assessing the feasibility of using satellite imagery for determining resource availability and distribution.

Sufficient information has been obtained to facilitate development of minimum levels of effort required to obtain usable ecological data for resource distribution studies. Acquired data has also provided insight into areas of investigation applicable to remote sensing surveys for assessment and monitoring of living marine resources. With this information, the scope and synoptic requirements necessary to acquire information on ecological relationships using remote sensing methods can now be more accurately assessed.

Synoptic overviews provided by ERTS-1 imagery have been used to facilitate generation of water (clarity) charts, and in addition, has provided insight into the general oceanographic condition of the test site coastal waters. When correlated with other timely associated information, these charts have been useful in determining the distribution of menhaden fish stocks. Conventional sampling techniques do not adequately define surface distributions of ecological data in terms of momentary areal extent, horizontal movement with passage of time, nor the short and/or long-range duration of

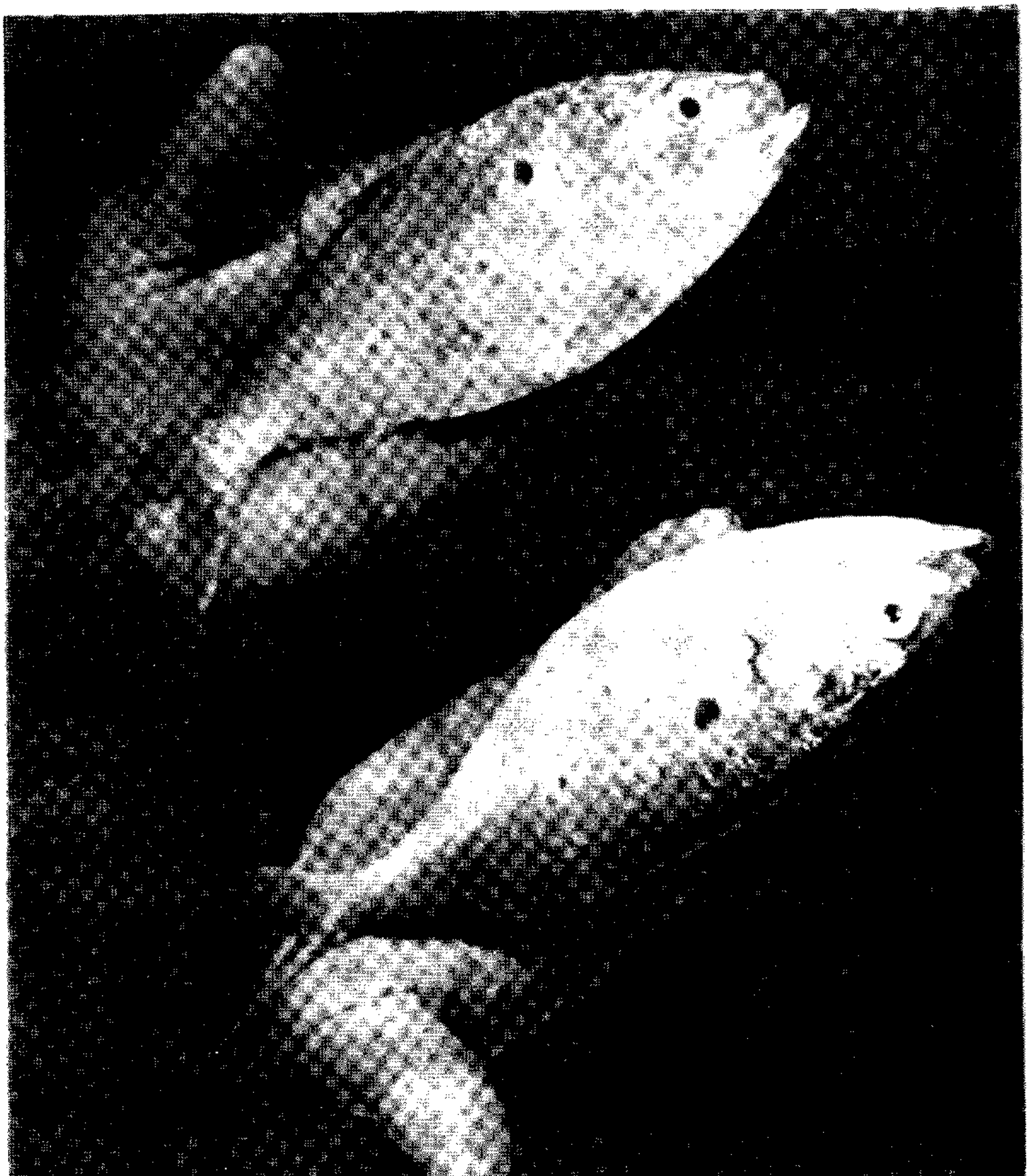


Figure 2. The Adult Menhaden, Brevoortia patronus. (S-70246-AG)

such phenomena. Synoptic data acquired via satellite and aircraft sensors has provided the biologist with a set of tools to more accurately assess and monitor fishery resources at or near the surface through interpretation of environmental parameter distributions.

A great amount of time and effort is expended in attempting to locate and assess pelagic fish concentrations. For example, menhaden occupy large areas of the coastal waters and previous research has shown that surface temperature alone is insufficient for predicting their location. Geographically charting either singularly or in combination information on five surface phenomena (salinity, temperature, color, turbidity [water clarity] and current), obtained simultaneously with remote sensing satellite and aircraft systems, as well as with surface sea truth methods, has tested the relationship of these parameters with observed fish distribution and availability.

1.5 PARTICIPANTS

This project was a cooperative venture whose participants originated from various Federal, state, and local government agencies, universities and commercial enterprises. Parent agencies and/or groups and their respective main-line components and/or contractors who are Principal Investigative and Co-Investigative were as follows:

- National Oceanic and Atmospheric Administration (NOAA)
  - National Marine Fisheries Service (NMFS)
    - Fisheries Engineering Laboratory (FEL)
    - Pascagoula Laboratory
- National Aeronautics and Space Administration (NASA)
  - Earth Resources Laboratory (ERL/MTF-Mississippi Test Facility)
- National Fish Meal and Oil Association (NFMOA)
- Earth Satellite Corporation (EarthSat)

Various groups and agencies who provided assistance in one form or another to the Principal and Co-Investigative elements within the project were as follows:

- National Oceanic and Atmospheric Administration (NOAA)
  - National Marine Fisheries Service (NMFS)
    - Southeast Fisheries Center (SEFC)
    - Atlantic Estuarine Fisheries Center (AEFC)
  - National Environmental Satellite Service (NESS)
  - Atlantic Oceanographic and Meteorological Laboratory (AOML)
  - National Weather Service (NWS)

National Aeronautics and Space Administration (NASA)
- Johnson Space Center (JSC)
- Goddard Space Flight Center (GSFC)
- Marshall Space Flight Center (MTF)
  - Contractor Support

Alabama Department of Conservation
Gulf Coast Research Laboratory (GCRL)
Gulf Universities Research Consortium (GURC)
U.S. Corps of Engineers
Mississippi State University (MSU)

SECTION 2

FISHERY RESOURCE

2.1 DESCRIPTION

Correlations between remotely sensed oceanographic and meteorological data, and living marine resource information can only be meaningful if adequate knowledge of the applicable parameters can be generated.

The menhaden is a surface pelagic, economically important, schooling fish (Figure 3) abundant within historically defined East and Northern Gulf of Mexico coastal areas of the United States.

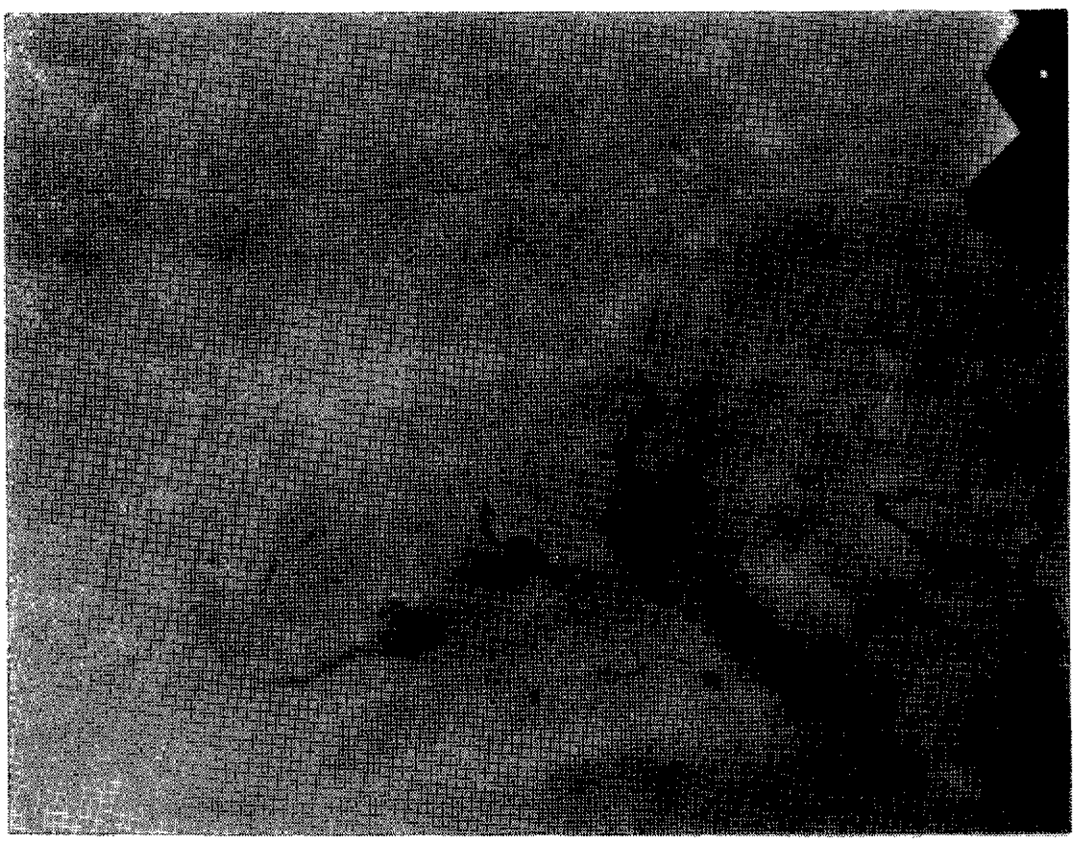


Figure 3. Menhaden Fish Schools Taken From 8,100 ft. Off The Coast Of Mississippi On 11 August 1972. (Orig. in Ektachrome Color IR). (S-70246-AG)

The menhaden species has been the subject of many investigations and considerable knowledge has been acquired concerning its habits and life cycle (8 thru 13). The available information and the commercial importance of menhaden provided sufficient justification to focus the data correlation on this species.

Gulf menhaden eggs are spawned in the offshore coastal waters from about November through February. Approximately 48 hours after the eggs are spawned, they hatch, becoming planktonic larvae which feed on zooplankton. During the same time frame the larvae, with feeble powers of locomotion and with the aid of surface currents, migrate to specific nursery grounds (embayments) along the Gulf Coast. Once in the nursery area, the larvae metamorphose into juveniles which feed on phytoplankton.

The juvenile menhaden remain in the nursery grounds for approximately one year after which they migrate into more open coastal waters. Emerging from the nursery grounds under their own power, the yearling menhaden continue to feed on phytoplankton, and are considered a harvestable resource. Adult females become roe-bearers when they are one year or older. Migration to offshore coastal waters begins during October, whereas the commercial harvesting season starts in mid-April and lasts through October.

2.2 SELECTION RATIONALE

The premises upon which the menhaden species was selected as the focal point in this study are as follows:

- Menhaden normally occur in dense surface schools facilitating the use and evaluation of remote sensing techniques.
- Fluctuations in catch quantities suggested a need for extending the understanding of the distribution and availability of this important resource.
- Environmental fluctuations are known to affect the species and these cause and effect relationships would probably facilitate correlative analyses.
- The manhaden industry is prevalent in the Northern Gulf of Mexico and can possibly provide significant data for incorporation in the experiment.

SECTION 3

ENVIRONMENTAL PARAMETERS

3.1 CONSIDERATIONS

Basic oceanographic and meteorological parameters had to be explored and defined prior to measurement, performance of meaningful analyses, and subsequent attempts to understand the total relationship between the menhaden marine resource and its environment. It was not feasible within the scope of this investigation to study all the parameters which may possibly affect the life cycle and movements of the Gulf menhaden; therefore, parameters were selected that could possibly be acquired synoptically using available remote sensing techniques.

Various studies of Gulf menhaden and other fishery resources have indicated that these resources are dependent upon the relative stability of certain parameters which either directly or indirectly influence the continuance, life cycle, movement and size of a given species. A primary aspect of this experiment considered a number of these parameters, either singularly and/or in combination, as possible indicators for the purpose of monitoring and assessing a segment of the Gulf menhaden fishery stock.

Table 1 identifies the parameters selected for analysis. The parameters thought to cause the greatest impact on the fishery resource, and those

Table 1. Environmental Parameters Selected For Analysis

DISCIPLINE	CHARACTERISTIC	PARAMETERS
Oceanographic	Physical	Temperature, Color, Transparency, Currents Relative Irradiance, Sea State, Depth
	Chemical	Salinity
	Biological	Chlorophyll, Carotenoids
Meteorological	Surface Atmosphere	Temperature, Wind Direction and Speed
	Lower Atmosphere	Temperature, Relative Humidity, Altitude, Cloud Cover

which could possible be directly correlated with the fishery data were: temperature, color, salinity, chlorophyll, and currents. The meteorological parameters were selected as atmospheric correction inputs to evaluate remotely sensed information.

3.2 SELECTION RATIONALE

The premises upon which the environmental parameters were selected for inclusion in this study were as follows:

- The probability of demonstrating a relationship between the fishery and its environment for the purpose of stock availability and distribution.
- Parameters which can be either measured using satellite and/or aircraft remote sensing techniques and devices, or the knowledge of which is necessary for analysis of the remotely sensed parameters.

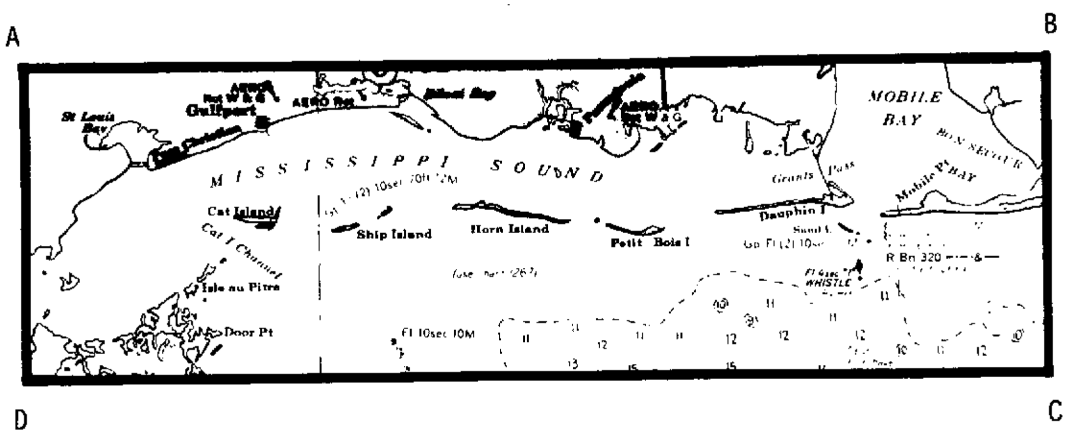
SECTION 4

TEST SITE

4.1 DESCRIPTION

The test site selected for study was the Mississippi Sound and environs (Figure 4) bounded by coordinates 30°27'N/89°30'W, 30°27'N/87°45'W, 30°00'N/87°45'W, and 30°00'W/89°30'W. Its linear dimensions are length: 170 km (91.7 n.mi.), width: 51 km (27.5 n.mi.), encompassing a total area of approximately 8670 km^2 (2522 n.mi.^{2}). The Mississippi Sound is an estuarine complex located in the northeastern part of the Gulf of Mexico, and interfaces with the oceanic water of the Gulf proper through a chain of barrier islands situated somewhat parallel to the coast. The shore boundary of the site includes coastal areas of Louisiana, Mississippi, and Alabama.

The Sound itself is approximately 17 km (9.2 n.mi.) wide by about 110 km (65.3 n.mi.) in length with an average depth of about four meters (13 ft.). Major brackish water embayments influencing the Sound's water characteristics are Mobile Bay to the east, Biloxi Bay just west of center to the north, and St. Louis Bay to the northwest. The Pearl and Pascagoula River systems provide an influx of fresh water to the Sound. The western part of the



TEST SITE COORDINATES

	LATITUDE	LONGITUDE
A)	30°27'N	89°30'W
B)	30°27'N	87°45'W
C)	30°00'N	87°45'W
D)	30°00'N	89°30'W

SCALE 1:875,000

N.MI. 10 20

KM. 10 20 30 40

TEST SITE DIMENSIONS

LENGTH: 170 KM.

WIDTH: 51 KM.

AREA: 8670 SQ. KM.

Figure 4. Project 240 Test Site. (S-70246-AG)

Sound is further influenced by the mixing of water from Lake Pontchartrain located to the northwest of the test area and interconnected via a body of shallow water referred to as Lake Borgne (unnamed in the figure) situated immediately east of Cat Island. The area immediately south of the barrier islands is characterized by near oceanic water which provides a contrast to the Sound proper.

4.2 SELECTION RATIONALE

A number of sites were considered; but, the selected area met all criteria inherent to the project objectives. The major advantages in choosing the test area included:

- The basic developmental phases (eggs, larvae, juveniles, and adults) of the Gulf menhaden fishery stock are known to inhabit various parts of the test site during prescribed times of any given year.
- Commercial fleets fish the adult menhaden from surface vessels within the area, and these could serve as sea truth acquisition platforms for fishery/oceanographic data.
- Local, state and Federal agencies, as well as university and commercial groups, have research and economic interests in the test area. Such mutual interests could provide a basis for cooperative ventures benefiting all participants.
- The test site would be in close proximity to the NMFS base of project operations, and within the framework of NMFS responsibilities on a regional level.
- Many port and marina facilities as well as air fields are located within the test area. These facilities could provide surface vessels and aircraft with docking, berthing, refueling, landing and maintenance services. They could also serve as logistical points of transfer for equipment, data, and collected samples.

SECTION 5

PROJECT COMPONENT HYPOTHESES

The three basic premises, upon which this project was based, were direct application of satellite and aircraft acquired data to fish distribution and availability, use of oceanographic information to assist fishermen in their routine activities, and existence of a cause/effect relationship between the ocean environment and fish stocks.

As noted in the Introduction (Section 1.2), this study was conducted through the implementation of four individual components; each with its own hypotheses, techniques and resulting data. Interrelationships existing between the components, and the subsequent interdependency resulted in a close coordination in achieving individual and collective objectives. The multidisciplined project approach provided a gestaltic effect by achieving results not derivable from the sum of the component parts.

5.1 UTILIZATION

The hypotheses were: 1. Remotely acquired data can be used to assist the fishing industry to deploy the harvesting fleet; and 2. Satellite and aircraft data can be compared and integrated with simultaneously acquired sea truth fishery and oceanographic information to provide correlations regarding the ecology of the resource.

5.2 LIVING MARINE RESOURCE

The hypotheses were: 1. Environmental conditions in the Mississippi Sound are related to a change in availability and distribution of adult menhaden (leading candidate indicators were chlorophyll, color, turbidity, salinity, and temperature); and 2. It is feasible to use satellite and aircraft acquired oceanographic data to determine the availability of the adult Gulf menhaden *Brevoortia patronus*.

5.3 OCEANOGRAPHIC

The hypotheses were: 1. Environmental conditions in the Mississippi Sound can be identified using synoptically acquired coastal oceanographic data; 2. Remotely sensed data acquired by satellite and aircraft can be successfully compared and integrated with sea surface data obtained by conventional techniques; 3. Techniques and devices which provide color and other bio-significant indicators of productivity can be tested and evaluated; and 4. Existing remote sensing techniques and instruments for the measurement and/or delineation of sea surface salinity, temperature, turbidity, chlorophyll, and color can provide a means for broad scale mapping of fisheries related environmental factors.

5.4 AEROSPACE

The hypotheses were: 1. Data acquired from ERTS-1 can be used to assist in determining environmental changes; and 2. Remotely sensed data acquired by satellite and aircraft can be successfully compared and integrated with sea surface data obtained by conventional techniques.

SECTION 6

DATA MANAGEMENT SYSTEM OVERVIEW

6.1 CONCEPTS

Each participating organizational element furnished unique data requirements for project implementation. These elements also collected supplementary data to satisfy their individual program objectives; however, these additional requirements were considered internal to the participant and not within the scope of this project.

Data requirements of the participating agencies supported one, or more, of the four basic phases used to describe and classify the objectives of this study.

- Utilization - Data were required to establish: correlations between catches and the environment fisheries industry planning; improved resource management techniques; and fundamental knowledge regarding the marine ecosystem.

- Living Marine Resources - Data were required to demonstrate the relationships between the marine environment and resource availability, as well as distribution within the test area.

- Oceanographic - Data were required to test the reliability of, and validate procedural techniques for, remote sensing information as a source of environmental and fisheries data.

- Aerospace - Data were required to demonstrate the application of information acquired by aircraft and satellite remote sensing systems and techniques to fisheries requirements.

6.2 COMPONENT DESCRIPTIONS

A data management system was devised and implemented (14) to handle participant requirements; data acquisition, processing and analysis, as well as generated user products. The basic flow structure of the system is illustrated as Figure 5.

All user requirements (input) were identified to the Data Requirements Committee established by FEL for this project. Each requirement was evaluated to determine its applicability to the project objectives. If the requirement was not within the predefined scope, it was returned to the requesting organization. Each request was further reviewed to: determine the acquisition, processing and analysis responsibilities; identify conflicting and redundant requirements; determine schedule requirements; and establish priority, data control factors and responsibilities. The Data Requirements and Analysis Coordinator was then informed of approved requests, and maintained a master listing of the accepted requirements.

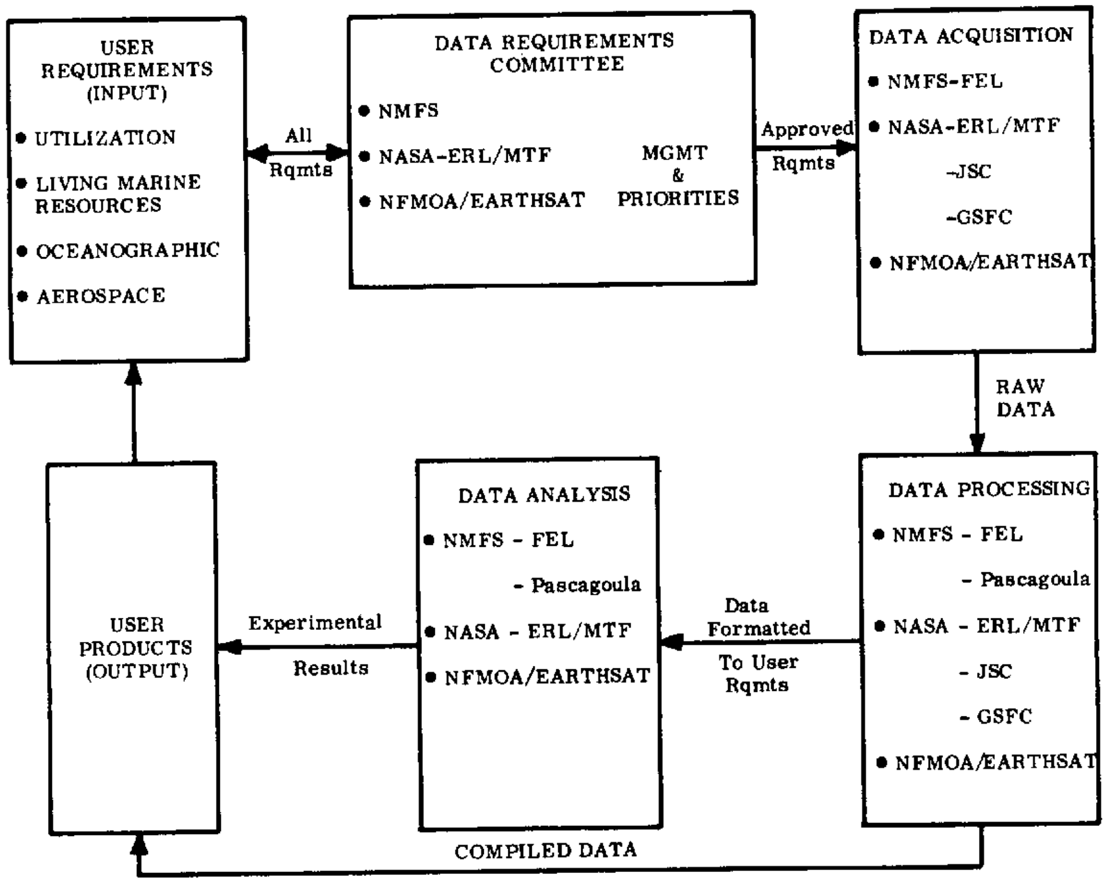


Figure 5. Data Management Flow. (S-70246-AG)

Approved data requirements were then forwarded to the Data Acquisition Coordinator for dissemination to the agency with designated responsibility for acquisition. It was the Coordinator's responsibility to provide the applicable information pertaining to the acquisition phase identified during the review cycle, and to maintain continued surveillance to ensure performance, reliability, and validity of the acquisition procedures and resultant data within the established constraints.

The Data Processing Coordinator was the focal point for all processing requirements. Raw data was forwarded to him for transmittal to the responsible processing agency. The Coordinator's responsibilities included: providing adequate information to the processing agency to ensure performance within the established constraints; monitoring activities to provide visibility for incoming raw data, processing tasks and analysis schedules; and assuring that reproduction and other supporting functions were available as required.

Processed data was provided in two forms. Some data was formatted in accordance with user requirements, and then forwarded to the Data Analysis Coordinator for dissemination. Other data were compiled and forwarded directly to the user by the Data Processing Coordinator.

The Data Requirements and Analysis Coordinator monitored all analytical activities, and additionally had responsibility for identifying and evaluating data requirements. Formatted data was forwarded to the responsible agency for analysis, and the coordinator monitored the activities to ensure adherence to schedule constraints, identified new/revised data requirements, and provided an interface with the users.

Certain data requirements were forwarded to responsible acquisition agencies who had responsibility for processing and analysis. In those instances, the data did not physically return to the data management flow until the analysis had been completed. It was each Coordinator's responsibility to maintain surveillance over their associated activities to ensure compliance with the established requirements and provide status as required.

SECTION 7

DATA/PARAMETER REQUIREMENTS

7.1 CONCEPTS

The data/parameter requirements for this project were established to provide the information necessary to accomplish the objectives, and in addition, provide each participant with associated data pertinent to his particular analysis needs. In this regard, individual requirements per parameter were merged with total project information needs reflecting and based on those environmental variables selected for analysis (Table 1). Resulting data/parameter requirements were therefore designed to provide the maximum amount of user oriented information subject to measurement criteria established by the users and suitable to all project participants.

7.2 OCEANOGRAPHIC

A summation of the oceanographic data/parameter requirements are shown in Table 2. In this regard, main days refer to a data acquisition time frame for any given parameter to be coincident with an ERTS-1 overpass accompanied by a maximum field operations effort. Secondary days, on the other hand, denote limited data acquisition field operations on a weekly basis in the absence of the satellite overpass. The accuracy of measurement criteria per parameter was established by a joint effort involving all participants based on their analysis requirements for any given set of environmental variables.

7.3 FISHERY RESOURCE

The measurements and observations, shown in Table 3, for fishery resource data was related to a specific area and a specific time period. The unit area was correlated back to longitude and latitude for data file structuring either automatically after the data entered the system, or manually prior to generation of the loading forms. The time of day was recorded for each biological data sample and this eliminated the need for consecutive numbering of sets. A set is defined as the act of deploying a net around a school, or a section of a school, of fish.

Under Spatial Requirements, Total Test Area is defined as the Project 240 Test Site. The term Operations Area denotes an area of commercial fishing activity where fish were actively caught.

Table 2. Summary of Oceanographic Data/Parameter Requirements

PARAMETER	TERMINOLOGY		ACCURACY	FINAL	MAIN	SECONDARY DAYS	
	SYMBOL	NOMENCLATURE	REQUIREMENT	CONVERSION	DAY	AIRCRAFT	VESSELS
Temperature	°C	Degrees Centigrade	±0.1°C	None	●	●	●
Color	FU-1,2	Forel-Ule Scale	Eye to Scale	None	●	●	●
Transparency	m or %	Meters or Percent Transmissivity	±0.25 m, ±1.0%	None	●	●	●
Current Speed	kts. or cm/sec.	Knots, Centimeters per sec.	±0.1 kts., ±0.1 cm/sec	cm/sec	●		
Current Direction	N,NE,W, etc.	Compass Direction	<45°	None	●		
Relative Irradiance	%	Percent of Incident Surface Value/Meter	±10% of Reading	None	●		●
Sea State	ft.	Feet	0.5 ft.	Meters	●		●
Depth	m or ft.	Meters or Feet	±0.1 m, ±0.5 ft.	Meters	●		●
Salinity	‰	Parts Per Thousand	±0.1 ‰	None	●		●
Chlorophyll _a_, _b_, _c_, & Carotenoids	mg/m^3	Milligrams Per Cubic Meter	±0.1 mg/m^3	None	●		●
Tide Height	ft.	Feet	±0.5 ft.	Meters	●		
Tide State	F or E	Flood or Ebb	Observation	None	●		

Table 3. Summary of Fishery Resource Data/Parameter Requirements

PARAMETER	PLATFORMS		UNIT OF MEASUREMENT	SPATIAL REQUIREMENT	TEMPORAL REQUIREMENT
	VESSELS	AIRCRAFT			
Number of Schools	●	●	Number	Total Test Area	Daily
Classification	●	●	Menhaden or Nonmenhaden	Total Test Area	Weekly
Number of Fish/Set	●		Thousands of Fish	Operations Area	Each Set
Grid Location	●	●	One Minute	Total Test Area	Each Observation
Time of Set	●		Day, Hour, Minute	Operations Area	Each Set
Surface Area		●	Square Meters	Total Test Area	Weekly
School Size		●	Number of Fish x 10^3	Operations Area	Each Observation
Time of Observation		●	Day, Hour, Minute	Total Test Area	Each Observation
Fishing Conditions	●	●	Coded	Operations Area	Daily
Area Observed - No Fish		●	Yes or No	Total Test Area	Weekly
Source Code	●	●	Coded	Total Test Area	Each Observation

7.4 METEOROLOGICAL

A summation of the meteorological data/parameter requirements are shown in Table 4. Data on these parameters were acquired on all main day and secondary missions.

Table 4. Summary of Meteorological Data/Parameter Requirements

PARAMETER	TERMINOLOGY SYMBOL	TERMINOLOGY NOMENCLATURE	ACCURACY REQUIREMENT	FINAL CONVERSION
Temperature	°C	Degrees Centigrade	±0.1°C	None
Wind Speed	kts. or km/hr.	Knots or Kilometers/ Hour	±0.1 kts. ±0.2 km/hr.	km/hr.
Wind Direction	N, NW, etc.	Compass Direction	<45°	None
Cloud Cover	% CLC	Percent Cloud Cover	±10%	None
Precipitation	cm/pr in/pr	Centimeters or Inches of Precip.	±0.25 cm, ±0.1 in.	cm/pr
Relative Humidity	%RH	Wet/Dry Bulb Ration in Percent	±1.0%	None

7.5 STANDARDIZATION

Standardization of data commenced when the parameter requirements were identified, and continued throughout all project activities. Initial standardization activities included definition of standard units of measurement for the various parameters, establishing standard acquisition techniques for each parameter, and developing standardized data codes, formats and input forms. New data requirements were reviewed, and added to the total project data requirements after standardization.

Other standardization efforts included compilation and coding techniques at the computer interface, edit features of processing software, and standard output formats. Standard operating procedures were developed and implemented for all project phases to ensure complete agreement.

SECTION 8

DATA ACQUISITION SYSTEMS UTILIZED

8.1 CONCEPTS

With the establishment of the data/parameter requirements necessary to meet the project objectives, it was apparent that neither ERTS-1, nor any other single data acquisition system, would be sufficient in providing all the required information. To fill this void, medium and low altitude remote sensing aircraft were utilized to augment ERTS acquired data, and in addition, provide data not obtainable via the satellite. Sea surface vessels were also used to provide sea truth data for purposes of validating the remotely acquired information, and for acquiring fishery resource information in association with environmental data.

The frequency of data acquisition, methods and/or devices used, types of platforms per system, data carriers, and those groups responsible for data/parameter acquisition are delineated in a Data Acquisition Matrix listed as Appendix A. The apparent redundancy, characterized by similar acquisition systems and platforms, was intentional in order to provide a minimum of acquired data in the event a system malfunctioned during mission field operations.

8.2 SATELLITES

This experiment utilized data obtained by remote sensors aboard the Earth Resources Technology Satellite - Series 1 (ERTS-1) and the NOAA-2 Improved TIROS Operational Satellite (formerly ITOS-D). Information from each of these satellites was used to determine the feasibility of applying satellite acquired data to fishery resource availability and distribution. For purposes of orientation, brief descriptions of the satellites, as well as their orbit coverage, and sensor systems follow.

8.2.1 ERTS-1

The primary satellite data utilized in this project was obtained by the ERTS-1 system launched into an average orbit of about 900 km (485 n.mi.) above our earth on 23 July 1972. The satellite system allowed for the repetitive acquisition of high resolution multispectral data over the test site, and provided quantitative measurements of the site's water surface features on a spectral, spatial and temporal basis.

The ERTS-1 orbit is nearly circular, sun-synchronous, and near-polar. The satellite circles the earth every 103 minutes, completing 14 orbits per day, and viewed the test site every 18 days. The orbit was adjusted to insure that the satellite ground trace repeated its coverage at about the same local time (1555 GMT) every 18-day period. The ERTS footprint is configured as a parallelogram measuring approximately 185 km (100 n.mi.) x 185 km (100 n.mi.).

A more detailed and comprehensive description of the satellite and associated systems is provided in the Earth Resources Technology Satellite Data Users Handbook (15).

A. Sensors/Equipment Utilized

Of the sensor systems aboard ERTS-1, this investigation examined data acquired by the MSS (MultiSpectral Scanner) and the RBV (Return Beam Vidicon).

- MSS Sensor System

  The MSS obtained data by imaging the test site in several spectral bands simultaneously through the same optical system. The MSS is a 4-band line-scanning device operating in the solar-reflected spectral band region from 0.5 to 1.1μ. It scans cross-track swaths of 185 km (100 n.mi.) width by simultaneously imaging six scan lines across in each of four spectral bands. Optical energy is sensed by an array of 24 detectors (6 per band) in the four discrete spectral ranges: 0.5 to 0.6μ (band 4), 0.6 to 0.7μ (band 5), 0.7 to 0.8μ (band 6) and 0.8 to 1.1μ (band 7).

- RBV Sensor System

  The ERTS-1 Return Beam Vidicon camera system provided test site information in three separate wavelengths: 0.475 to 0.575μ (band 1), 0.580 to 0.680μ (band 2), and 0.698 to 0.830μ (band 3). All three cameras operated simultaneously and viewed ground traces identical in size and geographic area as depicted by MSS imagery.

B. Sensor Selection/Parameter Rationale

The ERTS-1 MSS and RBV sensor systems, and their respective operational spectral ranges, were selected prior to the origination of this investigation. Even though these systems were designed to sense terrestrial features, their spectral regions of operation were applicable to sensing certain water surface phenomena within the test site. The parameter measured and/or detected with the MSS and RBV through black and white, and false color interpretation of ERTS-1 imagery was water color. The water color data was to be analyzed for turbidity patterns, distribution of chlorophyll, surface current patterns, and surface water mass delineations.

8.2.2 NOAA-2

NOAA-2, the second operational spacecraft of a series of second-generation meteorological satellites, was launched on 15 October 1972, with operational control under the direction and responsibility of the National Environmental Satellite Service (NESS). The NOAA-2 orbit is approximately 1680 km (909 n.mi.) high, nearly circular and polar, and also sun-synchronous as a result of an eastward drift. The satellite crosses the equator northbound three hours behind (1500 local time) and southbound nine hours ahead (0300 local time) of the sun. The slightly retrograde polar orbit causes successive photographs to veer almost north and south. Each picture covers an approximate square, 3700 km (2000 n.mi.) per side, with a resolution of about 3.7 km (2.0 n.mi.).

A more detailed and comprehensive description of the satellite and associated systems is provided in the NOAA Technical Memorandum NESS 35 (16).

A. Sensors/Equipment Utilized

Of the earth imaging sensors aboard NOAA-2, only data from the Scanning Radiometers (SR) were examined. As the satellite travels along its orbit, the scanning radiometers operate 24 hours a day and continually scan the earth's surface from horizon to horizon. During the daylight portion of an orbit the radiometers sensed reflected radiation in the visible (0.52μ to 0.73μ) region. During both day and night periods, the system provided data in the 10.5μ to 12.5μ region.

B. Sensor Selection/Parameter Rationale

The scanning radiometers for NOAA-2 were selected prior to the origination of this investigation. Even though these systems were primarily designed for meteorological purposes, their spectral regions of operation were applicable to sensing certain sea surface phenomena on a very large scale. The thermal and visual spectra were used in an effort to supplement the ERTS data through interpretation of large scale features outside the test site which may affect water characteristics within the test site. These imagery were analyzed for sea surface temperature patterns and delineation of surface current patterns.

8.3 AIRCRAFT

Various aircraft and respective onboard sensor systems (App. A) were utilized to augment satellite acquired data and provide pertinent information not obtainable by the satellite systems. Categorically, five different aircraft, based on function, were utilized during the operational phase of this investigation. The largest and most heavily instrumented aircraft were the NP3A (NASA 927) and the NC130B (NASA 929). A smaller aircraft, with less instrumentation, was a locally chartered, twin engine, Beechcraft E-18. An additional chartered light aircraft was used to obtain aerial photographs during the day. Several spotter, single engine, aircraft were also utilized, and these were operated on an infrequent basis coincident with commercial fishing operations.

Summations of the types of aircraft and associated major earth viewing sensor systems utilized during the data acquisition phase are noted in Table 5. A brief description of these aircraft and purpose, as well as spectral coverage, of sensor utilization follows. More detailed descritions of the NP3A and the NC130B, along with respective sensor systems are contained in the NASA documents 17, 18 and 19. More complete information on the Beechcraft E-18 can be obtained from the Beech Aircraft Corp., Wichita, Kansas, or the NASA Earth Resources Laboratory located at the Mississippi Test Facility, Bay Saint Louis, Mississippi.

Table 5. Summary of Aircraft and Sensor Systems Utilized

MAJOR SENSOR SYSTEMS USED	AIRCRAFT				
	NC130B	NP3A	E-18	PHOTO ONLY	FISH SPOTTER
Boresight Mod. 207 Camera		●			
E-20D Spectroradiometer			●		
Hasselblad EL-500 Cameras			●		
KA-62 Multiband Cameras		●			
Laser Profiler		●			
LLLII System			●		
MFMR System		●			
MSS (24-Channel)	●				
PRT-5	●	●	●		
RC-8 Cameras	●	●			
RS-14 Scanner		●			
RS-18 Scanner			●		
Zeiss RMK-1523 Camera				●	

8.3.1 NC130B NASA 929

The NC130B is a medium altitude aircraft powered by four turboprop engines capable of velocities from 150 to 330 knots true air speed. Fully loaded (130,000 lbs. gross take-off weight) and flying at its 30,000 ft. maximum operational ceiling at maximum airspeed, the aircraft has a range of about 2,500 n.mi.

A. Sensors/Equipment Utilized

The major sensor systems operated from this platform, and their operational characteristics as required by the projects' data users follows.

- 24-Channel Multispectral Scanner (MSS)

  This radiometric device optically/mechanically scanned successive contiguous lines across a predetermined flight path, and was to simultaneously provide a magnetic tape record of visible and infrared energy emitted and/or reflected from the test site area in 15 of the available 24 discrete spectral levels ranging from 0.4 to 13.0μ. Reflected energy was recorded to an accuracy of 0.05 to 1.2%, whereas emitted energy was recorded to an accuracy equivalent from 0.26 to 0.72°K. The 15 MSS channels (Table 6) ranged from two through 10 (0.4 - 1.05μ), and from 17 through 22 (8.3 - 13.0μ).

Table 6. NC130B MSS Channels Operated

MSS CHANNEL	BANDWIDTH (MICRONS)	MSS CHANNEL	BANDWIDTH (MICRONS)
2	.40 - .44	10	.97 - 1.05
3	.46 - .50	17	8.3 - 8.8
4	.53 - .57	18	8.8 - 9.3
5	.57 - .63	19	9.3 - 9.8
6	.64 - .68	20	10.1 -11.0
7	.71 - .75	21	11.0 -12.0
8	.76 - .80	22	12.0 -13.0
9	.82 - .87		

- Wild Heerbrugg RC-8 Camera

  This aerial survey camera was equipped with a 6-inch focal length f/5.6 Avigon lens, 9.5 inch Ektachrome Color IR film (2443), and a Wratten filter (WI2) to provide spectral coverage from 0.52 to 0.9μ. Provision was also made for the film to be automatically annotated through implementation of the system' ADAS (Auxiliary Data Annotation System).

- Barnes Precision Radiation Thermometer Model 5

  The PRT-5 was band pass filtered to record gross thermal infrared radiation in the 8.12 to 14.18μ range. The instrument is non-scanning and provided a 2° FOV (Field of View) along the NC130B flight path. Data was recorded on magnetic tape for eventual conversion to 70mm B&W film.

B. Sensor Selection/Parameter Rationale

The MSS was selected to provide information on water color at discrete spectral intervals, sea surface temperature variations, and surface current patterns. The PRT-5 was utilized to provide a thermal reference to sea truth temperature data, and was required for atmospheric corrections and correlation. Photographic imagery from the RC-8 camera system would provide a means to assess cloud cover and sea state, as well as for the location of sea truth surface vessels and the delineation of surface current patterns.

8.3.2 NP3A NASA 927

The NP3A is also a medium altitude, NASA/JSC operated, aircraft powered by four turboprop engines. It is a converted Lockheed Electra, capable of a 1600 n.mi. range, under a full load (113,000 lbs.), at an operational ceiling of 25,000 ft., flying at maximum airspeed of 330 knots.

A. Sensors/Equipment Utilized

The major sensor systems operated from this aircraft, and their operational characteristics as required by this project follows.

- Flight Research Boresight Camera Model 207

  The normal utilization of this camera is to provide a boresight reference for other onboard primary sensors. For this function, the camera was equipped with a 25mm lens (FOV of 53°), 35mm Ektachrome MS Aerographic film (2448), and a filter to provide information in the spectral region from 0.4 to 0.7μ.

- Chicago Aerial KA-62 Camera

  The KA-62 is a four-camera multiband system which provided an annotated five by five-inch record. This camera system was utilized with various film/filter combinations, and with three and six-inch lens (Table 7).

Table 7. KA-62 Camera Film/Filter/Lens Combinations Utilized

FILM TYPE (KODAK)	FILTER (WRATTEN)	LENS (IN.)	WAVELENGTH (MICRONS)
Plus-X Aerographic (2402)	47B + HF3	6	.44 - .46
Plus-X Aerographic (2402)	57 + 12	6	.53 - .55
Plus-X Aerographic (2402)	25A	6	.65 - .70
Plus-X Aerographic (2402)	47B	3	.38 - .48
Plus-X Aerographic (2402)	57	3	.48 - .59
Plus-X Aerographic (2402	25A	3	.65 - .70
Ektachrome Aerographic (SO-397)	Anti-Vignette	6	.42 - .70
Ektachrome Aerographic (SO-397)	Anti-Vignette	3	.42 - .70

- Laser Profiler

  The device is an absolute-altitude measuring instrument primarily used for vertical control over the aircraft's ground flight path. The profiler transmits a monochromatic laser beam, detects beam reflectance and measures phase delay. The operational limitations are from 0 to 15,000 ft. altitude, and temperatures from -28.9°C (-20°F) to 48.9°C (120°F). Maximum resolution is .003 ft. (.09 cm) at a frequency of 49.16471 MHz.

- Multifrequency Microwave Radiometer (MFMR)

  The MFMR is a four-channel passive microwave radiometer which measured absolute radiometric temperatures at four different frequencies to an accuracy equivalent of 1° to 2°K. The four channels utilized are noted in Table 8.

Table 8. MFMR Channels Used

MFMR CHANNEL	FREQUENCY (GHz)	WAVELENGTH (cm)	BANDWIDTH (MHz)
1	1.420	21.0	27
2	10.625	3.0	480
3	22.235	1.3	220
4	31.4	1.0	480

- Barnes Precision Radiation Thermometer (PRT-5)

  The PRT-5 description and range of operation was the same as in Section 8.3.1.A.

- Wild Heerbrugg RC-8 Camera

  The RC-8 camera operational characteristics are described in Section 8.3.1.A. Aboard the NP3A however, two RC-8 systems were utilized. Camera No. 1 used Ektachrome Aerographic film (SO-397), with a clear Anti-Vignette filter, and a six-inch focal length lens to provide coverage from 0.42 - 0.70μ. The second camera exposed Aerochrome Infrared film (2443) through a Wratten 12 filter filter and a six-inch lens to provide coverage from 0.52 to 0.90μ.

- RS-14 Dual Channel Scanner

  This scanning radiometer optically/mechanically scans successive contiguous lines across a given flight path, and records reflected or emitted energy in two of five discrete spectral intervals. User requirements, however, limited its operational use to only one spectral interval (Channel 2) providing information in the 8.0 to 14μ range.

B. Sensor Selection/Parameter Rationale

The Boresight camera was utilized to provide a reference for all the other major onboard sensors, especially the Multifrequency Microwave Radiometer. The MFMR channel of 1.4 GHz was operated to provide data on sea surface salinity. The KA-62 multiband camera system was utilized to provide information pertaining to phytoplankton concentration and distribution. The PRT-5 was used to provide a thermal reference to sea truth temperature data, atmospheric corrections, and as a RS-14 back-up. RS-14 scanner data was obtained for determining sea surface temperature and surface water circulation patterns. The Laser Profiler was operated to attempt assessment of sea state conditions. RC-8 photographic imagery would provide information on cloud cover, sea state, surface vessel location, and turbidity patterns as an indicator of surface water movement.

8.3.3 E-18/C-45 Beechcraft

The E-18 is a low-altitude aircraft powered by two 450 h.p. Pratt/Whitney radial engines. The aircraft possesses a 10,000 ft. operational ceiling with a maximum range of 630 n.mi., and is capable of 110 to 180 knots true airspeed.

A. Sensors/Equipment Utilized

The major sensor systems operated from the E-18, along with their operational characteristics, as defined by the project requirements, follows.

- Exotech Model 20-D Spectrometer

  The E-20D is a dual channel, interference type, device utilizing circular variable filters to limit and record incoming reflected or emitted radiation. A silicon detector was used to provide information in the range from .38 to .72μ, and from .60 to 1.10μ.

- Barnes Precision Radiation Thermometer (PRT-5)

  The PRT-5 description and range of operation was the same as in Section 8.3.1.A.

- Hasselblad EL500 Cameras

  The EL500 camera is capable of recording reflected energy from earth features within a spectral range from 0.4 to 0.92μ depending on film/filter combination. Two simultaneously operated cameras exposed Ektachrome MS Aerographic (2448) film through a HF4 + HF3 filter and a 40mm lens to provide information in the spectral interval from .42 to 0.7μ. The second Hasselblad camera was equipped with Aerochrome Infrared film (2443), a 40mm lens, and a W15 filter to record incoming radiation in the .52 to 0.90μ spectral range. Film format was 55mm x 55mm image on 70mm film.

- Low Light Level Image Intensifier System (LLLII)

The LLLII is a night operational image intensification system capable of detecting luminescing fish schools. As described by Roithmayr and Wittmann (20), the system is comprised of an RCA Model LC716 low light sensor camera, an image intensifier and supportive tubes, a television monitor and a 0.5 inch Sony videorecorder Model AU-3600. The interrelationship of these constituents are shown in Figure 6. The data obtained with this sensor system provided assistance in establishing the presence or absence of fish schools within the test area, their approximate location, and respective surface dimensions.

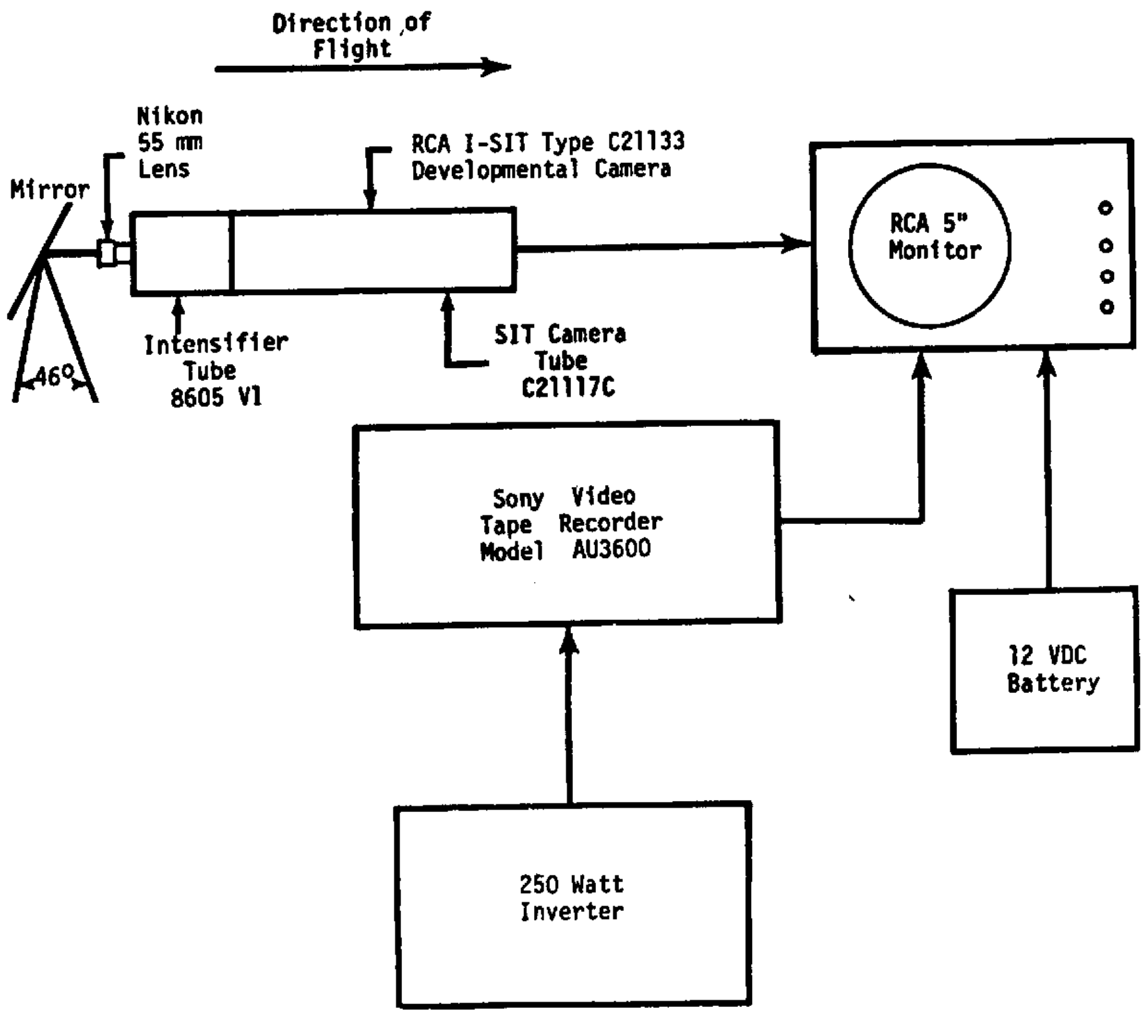


Figure 6. Schematic of Low Light Level Image Intensifier System. (S-70246-AG)

- RS-18 Scanning Radiometer

  The RS-18 is operationally similar to the the RS-14 scanning radiometer. However, the sensor is not dual channel and can provide emitted and reflected radiation data in four spectral range options depending on filter and detector selection. Throughout the operational phase, the RS-18 was used to obtain data in the 8.0 to 14.0μ spectral range. Data was recorded in an analog format on magnetic tape and on 70mm film.

B. Sensor Selection/Parameter Rationale

The E-20D Spectroradiometer and Hasselblad EL-500 camera were selected to provide information in the visible and near infrared region of the spectrum relating to water color, turbidity and surface current patterns, vessel location, and possibly photoplankton detection. The LLLII system, operated during dark of the moon periods, provided information on fish school location, presence or absence, identification and size. The PRT-5 aboard the E-18 was utilized in a fashion similar to its operation from the NP3A and NC130B aircraft, and scanner data from the RS-18 provided sea surface temperature distribution patterns.

8.3.4 Aerial Photo Reconnaissance Aircraft

Two types of low altitude aircraft were used to provide fishery information by means of low altitude aerial photography. One of these was a 240 h.p. Cessna Apache, Model 310, which has an operational ceiling of 5,472 m (18,000 ft), a range of 885 n.mi. (1020 statute miles), and is capable of a speed of 160 kts. at 2432 m (8,000 ft.). The other aircraft was a 250 h.p. Piper Aztec, Model PA-23, capable of a speed of 170 kts. at 2432 m. This aircraft possesses an operational ceiling of 6,384 m (21,000 ft.), and a range of 911 n.mi.

A. Sensors/Equipment Utilized

The photographic equipment utilized aboard these aircraft consisted of a Zeiss RMK-1523 mapping camera equipped with a 15.24 cm (6-inch) focal length lens. Two types of 22.86 cm (9-inch) format film/filter combinations were used during the entire data acquisition phase. One combination consisted of Color Infrared film (Aerochrome-2443) with a Zeiss-B (minus blue) filter which provided photographic imagery in the .48 to .90μ spectral range. The other combination consisted of GAF-1000 blue insensitive (2575) film coupled with a clear Anti-Vignette filter which recorded incoming energy in the .4 to .7μ range.

B. Sensor Selection/Parameter Rationale

The purpose of obtaining low altitude aerial photography over the test site was to provide a photographic record of the location, identification and distribution of menhaden fish schools.

8.3.5 Fish Spotter Aircraft

An undetermined number of these low altitude, fixed wing, single engine aircraft were utilized by fish spotter pilots during their normal mode of operation in assisting the commercial menhaden fishing fleet in harvesting the resource. No electronic remote sensing devices or cameras were utilized aboard these aircraft to obtain fisheries or oceanographic information. However, the visual acuity of the spotter pilot provided real-time fishery resource assessment information. The latter related to fish school location, size and individual number estimate, and identification of the resource.

8.4 ATMOSPHERIC SENSORS/PLATFORMS

A limited number of atmospheric sensors and respective platforms were utilized during the data acquisition phase. These platforms were radiosondes and medium altitude aircraft, the latter of which supported a number of external atmospheric sensors during mission operations at various altitudes.

8.4.1 Radiosondes

Radiosondes were deployed from the Mississippi Test Facility to a maximum altitude of 7,174 m (23,600 ft.). At various increments of altitude, atmospheric data was obtained on pressure, air temperatures and dew point temperatures to determine relative humidity. These data provided atmospheric correction inputs to aircraft remotely sensed information.

8.4.2 Aircraft

Of the different types of aircraft utilized, only the NC130B and the NP3A were equipped with externally situated atmospheric (environmental) sensors. The liquid-water content of the air outside the aircraft was measured by a Johnson-Williams Liquid Water Content Indicator and values recorded on magnetic tape. Total air temperature (TAT) was externally measured with a Rosemont Indicator, and values recorded on flight logs. Relative humidity values were calculated from ambient dew point temperatures measured with a Cambridge Dew Point Hygrometer. Both aircraft were equipped with identical atmospheric sensing instrumentation. These data were used in a fashion similar to that obtained with radiosondes.

8.5 SURFACE VESSELS

Surface vessels were utilized as platforms for the acquisition of sea truth oceanographic and fishery resource data. These data were obtained to support simultaneously acquired aircraft and satellite remotely sensed environmental and resource information. For purposes of organization and identification, all participating sea truth vessels were categorized according to their operational function:

- SVO - Surface Vessel/Oceanographic
- SVF - Surface Vessel/Fishing
- SVFO - Surface Vessel/Fishing-Oceanographic

8.5.1 Surface Vessel/Oceanographic

The oceanographic vessels were comprised of coastal and nearshore contractual (rented) and federal government (NOAA/NMFS and NASA/ERL) owned and operated boats. These SVO's occupied predetermined station locations within the test site, during the field operations phase for the sole purpose of obtaining oceanographic and meteorological information.

A. Sensors/Equipment Utilized

Basic and historical oceanographic and meteorological techniques and devices were used in conjunction with available electronic measuring instrumentation. For measurement of some parameters, various methods and devices were used to determine single parameter values. In this regard, a degree of acquisition system redundancy was implemented to insure data collection, as well as provide for a comparative check of measurement values per parameter. This concept is shown in Table 8, (extracted from Appendix 1, Tables 2 and 4) which notes the method/device used per parameter measurement from aboard a sea truth oceanographic vessel.

Not all SVO's were equipped with the devices noted in Table 8, and equipment use and distribution per vessel was governed by equipment availability and operational readiness.

- Bottle Float - A plastic jug, partially filled with water, and tethered to the anchored SVO, and a stopwatch, were used to obtain surface current speed to the nearest 0.1 knot.
- Compass - Onboard vessel compasses of various makes and models were used to ascertain surface current and wind direction to ± 5 degrees.
- Fathometer - Those SVO's possessing fathometers or depth sounders provided water depth on station to the nearest 0.5 feet.
- Forel-Ule Color Comparator - This hand-held color scale (Wildco mfg.) was used by an observor to estimate water color. The Forel part of the scale (eight colors) was used for comparing blue to green water. Yellow to brown water color comparisons were made using the Ule scale (eight colors). The scales were used in conjunction with the Secchi Disc situated one meter below the water's surface.

Table 9. Shipboard Data Acquisition Method/Device per Sea Truth Parameter Measured

METHOD/DEVICE	AIR TEMPERATURE	CHLOROPHYLL	CLOUD COVER	CURRENT DIRECTION	CURRENT SPEED	RADIATION	RELATIVE HUMIDITY	SALINITY	SEA STATE	WATER COLOR	WATER DEPTH	WATER TEMPERATURE	WATER TRANSPARENCY	WIND DIRECTION	WIND SPEED
	PARAMETERS MEASURED FROM SHIPBOARD														
Bottle Float				●	●										
Compass				●										●	
Fathometer											●				
Forel-Ule Scale										●					
Irradiance Meter						●									
Lead Line											●				
Observer Estimate			●						●					●	●
PRT-5						●						●			
Psychrometer							●								
RS5-3								●				●			
Secchi Disc													●		
Spectroradiometer						●				●					
Timing Device					●										
Thermometer	●											●			
Water Samples		●						●							

- Irradiance Meter - A Hydro Products Model 620-S Relative Irradiance and Direct Reading Photometer system was used to determine diffuse attenuation coefficients by measuring the ratio of irradiance (1-100%) incident on a subsurface and surface photocell to an accuracy of ±10% of reading.

- Lead Line - This primitive device was used to measure depth if a fathometer malfunctioned or was unavailable.

- PRT-5 - This portable, hand-held, precision radiation thermometer (Barnes Mfg.) was used to radiometrically measure sea surface temperature. The device was band-pass filtered to provide spectral coverage in the 8.0 to 14.0μ range. Surface PRT-5 values were acquired also for comparison with airborne PRT-5 sea surface temperature measurements (Section 8.3).

- Sling Psychrometer - This standard hand-held device was employed to determine relative humidity values at sea level from wet and dry bulb temperature readings.

- RS5-3 - The Beckman manufactured Model RS5-3 In-Situ Salinometer was used to measure surface and subsurface (at discrete depth levels) salinity and water temperature. The device internally computed salinity values to an accuracy of ±0.3‰ from measured conductivity and temperature values with respective accuracies of ±0.5 millimhos/cm and ±0.5°C.

- Secchi Disc - A 12-inch, white aluminum, disc was utilized to provide a consistent indication of water transparency (clarity). Consistency was achieved through implementation of a standard sampling procedure utilizing a uniformily configured apparatus. The disc was also used in conjunction with Forel-Ule water color measurements.

- Spectroradiometer - The ISCO (Instrument Specialties Company) Model SR spectroradiometer was used to determine spectral energy intensity at various wavelengths. The instrument measured the energy intensity of incident light expressed as units of microwatts per square centimeter per millimicron of bandwidth ($\mu wcm^{-2}m\mu$). Measurements at preselected wavelengths, from .45 to .75μ at .025μ increments, were made just above the water's surface by means of a fiber optics sensor probe connected to a deck readout unit.

- Thermometer - Calibrated, mercury bulb, immersion type, glass thermometers were used to obtain sea surface and air temperatures. Air temperatures were taken with unclad thermometers to an accuracy of 0.1°C. Identical thermometers were fitted into plastic "bucket-type" sleeves, which also served to contain surface water, for sea surface temperature measurements.

- Water Samples - Surface water samples were collected using the "bucket-skimming" technique, stored in sealed uncontaminated polyethylene bottles, and analyzed for salinity and chlorophyll content. All water samples were immediately refrigerated and stored in unlighted areas after collection to inhibit biodegredation of the sample.

8.5.2 Surface Vessel/Fishing

Commercial menhaden fishing vessels (SVF), which normally fish the Mississippi Sound for the resource, were utilized to obtain information on fish school location, catch effort, total catch data, and school size. The vessels were berthed at Moss Point, Mississippi, and were owned as well as operated by three commercial National Fishmeal and Oil Association member fishing and processing enterprises. They were the Zapata-Haynie Corp. (formerly Haynie Products, Inc.), Standard Products Co., and the Fish Products Company. The vessels operated in a normal fishing mode peculiar to the menhaden industry, and were therefore unencumbered with the responsibility of occupying predetermined oceanographic stations. The number of fish harvested per catch was automatically determined by an onboard counter device.

8.5.3 Surface Vessel/Fishing-Oceanographic

Selected commercial fishing vessels were manned with trained observers, under the direction of the Earth Satellite Corporation (EarthSat), and a limited suite of environmental measuring devices for the purpose of acquiring oceanographic and meteorological data prior to, during, and after a fish catch was made. Personnel aboard these vessels were instructed to obtain sea truth data in accord with data requirements during catch activities under the strict condition of non-interference with normal fishing procedures. As a result, certain parameters could not be measured with the degree of effectiveness afforded to the oceanographic vessels. Parameter measurements, utilizing those techniques and devices described in Section 8.5.1, included air temperature, cloud cover, relative humidity, salinity, sea state, water color, depth, and temperature, wind direction and speed, and collected water samples.

8.6 WATER SAMPLE ANALYSES

The water samples collected aboard the SVO's and SVFO's (Section 8.5) were transported to an MTF Laboratory where the water was analyzed for salinity and chlorophyll concentrations.

8.6.1 Salinity Determinations

The Beckman manufactured Model RS7-B Induction Salinometer provided rapid and accurate (0.003‰) determinations of collected sea water samples. Samples of 50-milliliters were compared to that of standard Copenhagen sea water (35‰), and temperature differences between sample and standard were internally compensated for by the instrument.

8.6.2 Chlorophyll Determinations

The technique and devices used for determination of chlorophyll, which provides a measure of the phytoplankton present, was that proposed by SCOR-UNESCO (21). Each water sample for chlorophyll analysis was filtered through a Millipore 0.45 micron acetate filter. The filters and their residue were stored at -15°C over activated silica gel. Each filter and its residue was ground in a teflon tissue grinder to which 90% acetone was added as the extracting agent. The acetone homogenates were stored in the dark for 10 minutes, then centrifuged at 2000g for approximately ten minutes to one hour depending on extract turbidity. The volume of each extract was recorded, and the absorpiton spectrum of the chlorophyll extract measured against a blank acetate filter dissolved in 90% acetone. The chlorophyll measurements were made on a Cary 17 Spectrophotometer.

The absorption spectra were indexed at 750, 663, 645, and 630 mμ. The absorption at 663, 645, and 630 mμ was corrected by comparison with the absorption of the "reference blank" at 750 mμ. These corrected values were used in the following formula to determine chlorophyll a.

$$\text{Chl } \underline{a} = (11.64 \times e_{633} - 2.16 \times e_{645} + 0.10 \times e_{630}) \frac{\text{ext (ml)}}{\text{vol (1)}} \times \frac{1}{\text{absorption cell light path (cm)}} \qquad [1]$$

where: e_{633} = absorption at 633 mμ and, ext = extract volume

e_{645} = absorption at 645 mμ vol = volume of sample

e_{630} = absorption at 630 mμ

SECTION 9

DATA ACQUISITION FIELD OPERATIONS

9.1 CONCEPTS

As noted in the Field Operations Overview (Figure 1 - Section 1.2), our concept of the ideal platform/utilization configuration necessary to meet this project's data requirements was to simultaneously acquire fishery and environmental information from satellites (ERTS-1 and NOAA-2), aircraft (NC130B, NP3A, E-18, Aerial Photo, LLLII-Low Light Level Image Intensifier, and fish spotter), radiosondes, and surface vessels (SVO-Surface Vessel/Oceanographic, SVF-Surface Vessel/Fishing, and SVFO-Surface Vessel/Fishing-Oceanographic) over the test site and the fishery resource contained therein. According to this pyramidal concept, as ERTS made a pass over the test site, the remote sensing aircraft would underfly the satellite as well as overfly select sea truth surface vessels. In this manner, similar and/or related environmental and resource data were coincidently acquired from platforms operating at various altitudes, and in-situ.

The organizational framework of our data acquisition activities was centered around three types of missions (field operations). These were classified as Mini, Primary, and Secondary mission efforts. The Mini-Missions were, in effect, dress rehearsals for the other mission types. Primary missions were defined as those field operations during which all data acquisition platforms were available for scheduled use. Primary mission dates were therefore intentionally selected to coincide with ERTS passes over the test site. Secondary missions were defined as those data acquisition operations during which a minimum number of platforms (excluding ERTS) were available for scheduled use. These mission dates were intentionally selected to fall on Tuesday of each consecutive week during the entire field operations period in order to provide a continum of data between the time frame of ERTS passes and/or Primary Mission dates.

As mentioned previously, a factor of redundancy was intentionally built in for each system/platform whenever and wherever possible. This concept was implemented to provide a high degree of assurance of acquiring certain types of data in the event of malfunction of any given acquisition system.

9.2 SUMMATION

Data acquisition field activities were scheduled from 27 June through 4 November 1972 to coincide within the historical time frame of resource availability native to the Mississippi Sound, and the commercial menhaden fishing industry operations.

9.2.1 Mission

A status summary of our field data acquisition operations during 1972 is listed as Appendix B. Abbreviations and symbols used in the table are defined as follows. Mini, Secondary, and Primary Missions are noted as M, S, and P. Missions which were cancelled, primarily due to inclement weather conditions, and recycled to another date are referred to as CR. On the other hand, those missions which were cancelled and not recycled are noted as CM. The notation PC indicates a partially completed mission resulting from a major malfunction or continuous sporadic functioning of any platform/system scheduled for use on a particular mission. In the same sense, MC refers to any mission during which all scheduled field components functioned to specification on a mission date. Terminated activity (T) refers to cessation of operations for the remainder of the data acquisition time frame. The symbol M-6/27, and similar expressions, denotes a Mini Mission (M) either scheduled and/or performed on June 27. As used in the table, a negative symbol (-) under headings of ERTS Pass, Aircraft or Boats denotes non-utilization of that particular platform and/or system as a result of either schedule conflicts or inoperativeness. Conversely, a positive sign (+) indicates affirmative usage.

A summary of mission efforts is provided as Table 9. A total of 33 data acquisition missions were attempted. Of this total, 20 were scheduled according to the concepts outlined in Section 9.1, whereas 13 were not scheduled. Ten mission dates were lost to inclement weather, and of this number, nine were recycled to a future date, whereas only one was completely cancelled. In reference to the total number of missions attempted, seven were completed, 11 were partially completed, 13 were cancelled but recycled, two were completely cancelled without benefit of recycle, and three missions were carried out under the sub-orbital pass of ERTS.

9.2.2 Aircraft

Aircraft participation was primarily governed by weather conditions, schedule comittments, and dark of the moon periods in the case of airborne utilization of the LLLII system. During the period of sanctioned project field operations the NC130B flew one mission day; two mission days are credited to the NP3A, and E-18 flight days totaled 13; seven mission dates were flown by the aerial photo aircraft, whereas eight LLLII night missions were flown. Fifteen mission dates were flown by various Spotter pilots in support of commercial menhaden fishing activities. With the exception of fish spotter operations, an aircraft flight summary is provided as Appendix C. The summation includes mission date, aircraft flown, altitude(s) of operation, total data miles flown at altitude, duration of flight (start/stop time), and sensors operated per mission date.

Table 10. Summary of Mini, Secondary and Primary Mission Efforts (1972)

EFFORT AND PLATFORM UTILIZATION PER MISSION DAY	MISSION TYPE/NO.			TOTALS
	M	S	P	
Scheduled	2	15	3	20
Unscheduled	3	7	3	13
Attempted	5	22	6	33
Completed (MC)	1	4	2	7
Partially Completed (PC)	2	8	1	11
Cancelled & Recycled (CR)	2	9	2	13
Cancelled - Not Recycled (CM)	0	1	1	2
With ERTS Pass	0	1	2	3
Inclement Weather Loss	1	6	3	10
NC130B Flights	1	0	0	1
NP3A Flights	0	0	2	2
E-18 Flights	1	10	2	13
Aerial Photo Flights	1	3	3	7
LLLII Flights	1	6	1	8
Spotter Operations	3	9	3	15
SVO Operations	3	11	3	17
SVF Operations	3	9	3	15
SVFO Operations	2	8	3	13

9.2.3 Surface Vessels

Surface vessel participation was also governed by weather conditions, as well as by vessel availability and operational characteristics. The designated strict oceanographic vessels (SVO) operated during 17 mission dates and were responsible for acting as sea truth data collection platforms on a total of 906 oceanographic and meteorological stations. Those vessels which acquired oceanographic/meteorological information, in addition to normal fishing operations, provided these data on 13 mission dates, and took a total of 575 stations. Commercial fishing vessels (SVF) operating five days per week (excluding weekends and weather permitting) provided resource information on 15 mission dates. A breakdown of the number of stations taken per date of observation by both the SVO's and SVFO's are provided as Appendix D.

9.2.4 Activity Cessation

Determining factors affecting culmination of field data acquisition operations were:

- Non-availability of schooling menhaden.
- Termination of commercial menhaden fishing fleet activities.
- The successive build-up and projected adverse weather conditions over the test site for the remainder of the fish availability time frame.

9.3 OPERATIONS MANAGEMENT

The "go" or "no-go" decision to undertake any particular mission was the responsibility of the Operations Management team comprised of members from each of the major participating groups. The ultimate decision to perform a mission rested with the Principal Investigator. Factors affecting a "go/no-go" decision and mission type to be performed were:

- Predicted weather conditions,
- Availability and system performance capability of all scheduled aircraft,
- Availability and capability of scheduled surface oceanographic vessels,
- Probable availability of the fishery resource within the test site,
- The probability of commercial fishing operations during the selected mission date, and
- The ERTS overpass date.

The evaluation of these factors was performed during an event/decision sequence established for the sole purpose of determining the probability of acquiring the minimal amount and type of data required to meet project objectives. During the sequence, current and predictive weather conditions over the test site were received from NWS and evaluated; all scheduled SVO's (ERL and contract) and aircraft (NASA and contract) were contacted to ascertain their readiness to participate; and updated information pertaining to fishing conditions were inputed by the commercial industry's SVF's, SVFO's, Spotter Pilots, as well as by the LLLII group. These data were provided with increased frequency as the mission date and implementation time was approached. With this information at hand, the operations management team, located at MTF headquarters, were able to formulate a mission "go/no-go" decision designed to provide the best chance for mission success.

9.4 PLATFORM/SYSTEM DEPLOYMENT

To provide platform/system deployment characteristics inherent to each field mission attempted (total of 33) would be of minor value at this juncture. In addition, most of this type of information can be gleaned from previous discussion. However, a supplemental discourse is warranted to provide a more composite picture of field data acquisition activities. In the following discussion, reference will be made to the 7 August 1972 primary mission efforts to provide examples of particular types and phases of field activity which were performed, at least in part, throughout all mission operations.

9.4.1 ERTS-1

During the period of data acquisition the ERTS made 12 passes (Table 10) over the test site. As configured by GSFC, the satellite's sub-orbital track allowed ERTS to provide coverage on two consecutive days per 18-day repetative period. For example, on 6 August, ERTS coverage included the eastern part of Mississippi Sound and Mobile Bay. On the following day, (7 August) satellite coverage included the western portion of the Sound as well as Lakes Borgne and Pontchartrain, and the northern part of Chandeleur Sound. In effect, two ERTS-1 frames were required for total test site coverage.

During the 12 available passes, three missions (two primary and one secondary) were performed with some degree of success. The 12 passes provided 10 complete sets (bands 4, 5, 6, and 7) and one incomplete set (bands 4, 6, and 7) of MSS imagery. Of the imagery received, eight sets were suitable for analysis as determined by percent cloud cover estimates over the test site and imagery availability. Project suitability of available imagery was however, another matter determined by availability of data derived from aircraft underflights and sea-truth information (oceanographic and fishery) coincident with a particular ERTS pass, and the imagery band coverage provided by that singular pass.

Table 11. Summary of ERTS-1 Imagery Data Acquisition During Field Operations As Related To Project Applicability

DATE OF ERTS PASS	MISSION DATE	IMAGERY DATA ACQUIRED									% CLOUD COVER	ANALYSIS SUITABLE	PROJECT SUITABLE
		IMAGERY I. D. NO.	BAND										
			1	2	3	4	5	6	7				
8-6	None	1014-15555	•	•	•	•	•	•	•	10	Yes	No
8-7	8-7	1015-16013				•	•	•	•	0	Yes	Yes
8-24	None	1032-15555				•	•	•	•	40	Yes	No
8-25	8-25	1033-16014				•		•	•	5	Yes	No
9-11	None	1050-15560				•	•	•	•	80	No	No
9-12	None	1051-16014				•	•	•	•	0	Yes	No
9-29	None	1068-15560				•	•	•	•	60	Yes	No
9-30	None	1069-16014				•	•	•	•	100	No	No
10-17	None	1086-15562				•	•	•	•	5	Yes	No
10-18	10-18	1087-16020				•	•	•	•	50	Yes	No
11-4	None	None			Not Available					-	-	-
11-5	None	1105-16022				•	•	•	•	100	No	No

In this regard, fishery resource information was not available during the mission/ERTS pass on 18 October. MSS band 5 was not available in the suite of ERTS imagery from 25 August, and this non-availability proved to be unfortunate as will be discussed in the Data Analysis Section. The remaining set of ERTS imagery, that acquired on 7 August, was therefore the only full set of quality and percent cloud cover acceptability by which was project suitable.

9.4.2 Test Site Delineation

The test site was delineated into five equal subsections defined as A, B, C, D, E (Figure 7) to provide more effective utilization of available resources as a result of the number of scheduled missions, and to concentrate data acquisition activities within the site as determined by predicted geographic availability of the fishery resource. Each rectangular subsection was 12 n.mi. x 10 n.mi., and were spaced two n.mi. apart. The selection of a particular subsection, combination of subsections, or the entire test site as the geographic range of singular mission efforts was determined a few hours prior to actual implementation of the field operations as noted in Section 9.3.

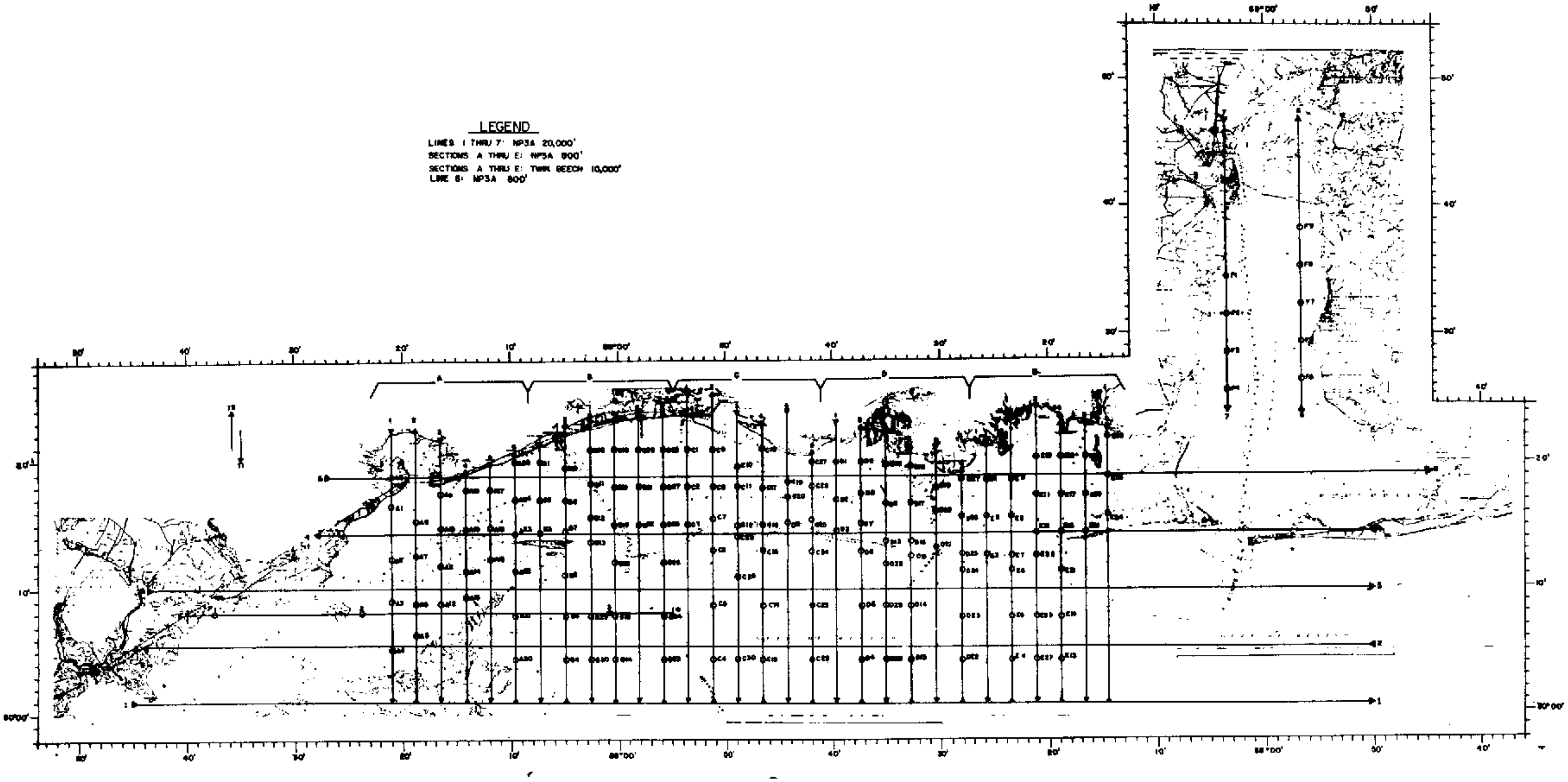


Figure 7. Test Site Subsections, Oceanographic Sampling Station Location, and Flight Line Chart for 7 August 1972 (S-70246-AG)

9.4.3 AIRCRAFT

A. NC130B, NP3A and E-18

Figure 7, although depicting 7 August, also illustrates the general flight patterns for the NP3A, the NC130B which flew lines similar to the NP3A, and the E-18. The North to South lines were spaced 1.5 n.mi. apart, wheareas spacing for the east to west lines was 4.0 n.mi. Total data miles flown by each of these aircraft during the field operations phase are NC130B: 311.8 n.mi., NP3A: 2,434.8 n.mi., and the E-18: 6,324.8 n.mi. A break-down of data miles and sensors operated at various altitudes of operation per aircraft and mission date are provided in Appendix C. The total mileage per aircraft excludes "up" and "down" transects as well as those required short flights over test patterns set up at MTF. All missions performed by these aircraft were daylight operations, except for one. On 25 August at an altitude of 21,500 feet, the NP3A flew a night mission in addition to its daytime flight pattern.

B. Photo, LLLII, and Spotter

The aircraft specifically utilized for the purpose of acquiring aerial photographic fishery data flew a total of 3,870 n.mi. during the Mini, Secondary and Primary mission operations. Figure 8 graphically illustrates the photo aircraft flight pattern it flew. The squares denote photographic frames and their configuration, which runs east to west and parallel to the Gulf Coast, indicates the line pattern. The remainder of this illustration will be discussed in the Data Analysis Section. For purposes of photographic/fish coverage, the test area was arbitrarily divided into two sections. One section included all waters north of the barrier islands (Petit Bois, Horn, etc.), whereas the other section included waters south of these islands out to approximately the 10 fathom curve. Ten flight lines were established to provide approximately 90 percent coverage of the two sections. The lines (not numbered in the figure) were numbered from north to south with line one as the most northern. Line nine is absent in the figure because it was not flown on 7 August. The lines were essentially flown parallel to the Gulf Coast and to each other, and each line was spaced about 2.2 n.mi. apart. The line spacing, coupled with the camera and lens utilized (described elsewhere) at an altitude of 8,100 feet prevented side overlap of resultant photographs, thereby reducing the possibility of counting fish schools twice in analysis.

The Low Light Level Image Intensifier was flown for a total of 1,154 n.mi. during dark of the moon periods as noted in Appendix C. Each of the two aircraft utilized for this purpose flew six parallel transects which covered areas of reported daytime fish school concentrations. The six east to west transects were spaced approximately one n.mi. apart with the length of each about 20 n.mi. Two additional transects, each 30 n.mi. long, searched additional sectors of the Sound.

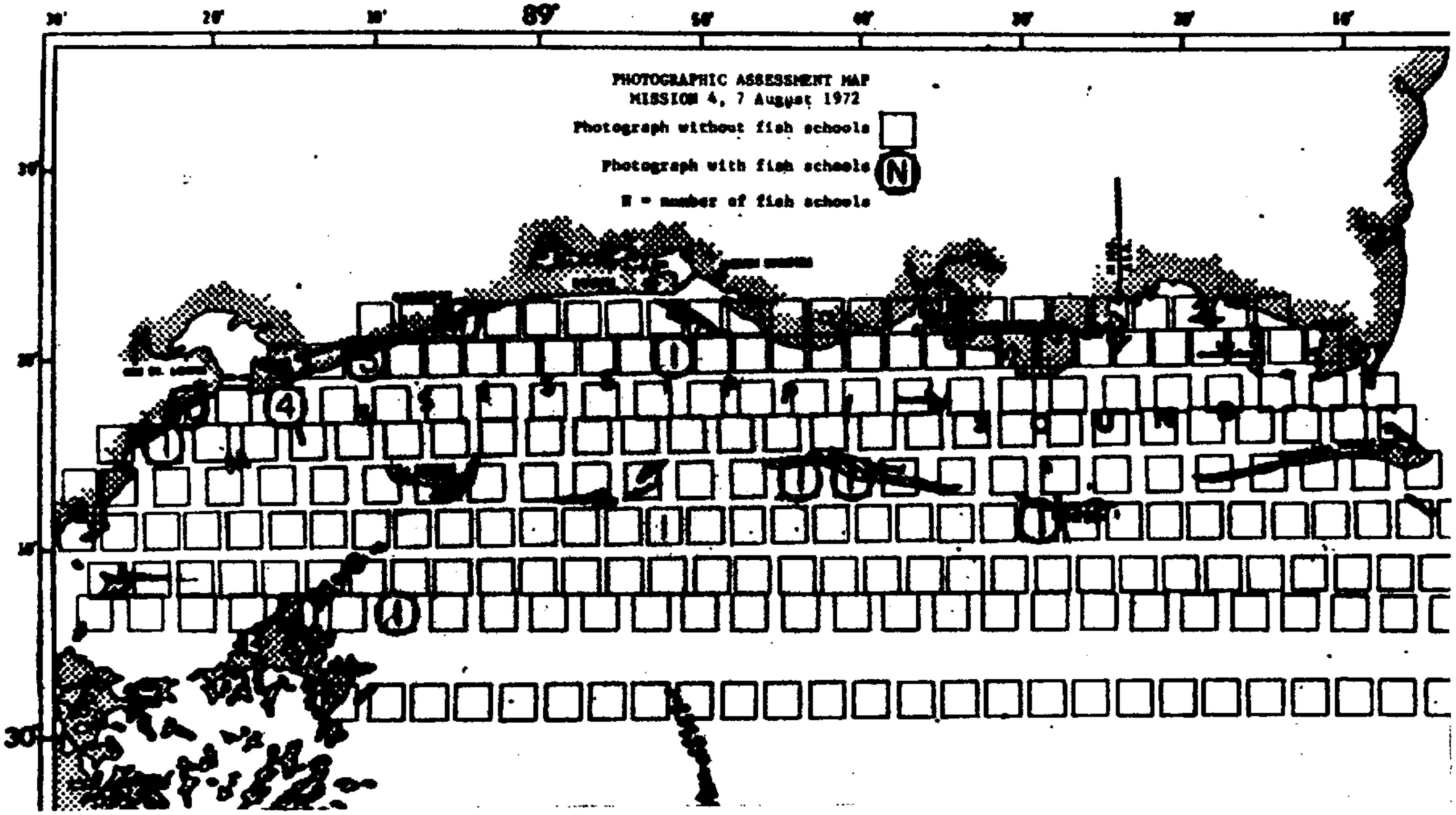


Figure 8. Photographic Coverage and Assessment Chart of 7 August 1972 Aerial Photo Mission. (S70246-AG)

Commercial fish spotter pilots flew single wing, light aircraft over the test area from Sunday through Friday of each week, weather permitting, in support of the surface vessel fleet operation. All flights were during daylight hours, and each pilot flew a random pattern of his own volition. Under normal commercial fishing operations, fish schools were visually located by the pilot from altitudes of approximately 800 to 1000 feet. Upon sighting a menhaden school of harvestable size, the pilot then radio-directed a carrier fishing vessel (SVF, SVFO) to the school; and through the utilization of radio communication, to the vessel captain, further proceeded to assist the fishermen by guiding smaller, net boats, around the school for the purpose of fish entrapment.

9.4.4 Radiosondes, Communications and Test Targets

A. Radiosondes

To obtain ancilliary meteorological data, radiosondes were launched to altitudes exceeding 7,000 meters from MTF and Boothville, Louisiana at a time coincident with the initiation of a Primary mission. Data acquired by these platforms were previously described in Section 8.4.1.

B. Communications

A communications network between the various field activity components provided a vital and necessary link during all attempted missions. A frequency of 6.9825 MHz was used between MTF headquarters, the ERL E-18 aircraft and the JSC (NP3A and NC130B) aircraft. Communications between the JSC aircraft, the E-18, spotter, and the photo aircraft were transceived on a frequency of 122.9 MHz.

C. Test Targets

Test targets, for the purpose of aircraft sensor instrument calibration, were located at the surface of a pond at MTF. Targets utilized were of the bar type, tricolor as well as grey-scale, and were deployed prior 0800 on mission dates. Contact temperatures of two, four, 16, 32, 64 and 90% grey-scale were taken at time of test target flyover.

9.4.5 Surface Vessels

As mentioned in preceeding sections the three types of surface vessels utilized to acquire sea truth data were arbitrarily designated as SVO (oceanographic and meteorological), SVF (commercial fishing), and SVFO (commercial fishing and oceanographic).

A. SVO

As many as 20 surface vessels were deployed at one time for the purpose of acquiring sea truth information in support of aircraft and satellite operations. The number of vessels used varied with the type of mission performed, but the sampling requirements were consistent with established procedure independent of the number of vessels operated during a given mission. Attempts to re-occupy station locations illustrated in Figure 7 proved to be highly successful by means of LORAN equipment operated onboard almost all the participating SVO's. Station coordinates were predetermined and provided to vessel captains prior to each mission as were respective area sub-section operational instructions. The coordinates (latitude and longitude) for each of the SVO stations noted in Figure 7 are provided as Appendix E. On 7 August, a total of 137 stations were occupied resulting in sea truth data computer printout listed as Appendix F.

Sea truth stations were also occupied to support the night LLLII flights. These stations, totaling 40, were located directly under the aircraft's flight path. The single charter vessel engaged for this purpose acted as a platform for water transmissivity, sea state, surface water temperature, current speed and direction, depth on station, and depth at which bioluminescence visually extinquishes. Additional samples and measurements were obtained at the MTF Test Pattern pond, and these included a water sample, and sling psychrometer data.

B. SVF

The commercial fishing vessels operated independently of mission activities, and therefore fished in a random fashion governed by the occurrance and geographic location of menhaden schools within the test site. As a result, the number of vessels, comprised from the three participating commercial menhaden fishing enterprises, varied from day to day dependent on fishing activity. Weather permitting, the SVF's fished from sun-up to sun-down Monday through Friday of each week of the fishing season.

C. SVFO

From one to three vessels out of the menhaden fishing fleet were utilized by EarthSat personnel for the purpose of acquiring oceanographic and meteorological data in conjunction with fish catch operations in order to assess environmental conditions just prior to resource entrapment. During the period of field activity, the SVFO's occupied 575 stations, and of these, 14 locations were sampled on 7 August. Appendix G provides the SVFO interpolated station coordinates and data values acquired on the 7 August mission.

The station coordinates listed however, do not represent the exact position of sampling in terms of latitude and longitude, but are within 0.6 n.mi. or less of the actual station location. As a result of an agreement with the fishing industry, precise station coordinates were not recorded in order to preclude the possible release of fish school locations and concentrations to industry competitors. During the course of fishing, vessel captains were requested to provide "general area" locations of fish schools coincident with sampling activity. These locations were then plotted on a 12-minute square grid pattern, which was further subdivided into 10 parts comprising 1.2 minute subsquares (1.2 n.mi.). Center point coordinates of each subsquare were computed, and these values thus constituted the coordinates of any station taken within that particular subsquare.

SECTION 10

DATA PROCESSING SYSTEM

10.1 OVERVIEW AND CONCEPTS

All FEL ERTS-1 data processing was handled by a central Data Processing Coordinator. This coordinator received all digital data in card format and prepared all incoming data for the next phase of processing. Types of data which were inputed to the ERTS-1 Processing Coordinator consisted of biological, environmental, meteorological, satellite, photographic, and aircraft observation information.

Appendix H identifies user format requirements associated with the information acquired during the data acquisition operations. Not all of the user requirements were cómpleted as specified. Only the biological, environmental and meteorological data were physically processed by the FEL at MTF. Other types of data were requested from, and all processing was done by, the responsible functional organization. The Data Processing Coordinator requested these data based on user requirements.

10.2 DATA FLOW

NFMOA/EARTHSAT and ERL sea truth data, as well as NFMOA/EARTHSAT and NMFS biological data were formatted and established as an ERTS-1 data file as shown in Figure 9. The available processing routines are also illustrated in Figure 9. Statistical routines were provided as required by the users, and all routines required were identified to the Data Processing Coordinator at least one month prior to the need for the information. If a new and/or special routine was required, the user forwarded a written request to the Coordinator for evaluation and possible implementation.

10.2.1 Sea Truth Data

All oceanographic, fishery and meteorological sea truth data in the form of keypunched cards was inputed to the Data Processing Coordinator. The Coordinator reviewed and submitted the cards to the MTF Data Operations Section for edit and format runs. The cards, card and image tape, as well as edit tabulations were routed back to the Coordinator for review and evaluation prior to routing to the Slidell Computer Facility.

At the computer facility, the card image tape was put into the ERTS-1 Data File. From this common stratified file, all major correlation functions were processed, along with standard tabulation routines and plots utilizing the Atlas Display Routines. All fishery data could be extracted and processed in conjunction with environmental data, or extracted and processed as fishery data only. From the data base, plots and tabulation will be provided as shown on Figure 9.

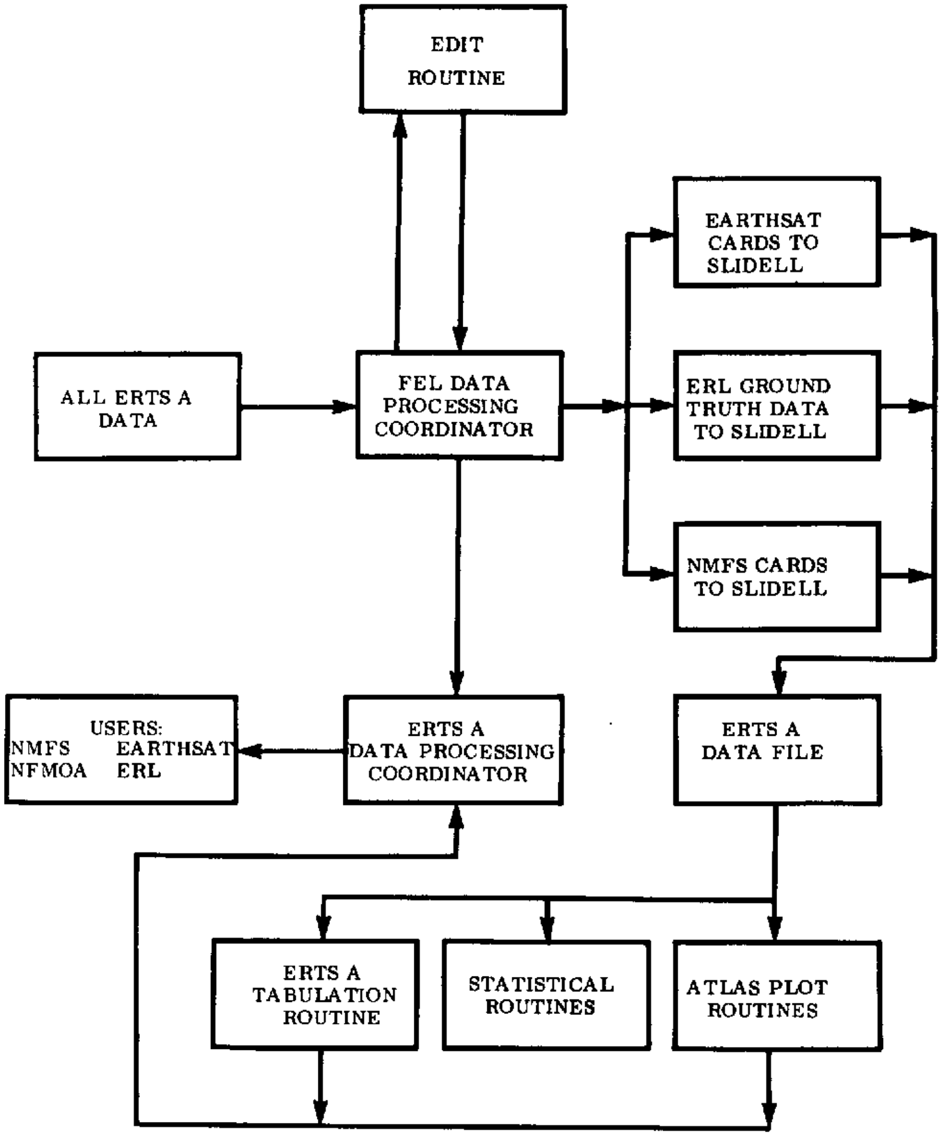


Figure 9. Data Processing Flow (S-70246-AG)

10.2.2 Satellite Data

The NASA Data Processing Facility (NDPF) provided users with ERTS-1 output products illustrated in Figure 10. However, during the course of this investigation, only system corrected images (SYCI) from the MSS were utilized. Products requested, and used were black and white 70mm negative and positive transparencies, as well as 9.5 inch positive and negative transparencies. Detailed discussions regarding ERTS imagery processing are contained in the ERTS Data Users Handbook (15). The NOAA-2 satellite imagery was processed by NESS. Processing particulars of these black and white images may be obtained from the NESS Documentation Section.

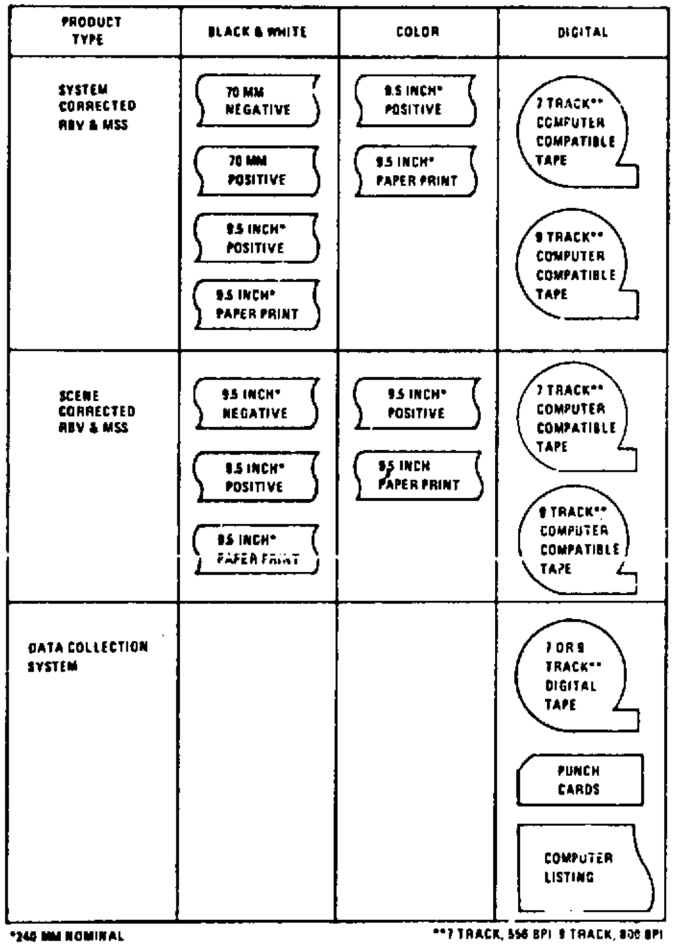


Figure 10. ERTS Output Products Available to Investigators. (S-70246-AG)

10.2.3 Aircraft Data

The NC130B, NP3A, and E-18 acquired remotely sensed data were processed by NASA/MSC and NASA/ERL/MTF. Low Light Level Image Intensifier and aerial photographic data collected by NMFS were inputted to the ERTS-1 Data File. The raw data log sheets prepared by NMFS were keypunched and routed to the Slidell Computer Facility for incorporation into the file. The data were identified by time of day and location of observation. Extraction of these data along with other related data were possible utilizing a selective storage and retrieval system.

10.3 FORMATS

Input formats for biological, environmental and meteorological data from the participating groups are listed as Appendix I. Copies of the established formats, and any subsequent changes, were submitted to the Data Processing Coordinator for development of data formatting and editing software capable of accepting the different formats and converting the data to a common base prior to insertion into the ERTS-1 Data File.

10.4 HARDWARE SYSTEMS

All computer processing was performed on the UNIVAC 1108 EXEC VIII Multiprocessing System located at the Slidell Computer Facility. A complete system diagram is depicted in Figure 11. The SC-4020 microfilm printer/plotter and Xero Copyflo printer were also used extensively during the life of this project to provide visual displays, report data, and information to be utilized by the various analysis groups.

During a segment of the analysis time frame, it became exceedingly difficult to obtain all the computer time required due to maximum utilization of the system in support of the Skylab Program. This occurrence resulted in a slow-down of computer oriented analyses during this time frame.

10.5 SOFTWARE SYSTEMS

In addition to the EXEC VIII system software, compilers, library routines and special processor, the statistical routines listed as Appendix J were also available, and several of these were converted for ERTS-1 data application. The step-wise multiple regression routine was used extensively in model development tasks which are discussed in the Data Analysis Section.

The application of software to establish, maintain, and utilize the ERTS project data (Figure 12) consisted of three main segments. The first segment was developed by the FEL to reformat all incoming digital data for input to the information storage and retrieval system. This particular segment was then utilized to prepare FEL, NFMOA/EARTHSAT, Pascagoula and ERL raw data tape files. The second segment, which is an Environmental Information Retrieval (ENVIR) System developed for NASA by the Gulf Universities Research Consortium (GURC), was used to construct compressed inverted binary data banks for each data source previously listed. The system provided simple English language commands which enabled users to selectively retrieve information subsets from the inverted files, print the information, and/or store it on magnetic tape to be later utilized by analysis programs. The system provided the capability of locating information in the Data Bank, and satisfying given search criteria by mathematical calculation, rather than by sequential searching processes. This particular segment was extensively used in the early stages of analysis to selectively retrieve subsets of information which were then utilized in the decision processes. The last segment was comprised of several computer programs developed by the FEL at MTF to analyze and display the selectively retrieved data subsets. The system provided required software packages for statistical analysis such as data grouping, moment computations, arithmetic means, standard deviation, linear and multiple regressions, etc.

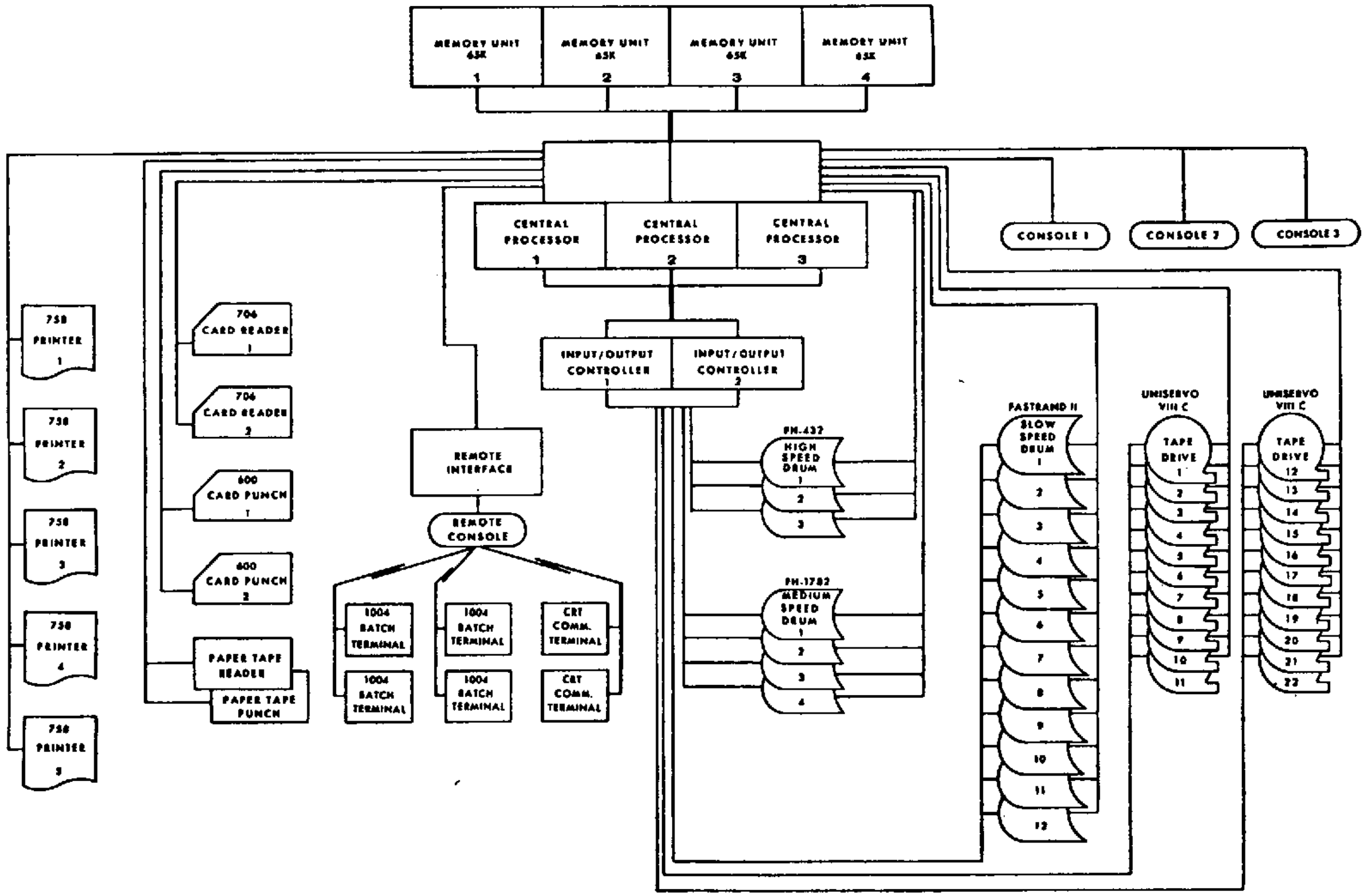


Figure 11. UNIVAC 1108 EXEC VIII Multiprocessor System. (S-70246-AG)

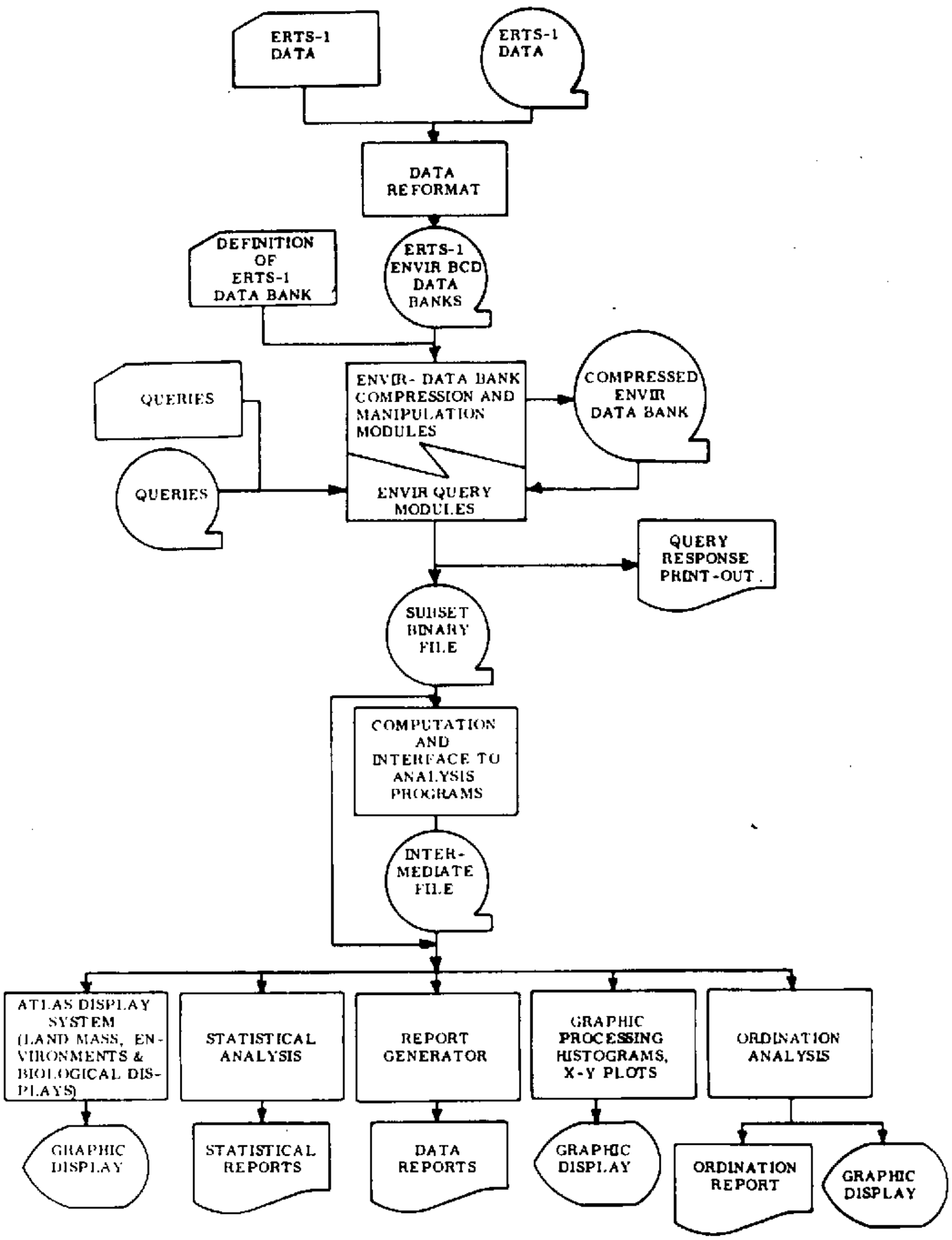


Figure 12. Data Management Software System. (S-70246-AG)

Specialized software was prepared to perform similarity/ordination analysis, and various mathematical computations. The graphic Atlas Display System (ADS) was utilized to display fishery, oceanographic and meteorological data at the proper latitude and longitude, as well as to display any land mass applicable and/or associated with the locations of sampling. A report generator system, in a format requested by users, was also developed by the FEL to provide necessary data tabulations.

10.6 SPECIAL PRODUCTS

As per user requirements, a number of special products, in addition to those previously enumerated, were also generated to assist individual analysis groups. As a matter of predetermined agreement between all project participants, these products, which constituted a degree of analysis in themselves, were available to all participants. For example, the ERL and their contractor support teams provided computer generated sea surface radiometric temperature plots in association with RS-18 Infrared Scanner imagery (Figures 13 and 14). Figure 14 is a continuation of Figure 13.

The infrared scanner imagery shows the initial scanner data transformed from analog tape to positive print (via a film negative) without atmospheric correction processing. The radiometric temperature maps show the scanner data after digital processing, which includes correction for atmosphere, into gray level prints which depict temperature gradients in levels of 0.5°C. Inscribed on the gray level prints is a temperature grid giving corrected radiometric temperature to the nearest 0.1°C. A more comprehensive discussion regarding the prints is presented in the Data Analysis Section.

Other special product examples are illustrated as hand contour plots of 7 August Secchi visibility (Figure 15), sea surface temperature distribution (Figure 16), surface salinity distribution (Figure 17), and surface chlorophyll a concentrations (Figure 18). These products were constructed using sea truth data only. The low light image intensifier system provided video taped images of menhaden schools at night. Some of these video fish school images were photographed off a television monitor for specific analysis. An example of such a product is presented as Figure 19 in which the menhaden schools are depicted as light toned "strings" against the darker water.

MISSISSIPPI SOUND 7 AUGUST 1972

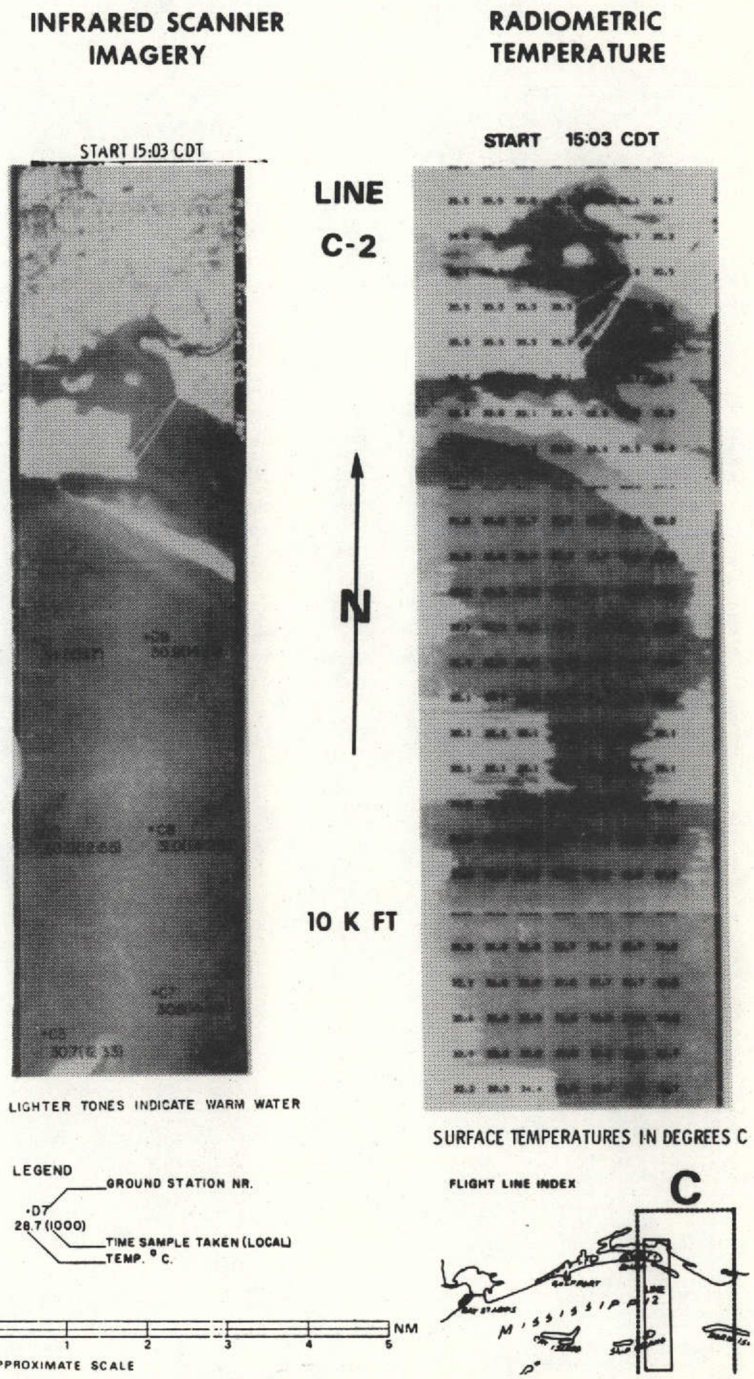


Figure 13. RS-18 Infrared Scanner Imagery Compared with Computer Generated Radiometric Sea Surface Temperatures of The Same Scene (Line C-2) Acquired Over The Test Site (10K feet) On 7 August 1972 (Part 1). (S-70246-AG)

MISSISSIPPI SOUND 7 AUGUST 1972

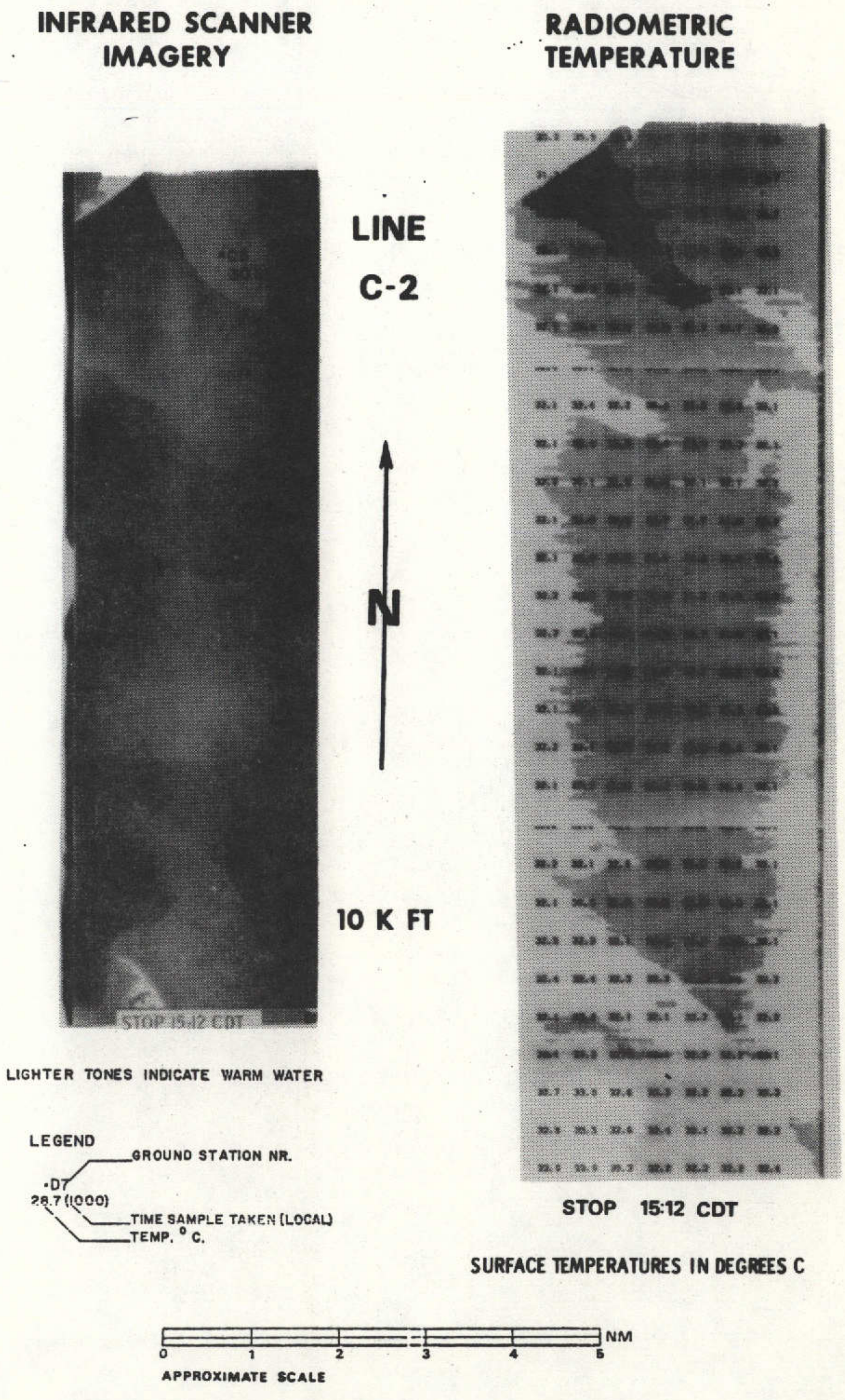


Figure 14. RS-18 Infrared Scanner Imagery Compared with Computer Generated Radiometric Sea Surface Temperatures Over The Test Site (10K feet) on 7 August 1972 (Part 2). (S-70246-AG)

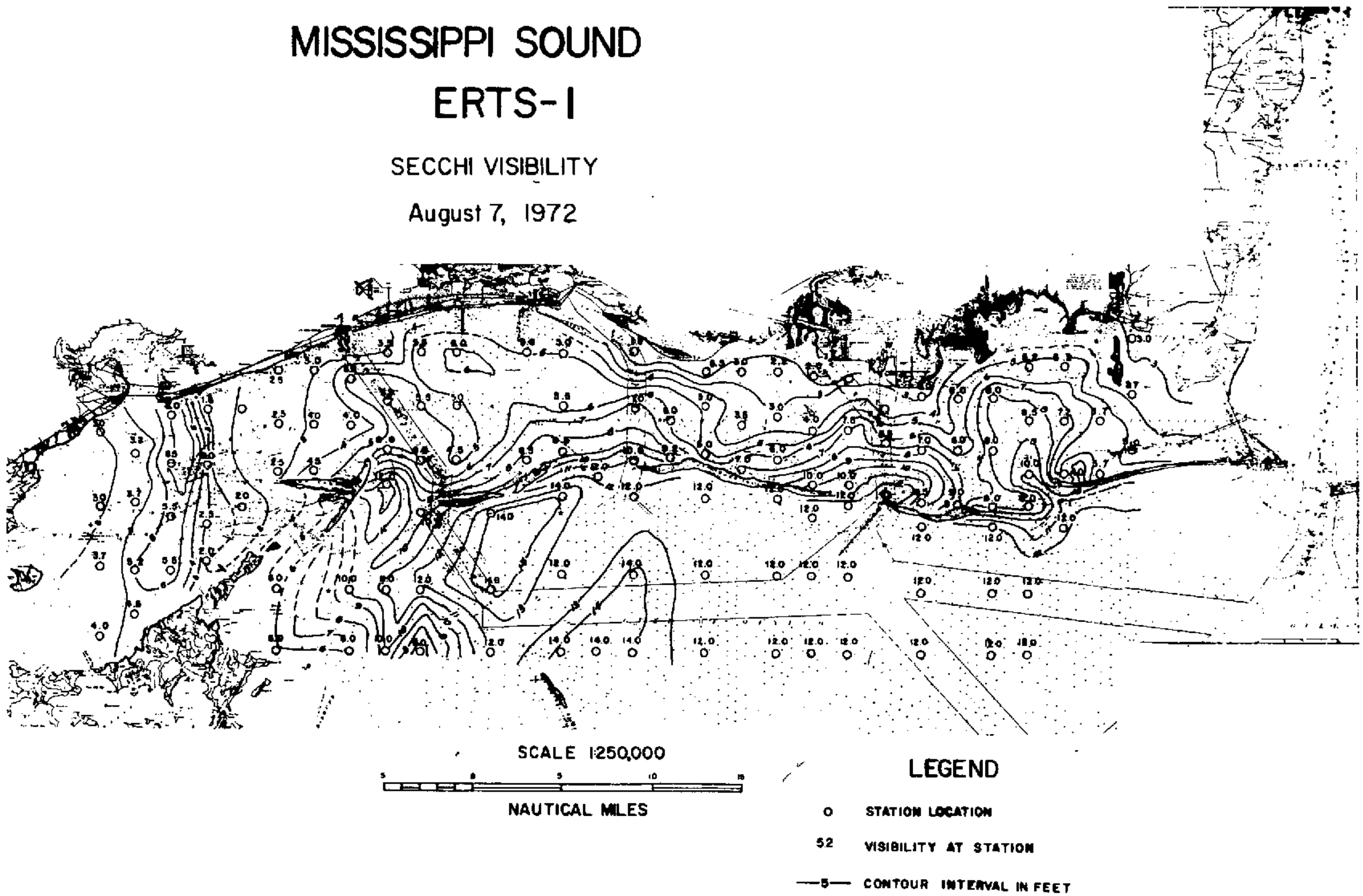


Figure 15. Secchi Visibility Contour Chart for Mississippi Sound (7 August 1972) (S-70246-AG)

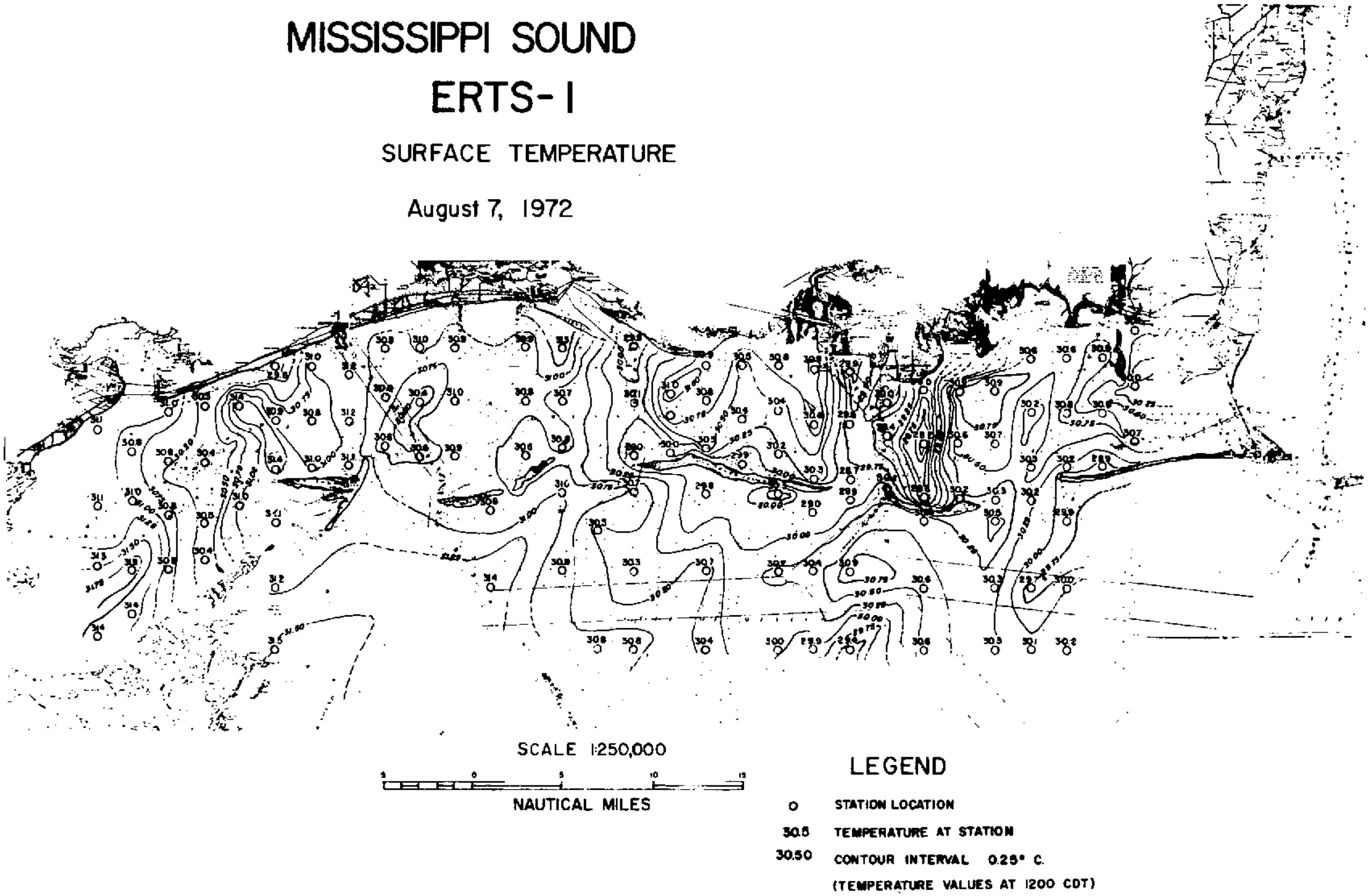


Figure 16. Sea Surface Temperature Contour Chart for Mississippi Sound (7 August 1972) (S-70246-AG)

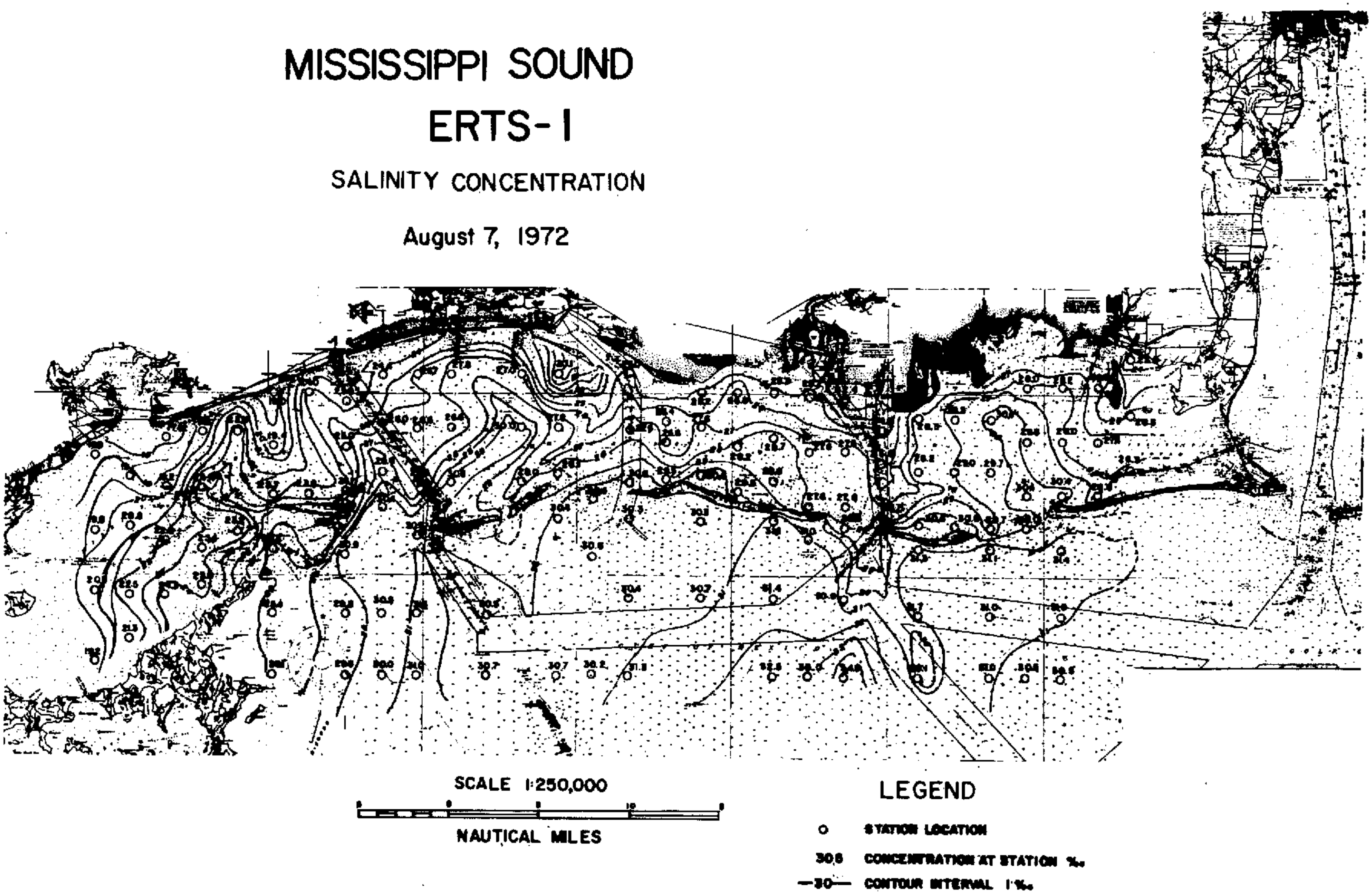


Figure 17. Sea Surface Salinity Contour Chart for Mississippi Sound (7 August 1972) (S-70246-AG)

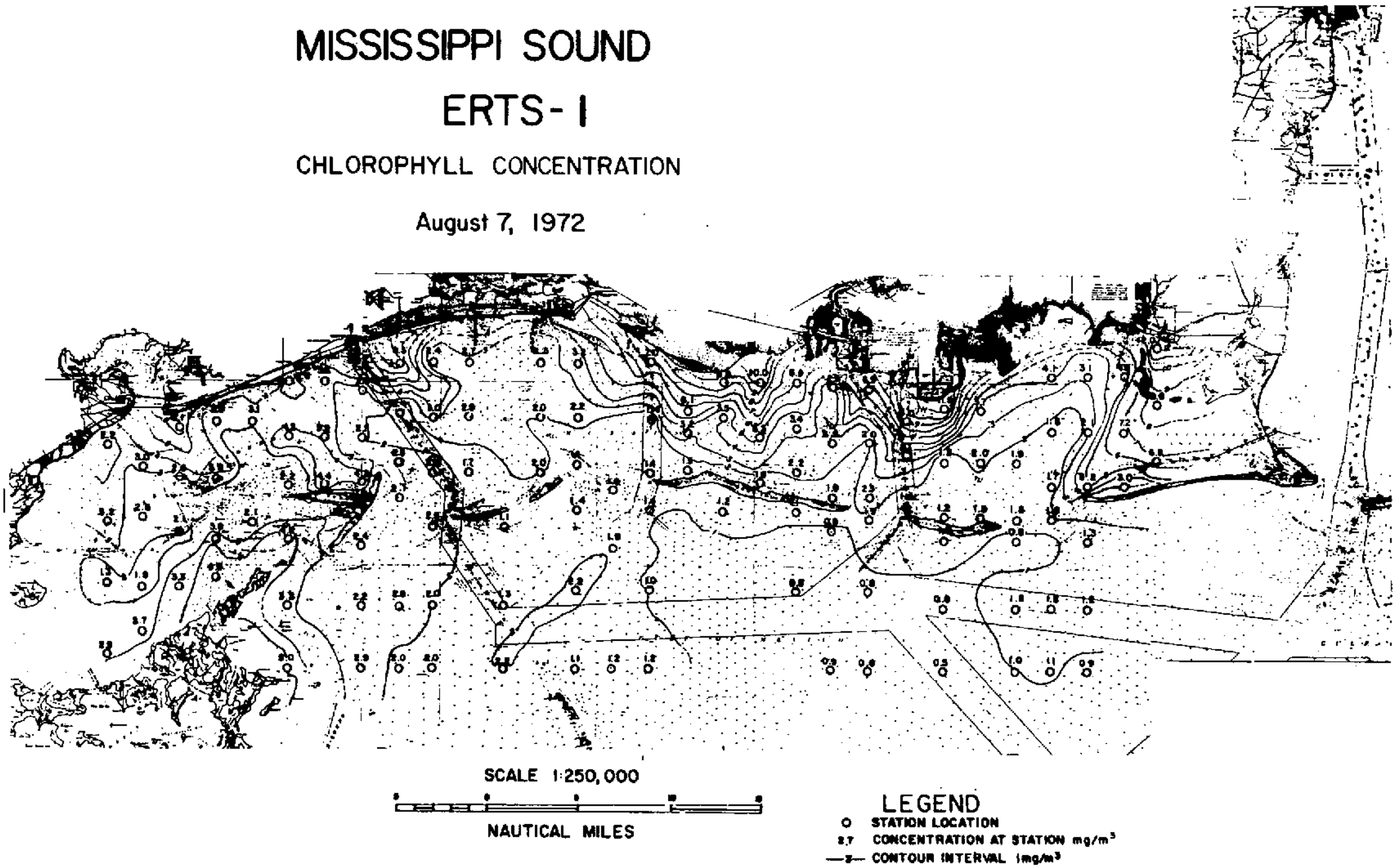


Figure 18. Chlorophyll a Surface Distribution Chart for Mississippi Sound (7 August 1972) (S-70246-AG)

Figure 19. Low Light Level Image Intensifier Photograph of Lumenescing Menhaden Fish Schools Taken From 3,000 Feet Altitude. Photo Was Taken Off A Video Tape Television Monitor. (S-70246-AG)

SECTION 11

DATA ARCHIVING SYSTEM

11.1 CONCEPTS

The FEL Data Processing Coordinator maintained an archive of raw and processed data, as well as a file on satellite imagery and aircraft photography utilized by the project participants. The flow of data from the raw input, through processing, to the archive is shown in Figure 20.

11.2 ARCHIVAL DATA TYPES

Several data sets were received from the various participating groups. The oceanographic and meteorological sea truth data was received from the NASA/ERL. Fishery resource information was received from both NFMOA/EARTHSAT and NMFS. The resource data was acquired from menhaden industry commercial fishing vessels, low altitude photography, and the low light level image intensifier system. All of the environmental and resource data are presently archived in card formats (see Appendix I) and on magnetic tape. The data from each of these sources can be retrieved in bulk and/or selective subset form via the information storage and retrieval system should only a subset of the data be required. Computer listings of the data taken directly from the cards to tape operation can be used to ascertain any pertinent information such as the collection and storage dates of a given information source, etc. This information has been extensively used in preparation of requests for more detailed processing.

Imagery from the ERTS-1 and NOAA-2 satellites acquired to date have been logged in and filed. Initially, a data bank for the imagery was constructed, and identification of the imagery keypunched. In this regard, the ENVIR system was utilized to prepare an information index of the imagery contained in the bank. However, this procedure was discontinued because the manual logging system was sufficient for the quantity of imagery acquired.

All aircraft acquired photography data was reduced by the NMFS Pascagoula Laboratory, and the film is presently located at that installation. Upon completion of the photo analysis, the film will be transferred to the NMFS/MTF archive.

A majority of the computer plots and tabulations, resulting from analysis program runs, have been recorded on micro-film and filed. A processing status log was generated and utilized to schedule, track, and log all processing activities requested and/or completed. The log can be used to retrieve information on any film archived for a particular request.

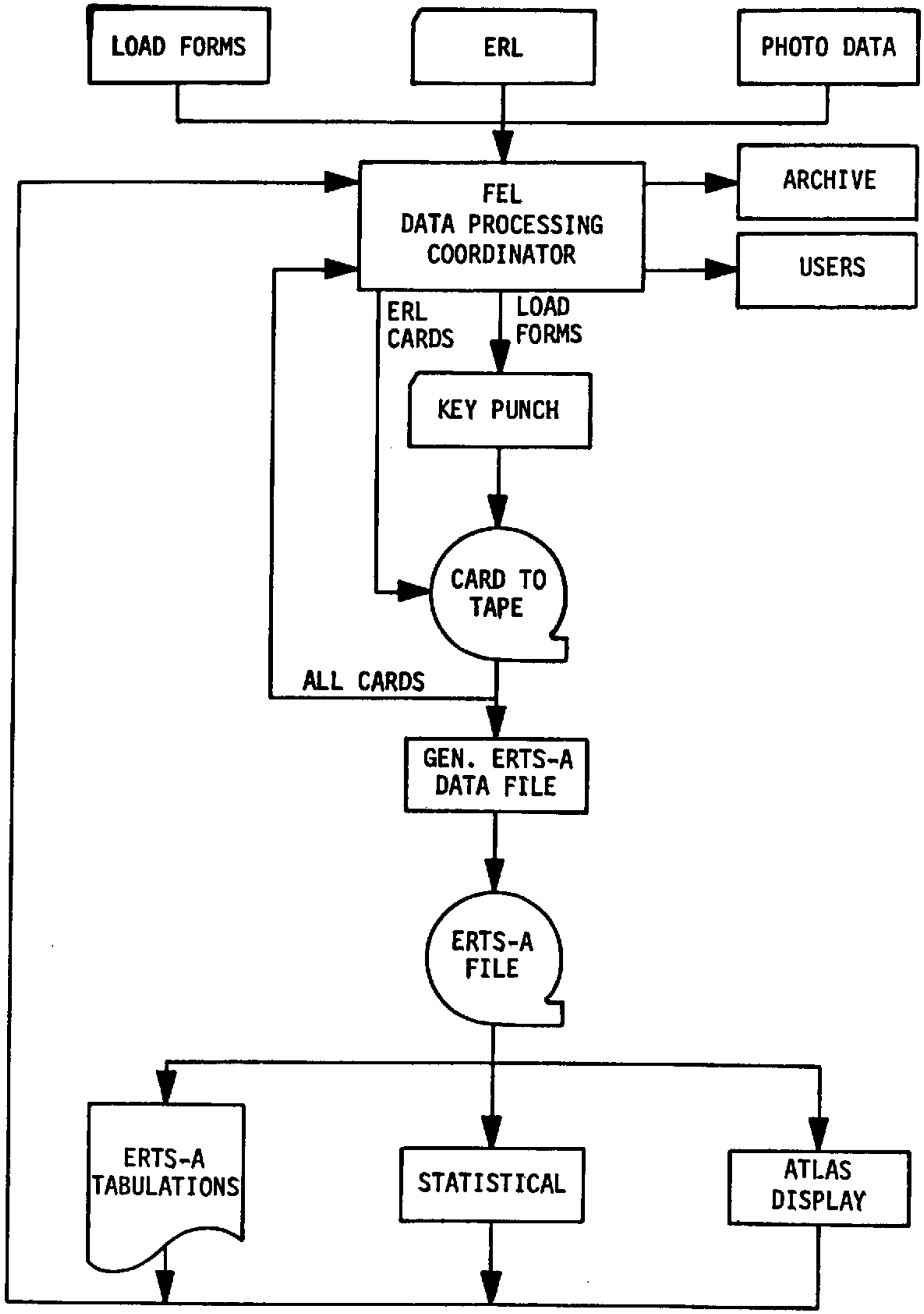


Figure 20. Data Archiving Flow Diagram. (S-70246-AG)

11.3 SYSTEM FLEXIBILITY AND ECONOMICS

The archival system is segmented into a manual system suitable for imagery and photography, whereas an automated system has been devised for accommodating digital data. The system possesses the capability and flexibility to handle all requested tasks thus far. The automated archiving system was a by-product of the information and retrieval system, and was therefore economically superior to a separate generation of such a system. In addition, the manual system requires only a small percentage of an individual's time, and in this regard, is also very economical. In retrospect and summation, the archival system as configured has proved to be efficient and faborably cost effective for the data quantities encountered during project life.

SECTION 12

DATA ANALYSIS, RESULTS AND CONCLUSIONS

12.1 CONCEPTS

In general, analysis of acquired data has proceeded according to plan. Also as planned, data in excess of that required to meet and satisfy primary project objectives were obtained as a direct result of individual participant requirements and objectives. Some of this information is currently under evaluation as well as analysis by the participants, whereas other data has been momentarily set aside for future analysis due to reasons relating to a sufficient lack of resources. This philosophy was recognized and accepted prior to initiation of the project, and as noted earlier in this report, spin-off products including certain areas of data analysis not directly related to the primary objectives were projected to ensue for approximately five or more years after project completion.

During the preceeding months, and as a result of this philosophy, the NMFS/FEL placed concentrated emphasis on those areas of data analysis directly related to meeting the primary objectives as interpreted through the interrelationship of the four design elements of Aerospace, Oceanography, Resource and Utilization (Primary Objective Efforts). Secondary objectives were explored through participant analysis of data subsets relating to one or more of the design elements (Supplemental Objective Efforts).

12.2 SUPPLEMENTAL OBJECTIVE EFFORTS

12.2.1 Environmental Data

The NASA Earth Resources Laboratory at MTF was one of the major participants in Project 240. Prior to becoming a participant, they initiated a study of the Mississippi Sound during the early part of 1971 as part of their remote sensing program. Results of their research efforts were provided to the NMFS/FEL in the form of ERL internal data reports. These reports became the "backbone" of a historical oceanographic and remote sensing data base for Project 240. During the early part of 1972, the NASA/ERL agreed to participate in Project 240, and to continue providing the necessary sea truth and remote sensing data required under the Project Plan developed for the FEL ERTS-1 Experiment. In support of the project, and as a direct result of these efforts, the ERL has internally published a number of reports categorized as to type of field measurement. They are: (A) Surface Measurements, and (B) Remote Measurements. Each report title bears a date signifying either a Primary, Secondary, or Mini mission field data acquisition activity. These reports are listed in the Bibliography under the general title of "Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study...". Information concerning these reports can be obtained by contacting the NASA/ERL at MTF.

A. Surface Measurements

The ERL internal reports dealing with surface measurements are basically oceanographic sea truth data compilations listed according to oceanographic station number, station location, and time of station occupation. In addition to parameter values acquired by in-situ techniques, specific parameter measurements derived from laboratory analysis of sea water samples acquired per station, as well as simultaneously obtained meteorological data, are also listed. The parameter per station listing includes sea surface temperature, chlorophyll-a, salinity, water clarity and color, sea state, water depth, surface current speed and direction, air temperature, relative humidity, wind speed and direction. Additional information included within each report are surface weather maps, atmospheric pressure height contours, machine processed radiosonde data, graphic representations of tidal fluctuations, and maps illustrating remote sensing aircraft flight lines, oceanographic station locations, sea surface temperature contours, surface salinity contours, surface chlorophyll distribution patterns, and water clarity contours. Examples of this information, reflecting the 7 August mission, has been discussed and illustrated elsewhere in this document. Each report also contains a section on materials and analysis methods which is further delineated into field and laboratory procedures (see Sections 8.5 and 8.6).

Efforts to provide a complete treatise on environmental conditions within the Mississippi Sound during the data acquisition phase have been nearly completed. This comprehensive report is now in review and publication preparation, and will soon be released as an ERL report.

B. Remote Measurements

1. Satellite

The near-daily acquired NOAA grey scale imagery was minimumly utilized during the course of this investigation. The inadequate resolution characteristics as well as more than ample coverage of each image containing the test site precluded intended utilization. However, the images were visually analyzed to provide cloud cover information and grose indications of sea surface temperature phenomena.

Analysis of ERTS-1 imagery for oceanographic information utilization has been previously discussed in Section 9.4.1 in relation to project usability. In this regard, only imagery from 7 August 1972 has been extensively analyzed, and such analysis will be discussed in the forthcoming section on Primary Objective Efforts. There are plans however, to continue examination of the available imagery suitable for analysis as part of our pending investigative efforts.

2. Aircraft

The ERL Remote Measurement Reports include those remote sensing measurements acquired by either the NASA/NC130B or the NP3A whenever applicable. The reports contain aerial remote sensing information provided during overflights on mission days, and coincide with the surface measurement reports. The format and contents of each report varies with the type of aircraft utilized, its sensor complement, and the data products generated from each specific overflight. A data accuracy summary is provided in which the output accuracy per product of each sensor flown for that particular mission is discussed and analyzed in terms of system capability, operational constraints, and data processing and analyzation techniques utilized. A copy of the flight request is included to provide points of reference on the types of sensors requested to be flown, operational periods, flight requirements and constraints, communication requirements, sensor requirements and respective operational constraints, and target calibration requirements. Another section, titled "Flight Operations Report" systematically describes the actual flight and sensor operations, and includes a subsection on anomalies and/or malfunctions encountered. Data product information sheets on each sensor from which a user product is generated are also provided. These sheets offer the user detailed product information required for data analysis. Specifically, the sheets provide information on data acquisition start and stop time, as well as mission date, product format, actual altitude flown per flight line, scale of imagery, field of view per frame, side and forward overlap if any, film type and processing particulars, footage available and a list of frames/time, atmospheric corrections and actual conditions and an assessment of product quality in conjunction with any anomalies and/or perturbations per sensor system encountered. Each report also contains a number of standard products inherent to each particular overflight. These include flight line and oceanographic station location maps, and actual flight index maps which allow the user to relate specific sensor product imagery to sea truth data acquisition locations. Depending on user product requirements, established in advance of a particular overflight, the report may include a copy of a specific data product not ordinarily contained within the remote measurements report.

a. Water Color

An investigation was conducted by Weldon (22) to develop procedures for the acquisition of chlorophyll and turbidity values in coastal waters by observing the changes in spectral radiance of the backscattered spectrum. The technique used consisted of examining Exotech Model 20-D spectral radiometer data obtained over the test area for the purpose of determining which radiance ratios correlated best with chlorophyll and turbidity measurements as acquired from analysis of water samples and Secchi visibility values from the same area.

- Objectives

The initial study phase utilized existing spectral radiometer computer programming capabilities to investigate the feasibility of correlating selected wavelength radiance values with chlorophyll and Secchi visibility data obtained from sea truth samples. The information gained about the characteristics of the spectral data from the Mississippi Sound waters during this phase were subsequently used to develop a statistical technique for determining chlorophyll and turbidity values from the spectral radiometer data. The first objective of the initial phase was the extrapolation of an open ocean method of determining chlorophyll concentrations to remotely sensed chlorophyll in the turbid waters of the Mississippi Sound. The second objective was to determine wavelengths in the backscattered spectrum which could be used to remotely measure turbidity characterized by the Secchi depth of the water. Additional objectives were to establish some basic characteristics of the spectral radiometer data obtained from the water in the Mississippi Sound. These were: 1. Repeatability of the water spectrum signatures from flights over the same area, 2. The effect that changes in altitude have on the water spectrum signatures, 3. The wavelengths that are best for determining changes in chlorophyll concentrations and Secchi visibility, and 4. The effect changes in sun angle have on determining remotely sensed values for chlorophyll and Secchi visibility.

- Spectral Radiometer Calibrations

The E-20D spectral radiometer (Section 8.3.3) was calibrated in the ERL calibration laboratory utilizing standard techniques recommended by the manufacturer. The radiometer was calibrated at the following wavelengths: 0.41 - 0.66μ at 0.01μ increments, and 0.69 - 1.29μ at 0.02μ increments. Radiometer calibrations were made in radiance per unit wavelength intervals (watts/cm^2/SR/micron), and the associated calibration computer programs assumed that all the spectral flux incident on the radiometer was emitted from the earth's surface. Atmospheric corrections were not inputted to this program during the investigation.

- Computer Programs

The analog E-20D data tapes from the E-18 aircraft were digitized at the Slidell Computer Center utilizing the SDS930 computer, the A/D (analog to digital) system, and a computer program prepared by Computing and Software Incorporated. A spectral radiometer software program (23), developed by the ERL, retrieved the recorded data from the prepared digital tape to provide the following information:

- Voltage versus filter wheel pulse position (tabulation)

- Voltage versus wavelength (plots and tabulations)

- Radiance versus wavelength (plots and tabulations)

- Radiance of selected wavelengths versus time (plots)

- Ratio of selected wavelengths versus time (plots)

- Flight Line Selection

  As noted previously, the E-18 aircraft flew quite a number of flight lines on various mission dates. The lines were reviewed in regards to the following criteria deemed necessary to provide data for analysis.

  - Large variation in chlorophyll and secchi visibility sea truth measurements.

  - Existance of multiple flights flown over the same area at different altitudes.

  - Good meteorological conditions, i.e. minimal haze and cloud cover.

  - Operational to specification radiometer and aircraft data systems.

  Table 12 lists the selected E-18 mission dates, the number of flight lines per area, and the altitude flown per line.

Table 12. Selected E-18 Water Color Missions

MISSION DATE	FLIGHT AREA LOCATION	NO. LINES	ALTITUDE (K - ft.)
7/24	Mississippi Sound	2 2	2.5 10.0
8/4	Mississippi Sound	2 2	2.5 10.0
8/7	Mississippi Sound	3	10.0
10/18	Biloxi Bay	3	2.0

- Sea Truth Data

  A summary of the sea truth data acquired for this particular water color investigation is provided as Appendix K (modified after Weldon). There data were collected according to the procedures and methodology used for all sea truth and laboratory measurements incurred during the total project life.

- Flight Line Repeatability

  The two 2.5K feet (0.76 km) flight lines flown on 4 August 1972 were selected for determining the repeatability of the spectral radiometer. These flight lines more nearly overlapped each other than other available lines. However, there was still only a few places along the line in which the footprint of the radiometer from both lines viewed the same geographical area of water. These points were selected for comparison. The size of the spectral radiometer footprint at 2.5K feet, at a ground speed of 140 kts., was approximately 33 feet (10.1 m) wide by 236 feet (72 m) long for one filter wheel revolution. It was assumed that the water was homogeneous in the footprint. The spectrum revealed by the radiometer was in reality, derived from different segments of water in the footprint, and the spectral wavelengths were evenly distributed along the length of the footprint. The radiance values for the blue wavelengths were thus obtained from one end of the footprint, and the near infrared wavelengths radiance values from the other end of the footprint.

  Analysis of backscattered radiance plot shapes, from the two flight lines, was very similar, with main differences observed in the absolute radiance values and the longitudinal scale. The change in radiance values between the two flights for a given location was approximately 12 to 13%. The primary cause of this increase in radiance in the second flight was attributed to the change in the apparent sun zenith angle, which changed from 66° to 63°. This resulted in a .26 reduction of the apparent optical air mass. Calculations showed that for the atmospheric conditions during this flight, the expected changes in radiance caused by the change in zenith angle should be approximately 11% (24). This computer value was in agreement with the measured value of 12 to 13%. The remaining difference can probably be attributed to changes in the surface reflectivity or other variables (sun glint, polarization, atmospherics, etc.) which can affect the radiation received by the spectral radiometer, or by actual changes in the water. The longitudinal scale was based on the estimated ground speed of the aircraft, and aircraft speed inaccuracies resulted in the different longitudinal scales.

- Effect Of Altitude Variations

The two high altitude flight lines on the 4 August 1972 mission were flown at 10K feet (3.04 km). The spectral radiometer ground spot coverage at this altitude with a 180 kts. ground speed was approximately 304 feet (92.7 m) in length by 131 feet (40 m) in width as compared to 236 feet (72 m) in length by 33 feet (10.1 m) in width for 25K feet (0.76 km) altitude and 140 kts. air speed.

A comparison of the 2.5K feet and 10K feet flight lines for the same flight line area reveals the same characteristic shape. The small surface irregularities observed in the 2.5K feet flight line were averaged out in the 10K feet lines because of the larger spectral radiometer footprint at this altitude. The overall radiance level at the 10K feet was 100% larger over the visible band than at 2.5K feet. Approximately 45% of this increase can be attributed to the decrease in sun zenith angle. A large percentage of the remaining increase can be attributed to "air light". Air light is defined as direct sunlight, skylight and terrain reflected light that has been scattered by the air, and by the particles in the air between the sea surface and the aircraft (25). As the altitude increases, the area observed by the instrument increases, and the path length through the atmosphere increases, and thus the amount of air light that can enter the instrument increases. The increase in radiance at the high altitude was not uniform over the visible band. The shorter wavelength had a larger percentage increase. This increase was caused by the preferential scattering of the shorter wavelengths by the atmosphere.

- Chlorophyll Determination

The objective of this phase in developing a method of determining chlorophyll concentration was to find wavelengths whose change in radiance values could be correlated with changes in sea truth chlorophyll.

Figure 21 illustrates the spectral reflectance of two different areas of the Mississippi Sound flown at 2.5K feet on 24 July. The sea truth for this area indicated a similar secchi visibility of 3.5 feet (1.07 m) and 5 feet (1.53 m), but a chlorophyll value of 16.9 mg/m^3 (Spectra-1) for one area and 2 mg/m^3 (Spectra-2) for the other. An examination of the two curves reveals that the visible spectrum between 450 nm (nanometers) and 650 nm (0.65μ) for the high chlorophyll spectra has shifted toward the longer wavelengths with respect to the spectra with the lower chlorophyll content.

The radiance values for the two curves are identical at 560 nm. For oceanic waters, Arvesen, et al (26) indicate that wavelengths around 520 nm are not affected by changes in chlorophyll concentrations. Assuming that the differences in chlorophyll concentrations are the primary factors which has caused the two curves to differ, then the wavelength which is not affected by chlorophyll has shifted from 520 nm, for oceanic waters, to 560 nm for very turbid waters.

The high chlorophyll radiance curves display a reduction in radiance values in the blue region of the spectra, and an increase in radiance values in the orange to red region of the spectrum. This blue-red shift in the spectra is consistent with the results reported by Clarke, et al (1970) in their investigation of measuring chlorophyll concentration from aircraft. The shift in the spectra observed in Figure 21 for chlorophyll changes is somewhat masked when there is also a large change in turbidity. An example of how the spectra shifts, and changes in amplitude, for changes in chlorophyll and secchi visibility are depicted in Figure 22. These spectra are from the 7 August 1972 mission, Line C2.

The first spectra, which is nearer to shore, compared with the other three spectra is considerably larger in amplitude, and has a general shift to the longer wavelengths. An examination of the second and third spectra indicates that the majority of the amplitude change is caused by the difference in secchi visibility, for the chlorophyll concentration at the location of these spectra curves is the same. However, a comparison of the third spectra with the fourth spectra indicates that secchi visibility is not the only factor affecting amplitude, for both of these curves have the same secchi visibility, but different amplitudes. The shift in wavelength, as noted in Figure 21, also observed is comparing the third and fourth spectra, which have similar secchi visibility values but different chlorophyll concentrations.

From the changes observed in Figure 21, several algorithms were tried in order to arrive at one which could be used to obtain chlorophyll concentrations based on the backscattered light received by the spectral radiometer. The algorithm used was the radiance values at 620 nm less the radiance values at 470 nm divided by the radiance values at 520 nm.

$$R = \frac{I620 - I47C}{I520} \qquad [2]$$

The 470 nm value was selected because of sensitivity limitations of the detector that was installed in the spectral ratiometer. The radiance values below 470 nm were not considered useful. The detector has been replaced, and radiance below 470 nm should be useful in later tests. Yentsch (27) indicates that for a variety of phytoplankton there is a maximum absorption in the blue at about 440 nm due to chlorophyll. The radiance at 520 nm was in this study to normalize the airborne data based on the information from the literature for oceanic type of water. However, as indicated in Figure 21 for turbid

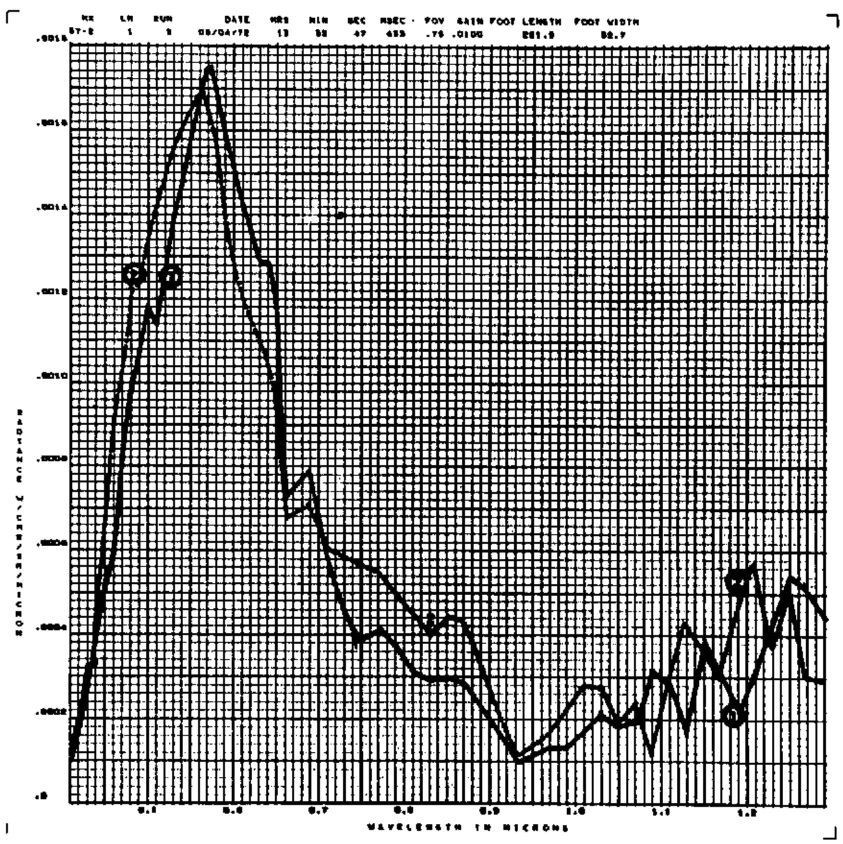
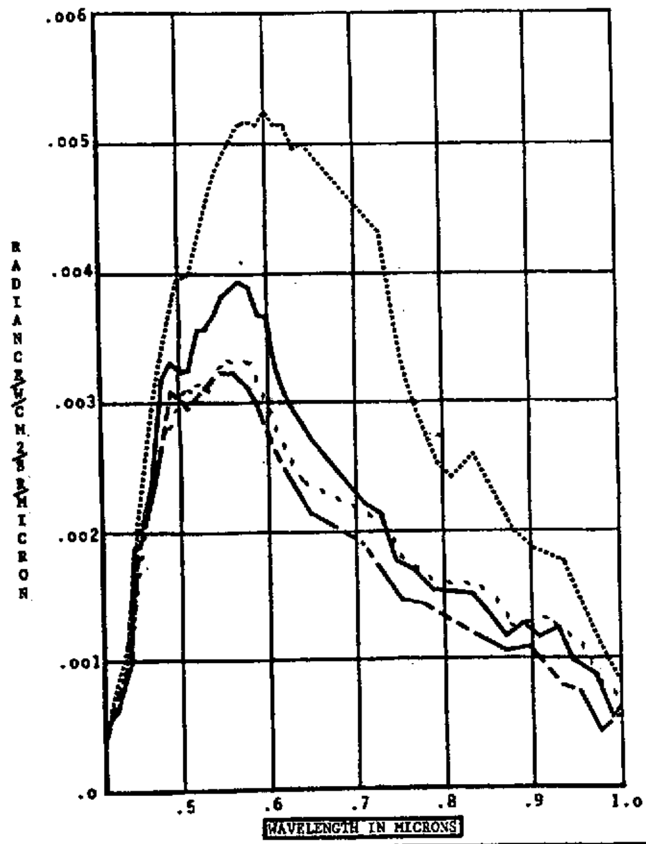


Figure 21. Spectra of Backscattered Light From The Mississippi Sound Taken At 2,500 Feet On 24 July 1972. (S-70246-AG)



	Chlorophyll mg/m^3	SECCHI VISIBILITY FT.
.... 1 - 2 miles south of Deer Island	3.2	5
——— 2 - 1 mile north of Ship Island	1.4	8.5
. - . 3 - 1 mile south of Ship Island	1.4	14
- — 4 - 1 mile north of Chandeleur Islands	1.1	14

Figure 22. Spectra Shifts Of Backscattered Light From The Mississippi Sound Taken At 2,500 Feet On 7 August 1972. (S-70246-AG)

waters, 560 nm may have been a better wavelength at which to perform this normalization. The radiance at 620 nm was selected because of the large differences in radiance values at this wavelength for changes in chlorophyll concentration.

The chlorophyll algorithm was computed for the entire length of each flight line. The value of the algorithm at selected sea truth stations was plotted against chlorophyll values at the same locations, and a straight line was drawn through the points. This line was then used in the conversion of all the values of the chlorophyll algorithm for the low altitude (2.5K ft.) flight lines into chlorophyll concentrations.

A similar conversion plot was prepared for the high altitude flight lines using values of the algorithm derived from the high altitude spectral radiometer data. The low altitude plot could not be used to convert the high altitude algorithm value to chlorophyll concentration because the blue region of the spectra had a large increase in radiance as a result of increased atmospheric scattering in this region of the spectra. This caused the algorithm ratio to be smaller for high altitude data than for low altitude data for the same value of chlorophyll concentration.

A summary plot of the chlorophyll algorithm ratio with respect to the sea truth chlorophyll value at each sea truth station for low altitude flight lines was constructed, and values above 5 mg/m^3 were included. The computer program that was used to plot the algorithm values for chlorophyll concentration used a linear relationship for the change in spectral signature (algorithm value), and the sea truth chlorophyll concentration. A review of the summary plot data indicated that this relationship was not linear, especially for values of chlorophyll above 5 mg/m^3. This non-linear relationship was therefore evident in chlorophyll plots for the 24 July, 4 August, and 7 August missions. The chlorophyll values for the 18 October 1972 mission were not plotted along the first flight lines because of the limited number of sea truth collection stations overflown by the aircraft.

An example of the chlorophyll plots constructed is illustrated as Figure 23 depicting remotely sensed calculated values against sea truth chlorophyll values acquired on the 7 August mission on a short north to south flight line originating just east of Biloxi Bay. Station C9 is the sea truth station closer to shore with stations C8 and C7 located in the Sound and stations C6, C5, and C4 located outside the Sound in the Gulf. Interpretation of this particular plot reveals that there is a decrease in chlorophyll concentration from the coast to the barrier islands (Station C7), and then an increase Gulfward to a point offshore where concentrations once more decrease.

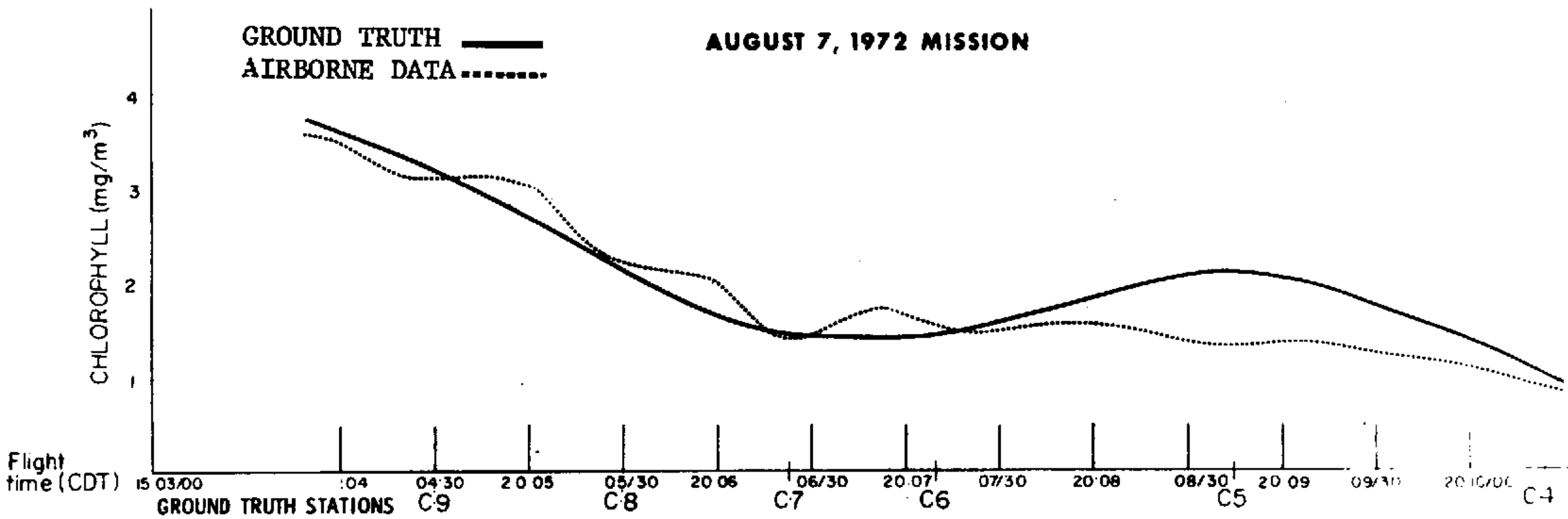


Figure 23. Calculated Airborne Chlorophyll Values Versus Sea Truth Chlorophyll Values For Line C2 At 10,000 Feet On 7 August 1972. (S-70246-AG)

- Secchi Visibility

An example of remote and surface secchi visibility measurements obtained during the three 7 August 1972 missions is plotted in Figure 24. Coverage in this figure is identical to Figure 23. Flights during this mission produced some of the best correlations between airborne and secchi surface data. Whether the clear sky condition during the mission, or the improvement in the sea truth sampling time and location with respect to aircraft overflight, was responsible for the improvement in the data is not known. The large number of sea truth measurements collected during the mission did allow an interpolation of sea truth measurements to be used when the aircraft did not directly overfly a measurement station. This was not possible with the other on 24 July and 4 August because of the limited number of sea truth measurements obtained.

- Results and Conclusions

The primary objective of the water color investigation was to determine if chlorophyll and secchi visibility sea truth measurements could be correlated with data collected by a spectral radiometer over coastal waters. Initial results of this study have indicated that it is possible to correlate airborne derived values for these parameters with corresponding sea truth over certain measurement ranges.

The accuracy of the low altitude (2.5K feet) airborne derived chlorophyll values in the zero to 5 mg/m^3 range was $\pm 20\%$. The ratio method used in the investigation does not compensate for the non-linearity of the relationship above 5 mg/m^3 chlorophyll concentration. Therefore, above 5 mg/m^3 the chlorophyll correlation becomes progressively worse. The accuracy of the high altitude data (10K feet) on a clear day, with low haze, approaches that obtained at low altitude.

The non-linearity expreienced in the chlorophyll relationship was not as pronounced in the secchi visibility measurements obtained during this experiment. This non-linearity may exist for values of secchi readings over 10 feet (3.06 m). Only a few secchi readings above ten feet were obtained during this investigation and the behavior of the algorithm for greater secchi visibility depths was not evaluated.

The secchi correlation on most of the flight lines was within the error that was expected by the inaccuracies in reading the secchi disk, and the changes in water conditions that could be experienced by aircraft and boat location error. The main exception to this was a discrepancy between the sea truth and the airborne data (10K feet) in the last half of the 4 August mission. The reason for this difference is not known.

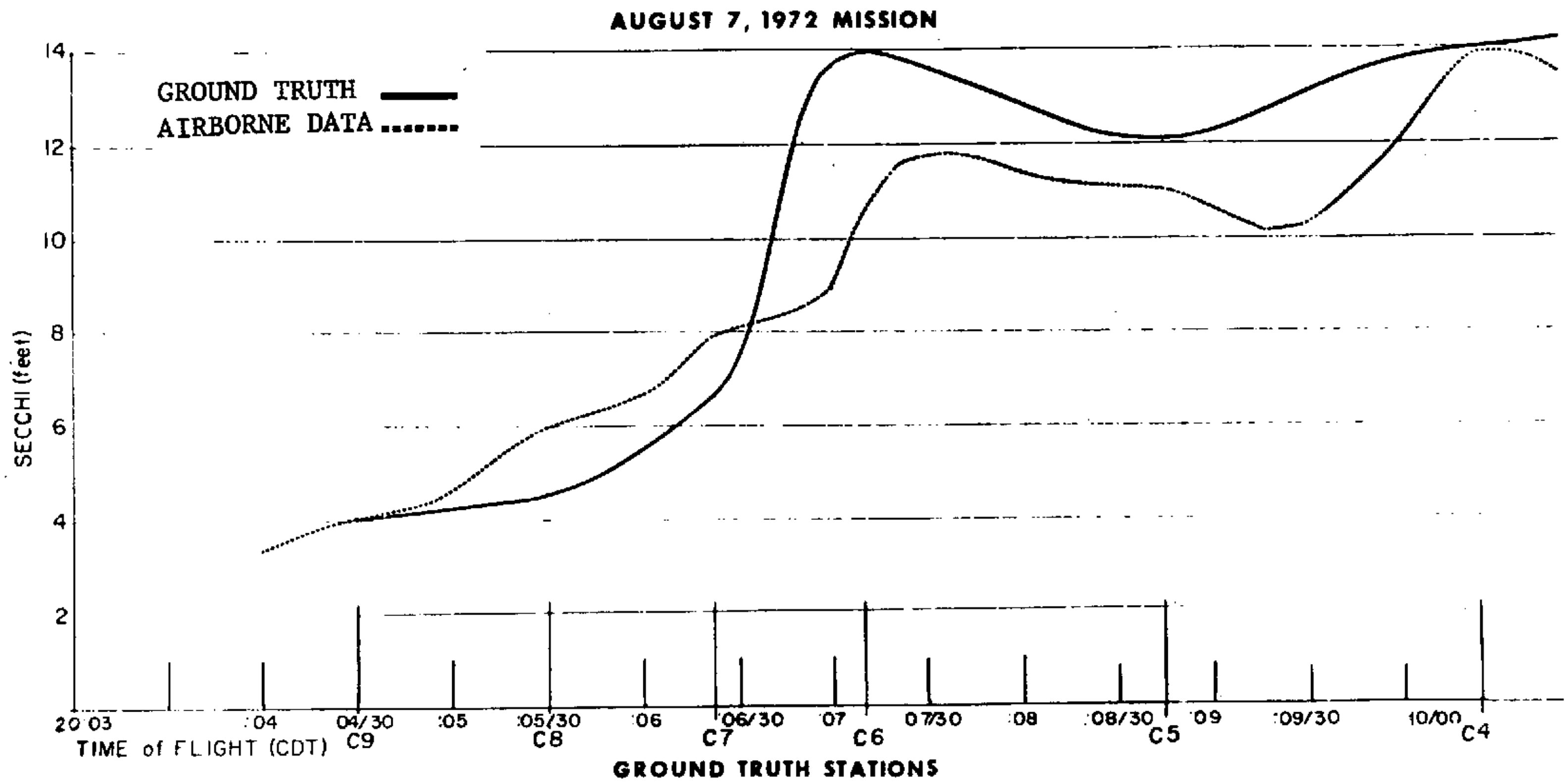


Figure 24. Calculated Airborne Secchi Visibility Values Versus Sea Truth Secchi Values For Line C2 At 10,000 Feet On 7 August 1972. (S-70246-AG)

A large part of the deviation between the airborne and sea truth chlorophyll and secchi visibility measurements can probably be attributed to the sea truth values with which the airborne data was compared. In a number of cases the sea truth was collected three to four hours before or after the flight of the aircraft. Also, the aircraft, in only a few cases, flew over the exact area in which the sea truth was obtained. In a dynamic body of water like the Mississippi Sound this could have a marked effect on the accuracy of comparing the airborne data with the sea truth.

The study also indicated that the accuracy of the airborne data can also be improved by adding corrections to the chlorophyll and secchi visibility algorithm for changes in sun angle, altitude and the non-linearity of the relationships.

b. Sea Surface Temperature

An investigation by Worthington (29) is currently in progress to determine the validity of weekly sea surface temperatures, as acquired with the RS-18 infrared scanner flown aboard the E-18 aircraft, as compared to simultaneously obtained sea truth surface temperatures. These data were acquired during the data acquisition phase of this project, and the document to be generated will be in a NASA/ERL internal report format.

One set of RS-18 mission data presently under analysis in relation to all such missions are information acquired on 7 August 1972 (30). These data, are in part, exemplified by Figures 13 and 14 which shows the initial scanner data transformed from analog tape to positive print (via a film negative) without atmospheric correction processing. The radiometric temperature maps show the scanner data after digital processing, which included correction for atmosphere, into gray level prints depicting temperature gradients in levels of 0.5°C. Inscribed on the gray level prints is a temperature grid giving corrected radiometric temperature to the nearest 0.1°C (See Appendix L, Section B, Item 3).

- Infrared Scanner Imagery

  The infrared imagery (analog tape to film) was not subjected to corrections for velocity/height ratio and therefore display differences in scale for the various strips (See Appendix L, Section A, Items 26a and 23, Line C2) primarily in directions parallel to direction of flight. Since all flight lines of this mission were flown at the same altitude the total distance across each strip is about the same, i.e., 3.5 n.mi. It was estimated that, using the appropriate scale factor as given in the Appendix, relative distances in each strip can be measured to an accuracy of about ±0.25 n.mi.

Interpretation of imagery strips for temperature patterns was difficult in some areas (particularly lines 3 and 5) due to excessive film density and/or a banding problem (alternating light and dark bands across the format). No atmospheric corrections were applied to this product (not shown) and some variations in film density across the scan were due to change in atmospheric path length with scan angle.

- Radiometric Temperatures

Positional errors for the imagery were estimated to be more constant than the infrared imagery within a flight strip, as well as between adjacent strips. During the final production procedure, enlargement of this material with respect to map scales could be accomplished together with a certain amount of scale correction for dimensions across flight direction versus dimensions parallel to flight direction as part of the digital processing. Scales for the imagery strips are given in Appendix L, Section B, Item 2. It was estimated that relative distances between well defined features can be measured with errors less than 0.25 n.mi., when observing appropriate scale factors.

There were some discrepancies between the RS-18 temperatures and those reported by boats, as well as discrepancies between the gray level displays and grid temperature values of adjacent flight strips. At this time, these differences are attributed to data collection and/or processing techniques which are still under development.

A comparison was made between 92 "bulk" temperatures measured at the surface and radiometric temperatures as given by the temperature grid. (Appendix M). It was determined that 41 of these stations fell within the appropriate gray level as temperature differences were less than $\pm 0.5°C$. The average temperature difference for the 92 stations was 0.6°C.

c. Additional Parameters

Reports are in preparation by ERL personnel dealing with a comprehensive treatise on Mississippi Sound oceanographic conditions during the data acquisition phase, as well as an analysis of MFMR overflight data for sea surface salinity determinations.

12.2.2 RESOURCE DATA

A. Surface Measurements

Gulf menhaden statistical catch estimates for 1972 are provided in Table 13 (31). The Mississippi Sound values were calculated from information furnished by the three menhaden processing plants located at Moss Point, Mississippi. To determine the number of pounds of fish, the metric ton value was multiplied by a factor of 2205. Values for number of fish were based on an experienced average estimate of four fish per pound.

Table 13. Gulf Menhaden Statistical Catch Estimates

SOURCE	1972 GULF MENHADEN CATCH ESTIMATES		
	METRIC TONS	POUNDS	NUMBER OF FISH
East of Mississippi River, Mississippi and Chandeleur Sounds	68,705	151,494,525	605,978,100
Mississippi Sound (total season)	35,000	77,175,000	308,700,000
Mississippi Sound (30 June - 17 October)	18,234	40,205,970	160,823,880

B. Remote Measurements

1. Airborne Low Light Level System

- Analysis Objectives

As noted previously (Sections 8.0 and 9.0), the LLLII sensor system provided resource information during dark of the moon periods of the data acquisition phase. Data analysis was performed (32) to provide the following information and/or service:

- Determination of transects and flight time for each.
- Observation, counting of schools and determination of school size.
- Determination of school location.
- Data recording, tape generation, and map transfer.

- Transect Determinations

Prior to observation and recording of any data from video tapes, it was necessary to determine the number of transects flown and the location and length of each transect. The number of transects flown on each flight was determined from the flight logs, whereas the location of each transect or flight path was somewhat more difficult to determine accurately, Initially, an effort was made to determine the location of transects from references in the flight log relative to location of schools of fish spotted while on a particular transect. Due to these references being approximations in both direction and distance, this method proved to be extremely unreliable. Consequently, the flight paths or transects were determined by aircraft heading, identification of starting point, and distance between transects. Since all analyzed Mississippi Sound data was acquired in the same area and utilizing the same flight paths, this determination had to be made only once.

Transects were subsequently drawn on an area map, and the distance flown on each transect was determined by multiplying the time required for each transect by the speed of the aircraft which was nearly a constant 100 kts.

- Observation

For observation of fish schools recorded on video tape, a video recorder with playback capability and a television receiver were utilized. At the normal flight altitude of 3,000 feet (915 m) schools of menhaden covering a surface area as small as 25-30 square meters were detected.

- Number of Schools

The number of schools of menhaden were determined for each flight by visual observation of the schools on a television monitor. When large numbers of schools were observed, numerous stops of the tape had to be made, often stopping each revolution of the counter for many feet of film. The number of menhaden schools thus identified per mission date are provided in Table 14.

- School Size

In order that the size of menhaden or other fish schools might be determined, a scale overlay, based on a flight altitude of 3,000 feet and a 295 square inch television receiver, was used. The overlay was of transparent plastic with lines forming rectangular areas which represented 100 square meters of surface area. By placing the mask over each fish school on the monitor screen, the size of the school was determined. Schools smaller than 33 m^2 (1/3 of 100 m^2 block) were not counted or recorded.

- School Location

The location of each fish school was determined to the nearest degree and minute in both latitude and longitude. In order to determine the location of a fish school along a transect, the distance of aircraft travel for each number on the revolution counter for each transect was calculated. This distance per revolution was then multiplied by the number of revolutions from the beginning of the transect to determine the location of the school. The school location was then taken from the transect map and recorded on loading forms.

Table 14. Date and Number of Menhaden Fish Schools Identified From LLLII and Aerial Photograph Data.

DATE OF OBS. (1972)	NUMBER OF FISH SCHOOLS IDENTIFIED		DATE OF OBS. (1972)	NUMBER OF FISH SCHOOLS IDENTIFIED	
	LLLII	PHOTO		LLLII	PHOTO
7-6	-	4	10-1	-	22
7-11	-	29	10-2	-	7
8-6	1	-	10-4	1146	53
8-7	10	27	10-5	279	-
8-8	4	-	10-6	403	97
8-17	-	25	10-11	372	-
8-25	-	55	10-12	609	-
8-29	-	5	10-13	317	-
9-13	572	74	10-30	-	11
9-14	213	-	10-31	-	1
9-15	331	-	11-3	20	-
9-19	-	41	11-4	12	-
9-20	-	10	11-8	-	1197
9-22	-	23			
9-28	-	179	Total	4289	1859

- Data Recording, Tape Generation, and Transfer

  Data taken from the video tapes by observation and calculation were recorded on loading forms and keypunched for data bank input to the Slidell Computer Center. Selected data observations from individual video tapes were utilized to generate a composite magnetic tape. Upon completion of data recording for entry into the data bank, the information from the loading forms was transferred manually to area maps for comparison with maps generated from the data bank. The number of schools and total surface area were plotted per degree/minute in latitude and longitude along a transect for each flight. This information was then utilized to plot a composite map for each month for which data had been analyzed.

- Conclusions

  The low light level image intensifier system utilized during the course of the data acquisition provided timely and documented resource information prior to, during, and after a particular mission. It was the only source of nighttime resource assessment information which was essentially used as input to mission location decision processes.

2. Aerial Photography

Photographs taken with the Zeiss RMK-1523 Mapping Camera were interpreted at the NMFS Laboratory at Pascagoula, Mississippi. Interpretations were made using the original film positives over a light table and a Houston-Feerless Viewer. Data taken from the photographs included number of fish schools as well as average size, shape, and density of each school. The number of schools were obtained by a direct count, whereas the size of each school was estimated by placing a transparent grid over magnified schools. The shape of each school was approximated by using five shape classifications: amoeboid, crescent, round, elliptical, and string. Density was regarded either as heterogenous or homogenous. Other data taken from the photographs included cloud coverage, cloud shadow coverage, sun glare, number of menhaden boats, number of trawlers, number of sport boats, and estimates of sea state. Any unusual oceanographic or biological phenomena such as tide rips was also noted, but this information was not keypunched.

Information obtained from a photograph was recorded on the basis of the following procedure. Each photograph was subdivided into four equal sections. Assuming a four square nautical mile coverage by each photograph, each section represented an area of 1 n.mi.^{2}. The longitude and latitude recorded to the nearest second of the center point of each section was used to indicate section location. Photographic information recorded included mission number, film roll number, photograph number, time of photograph, photographic scale, date, section identification, size of section, and altitude of the aircraft.

12.3 PRIMARY OBJECTIVE EFFORTS

An extensive analysis of acquired data leading to the unification of the four major design elements, i.e., Aerospace, Oceanography, Resource and Utilization, was provided by Kemmerer and Benigno (33), Kemmerer, et al (34), and other NMFS personnel located at the FEL, as well as MTF contractor support personnel.

12.3.1 Analytical Rationale and Data Limitations

In general the overall success of the experiment depended upon finding relationships between menhaden distribution and abundance and oceanographic parameters, and as a starting point, the logical point of departure was with these relationships. Therefore initial impetus was given to exploring relationships between fish distribution, abundance, and selected oceanographic parameters, and then to determine if parameters which had fisheries significance could be measured remotely with sufficient accuracy for precise correlation analysis. The last step in the analytical rationale was to determine what, if any, uses these relationships might have for commercial fishing and resource management.

The principal data limitation placed on early analyses was a general lack of remotely-acquired synoptic oceanographic parameter measurements. The conversion of remotely-sensed oceanographic data into meaningful information proceeded slowly because of interpretation difficulties. Thus, reported fisheries oceanographic-parameter relationship analyses depended primarily upon sea truth measurements. An essential exception was the photographically acquired menhaden distribution and abundance information.

12.3.2 Oceanographic/Resource Relationship

A. Analysis

The distribution and abundance of menhaden in the study area, principally in the Mississippi Sound, can be placed into a simplified systems context illustrated in Figure 25 described only in terms of distribution and abundance. Factors directly affecting the system include fish input, fish output (including harvest, death, and emigration), the environment, and the innate behavior of the menhaden not directly or immediately influenced by environmental conditions. Examples of this latter factor include fish age and degree of sexual maturity. This system concept can be modified slightly and expressed as an algebraic argument:

$$A_{x,y} = f(E,B,P) \qquad [3]$$

where:

A = number of menhaden schools

x and y = refer to school location coordinates

E = environmental conditions

B = innate fish behavior

P = instantaneous menhaden school population

The problem with the argument is that the depent variable, $A_{x,y}$, is a function of more than just the environment, E, and as such cannot be solved with available information. To simplify the expression, several assumptions were made. First, it was assumed that because only adult menhaden (i.e., the fishable stock) were considered in the experiment while they were in the Mississippi Sound area, a relatively short period of time, B, was constant and thus could be ignored in the expression. This assumption led to the development of a new expression where $A_{x,y}$ became a function of E and P alone. To remove P from the right side of the argument, an assumption was made that $A_{x,y}$ could be expressed in relative terms such that:

$$\frac{A_{x,y}}{P} = f(E) \qquad [4]$$

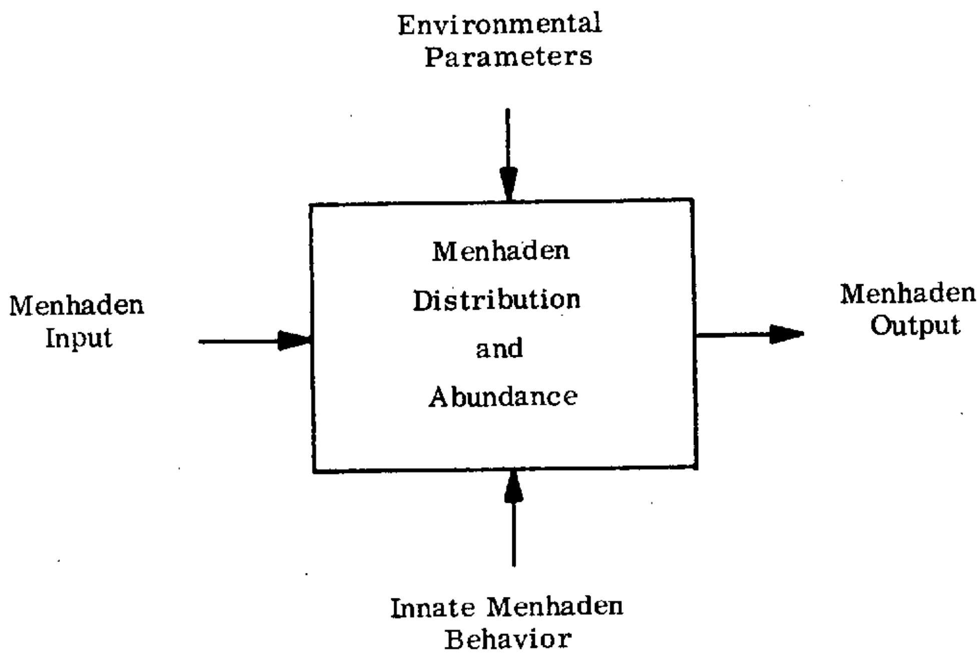


Figure 25. Simplified Systems View Of The Mississippi Sound Menhaden Population. (S-70246-AG)

In the subsequent analyses, the number of photographically detected menhaden schools at any given point was used as an estimator of $A_{x,y}$ and the total number of detected menhaden schools was used as an estimator of P. If there was a constant sensor-caused bias in the photography data, the quotient $A_{x,y}/P$ should not be affected seriously, as the bias cancels. However, if the bias was not constant but instead was a variable function of the environment, then the bias would affect the quotient. Whether or not the effect would be significant would depend on the magnitude and variability of the bias.

Because of a concern about the possibility of bias affecting the relationships, a second approach also was used which should have reduced sensor bias. A new dependent variable, D, was defined which reflected only the distribution of menhaden and was related to the environment as:

$$D = f(E) \qquad [5]$$

Inherent in this expression is the assumption that P does not affect the distribution of menhaden within the extremes of P characteristic of the menhaden population during the experiment. Neither photographic nor commercial fishing data indicated a major change in P on main days, which lends credibility to this assumption. As defined, D can have two possible outcomes: yes, menhaden are present and no, menhaden are not present. In the analysis, areas where menhaden were detected were assigned a value of 1 and areas where fish were not detected were assigned a value of 0. Although D is clearly a discontinuous dependent variable, the statistical techniques used in the analyses converted it into a continuous variable ranging from about 0 to 1. The general interpretation applied to predicted values is that as the values approached 1, the chance of finding fish increased proportionately.

The predominant mathematical methods utilized in the analysis consisted of correlation analysis and step-wise multiple regression. The program calculated the variance-covariance matrix, the matrix of correlation coefficients, and the array of partial correlation coefficients for a group of variables, X_1, X_2, ..., X_m. There were assumed to be n values for each of the variables. An individual observation was given two subscripts so that X_{ij} was the ith observation on the jth variable. The matrix X with elements X_{ij} had n rows and m columns, $n \geq m$. The M by M variance-covariance matrix S had elements s_{kp} given by:

$$s_{kp} = \frac{1}{n-1} \sum_{i=1}^{n} (X_{ik} - \overline{X}_k)(X_{ip} - \overline{X}_p) \qquad [6]$$

where:

$$\overline{X}_k = \frac{1}{n} \sum_{i=1}^{n} X_{ip} \text{ and } \overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_p \qquad [7]$$

and:

$$s_{pk} = s_{kp} \qquad [8]$$

The (k,p) element of the matrix of correlation coefficients is given by:

$$r_{kp} = \frac{s_{kp}}{\sqrt{s_{kk} s_{pp}}}, \quad r_{pk} = r_{kp} \qquad [9]$$

The partial correlation coefficients $r_{kp.q}$ is given by:

$$r_{kp.q} = \frac{r_{kp} - r_{kq}r_{pq}}{\sqrt{k-r^2_{kq}}\ \sqrt{p-r^2_{pq}}}, \quad k < p < q \qquad [10]$$

The regression analysis technique utilized least squares and involved the following model:

$$Y = X'b \qquad [11]$$

where: Y is the n by one known dependent variable vector;

X' is the n by p known matrix of independent variables;

b is the p by one vector of unknown coefficients of the dependent variables.

In order to solve this equation using the least squares technique, one must solve the normal equations for b:

$$XY = (XX')b \qquad [12]$$

or,

$$(XX')^{-1}XY = b. \qquad [13]$$

Now let $XX' = A$, a p by p matrix, and suppose A^{-1} has been calculated and it is desired to remove variable b_p from the regression. Let the matrices A and A^{-1} be partitioned as follows:

$$A = \begin{bmatrix} A_{11} & a_{(1)} \\ a'_{(1)} & a_{pp} \end{bmatrix}, \text{and } A^{-1} = \begin{bmatrix} A^{11} & a^{(1)} \\ a^{(1)'} & a^{pp} \end{bmatrix}. \qquad [14],[15]$$

Note that these results extend readily to adding or subtracting the ith variable where $i = 1,\ldots,p$.

It is desired to find A^{-1}_{11} given A^{-1}. Since $AA^{-1} - 1$ we have the equations:

$$A_{11}A^{11} + a_{(1)}a^{(1)'} = 1 \qquad [16]$$

$$A_{11}a^{(1)} + a_{(1)}a^{pp} = 0 \qquad [17]$$

$$a'_{(1)}A^{11} + a_{pp}a^{(1)'} = 0 \quad [18]$$

$$a'_{(1)}a^{(1)} + a_{pp}a^{pp} = 1 \quad [19)$$

so that,

$$A^{11} + A_{11}^{-1}a_{(1)}a^{(1)'} = A_{11}^{-1} \quad [20]$$

and,
$$-A_{11}^{-1}a_{(1)}a^{pp} = a^{(1)} \quad [21]$$

or,
$$A_{11}^{-1}a_{(1)} = -a^{(1)}/a^{pp}. \quad [22]$$

Hence,

$$A_{11}^{-1} = A^{11}-(a^{(1)}a^{(1)'}/a^{pp}). \quad [23]$$

If the old solution was:

$$b = \begin{bmatrix} b_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ b_p \end{bmatrix}, \quad [24]$$

The new solution becomes:

$$\left(A^{11}-(a^{(1)}a^{(1)'}/a^{pp})\right) X_1Y = \begin{bmatrix} b_1' \\ \cdot \\ \cdot \\ \cdot \\ b'_{p-1} \end{bmatrix} \quad [25]$$

where X_1 is the matrix X with the pth column removed. This expression is the new coefficient vector that can be obtained from the old, by:

$$\begin{bmatrix} b_1' \\ b_2' \\ \cdot \\ \cdot \\ \cdot \\ b'_{p-1} \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \cdot \\ \cdot \\ \cdot \\ b_{p-1} \end{bmatrix} - \frac{b_p}{a_{pp}} a_{(1)}. \quad [26]$$

If, on the other hand, it is desired to add a variable to the analysis, we must solve the equations:

$$\begin{bmatrix} A_{pp} & a_{(p)} \\ a'_{(p)} & a_{p+1,p+1} \end{bmatrix} \begin{bmatrix} A^{pp} & a^{(p)} \\ a'^{(p)} & a^{p+1,p+1} \end{bmatrix} = \begin{matrix} 1_{pxp} & 0 \\ 0 & 1 \end{matrix} \qquad [27]$$

where A_{pp}^{-1} is known for A^{pp}, $a^{(p)}$, a^{p+3,pp^1}.

Hence we have:

$$A_{pp}A^{pp} + a_{(p)}a'^{(p)} = 1 \qquad [28]$$

$$A_{pp}a^{(p)} + a_{(p)}a^{p+1,p+1} = 0 \qquad [29]$$

$$a_{(p)}A^{pp} + a_{p+1,p+1}a'^{(p)} = 0 \qquad [30]$$

$$a'_{(p)}a^{(p)} + a_{p+1,p+1}a^{p+1,p+1} = 1 \qquad [31]$$

and,

$$A^{pp} = A_{pp}^{-1}\left(I-a_{(p)}a'^{(p)}\right) \qquad [32]$$

$$a^{(p)} = A_{pp}^{-1}a_{(p)}a^{p+1,p+1} \qquad [33]$$

or,

$$a'_{(p)}a^{(p)} = -a^{p+1,p+1}\; a'_{(p)}A_{pp}^{-1}a_{(p)} \qquad [34]$$

so that:

$$a^{p+1,p+1} = 1/(a_{p+1,p+1} - a'_{(p)}A_{pp}^{-1}a_{(p)}). \qquad [35]$$

Hence,

$$a^{(p)} = -A_{pp}^{-1}\; a_{(p)}/(a_{p+1,p+1} - a'_{p}A_{pp}^{-1}\; a_{p}) \qquad [36]$$

and,

$$A^{pp} = A_{pp}^{-1}(I + (a_{(p)}a'_{(p)}\ A_{pp}^{-1}/a_{p+1,p+1} - a_p'A_{pp}^{-1}a)\ ) \qquad [37]$$

$$= A_{pp}^{-1} + (a^{(p)}a^{(p)\prime}/a^{p+1,p+1}) \quad , \qquad [38]$$

and the solution of equations proceeds similarly to the case of removing a variable.

Thus, adding the (p+1)st variate, we get for $b' = (b_1', \ldots, b_p')$,

$$b' = b + \frac{b_{p+1}'}{a_{p+1,p+1}}\ a_{(p)} \qquad [39]$$

and,

$$b_{p+1} = a^{(p)}X_p'Y. \qquad [40]$$

Regression techniques were used exclusively to define relationships between the abundance and/or distribution of menhaden and available measurements of oceanographic parameters. Because remotely-sensed oceanographic data were not available, environmental conditions where fish were detected had to be interpolated and, in some cases, extrapolated from nearby sea-truth sampling stations. This procedure probably introduced experimental error into the analyses and as such, may have obscured subtle relationships.

B. Results

Photographically-sensed menhaden distribution and abundance $(\frac{A_{x,y}}{P})$ and distribution (D) information were regressed against available oceanographic parameter measurements (Table 15). These analyses reflect only those data collected on 7 August, 25 August, and 28 September 1972 (i.e., primary missions) from the Mississippi Sound portion of the study area. Forel-Ule color data were not collected on 7 August 1972, consequently, color analysis was limited to 25 August and 28 September. Clouds and cloud shadow obscured portions of the Sound on 25 August and 28 September; these areas were ignored in the analysis.

In general, the two approaches, i.e., relative abundance and distribution dependent variables, gave similar results. The type of relationship, either positive or negative, was the same in every case. Their precision

Table 15. Correlations Between Menhaden Relative Abundance ($A_{x,y}$/P) And Distribution (D) Estimates and Selected Oceanographic Parameters (E).

PARAMETER	DEGREES OF FREEDOM	CORRELATION COEFFICIENT (r)		MEAN CONDITIONS WHERE MENHADEN WERE DETECTED (±95% CONFIDENCE LIMIT)
		RELATIVE ABUNDANCE	DISTRIBUTION	
Temperature (°C)	195	0.009	0.044	29.75 (0.33)
Salinity (ppt)	195	-0.257***	-0.222***	25.53 (1.85)
Chlorophyll-a (mg/m^3)	195	0.025	0.119*	5.61 (1.95)
Current speed (cm/sec)	195	-0.062	0.027	13.61 (5.50)
Sea state (m)	195	-0.064	-0.103	0.25 (0.08)
Forel-Ule color (units)	113	-0.256***	-0.150*	13.69 (1.21)
Water depth (m)	195	-0.216***	-0.404***	1.91 (0.47)
Secchi disc transparency (m)	195	-0.093	-0.146**	1.25 (0.17)

* 90% significance level
** 95% significance level
*** 99% significance level

varied, however, which affected level of significance. Of the two approaches, relationships derived using distribution as the dependent variable probably were the most reliable. Recent work (35) has shown that there may have been a variable bias associated with the photographic sensor system used to obtain the fisheries data. The bias appeared to relate to school size and atmospheric conditions and apparently affected the number of schools detected, i.e., the possible detection of schools decreased with a decrease in school size and atmospheric quality.

Assignment of biological significance to these correlations is difficult in that the parameters may be serving as indices of unmeasured parameters. In other words, there is a question of concomitance. Nevertheless, there does appear to be support for the distribution significant (≥90% confidence level) correlations presented in Table 15. Menhaden fishermen frequently are frustrated in attempts to capture schools because the schools often inhabit waters too shallow for efficient boat and net operations (negative correlation associated with depth). Spotter pilots tend to concentrate their fish-searching efforts on turbid waters because of relatively high frequency of fish encounter in these waters (negative correlation associated with Secchi disc transparency). The positive correlation associated with chlorophyll-a seems reasonable in that menhaden are plankton feeders. Salinity is a questionable concomitant factor although, because these fish are euryhaline organisms and inhabit estuarine waters throughout most of their lives, a preferred association with waters of low salinity seems plausible (negative correlation associated with salinity). Christmas and Gunter (12) reported that 70% of the catch from 87 sets in the Mississippi Sound came from waters ranging from five to 24 ppt salinity, suggesting also a menhaden preference for low salinity waters. No biological significance can be attached directly to Forel-Ule color (negative correlation) yet, although this color may manifest water transparency and chlorophyll content. Correlation coefficients between Forel-Ule color and Secchi disc transparency and chlorophyll-a were -0.404 and 0.369 respectively, significant at the 99% confidence level.

This concern over a possible significant sensor bias in the menhaden distribution estimates prompted attempts to substantiate the results through other approaches. The set of commercial fishing data which included measurements of selected oceanographic parameters provided the only avenue through which substantiation could be accomplished. However, these data are noticeably biased in that environmental measurements were obtained only from areas where catches were made or attempted. In addition, the boats did not fish randomly throughout the study area; rather, they fished according to fish availability, distance from home port (minimized to reduce operating expense), day of the week (tendency to fish farther from home port as the fishing week progressed), and water depth (usually about two meters for efficient boat operation). Nevertheless, if caution is used in the analysis, the data can be used to substantiate some of the results gained through photographic sensing of the menhaden stocks.

In the classical statistical situation, one generally attempts to differentiate between two presumably different populations, e.g., with and without menhaden. As noted previously, the principal problem with the commercial fishing data is that data were not obtained from areas without fish. However, if the assumption is made that all other environmental measurements collected throughout the study period (primary and secondary mission events) were taken at random in terms of temporal and spatial coverage, then it is logical to assume that these latter measurements included areas with and without menhaden. The commercial fishing data can then be handled as a "with fish" subset of the total data population, i.e., with and without fish.

The difficulty in this approach is that differences are difficult to demonstrate with a high level of statistical significance because the subset (with fish) is not discrete from the total population (with and without fish). The hypotheses which can be tested are that the means ($\bar{x}$) and standard deviations (s) of the subset and total population are different, resulting in the following four general conditions and accompanying conclusions:

- Means and standard deviations are not significantly different; conclusion: fish distribution is not related to the parameter tested.

- Means are significantly different but standard deviations are not; conclusion: fish distribution is related to the parameter tested.

- Means are not significantly different but standard deviations are; conclusion: fish distribution is related to the parameter tested.

- Means and standard deviations are both significantly different; conclusion: fish distribution is related to the parameter tested.

A note of caution should accompany the conclusions, however. They are valid only for the data collected under the conditions of the experiment and therefore extrapolation to other areas or to the same area under different experimental conditions might not be valid.

The commercial fishing data demonstrated the last general condition, i.e., means and standard deviations different with respect to water depth, Forel-Ule color, and Secchi disc transparency (Table 16). Temperature and sea state were not tested and data were not available for chlorophyll-a and currents. The subset of fishing data included measurements from 237 "fish sets" and the total population of oceanographic conditions included measurements from 29 June, 30 June, 6 July, 7 August, 25 August, and 28 September 1972. For each parameter, a negative correlation is indicated as the mean parameter values for the fishing subsets were significantly less than the mean values for the total parameter populations. The lack of high significance levels for mean salinity and Forel-Ule color value differences was not particularly surprising in that the subset approach tends to preclude such significance. In any case, the relationships shown in Table 16 substantiate those shown in Table 15.

A second approach was used to substantiate still further the correlations formed between fish distribution and salinity, Forel-Ule color, Secchi disc transparency, and water depth. Mean parameter values for conditions where menhaden were photographically detected (Table 15) were compared with similar values from the fishing subset (Table 16). None of these values were significantly different at levels down to 80% (t-test).

In summary, water depth, Secchi disc visibility depth, surface salinity, and Forel-Ule color were found to correlate negatively with the distribution of menhaden. Chlorophyll-a correlated positively with fish distribution, although independent data were not available with which to corroborate this relationship as in the case of the other four parameters.

Table 16. Comparison Of Total Parameter Populations (With And Without Fish) And Fish Parameter Population Subsets (With Fish)

PARAMETER	TOTAL POPULATION			FISHING SUBSET POPULATION			LEVEL OF SIGNIFICANT DIFFERENCE (%)*	
	n	$\bar{x}$	s	n	$\bar{x}$	s	$\bar{x}$	s
Water depth (m)	354	3.41	1.27	237	2.19	1.17	99	90
Secchi disc transparency (m)	348	1.45	0.71	237	1.10	0.32	99	99
Salinity (ppt)	357	26.30	4.15	237	25.85	2.95	80	99
Forel-Ule color	166	14.16	3.04	237	13.78	2.44	80	99

*t-tests for difference between means for populations with unequal variances, and F-tests for differences between standard deviations (36)

12.3.3 Aerospace/Resource Relationship

A. Analysis

As noted earlier, the only ERTS-1 imagery project suitable for analysis was acquired on 7 August 1972. The four MSS bands from 7 August were examined, using an I^2S DIGICOL analysis device, to determine if their density levels related to fish distribution. Bands 6 and 7 did not contain any readily apparent useful density detail. Band 4, for reasons which are still unclear, seemed to contain too much density detail. Density levels in Band 5, however, appeared to relate to menhaden distribution. The portion of the image test site which was false color enhanced and density sliced has been black-line delineated in Figure 26.

B. Results

Figure 27 shows a portion (Figure 26) of the ERTS-1 Band 5 imagery covering the western portion of the Mississippi Sound and adjacent offshore waters as displayed on the I^2S DIGICOL video screen. Superimposed on the image are locations of 23 photographically detected menhaden schools. Water imagery densities were divided into two density ranges and color enhanced (Figure 28). All menhaden schools were found to lie in the less dense range, enhanced as orange. This density range was further reduced by slicing it to the narrowest range possible with the instrument. All of the fish schools can be found to either lie in or immediately adjacent to this range, enhanced as orange (Figure 29).

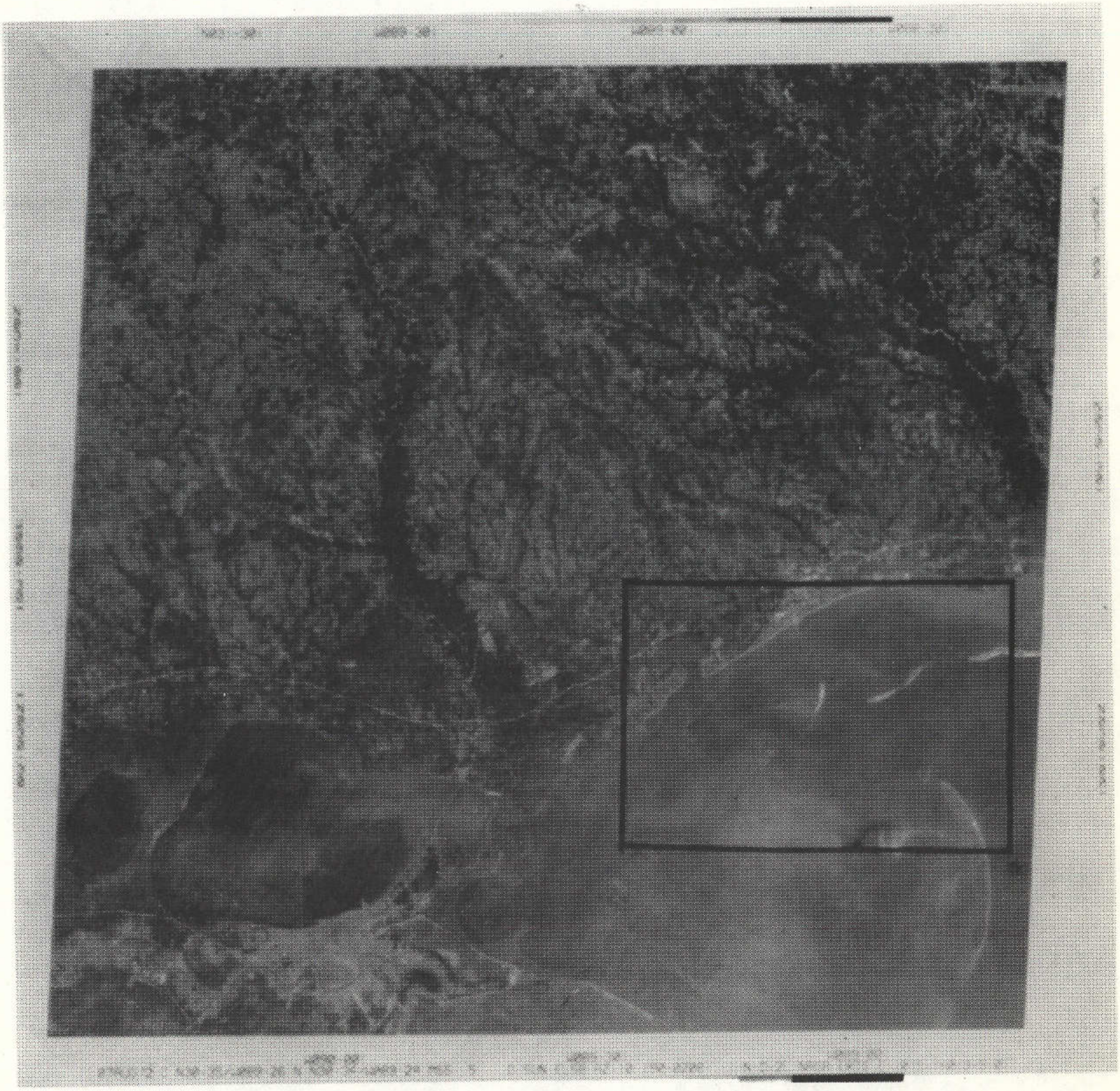


Figure 26. False Color Enhancement Area (Black-Line Enclosed) Within The Western Part of The Mississippi Sound Test Site. ERTS-1 MSS Image, Band 5 (1015-16013-5) From 7 August 1972. (S-70246-AG)

Figure 27. I^2S DIGICOL Television Screen Image Sectional Enlargement Of ERTS-1, MSS Band 5 Image (1015-16013-5) Acquired On 7 August 1972. Black Dots Indicate Fish School Locations. (S-70246-AG)

Figure 28. False Color Enhancement Of Figure 27 Water Areas Into Two Density Ranges. Fish School Locations (Black Dots) Are Identical To Those In Figure 27. (S-70246-AG)

Unfortunately, the lack of additional data to test the persistence of the relationship between menhaden distribution and MSS Band 5 imagery density levels precludes any but the most tentative of conclusions. However, the data are sufficient to warrant an observation that the imagery does appear to contain information relating to the distribution of menhaden schools.

12.3.4 Aerospace/Oceanographic Relationship

A. Analysis

An analysis was performed on the MSS Band 5 imagery for 7 August 1972 to determine if image densities could be explained based on oceanographic parameter measurements. An isodensity tracing was made of that portion of the imagery covering the study area to provide quantitative relative density data. The tracing was not particularly satisfactory because of instrument limitations which caused more than one density range to be represented by the same color trace, but accurate enough to demonstrate relationships.

B. Results

Water depth, secchi depth visibility, and the interaction between the two parameters formed by their product (36) were regressed against relative image densities. Simple correlations (r) between these parameters and image density were 0.56, 0.73, and 0.69, respectively, significant at the 99% confidence level. A slight improvement in precision ($r = 0.77$) was realized when the parameters were combined through multiple regression (Table 17) into the following equation:

$$\text{Image Density} = 0.5776 + 0.0222B + 0.07625T - 0.0051BT \quad [41]$$

where:

B = water depth in meters

T = Secchi disc transparency in meters

BT = interaction formed as the product of B and T

Of the parameters, Secchi disc transparency was the most important one in the equation as indicated by the relative magnitude of the coefficients and the simple correlation coefficients. The most meaningful facet of this analysis is that the two parameters correlating significantly with image density levels also correlated significantly with menhaden distribution (Tables 16 and 17). Thus, it appears that the apparent correlation between menhaden distribution and Band 5 density levels (Figures 28 and 29) is more than a chance occurrence and can be explained based upon Secchi disc transparency and water depth measurements.

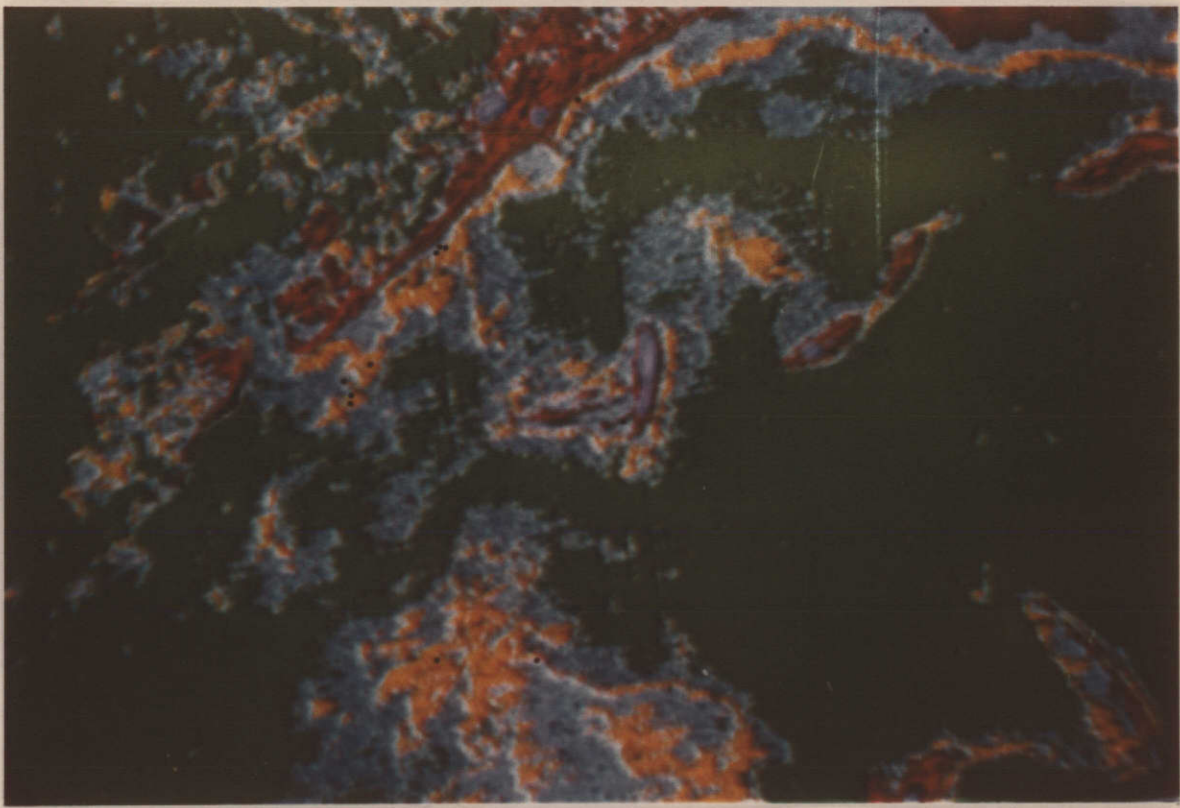


Figure 29. Additional False Color Enhancement Of Figure 28 Water Areas And Fish School Locations (Black Dots). Schools Are Within And/Or Adjacent To A Narrow Density Color Range. (S-70246-AG)

Table 17. Analysis Of Variance For The Relationship Between ERTS-1 Image Density And Two Oceanographic Parameters.

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	F-VALUE
Total	47	0.0051	
Regression (Secchi disc transparency, water depth, and interaction)	3	0.0469	21.040***
Error	44	0.0022	

12.3.5 Resource Management and Utilization

A potential management and utilization benefit from this experiment is identification of an approach through which remotely sensed environmental data could be used to provide distribution information about menhaden stocks in the study area. This information could be used to reduce search time for commercial concentrations of menhaden by fishermen and as a means to develop efficient survey designs by resource managers. Ideally, distribution information should be valid for the entire Gulf Coast menhaden fishery; however, this ideal case cannot be supported with results from this experiment but can be realized only through future experiments specifically designed to test demonstrated relationships in other areas.

A. Model Development

Demonstrated menhaden distribution-oceanographic parameter relationships (Table 15) were placed into a context potentially useful to commercial fishermen and resource managers. Multiple regression analysis was used to develop eight empirical models to predict menhaden distribution (D) in the study area based on four oceanographic parameters: water depth, Secchi disc transparency, Forel-Ule color, and salinity (Table 18). The models contain selected 2-factor interactions formed as products between parameters and treated as additional indepent variables. Interaction selection was based on whether or not an interaction significantly increased the precision of the estimate ($\hat{D}$). The models were constructed from data collected on main days (i.e., 7 August, 25 August, and 28 September 1972), and are presented separately and in combination and without the inclusion of color as an independent variable.

B. Model Testing and Interpretation

The models were tested by playing them with oceanographic data collected during commercial fishing operations and main day sea-truth station data stratified to include only those stations where menhaden were not detected photographically (Figure 30). Ideally, model products for fishing data should have grouped close to 1 and products for the "without fish" sea

Table 18. Empirical Regression Models Which Predict Menhaden Distribution (D) In The ERTS-1 Study Area.

B = water depth (m)
S = salinity (ppt)
T = Secchi disc transparency (m)
C = Forel-Ule color (units)
BT, BS, ST, CT, and CS = interactions formed as the products of the respective parameters

MODEL	INCLUSIVE DATES (1972)	n	REGRESSION MODEL	STANDARD ERROR OF $\hat{D}$	MODEL CORRELATION COEFFICIENT	SIGNIFICANCE LEVEL (%)
D1	7 Aug	82	$\hat{D} = 1.9959 - 0.0664S + 0.7453T - 0.6820B - 0.0233ST - 0.0144BT + 0.0230BS$	0.2492	0.596	99
D2	25 Aug	42	$\hat{D} = 5.1537 - 0.1740S - 0.9195T - 0.0371C - 0.4350B + 0.0502ST - 0.1243BT + 0.0195BS$	0.3793	0.630	99
D3	28 Sep	73	$\hat{D} = 2.3473 - 0.0934C - 0.8117B - 0.0358ST - 0.0007CS + 0.0528CT + 0.0516BT + 0.0235BS$	0.2443	0.409	90
D4	7 & 25	124	$\hat{D} = 2.4691 - 0.0855S + 0.3948T - 0.6477B - 0.0054ST - 0.0441BT + 0.0223BS$	0.3009	0.584	99
D5	7 Aug & 28 Sep	155	$\hat{D} = 1.8559 - 0.0577S + 0.5604T - 0.6954B - 0.0191ST - 0.0079BT + 0.0232BS$	0.2489	0.480	99
D6	25 Aug & 28 Sep	115	$\hat{D} = 2.9396 - 0.1024S + 0.1522T - 0.7486B - 0.0026ST - 0.0547BT + 0.0268BS$	0.3118	0.488	99
D7	25 Aug & 28 Sep	115	$\hat{D} = 3.6035 - 0.0987S - 0.1249T - 0.0416C -0.6717B + 0.0087ST - 0.0441BT + 0.0234BS$	0.3090	0.508	99
D8	7 & 25 Aug & 28 Sep	197	$\hat{D} = 2.3759 - 0.0797S + 0.3928T - 0.7051B - 0.0086ST - 0.0326BT + 0.0242BS$	0.2856	0.515	99

truth stations should have grouped close to 0; obviously, this type of grouping is not demonstrated in Figure 30, indicating a general lack of accuracy and precision in the models. Product populations, however, are significantly different for each model even though the distributions overlap without a wide margin of difference between means (Table 19).

A number of factors probably contributed to the failure of the models to group fishing data closer to 1. It should be pointed out first, however, that no seasonally-caused variation in products was noted, suggesting that the nonparametric grouping was caused by factors prevalent throughout the June through September commercial fishing sampling period. One of these factors may have been the effect of commercial fishing operations on the distribution of fish as evidenced by visual observations made during the photographic surveys of the study area. Menhaden schools frequently were observed being chased by purse boats through waters of varying visual qualities (i.e., turbidity). In addition, oceanographic parameter measurements generally were taken from the mother vessel rather than the purse boats, which often was several kilometers distant from the actual site of fish capture. Another of these factors is that there is no biological reason to suspect menhaden distribution to be wholly a deterministic function of environmental conditions; rather, there most likely is a probability associated with how and where fish are distributed in response to these conditions. Also, there were errors associated with all of the parameter measurements used to develop and test the models as well as a distinct possibility that other parameters having a direct influence on menhaden distribution might not have been measured (e.g., zoo-plankton biomass, presence or absence of predators, oxygen tensions, etc.). An finally, there is the linear additive nature of the models which at best probably only approximates the real world situation.

Selection of a best model was difficult in that they all provide similar products. On the basis of sample size, number of parameters (minimum), and difference between means (Table 19), Model D8 would have to be given selection priority, however.

A number of interpretations and presentation methods can be applied to model products as long as the imprecision of the models is recognized. An example of one method applied to Model D8 for 7 August 1972 sea truth data is presented in Figure 31. The categorization of model products was done by dividing the values shown in Figure 30 for Model D8 into three ranges based upon a direct comparison of fishing and non-fishing histograms:

high potential	=	< 0.2
moderate potential	=	-1.0 to 0.2
low potential	=	<-1.0

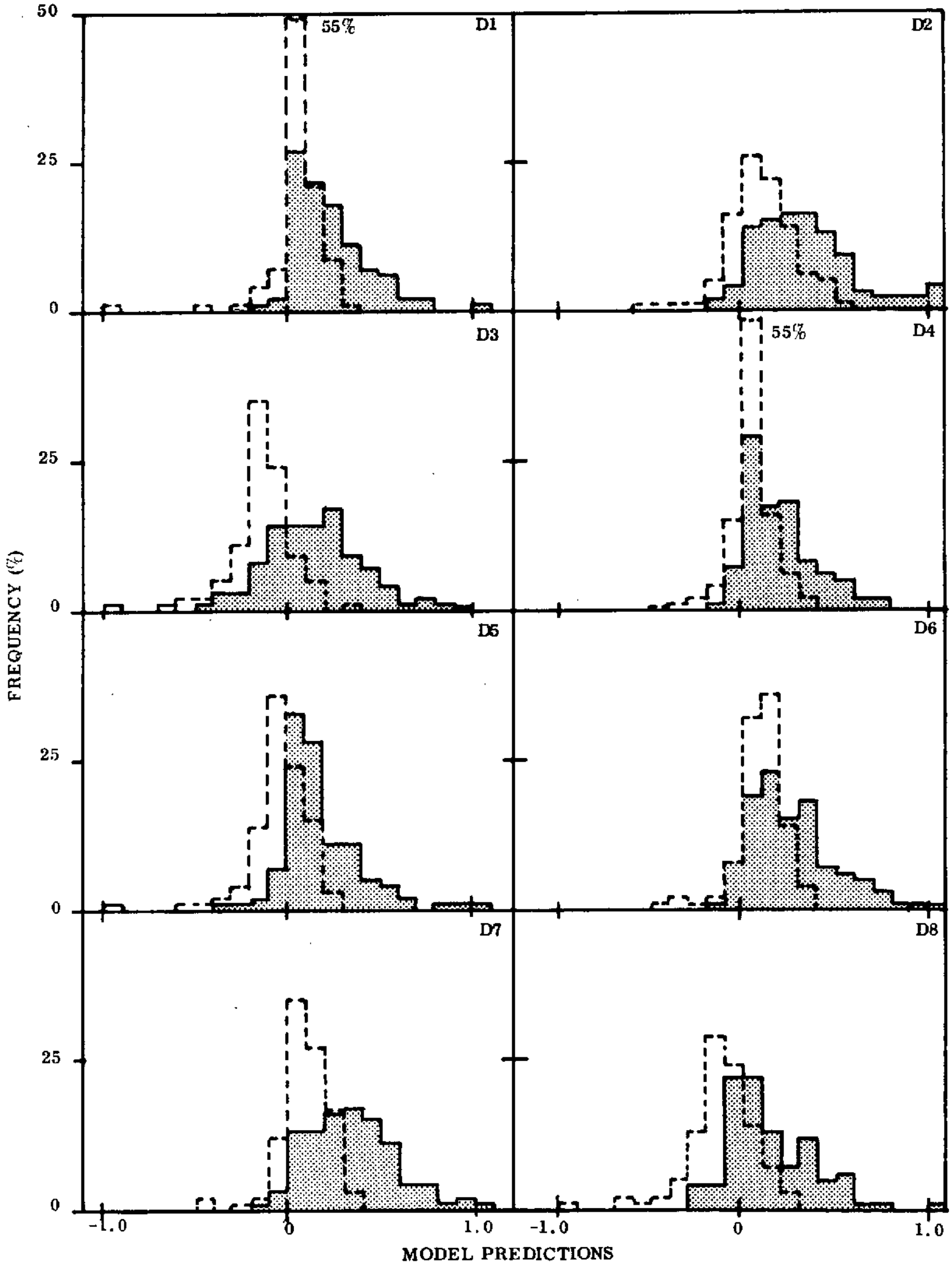


Figure 30. Histogram Plots Of "With Fish" (Shaded) And "Without Fish" (Un-Shaded) Model Products. (S-70246-AG)

Table 19. Tests Of Empirical Models Played With Oceanographic Data Taken Near Sites Of Commercial Fish Capture (With Fish) And During Primary Mission Events, The Latter Stratified To Include Only Those Areas Where Fish Were Not detected Photographically (Without Fish).

MODEL	WITH FISH			WITHOUT FISH			SIGNIFICANCE LEVEL FOR DIFFERENCE BETWEEN MEANS (%)[2]
	n	$\overline{D}$	C.V.(%)[1]	n	$\overline{D}$	C.V.(%)[1]	
D1	225	0.202	86	165	0.071	147	99
D2	225	0.371	78	94	0.100	187	99
D3	225	0.146	184	94	-0.115	132	99
D4	225	0.305	67	165	0.139	80	99
D5	225	0.175	106	165	-0.017	755	99
D6	225	0.288	79	165	0.089	165	99
D7	225	0.338	70	94	0.093	151	99
D8	225	0.145	163	165	-0.111	160	99

[1] Coefficient of variation

[2] t-test for populations with unequal variances (35)

The interpretation applied to high, moderate, and low potential areas is related to relative probability. In high potential areas, the probability of fish capture is higher than in moderate or low potential areas and higher in moderate than in low potential areas. Incomplete commercial fishing reports from 7 August 1972 indicate that most, if not all, fishing occurred in the high potential areas.

An additional analysis was performed on the commercial fishing data to determine if relationships could be demonstrated between catch size and the four oceanographic parameters which made up the models. Catch size ranged from five to 225 thousand and averaged about 38 thousand fish. Catch size was divided into three categories: 0-50, 50-100, and more than 100 thousand fish, and an analysis of variance applied to the categories to test for differences between mean parameter conditions. No significant differences were found between catch size and salinity, Forel-Ule color, and depth parameters at significance levels down to 50%. However, a significant difference at 95% was found between the first and third catch size category for averaged Secchi disc transparency values ($\overline{T}_{0-50K}$ = 1.09m and $\overline{T}_{>100K}$ = 1.32m). This significance probably does not have biological meaning, however. It probably reflects changes in the ability of fishermen to selectively detect and capture fish schools with respect to water clarity.

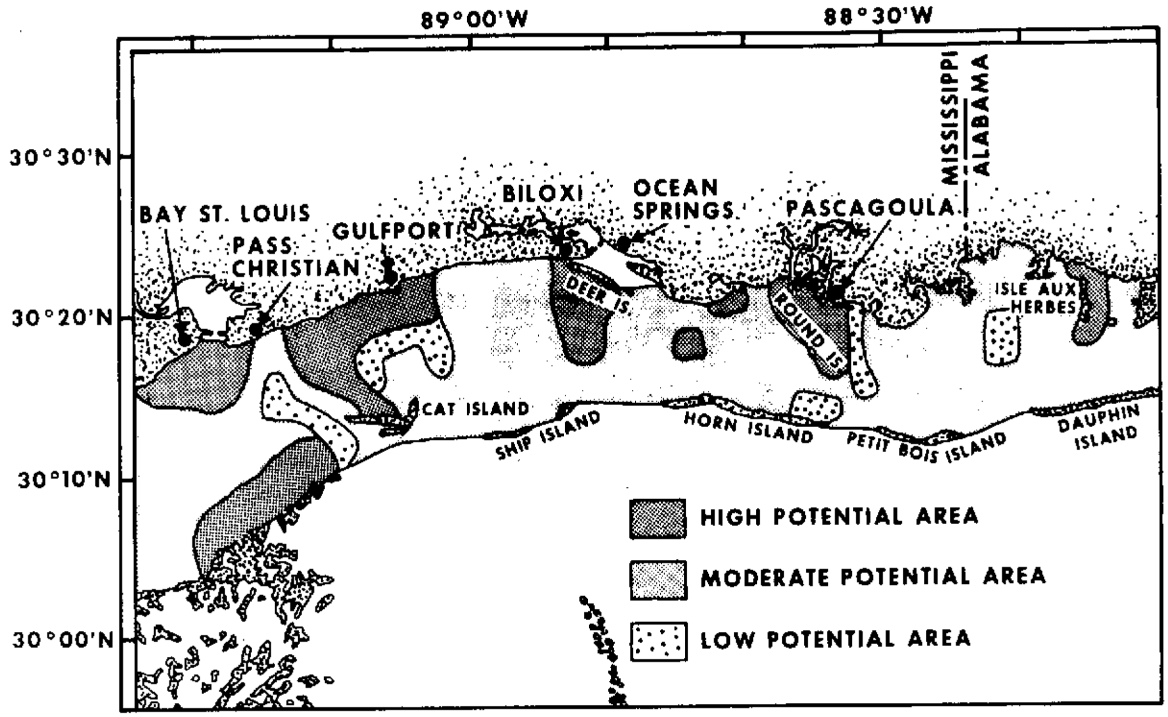


Figure 31. Model D8 Predictions For Menhaden Distribution In The Mississippi Sound On 7 August 1972 Between 0900-1500 Hours CDT Based On 95 Sea Truth Measurements. (S-70246-AG)

12.3.6 Analysis Summary and Conclusions

The feasibility of using satellite-supported environmental sensors to predict fish distribution was demonstrated. ERTS-1, MSS Band 5 imagery was shown to contain density levels which correlated with menhaden distribution. These density levels were further shown to correlate significantly with sea truth measurements of Secchi disc transparency and water depth, two parameters which also correlated significantly with menhaden distribution. Additionally, surface salinity, Forel-Ule color, and chlorophyll-a were found to correlate significantly with menhaden distribution. Independent tests of four oceanographic parameter-menhaden distribution relationships with oceanographic information taken at or near sites of commercial menhaden capture corroborated these relationships. The correlation between chlorophyll-a and menhaden distribution could not be substantiated because of insufficient data.

Eight empirical regression models which predict menhaden distribution in the study area were constructed from combinations of four oceanographic parameters: water depth, secchi disc transparency, surface salinity, and Forel-Ule color. Although the models did not provide particularly precise predictions about menhaden distributions, their predictions nevertheless were statistically significant. The importance of the models is that they demonstrate a potential means or direction through which remotely-sensed oceanographic information can be used to provide menhaden distribution information on a real-time basis. This information could be used by the commercial industry to increase fishing efficiency and by resource managers as an aid in planning assessment surveys.

APPENDIX A

DATA ACQUISITION MATRIX

APPENDIX A - DATA ACQUISITION MATRIX

PARAMETER	ACQUISITION METHOD/DEVICE	PLATFORM USED	DATA CARRIER	AGENCY	ACQUISITION FREQUENCY
OCEANOGRAPHIC					
• Sea Surface Temperature	SR (Scanning Radiometer - infra-red)	NOAA-2	Film	NOAA/NESS	Daily
	PRT-5 (Precision Radiation Thermometer)	Aircraft	Magnetic Tape	NASA/ERL	Main and Secondary Days
	RS-14 (Dual Channel Radiometric Scanner)	Aircraft	Magnetic Tape Film	NASA/JSC	Main Days
	RS-18 (Dual Channel Radiometric Scanner)	Aircraft	Magnetic Tape Film	NASA/ERL	Main and Secondary Days
	Bucket Thermometer	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
	RS5-3 (In Situ Temperature/Salinometer)	Surface Vessel	Log Sheet	NMFS, ERL	Main and Secondary Days
	MSS (24-Channel Multispectral Scanner)	Aircraft	Magnetic Tape, Film	NASA/JSC	Mini-Mission Day
• Water Color	Forel-Ule Water Color Comparator Scale	Surface Vessel	Log Sheet	NMFS, ERL NFMOA	Main and Secondary Days
	MSS (4-Channel Multispectral Scanner)	ERTS-1	Film	NASA/GSFC	Every 18 Days
	MSS (24-Channel Multispectral Scanner)	Aircraft	Magnetic Tape	NASA/JSC	Mini-Mission Day
	RBV (3-Channel Return Beam Vidicon)	ERTS-1	Film	NASA/JSC	Every 18 Days

APPENDIX A - DATA ACQUISITION MATRIX (CONTINUED)

PARAMETER	ACQUISITION METHOD/DEVICE	PLATFORM USED	DATA CARRIER	AGENCY	ACQUISITION FREQUENCY
	RC-8 (Wild Heerbrugg Camera System)	Aircraft	Film	NASA/JSC	Mini-Mission Day and Main Days
	KA-62 (Chicago Aerial Camera System	Aircraft	Film	NASA/JSC	Main Days
	Hasselblad Camera System	Aircraft	Film	NASA/ERL	Main and Secondary Days
	E-20D Spectrometer	Aircraft	Log Sheet	NASA/ERL	Main and Secondary Days
• Water Transparency	Secchi Disc	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
• Surface Current Speed	Drift Bottles	Surface Vessel	Log Sheet	NASA/ERL	Main Days
• Surface Current Direction	All Imaging Sensors and Drift Bottles	All Platforms	Film, Log Sheets	All Agencies	Main and Secondary Days
• Relative Irradiance	Irradiance Meter	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
• Sea State	Observer Estimate	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
• Water Depth To Bottom	Fathometer and Lead Line	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
• Surface Salinity	RS-5 (In Situ Temperature/ Salinometer	Surface Vessel	Log Sheet	NMFS, ERL	Main and Secondary Days

APPENDIX A - DATA ACQUISITION MATRIX (CONTINUED)

PARAMETER	ACQUISITION METHOD/DEVICE	PLATFORM USED	DATA CARRIER	AGENCY	ACQUISITION FREQUENCY
	Water Bottle Sample and Lab Analysis	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
	MFMR (Multifrequency Microwave Radiometer)	Aircraft	Magnetic Tape	NASA/JSC	Main Days
• Tide State	Tide Gauge	Coastal Station	Record Log	C&GS	Daily
• Chlorophyll a, b, c, and Carotenoids	Water Bottle Sample and Lab Analysis	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
	KA-62 Camera System	Aircraft	Film	NASA/JSC	Main Days
	MSS (Multispectral Scanner)	ERTS-1	Film	NASA/GSFC	Every 18 Days
		Aircraft	Magnetic Tape, Film	NASA/JSC	Mini-Mission Day
	RBV (Return Beam Vidicon)	ERTS-1	Film	NASA/GSFC	Every 18 Days
• Time	24-Hour Clock	All Platforms	Log Sheets, Film, Tape	All Agencies	Every Data Point
• Location	NAVAID Per Data Acquisition System	All Platforms	Log Sheets, Film, Tape	All Agencies	Every Data Point
METEOROLOGICAL					
• Air Temperature	Mercury Bulb Thermometer	Surface Vessel	Log Sheet	NMFS, ERL NFMOA	Main and Secondary Days
	TAT (Total Air Temperature System)	Aircraft	Log Sheet	NASA/JSC	Main Days

APPENDIX A - DATA ACQUISITION MATRIX (CONTINUED)

PARAMETER	ACQUISITION METHOD/DEVICE	PLATFORM USED	DATA CARRIER	AGENCY	ACQUISITION FREQUENCY
	Radiosonde	Balloon	Log Sheet	NWS	Main Days
• Wind Speed	Observer Estimate	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
• Wind Direction	Compass and Observer Estimate	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
• Cloud Cover	Observer Estimate	Surface Vessel	Log Sheet	NMFS, ERL, NFMOA	Main and Secondary Days
	Satellite Imagery (MSS, RBV, SR, VHRR)	ERTS-1	Film	NASA/GSFC	Every 18 Days
		NOAA-2	Film	NOAA/NESS	Daily
• Precipitation	Rain Gauge	Land Station	Log Sheet	NWS	Daily
• Relative Humidity	Psychrometer	Surface Vessel	Log Sheet	NMFS, ERL	Main and Secondary Days
<u>LIVING MARINE RESOURCE</u>					
• Number of Fish Schools	Observer Estimate	Aircraft and Surface Vessel	Log Sheet	NFMOA	1-3 Days/Week
	LLLII (Low Light Level Image Intensifier)	Aircraft	Video Tape	NMFS	Dark Of The Moon Periods
	Visible Range Camera Systems	Aircraft	Film	NMFS	Weekly
• Fish Classification	Observer Estimate	Aircraft	Log Sheet	NFMOA	Each Set and Weekly

PARAMETER	ACQUISITION METHOD/DEVICE	PLATFORM USED	DATA CARRIER	AGENCY	ACQUISITION FREQUENCY
	Visible Range Camera Systems	Aircraft	Film	NMFS	Weekly
	LLLII	Aircraft	Video Tape	NMFS	Dark Of Moon Periods
• Number Of Fish Per Set	Observer Count Estimate	Surface Vessel	Log Sheet	NFMOA	Each Set
• Time Of Set	24-Hour Clock	Surface Vessel	Log Sheet	NFMOA	Each Set
• School Surface Area	Visible Range Camera Systems	Aircraft	Film	NMFS	Weekly
	LLLII	Aircraft	Video Tape	NMFS	Weekly
• School Size	Observer Estimate	Aircraft	Log Sheet	NFMOA	Each Observation
• Time Of Observation	24-Hour Clock	All Platforms	Log Sheet	NMFS, NFMOA	Each Observation
• Fishing Conditions	Observer Estimate	Aircraft and Surface Vessels	Log Sheet	NFMOA	Main and Secondary Days
• Area Observed - No Fish	Observer Estimate	Aircraft and Surface Vessels	Log Sheet	NMFS, NFMOA	Weekly
• Location Of Observation	Closed Grid Chart	Aircraft and Surface Vessels	Log Sheet	NMFS, NFMOA	Each Observation

APPENDIX B

STATUS SUMMARY OF FIELD DATA ACQUISITION OPERATIONS DURING 1972

SCHEDULED MISSION DATE	MISSION OPERATIONS DATE	MISSION RECYCLE DATE	MISSION STATUS	ERTS PASS	AIRCRAFT						BOATS		
					NC130B	NP3A	E-18	PHOTO	LLLII	SPOTTER	SVO	SVF	SVFO
M-6/27	None	M-6/29	CR	–			INCLEMENT WEATHER						
	M-6/29	M-6/30	PC	–	–	–	–	–	–	+	+	+	+
	M-6/30	None	PC	–	–	–	–	–	–	+	+	+	–
M-7/14	None	M-7/6	CR	–			HOLIDAY						
	M-7/6	None	MC	–	+	–	+	+	+	+	+	+	+
S-7/11	S-7/11	None	MC	–	–	–	+	+	+	+	+	+	+
S-7/18	None	S-7/19	CR	–			INCLEMENT WEATHER						
	S-7/19	None	PC	–	–	–	+	–	–	+	+	+	+
S-7/25	S-7/25	None	MC	–	–	–	+	–	–	+	+	+	+
S-8/1	S-8/1	None	MC	–	–	–	+	–	–	+	+	+	+
	P-8/7	None	MC	+	–	–	+	+	+	+	+	+	+
S-8/8	None	None	CM	–			P-8/7 EVALUATION						
S-8/15	S-8/15	None	PC	–	–	–	+	–	+	+	+	+	+
S-8/22	None	P-8/25	CR	–			P-8/25 PREPARATION						
	P-8/25	None	MC	+	–	+	–	+	–	+	+	+	+
S-8/29	S-8/29	None	PC	–	–	–	+	–	–	+	+	+	+
S-9/5	None	S-9/7	CR	–			INCLEMENT WEATHER						
	S-9/7	None	PC	–	–	–	+	–	+	+	+	+	–
P-9/11	None	P-9/12	CR	+			INCLEMENT WEATHER						
	None	S-9/13	CR	+			INCLEMENT WEATHER						
	S-9/13	None	PC	–	–	–	–	+	+	+	+	+	+
S-9/19	S-9/19	None	MC	–	–	–	+	+	–	+	+	+	+
S-9/26	None	P-9/29	CR				P-9/29 PREPARATION						
	P-9/28	None	PC	–	–	+	+	+	–	+	+	+	+
S-10/3	None	S-10/4	CR	–			INCLEMENT WEATHER						
	S-10/4	None	PC	–	–	–	+	–	+	T	+	T	T
S-10/10	None	S-10/11	CR	–			INCLEMENT WEATHER						
	S-10/11	None	PC	–	–	–	–	–	+	T	–	T	T
P-10/17	None	S-10/18	CR	+			INCLEMENT WEATHER						
	S-10/18	None	PC	+	–	–	+	–	–	T	+	T	T
S-10/24	None	P-11/4	CR	–			INCLEMENT WEATHER						
S-10/31	None	P-11/4	CR	–			P-11/4 PREPARATION						
P-11/4	None	None	CM	+			INCLEMENT WEATHER						
NO FIELD OPERATIONS SCHEDULED OR ATTEMPTED AFTER 11/4													

APPENDIX C

AIRCRAFT FLIGHT SUMMARY

MISSION OPS. DATE (1972)	AIRCRAFT OPERATED	FLIGHT ALTITUDE (K')	DATA MILES FLOWN AT ALTITUDE (n.mi.)	SENSORS OPERATED													
				207 CAM.	E-20D SPEC.	EL-500 CAM.	KA-62 CAM	LASER PROF.	LLLII	MFMR	MSS	PRT-5	RC-8 CAM.	RS-14 SCAN.	RS-18 SCAN.	RMK-1523 CAM.	A/C ENVIRON
7-6	NC130B	4.0	69.4									●	●				●
		5.0	69.4								●	●					●
		25.0	86.5								●	●					●
		27.0	86.5									●	●				●
	E-18	10.0	379.1		●	●						●			●		
	Photo	8.1	560.0													●	
	LLLII	3.0	152.6						●								
7-11	E-18	10.0	656.0			●						●			●		
	Photo	8.1	550.0													●	
	LLLII	3.0	152.6						●								
7-19	E-18	10.0	379.1		●	●						●					
7-25	E-18	10.0	379.1		●	●						●			●		
8-1	E-18	10.0	379.1		●	●						●			●		
8-7	E-18	10.0	656.0		●	●						●			●		
	Photo	8.1	590.0													●	
	LLLII	3.0	152.6						●								
8-15	E-18	10.0	656.0		●	●						●			●		
	LLLII	3.0	152.6						●								
8-25	NP3A	0.8	359.0	●			●			●		●					●
		21.4	183.0									●	●	●			●
		21.5	548.0	●								●	●	●			●
	Photo	8.1	575.0													●	
8-29	E-18	10.0	450.1		●	●						●			●		
9-7	E-18	10.0	450.1		●	●						●			●		
	LLLII	3.0	152.6						●								
9-13	Photo	8.1	660.0													●	
	LLLII	3.0	107.2						●								
9-19	E-18	10.0	450.1			●									●		
	Photo	8.1	310.0													●	
9-28	NP3A	0.8	128.0	●			●					●					●
		20.0	905.0	●								●	●	●			●
	E-18	1.0	825.0		●	●									●		
	Photo	8.1	625.0													●	
10-4	E-18	10.0	107.8		●	●						●			●		
	LLLII	3.0	131.0						●								
10-11	LLLII	3.0	153.0						●								
10-18	E-18	10.0	450.1		●	●						●			●		

APPENDIX D

DATE AND NUMBER OF OCEANOGRAPHIC AND METEOROLOGICAL STATIONS TAKEN BY VESSEL

DATE OF OBS. (1972)	NUMBER OF OCEANO./MET. STATIONS TAKEN	
	SVO	SVFO
6-7	-	5
6-9	-	3
6-10	-	1
6-11	-	7
6-12	-	15
6-18	-	1
6-21	-	2
6-22	-	5
6-23	-	4
6-25	-	1
6-26	-	2
6-27	-	7
6-28	-	4
6-29	126	5
6-30	64	-
7-2	-	15
7-3	-	9
7-4	-	15
7-5	-	3
7-6	42	10
7-7	-	11
7-8	-	4
7-10	-	10
7-11	14	11

DATE OF OBS. (1972)	NUMBER OF OCEANO./MET. STATIONS TAKEN	
	SVO	SVFO
7-13	-	4
7-16	-	18
7-17	-	10
7-18	-	23
7-19	14	7
7-21	-	1
7-23	-	25
7-24	-	20
7-25	19	61
7-26	-	6
7-31	-	13
8-1	17	14
8-2	-	6
8-6	-	10
8-7	137	14
8-8	-	8
8-9	-	3
8-13	-	8
8-14	-	15
8-15	11	14
8-16	-	11
8-20	-	8
8-21	-	5
8-22	-	3

DATE OF OBS. (1972)	NUMBER OF OCEANO./MET. STATIONS TAKEN	
	SVO	SVFO
8-23	-	12
8-24	-	15
8-25	193	9
8-28	-	5
8-29	12	3
8-30	-	4
9-3	-	18
9-5	-	4
9-6	-	1
9-7	12	-
9-13	-	4
9-14	-	6
9-18	-	8
9-19	12	1
9-20	-	1
9-26	-	8
9-27	-	6
9-28	209	6
9-29	-	7
10-4	12	-
10-18	12	-
TOTAL	906	575

APPENDIX E

SVO SEA TRUTH STATION COORDINATES

FOR 7 AUGUST 1972

STATION	LATITUDE(N)	LONGITUDE(W)	STATION	LATITUDE(N)	LONGITUDE(W)
A-1	30°16'36"	89°21'04"	A-21	30°07'48"	89°09'37"
A-2	30°12'27"	89°21'04"	A-22	30°11'27"	89°09'27"
A-3	30°09'00"	89°21'04"	A-23	30°14'24"	89°09'37"
A-4	30°05'12"	89°21'04"	A-24	30°17'02"	89°09'37"
A-5	30°06'27"	89°18'48"	A-25	30°20'00"	89°09'37"
A-6	30°09'00"	89°18'48"	B-1	30"20'00"	89°07'19"
A-7	30"12'39"	89°18'48"	B-2	30"17'02"	89°07'19"
A-8	30°15'27"	89°18'48"	B-3	30°14'30"	89°07'19"
A-9	30°17'30"	89°16'32"	B-4	30°04'30"	89°04'56"
A-10	30°14'51"	89°16'32"	B-5	30"07'48"	89°04'56"
A-11	30°11'51"	89°16'32"	B-6	30°11'01"	89°04'56"
A-12	30"08'51"	89°16'32"	B-7	30°14'37"	89°04'56"
A-13	30°09'18"	89°14'09"	B-8	30°17'02"	89°04'56"
A-14	30°11'24"	89°14'09"	B-9	30°19'30"	89°04'56"
A-15	30°14'41"	89°14'09"	B-10	30°21'00"	89°02'41"
A-16	30°17'52"	89°14'09"	B-11	30°18'18"	89°02'41"
A-17	30°17'52"	89°11'54"	B-12	30°15'39"	89°02'41"
A-18	30°14'51"	89°11'54"	B-13	30°13'45"	89°02'41"
A-19	30°12'24"	89°11'54"	B-14	30°04'30"	89°00'26"
A-20	30°04'30"	89°09'37"	B-15	30°07'48"	89°00'26"

STATION	LATITUDE(N)	LONGITUDE(W)	STATION	LATITUDE(N)	LONGITUDE(W)
B-16	30°12'01"	89°00'26"	C-8	30°18'01"	88°51'12"
B-17	30°15'01"	89"00'26"	C-9	30°21'00"	88°51'12"
B-18	30°18'01"	89°00'26"	C-13	30°04'30"	88°46'29"
B-19	30°21'00"	89°00'26"	C-14	30°08'46"	88°46'29"
B-20	30°21'00"	88°57'59"	C-15	30°13'01"	88°46'29"
B-21	30°18'01"	88°57'59"	C-16	30°15'00"	88°46'29"
B-22	30°15'01"	88°57'59"	C-17	30°18'01"	88°46'29"
B-23	30°04'30"	88°55'44"	C-18	30°21'00"	88°46'29"
B-24	30°07'48"	88°55'44"	C-19	30°18'30"	88°44'13"
B-25	30°12'01"	88°55'44"	C-20	30°17'12"	88°44'13"
B-28	30°21'00"	88°55'44"	C-21	30°15'18"	88°44'13"
B-29	30°07'45"	89°02'41"	C-22	30°04'30"	88°41'57"
B-30	30°04'21"	89°02'41"	C-23	30°08'46"	88°41'57"
C-1	30°21'00"	88°53'27"	C-24	30°13'01"	88°41'57"
C-2	30°18'01"	88°53'27"	C-25	30°15'29"	88°41'57"
C-3	30°15'01"	88°53'27"	C-26	30°18'01"	88°41'57"
C-4	30°04'30"	88°51'12"	C-27	30°20'00"	88°41'57"
C-5	30°08'45"	88°51'12"	C-28	30°14'09"	88°48'46"
C-6	30°13'01"	88°51'12"	C-29	30°11'00"	88°48'46"
C-7	30°15'24"	88°51'12"	C-30	30°04'30"	88°48'46"

STATION	LATITUDE(N)	LONGITUDE(W)	STATION	LATITUDE(N)	LONGITUDE(W)
D-1	30°20'00"	88°39'30"	D-21	30°13'14"	88°30'24"
D-2	30°17'00"	88°30'30"	D-22	30°04'30"	88°27'57"
D-3	30"14'36"	88°30'30"	D-23	30°07'48"	88°27'57"
D-4	30°04'30"	88°37'13"	D-24	30°11'28"	88°27'57"
D-5	30°08'46"	88°37'13"	D-25	30°12'43"	88°27'57"
D-6	30°13'01"	88°37'13"	D-26	30°15'43"	88°27'57"
D-7	30°15'04"	88°37'13"	D-27	30°18'42"	88°27'57"
D-8	30°17'00"	88°37'13"	D-28	20°12'00"	88°34'57"
D-9	30°20'00"	88°37'13"	D-29	30°08'45"	88°34'57"
D-10	30°19'42"	88°34'57"	D-30	30°04'30"	88°34'57"
D-11	30°16'43"	88°34'57"	E-1	30°18'42"	88"25'41"
D-12	30°13'42"	88°34'57"	E-2	30°15'43"	88°25'41"
D-13	30°04'30"	88°32'40"	E-3	30°12'43"	88°25'41"
D-14	30°08'45"	88°32'40"	E-4	30°04'30"	88°23'25"
D-15	30°12'30"	88°32'40"	E-5	30°07'48"	88°23'25"
D-16	30°13'42"	88°32'40"	E-6	30°11'28"	88°23'25"
D-17	30°16'43"	88°32'40"	E-7	30°12'43"	88°23'25"
D-18	30°19'42"	88°32'40"	E-8	30°15'43"	88°23'25"
D-19	30°17'54"	88°30'24"	E-9	30°18'42"	88°23'25"
D-20	30°16'12"	88°30'24"	E-10	30°20'24"	88°21'09"

STATION	LATITUDE(N)	LONGITUDE(W)
E-11	30°17'27"	88°21'09"
E-12	30°14'28"	88°21'09"
E-13	30°04'30"	88°18'54"
E-14	30°07'48"	88°18'54"
E-15	30°11'28"	88°18'54"
E-16	30°14'28"	88°18'54"
E-17	30°17'27"	88"18'54"
E-18	30°20'24"	88°18'54"
E-19	30°20'24"	88°16'39"
E-20	30°17'27"	88°16'39"
E-21	30°14'28"	88°16'39"
E-22	30°12'43"	88°21'05"
E-23	30°07'48"	88°21'09"
E-24	30°15'54"	88°14'30"
E-25	30°18'56"	88°14'30"
E-26	30"21'57"	88°14'30"
E-27	30°04'30"	88°21'09"

APPENDIX F

SVO SEA TRUTH DATA VALUES

ACQUIRED ON 7 AUGUST 1972

FIELD AND LABORATORY MEASUREMENTS

STAT NUM3	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
A1	830	30.3	2.2	18,85	27.5	60.5	270	8	3.0	1.0	.36	240	10.0	1
A2	930	30.5	3.0	19.78	28.0	63.3	270	8	3.0	1.0	.20	240	12.0	2
A3	1000	30.9	1.2	20,87	27.9	61.3	270	8	3.5	1.0	.20	240	12.0	3
A4	1025	30.8	2.8	19.15	31.0	53.6	270	10	4.0	1.5	.34	250	12.0	4
A5	1100	31.0	1.9	22,84	31.3	52.7	260	8	3.5	1.5	.25	210	12.0	5
A5	1550	31.5	3.5	21.34	29.7	60.5	250	10	5.5	1.5	.81	90	12.0	12
A6	1130	31.5	.9	23,31	30.5	56.0	270	8	5.0	1.0	.33	180	12.0	6
A6	1660	31.5	3.0	22.51	32.0	61.3	250	10	5.5	1.5	.89	70	12.0	14
A7	1150	31.0	3.1	21.71	33.1	53.6	270	8	4.5	1.0	.25	180	12.0	7
A7	1635	31.0	2.0	20,82	29.8	67.3	250	10	5.0	1.5	.59	90	12.0	15
A8	1300	30.8	2.4	19.50	31.2	53.6	210	6	5.0	.5	.42	90	12.0	8
A8	1720	31.3	3.7	19.12	31.5	59.0	225	12	1.5	1.5	.40	50	6.0	16
A9	1330	31.1	6.1	17.81	31.5	59.4	180	10	6.0	.5	.33	90	8.0	9
A10	1430	30.6	2.6	19.17	31.7	58.6	240	11	6.0	1.0	.59	90	6.0	10
A11	1500	31.4	2.1	22,28	29.9	64.4	240	14	5.5	2.0	.74	70	12.0	11
A12	1520	31.6	3.3	24.25	31.5	64.1	250	10	5.5	1.5	.99	70	12.0	12

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
A13	1045	30.0	4.5	23.79	29.0	29.7	270	9	2.0	•••••	•••••	•••	10.0	167
A14	1030	30.0	3.9	23.44	31.0	34.5	270	10	2.5	•••••	•••••	•••	8.0	163
A15	930	29.5	3.9	24.90	29.0	62.9	270	7	1.5	•••••	•••••	•••	25.0	166
A16	830	29.5	3.5	19.27	29.0	69.7	270	7	1.5	•••••	•••••	•••	10.0	21
A17	1115	31.0	2.4	23.35	29.5	41.6	270	9	2.5	•••••	•••••	•••	11.0	165
A17	1130	31.0	3.8	23.35	29.5	56.0	90	9	2.5	•••••	•••••	•••	11.0	164
A19	1145	32.5	2.8	23.21	29.5	64.7	235	10	2.0	•••••	•••••	•••	15.0	168
A19	1155	31.0	1.5	23.11	30.0	85.0	235	10	2.0	•••••	•••••	•••	15.5	170
A20	955	31.1	5.0	28.01	32.5	64.4	270	8	6.0	2.5	•••••	•••	15.0	153
A21	910	30.8	2.5	28.35	29.3	63.7	270	8	6.0	2.5	.74	270	16.0	152
A22	830	30.3	4.2	28.13	29.0	69.1	270	8	••••	2.0	•••••	•••	7.0	151
A23	1220	31.5	2.2	22.66	30.0	61.3	235	10	2.5	•••••	•••••	•••	14.0	169
A24	1300	31.0	4.2	19.04	30.0	45.3	235	8	2.5	•••••	•••••	•••	12.0	171
A25	1400	30.0	2.6	19.00	30.0	44.8	235	8	2.5	•••••	•••••	•••	12.0	173
B1	830	30.2	3.6	21.51	30.5	59.2	290	4	3.0	1.0	.21	270	8.5	33
B2	921	30.2	3.9	••••••	30.6	60.1	290	4	4.0	2.0	.30	270	14.0	34

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
B3	954	30.6	4.4	23.80	30.4	56.9	290	4	4.5	2.0	.11	300	8.0	35
B4	1025	••••	2.9	29.52	33.2	87.5	270	6	6.0	2.0	•••••	•••	10.0	154
B5	1055	••••	2.2	29.80	32.0	64.1	270	6	10.0	2.0	•••••	•••	14.0	155
B6	1110	••••	2.4	30.53	31.2	61.6	270	6	••••	2.0	•••••	•••	13.0	156
B7	1037	30.6	4.4	24.15	31.1	57.8	280	3	3.5	2.0	.10	80	9.0	36
B7	1343	31.1	4.1	24.20	32.0	58.6	250	7	4.0	2.0	.56	70	9.0	42
B8	1115	30.8	2.4	25.03	31.1	58.2	290	4	4.5	2.0	.33	190	14.0	37
B8	1411	31.2	1.9	24.93	32.6	58.6	260	5	5.3	2.0	.50	110	14.0	43
B9	1137	30.8	3.4	24.92	31.5	53.1	290	3	4.5	2.0	.27	150	9.0	38
B9	1435	30.8	2.5	23.87	32.4	61.6	250	6	5.8	2.0	.68	100	9.0	44
B10	1205	30.8	8.3	24.42	32.5	50.3	250	5	3.5	2.0	.23	70	9.0	39
B11	1237	30.9	1.4	25.97	31.9	58.6	250	4	5.3	2.0	.52	185	25.0	40
B12	1308	30.7	2.5	28.58	31.8	53.1	270	5	6.0	2.0	.56	110	12.0	41
B13	1245	••••	2.1	30.44	32.0	64.4	270	6	12.0	1.0	•••••	•••	12.0	162
B14	1200	••••	2.0	31.01	32.5	56.4	270	6	6.0	1.5	•••••	•••	15.0	159
B15	1145	••••	2.0	31.31	31.0	55.6	270	6	12.0	1.0	•••••	•••	24.0	158

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
B16	1130	....	2.5	30.87	30.5	58.6	270	6	10.0	1.0	.....	...	25.0	157
B17	920	29.9	2.9	30.55	33.2	60.9	300	6	6.0	2.5	.26	60	16.0	49
B18	855	30.0	3.0	28.64	33.3	66.6	290	6	5.0	2.0	.23	290	12.0	51
B19	830	30.2	2.4	26.72	33.1	63.7	290	6	5.5	2.0	.20	290	11.0	56
B20	1050	30.5	2.7	27.34	33.3	60.9	280	3	6.0	1.0	.14	60	11.0	53
B21	1017	30.5	2.5	26.59	33.3	67.3	305	3	5.0	1.0	.19	60	13.0	55
B22	952	30.5	1.7	30.65	33.4	67.3	310	5	4.5	2.0	.27	60	16.0	54
B23	945	30.6	2.2	30.68	32.1	67.9	240	12	12.0	1.0	.....	...	35.0	23
B24	905	31.0	1.3	30.05	31.5	77.3	240	12	14.0	.8	.31	230	38.0	24
B25	830	30.0	1.1	*****	30.2	84.0	240	10	14.0	.8	.....	...	18.0	25
B29	1220	....	2.8	30.53	31.9	56.4	270	6	11.0	1.0	.....	...	18.0	161
B30	1210	....	2.0	30.16	31.8	56.0	270	6	10.0	1.0	.....	...	11.0	160
C1	1317	31.1	2.3	26.92	34.9	64.7	245	3	5.0	1.5	.56	70	11.0	52
C2	1255	30.9	1.9	29.96	34.5	71.2	245	3	7.0	1.5	.59	80	13.0	46
C3	1233	30.7	2.0	28.04	34.5	67.6	245	3	8.5	1.5	.40	95	17.0	45
C4	1015	30.4	1.1	30.74	31.6	74.0	305	13	14.0	1.0	.....	...	43.0	4

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
C5	1045	30.4	2.2	......	32.4	70.6	325	13	12.0	1.0	.....	...	35.0	5
C6	1105	30.6	1.4	30.44	32.6	67.6	330	12	14.0	1.0	.....	...	30.0	6
C7	1213	30.8	1.4	28.09	34.3	61.3	250	3	8.5	1.5	.47	120	13.0	47
C7	1448	30.8	.....	......	34.1	80.5	240	5	6.5	2.0	.....	...	18.0	
C8	1152	30.7	2.2	27.85	33.9	64.4	260	2	5.5	1.0	.49	95	13.0	50
C8	1426	31.0	.....	......	33.9	70.6	240	5	4.5	2.0	.....	...	16.0	
C9	1127	30.9	3.2	20.01	33.3	61.3	240	2	5.0	1.0	.21	120	11.0	48
C9	1414	30.9	.....	......	33.9	74.3	230	5	4.0	2.0	.....	...	12.0	
C13	1210	30.8	1.2	31.26	32.3	71.2	300	10	>14.0	.8	.....	...	42.0	13
C14	1150	30.3	1.0	30.41	32.2	77.5	300	12	14.0	1.0	.....	...	40.0	14
C15	1130	30.3	1.0	30.33	32.4	67.6	330	12	12.0	1.0	.....	...	18.0	15
C16	1000	29.4	1.4	30.66	34.0	63.7	260	6	10.5	1.0	.89	95	24.0	95
C17	920	29.5	1.4	27.60	30.5	60.5	280	6	7.0	1.0	.70	115	12.0	94
C18	830	29.1	7.0	25.02	29.0	66.3	290	6	1.5	1.0	.14	70	10.0	93
C19	1135	30.6	5.8	26.35	32.5	55.6	265	5	1.5	1.0	.49	90	7.0	98
C19	1420	31.0	6.4	26.34	33.1	59.0	235	8	1.0	1.0	.36	115	6.5	104

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRNT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
C20	1055	30.5	2.0	26.98	31.7	52.7	285	6	8.0	1.0	.68	105	9.5	97
C20	1355	31.2	4.4	26.59	32.0	55.6	250	7	4.0	1.0	.99	115	9.5	103
C21	1023	29.5	1.0	30.64	31.4	60.5	280	6	10.0	1.0	.77	90	10.5	96
C21	1327	30.2	1.9	29.54	32.0	58.6	260	6	8.5	1.0	.59	115	11.0	102
C22	1000	30.0	•••••	••••••	32.0	73.2	315	10	12.0	•••••	•••••	•••	58.0	177
C23	915	29.5	•••••	••••••	30.0	70.0	315	10	12.0	•••••	•••••	•••	52.0	176
C24	830	29.0	1.2	30.35	31.0	66.6	315	7	12.0	•••••	•••••	•••	31.0	175
C25	1305	30.4	•••••	30.62	31.9	58.6	280	6	5.0	1.0	.66	90	8.0	101
C26	1240	30.9	3.0	27.61	32.6	61.3	255	5	5.0	1.0	.99	90	12.0	100
C27	1215	30.9	8.8	25.15	32.9	58.6	255	5	1.5	1.0	.42	90	6.5	99
C28	1400	30.5	1.9	30.40	33.9	68.2	210	10	12.0	.8	•••••	•••	20.0	28
C29	1320	30.7	1.4	30.58	34.0	68.2	270	10	>14.0	.8	•••••	•••	40.0	29
C30	1225	30.9	1.2	30.96	32.6	67.6	270	10	>14.0	.8	•••••	•••	45.0	30
D1	830	29.5	10.0	26.61	28.5	72.9	270	6	3.0	.5	.25	90	8.0	67
D2	855	30.0	5.3	28.21	28.6	72.9	270	8	3.5	1.0	•••••	•••	14.0	68
D3	910	29.5	1.9	29.59	29.4	70.0	270	8	7.0	1.0	•••••	•••	17.0	58

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
D4	1025	29.5	.8	32.52	31.5	70.0	315	10	12.0	•••••	•••••	•••	60.0	178
D5	1350	30.5	.5	31.48	32.5	•••••	315	10	12.0	•••••	•••••	•••	47.0	186
D6	1335	30.5	1.1	31.37	32.5	•••••	315	10	12.0	•••••	•••••	•••	36.0	185
D7	930	29.6	2.1	29.02	29.8	72.9	270	8	5.0	1.0	•••••	•••	14.0	63
D7	1210	30.5	2.4	28.93	29.8	54.0	270	8	7.0	1.0	•••••	•••	13.0	62
D8	950	30.0	4.5	28.23	30.1	66.6	280	8	2.5	1.0	•••••	•••	12.0	65
D8	1225	30.5	2.4	28.72	30.2	67.0	270	8	4.0	1.0	•••••	•••	11.0	58
D9	1005	30.4	4.7	24.42	31.0	60.5	270	6	2.5	.5	•••••	•••	7.0	57
D9	1240	31.2	7.2	25.32	30.5	64.7	270	8	2.0	1.0	•••••	•••	6.0	61
D10	1017	30.5	2.9	25.65	31.5	58.6	270	6	2.0	.5	•••••	•••	6.0	66
D11	1035	30.3	2.2	27.63	31.0	64.1	270	8	4.0	1.0	•••••	•••	8.0	60
D12	1050	29.9	1.9	27.52	31.8	64.1	300	8	10.0	1.0	•••••	•••	22.0	64
D13	1120	29.0	.6	34.81	31.5	70.0	315	10	12.0	•••••	•••••	•••	65.0	180
D14	1305	31.0	.8	30.92	32.5	•••••	315	10	12.0	•••••	•••••	•••	41.0	182
D15	1315	30.0	1.9	28.80	32.5	•••••	315	10	12.0	•••••	•••••	•••	25.0	183
D16	920	29.1	2.3	27.84	31.8	70.0	290	9	10.0	1.0	.42	120	15.0	75

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
D17	855	29.2	2.0	27.79	30.1	72.9	315	6	7.5	1.0	.30	145	15.0	69
D18	825	28.4	6.9	22.47	29.0	69.1	315	6	3.5	.5	.21	145	7.0	71
D19	1020	29.5	6.8	24.89	31.0	70.0	290	3	4.0	.5	.49	120	11.0	77
D19	1310	28.5	11.4	24.54	31.0	63.3	225	10	3.5	1.0	.49	120	11.0	73
D20	1000	29.0	3.1	27.61	32.0	60.9	290	6	8.0	1.0	.30	120	20.0	70
D20	1225	30.2	5.1	25.49	31.5	64.1	225	10	5.0	1.0	.21	210	16.0	74
D21	935	29.5	1.7	30.85	31.6	70.0	290	12	11.0	1.0	•••••	•••	20.0	79
D21	1150	29.5	1.1	28.02	31.0	70.6	270	7	>12.0	1.5	.25	135	20.0	72
D22	1000	30.2	.5	32.09	32.8	70.6	310	14	>12.0	2.5	•••••	•••	•••••	196
D23	935	30.0	.8	30.98	30.2	70.3	310	12	>12.0	2.0	.56	120	•••••	197
D24	920	29.8	1.3	31.26	30.3	70.0	310	12	>12.0	1.5	•••••	•••	•••••	198
D25	1120	27.4	1.2	30.82	29.6	72.9	270	7	9.5	1.5	.11	120	14.0	80
D26	1055	27.8	1.3	28.24	30.0	70.0	270	4	7.0	1.5	.30	150	16.0	78
D27	1035	28.5	11.1	28.54	31.0	70.0	270	4	3.0	.5	.16	90	5.0	76
D28	1325	30.0	.9	31.04	32.5	•••••	315	10	12.0	•••••	•••••	•••	36.0	184
D29	1245	30.5	•••••	••••••	32.5	•••••	315	10	12.0	•••••	•••••	•••	45.0	181

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
D30	1040	29.5	.9	32.99	31.2	70.0	315	10	12.0	•••••	•••••	•••	62.0	179
E1	835	30.1	•••••	••••••	30.2	73.8	270	4	6.0	1.0	.26	135	12.0	114
E1	1130	30.5	3.7	29.21	31.1	64.7	270	4	5.0	.5	.74	135	12.0	109
E2	917	30.0	•••••	••••••	28.8	70.0	270	5	6.0	1.0	.63	90	12.0	115
E2	1200	30.7	2.0	29.08	30.0	61.3	270	6	6.0	1.0	.74	110	18.0	105
E3	945	29.6	•••••	••••••	29.0	67.0	295	8	6.0	1.5	.54	45	8.0	116
E3	1225	29.8	1.9	30.80	30.0	58.6	270	7	8.0	.5	.99	90	10.0	110
E4	1020	29.8	1.0	30.95	31.2	67.6	310	12	> 12.0	2.0	•••••	•••	•••••	195
E7	1240	30.5	•••••	••••••	30.4	58.6	270	8	6.0	1.5	1.27	90	10.0	107
E5	1035	29.8	1.2	31.03	30.8	67.3	310	12	> 12.0	2.0	•••••	•••	•••••	191
E6	1050	29.6	.8	31.09	31.1	64.4	310	12	> 12.0	2.0	•••••	•••	•••••	189
E7	1015	29.9	1.8	28.72	29.2	64.1	295	8	8.0	1.5	.63	90	10.0	111
E8	1040	30.2	1.9	29.72	30.5	61.3	295	8	8.0	1.0	.74	90	20.0	112
E8	1300	30.9	•••••	••••••	30.5	61.6	270	8	8.0	1.5	.74	90	19.0	108
E9	1110	30.5	•••••	30.57	30.8	61.3	270	4	8.0	.5	.74	.35	14.0	113
E9	1320	30.8	•••••	••••••	30.5	61.6	270	8	••••	1.0	.74	90	16.0	

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
E10	912	30.2	5.1	28.31	31.1	63.7	320	6	5.0	1.0	.24	140	11.0	139
E10	1225	30.5	3.1	28.02	31.8	61.3	240	8	5.5	1.5	.25	130	11.0	148
E11	1150	30.2	2.5	29.85	31.5	61.3	270	6	8.0	2.0	.18	150	17.0	147
E11	1415	30.5	1.4	29.92	31.4	61.6	280	8	8.5	2.0	.18	150	17.0	144
E12	1130	30.1	1.5	30.41	31.4	58.6	320	6	10.0	2.0	.25	120	18.0	143
E12	1400	30.3	2.0	30.49	31.1	61.3	320	8	10.0	2.0	.25	120	18.0	145
E13	1140	29.8	.9	30.50	32.1	67.3	310	12	>12.0	2.0	.....	...	.....	193
E14	1125	29.6	1.2	30.96	31.5	70.3	310	10	>12.0	2.5	.....	...	.....	192
E15	1110	29.5	1.3	31.38	32.5	61.6	310	10	>12.0	2.5	.....	...	.....	188
E16	1100	29.8	5.2	30.44	30.9	58.6	320	7	4.0	2.0	.44	270	16.0	140
E16	1435	30.5	.....	......	31.0	61.3	....	....	....	2.5	.....	...	16.0	
E16	1340	30.1	5.2	28.98	31.1	61.6	230	8	4.0	2.0	.42	135	16.0	149
E17	1020	30.3	2.3	27.99	32.2	61.3	305	7	7.0	1.5	.24	130	15.0	141
E17	1310	30.6	1.9	29.94	31.7	61.6	240	8	7.5	2.0	.25	130	15.0	146
E17	1445	30.9	.....	......	31.5	61.3	....	....	....	2.5	.....	...	15.0	
E18	950	30.2	3.2	28.30	31.8	61.3	320	6	5.5	1.0	.25	95	12.0	142

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
E1A	1245	30.8	3.1	28.22	31.7	61.6	240	8	5.0	2.0	.25	120	12.0	150
E1A	1456	31.0	•••••	••••••	31.4	61.6	••••	••••	••••	2.5	•••••	•••	12.0	
E19	1112	30.5	5.0	26.68	31.1	60.9	315	12	3.0	1.0	.21	120	9.0	136
E19	1447	31.1	4.7	26.67	30.3	67.3	285	17	2.0	1.5	.30	190	9.0	134
E20	1155	30.8	10.7	27.41	30.5	67.3	290	12	5.5	1.0	.16	120	12.0	131
E20	1530	31.0	3.8	27.84	31.5	67.3	290	18	6.0	2.0	.21	310	12.0	129
E21	1225	30.0	3.7	28.83	30.3	67.0	290	14	6.0	1.0	.25	180	11.0	133
E21	1555	30.3	2.4	28.66	31.5	64.4	300	18	5.5	2.5	.30	286	11.0	25
E22	1300	30.3	1.9	29.99	32.8	64.7	310	12	8.0	2.0	•••••	•••	•••••	190
E23	1235	29.8	1.2	••••••	32.5	64.7	310	12	>12.0	2.0	•••••	•••	•••••	194
E24	907	30.3	8.8	28.29	28.3	67.3	330	14	4.5	1.5	.21	120	10.0	17
E25	954	29.6	8.4	26.89	29.8	67.0	320	14	3.5	1.5	.42	160	6.0	132
E26	1044	30.2	11.7	25.11	30.2	64.1	315	8	3.0	.3	.21	180	7.0	138
E24	1252	30.4	5.1	28.16	30.1	63.7	290	14	5.5	1.0	.21	360	10.0	130
E25	1323	31.1	8.8	26.50	30.4	67.3	290	14	4.0	1.0	.16	140	7.0	19
E26	1415	31.4	12.4	23.86	31.4	67.6	290	17	2.0	1.5	.19	40	7.0	137

FIELD AND LABORATORY MEASUREMENTS

STAT NUMB	TIME CDT	WATER TEMP DEG C	CHLO PH A MG/M3	SALNTY PTS/K	AIR TEMP DG C	RELAT HUMDY PERCT	WIND DIR DEG	WIND SPD KN	SECH VISB FT	SEA STAT FT	CURRT KN	CUR DIR DEG	WATER DEPTH FT	BOTL NO.
E27	1220	30.2	1.1	30.53	31.9	67.3	310	12	>12.0	2.5	•••••	•••	•••••	187
D	1530	30.8	•••••	.49	••••	49.0	••••	••••	••••	•••••	•••••	•••	•••••	

APPENDIX G

SVFO SEA TRUTH STATION COORDINATES

AND VALUES ACQUIRED ON 7 AUGUST 1972

STATION NUMBER	STATION LOCATION LAT. DEG. N	STATION LOCATION LONG. DEG. W	NUMBER FISH PER SET (K)	WATER TEMP. (°C)	SALINITY (°/oo)	SECCHI DEPTH (M)	FOREL-ULE COLOR	AIR TEMP. (°C)	WIND SPEED (CM/SEC)	WIND DIRECTION	SEA STATE (M)	CLOUD COVER (%)
1	30.20	89.40	40	-	19.2	1.2	16	-	514	-	0.3	0
2	30.22	89.36	35	-	19.1	0.9	17	30.2	411	-	0.3	0
3	30.22	89.36	100	-	19.8	1.5	15	-	411	-	0.3	0
4	30.22	89.36	130	-	28.2	1.5	15	-	411	-	0.3	0
5	30.30	88.20	13	31.3	27.8	1.5	16	32.5	668	-	0.5	5
6	30.30	88.26	0	-	-	-	-	32.1	463	-	0.8	10
7	30.30	88.26	25	-	-	-	-	-	308	-	0.3	0
8	30.30	88.50	25	30.3	27.0	-	-	31.4	411	-	0.3	10
9	30.32	88.28	45	30.2	27.0	0.9	-	31.4	360	-	0.3	0
10	30.32	88.30	0	31.1	27.6	1.2	16	31.0	360	-	0.6	10
11	30.32	88.52	25	31.5	27.3	0.9	10	31.7	617	-	0.9	10
12	30.32	88.52	50	29.4	23.5	1.2	14	28.2	257	-	0.2	0
13	30.32	88.54	50	29.5	21.5	1.1	17	28.0	257	-	0.3	0
14	30.34	88.26	25	31.2	26.9	0.9	14	32.0	411	-	0.8	10

APPENDIX H

USER DATA FORMAT MATRIX

PARAMETER	ACCURACY REQUIRED	DATA FORMAT REQUESTED	FORMAT GROUP			PROJECTED AVAILABILITY OF DATA		USER			
			ERL	FEL	NWS	WEEKS	DAYS	PASC	FEL	ERL	EARTHSAT
• Sea Surface Temperature	0.5°C	Contour	●			3		●	●	●	●
	0.1°C	Tabular	●	●		3		●	●	●	●
• Water Color	F-U Scale	Contour	●			3		●	●	●	●
		Tabular	●	●		3		●	●	●	●
	System	Film	●			2		●	●	●	●
• Water Transparency	25 cm	Contour	●			3		●	●	●	●
	10 cm	Tabular	●	●		3		●	●	●	●
• Surface Current Speed	cm/sec	Vector Diagram	●			3			●	●	
• Surface Current Direction	5°	Vector Diagram	●			3			●	●	
• Relative Irradiance	.01 $\log^{10}$	Contour		●		3		●	●	●	●
	Ext. Coeff	Tabular		●		3		●	●	●	●
• Sea State	±0.25 m	Tabular	●	●		3		●	●	●	
• Depth	±0.25 m	Tabular	●			3		●	●	●	
• Surface Salinity	0.1 °/oo	Contour	●			3		●	●	●	●
		Tabular	●	●		3		●	●	●	●
• Tide Height	±0.1 m	Tabular	●			3		●	●	●	
• Tide State	Flood or Ebb	Tabular	●			3		●	●	●	
• Chlorophyll <u>a</u>	$0.1\ mg/m^3$	Contour	●	●		6		●	●	●	●
<u>a</u>, <u>b</u>, <u>c</u>	$0.1\ mg/m^3$	Tabular	●	●		6		●	●	●	●
Carotenoids	$0.1\ mg/m^3$	Tabular	●	●		6		●	●	●	●
• Air Temperature	0.1°C	Tabular	●			3		●	●	●	●
• Wind Speed	cm/sec	Tabular	●			3		●	●	●	●

PARAMETER	ACCURACY REQUIRED	DATA FORMAT REQUESTED	FORMAT GROUP ERL	FORMAT GROUP FEL	FORMAT GROUP NWS	PROJECTED AVAILABILITY OF DATA WEEKS	PROJECTED AVAILABILITY OF DATA DAYS	USER PASC	USER FEL	USER ERL	USER EARTHSAT
• Wind Direction	5°	Tabular	●			3		●	●	●	●
• Cloud Cover	±10%	Tabular	●			3		●	●	●	●
• Rainfall	0.25 cm	Tabular			●	3		●		●	
• Relative Humidity	1.0%	Tabular	●			3		●			
• Number of Fish Schools	Number	Tabular Plot		● ●			40 40	● ●	● ●		● ●
• School Clas-sification	Men/Non-Men	Tabular Plot		● ●			40 40	● ●	● ●		● ●
• Fish Per Set	1,000's	Tabular Plot		● ●			40 40	● ●	● ●		● ●
• School Surface Area	m^2	Tabular Plot Location		● ●			40 40	● ●	● ●		● ●
• School Size	1,000's	Tabular Plot Location		● ●			40 40	● ●	● ●		● ●
• Fishing Conditions	Estimate (Code)	Tabular Plot Location		● ●			40 40	● ●			
• Area Observ-ed - No Fish	Yes/No	Plot Tabular		● ●			40 40	● ●			
• Source Code	N/A	Tabular		●			40	●	●		●
• Location Of Observation	0.5 km	Plot Tabular	● ●	 ●		3 3		● ●	● ●	● ●	● ●
• Time Of Observation	±5 Min.	Tabular (24 Hr. clock)	●	●		3		●	●	●	●

APPENDIX I

DATA LOAD FORMATS FOR

FIELD MEASUREMENTS

DATA SOURCE 1 ERTS-1 FIELD MEASUREMENTS - ERL PRIMARY MISSION

COL	1 2 3	4	5 6 7 8	9	10 11 12 13	14 15 16 17	18 19 20 21 22	23	24 25 26 27	28	29 30	31	32 33	34	35 36 37	38	39 40
FIELD	1		2		3	4	5		6		7		8		9		10

FIELD
1. Station Number
2. Time
3. Water Temperature In Degrees Centigrade (°C)
4. Chlorophyll a In Milligrams Per Cubic Meter (mg/cu.m.)
5. Salinity In Parts Per Thousand (^{o}/oo)
6. Air Temperature in Degrees Centigrade (°C)
7. Relative Humidity - Dry In Degrees Farenheit (°F)
8. Relative Humidity - Wet In Degrees Farenheit (°F)
9. Wind Direction In Degrees
10. Wind Speed in Knots

41	42 43 44 45	46	47 48 49 50	51 52 53	54	55 56 57	58	59 60 61 62	63	64 65 66 67 68	69	70 71	72	73 74 75 76 77 78 79 80
	11		12	13		14		15		16		17		18

FIELD
11. Secchi Disc Visibility In Feet
12. Sea State In Feet
13. Surface Current Speed In Centimeters Per Second (cm/sec.)
14. Current Direction In Degrees
15. Water Depth In Feet
16. Sample Bottle Number
17. Forel-Ule Color Number
18. Remarks

DATA SOURCE 1 ERTS-1 FIELD MEASUREMENTS - ERL SECONDARY MISSION

COL	1 2 3	4	5 6 7 8	9	10 11 12 13	14 15 16 17	18 19 20 21 22	23 24 25 26 27	28	29 30	31	32 33	34	35 36 37	38	39 40
FIELD	1		2		3	4	5	6		7		8		9		10

FIELD
1. Station Number
2. Time
3. Water Temperatature In Degrees Centigrade (°C)
4. Chlorophyll <u>a</u> In Milligrams Per Cubic Meter (mg/cu.m.)
5. Salinity In Parts Per Thousand (°/oo)
6. Air Temperature In Degrees Centigrade (°C)
7. Relative Humidity - Dry In Degrees Farenheit (°F)
8. Relative Humidity - Wet In Degrees Farenheit (°F)
9. Wind Direction In Degrees
10. Wind Speed In Knots

41	42 43 44 45	46	47 48 49 50	51	52 53 54 55	56	57 58 59 60 61	62	63 64	65	66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
	11		12		13		14		15		16

FIELD
11. Secchi Disc Visibility In Feet
12. Sea State In Feet
13. Water Depth In Feet
14. Bottle Number
15. Forel-Ule Color Number
16. Remarks

DATA SOURCE 2 FORMAT - LOW LIGHT SENSING DATA

COL	1 2 3 4 5 6	7 8	9 10 11 12 13 14	15 16 17 18	19 20 21 22	23 24 25 26	27	28 29	30 31 32	33 34 35	36 37 38	39 40
FIELD	1	2	3	4	5	6	7	8	9	10	11	12

FIELD
1. Date (MMDDYY)
2. Species, Coded MEN/NON-MEN (Menhaden/Non-Menhaden)
3. School Surface Area K Fish
4. Time of Observation (1508 equivalent to 3:08 pm)
5. Longitude (8714 equivalent to 87 degrees 14 minutes)
6. Latitude (3014 equivalent to 30 degrees 14 minutes)
7. Roll Number
8. Transect Number
9. Video Record Number
10. Altitude in K feet
11. Aircraft Velodity in knots
12. Aircraft Heading in degrees

41	42 43 44	45 46	47 48	49 50	51	52 53 54	55 56	57 58 59	60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
	13	14	15	16	17	18	19	20	21

FIELD
13. Cloud Cover in percent
14. Sea State in feet
15. Bioluminescende depth in feet
16. Transmissivity in percent (%)
17. Water Current Speed in knots
18. Water Temperature in degrees centigrade
19. Observation Depth in feet 0-99
20. Salinity in parts per thousand (^{o}/oo)
21. Not Used

DATA SOURCE 3 FORMAT - NFMOA/EARTHSAT

COL	1 2 3 4 5 6	7 8 9	10 11 12 13	14 15 16 17 18 19	20 21 22	23	24 25 26	27	28 29 30	31 32 33 34 35	36 37 38	39 40
FIELD	1	2	3	4	5	6	7	8	9	10	11	12

FIELD
1. Date (MMDDYY)
2. Set Number
3. Time (1508 equivalent to 3:08 pm)
4. Location (Grid Coordinates)
5. Number of Fish per Set
6. Fishing Conditions (Code)
7. School Size (In K fish via spotter pilot)
8. Class: In Data Bank Species Coded as Men/Non-Men (Menhaden/Non-Menhaden)
9. Water Temperature in Degrees Centigrade
10. Salinity in parts per thousand (^{o}/oo)
11. Secchi Disc Depth in feet
12. Forel-Ule Color Number

41 42 43	44 45	46	47 48 49	50 51	52 53	54 55 56 57	58 59 60 61	62 63 64 65	66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
13	14	15	16	17	18	19	20	21	22

FIELD
13. Air Temperature in Degrees Centigrade
14. Wind Speed in Knots
15. Wind Direction Coded in 8 Unit Compass Points
16. Sea State in feet
17. Cloud Cover in Percent (%)
18. Source (Code)
19. Aircraft Remarks (Coded)
20. Vessel Remarks (Coded)
21. Log Remarks (Coded)
22. Not Used

NFMOA/EARTHSAT CARD CODE

ITEM	FIELD SIZE	EXAMPLE	REMARKS
Date	6	052172	May 21, 1972
Set	3	305	
Time	4	1508	3:08 p.m.
Location	6	--	Grid Coordinates
No. Fish/Set	3	125	125,000 Fish
Fishing Conditions	1	2	Coded Entry re:
Aircraft School Size	3	125	125,000 Fish
Class	1	1	Coded: Men/Non-Men
Water Temperature	3	257	25.7°C
Salinity	5	31148	31.148 $^{o}/oo$
Secchi Depth	3	015	1.5 Feet
Forel-Ule Color	2	14	XIV From Comparator
Air Temperature	3	201	20.1°C
Wind Speed	2	18	18 Knots
Wind Direction	1		Coded by 8 Compass Points
Sea State	3	025	2.5 Feet
Cloud Cover	2	25	25%
Source Code	2	00	Coded:
Aircraft Remarks	4	0000	Coded:
Vessel Remarks	4	0000	Coded:
Log Remarks	4	0000	Coded:
Unallocated	15	--	--

DATA SOURCE 4 FORMAT - AERIAL PHOTOGRAPH, PASCAGOULA CARD-1

COL	1 2	3 4 5 6 7 8	9 10	11 12	13 14	15 16 17	18 19 20 21 22	23 24 25 26	27 28	29 30	31 32	33 34 35	36 37 38 39
FIELD	1	2	3	4	5	6	7	8	9	10	11	12	13

40 41	42 43	44 45	46 47	48	49	50 51	52 53 54 55 56	57 58 59 60 61	62 63 64	65 66 67	68 69 70	71 72	73 74	75 76	77 78	79 80
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

FIELD

1. Project ID (Code)
2. Date (MMDDYY)
3. Mission
4. Film Type (Code)
5. Film Roll Number
6. Aircraft Altitude in Hundreds of Feet
7. Photo Scale
8. Section Size in Square Nautical Miles
9. Sea State in Feet
10. Flight Number
11. Flight Line Number
12. Photograph Number
13. Time of Photograph (1300 equivalent to 1:00 p.m.)
14. Forward Overlap on West End of Photo in Percent (%)
15. Forward Overlap on East End of Photo in Percent (%)
16. Forward Overlap on North Side of Photo in Percent (%)
17. Forward Overlap on South Side of Photo in Percent (%)
18. Exposure Quality (Code)
19. Film Developing Quality (Code)
20. Section Number
21. Latitude (07455 equivalent to 7°45'30")
22. Longitude (10153 equivalent to 10°15'18")
23. Land Mass Photograph (061 equivalent to 61%)
24. Cloud Coverage (075 equivalent to 75%)
25. Cloud Shadow Coverage (087 equivalent to 87%)
26. Sun Glare Coverage (71 equivalent to 71%)
27. Number of Menhaden Boats
28. Number of Trawlers
29. Number of Sport Boats
30. Number of Oil Slicks

DATA SOURCE 4 AERIAL PHOTOGRAPH PASCAGOULA CARD-2

COL	1	2 3 4	5 6 7 8 9 10	11 12 13	14 15 16	17 18	19 20	21 22 23 24 25 26	27 28	29	30 31	32 33 34 35 36 37	38 39	40
FIELD		1	2	3	4	5	6	7	8	9	6	7	8	9

41 42	43 44 45 46 47 48	49 50	51	52 53	54 55 56 57 58 59	60 61	62	63 64	65 66 67 68 69 70	71 72	73	74 75 76 77 78 79 80
6	7	8	9	6	7	8	9	6	7	8	9	

FIELD
1. Project ID (Code)
2. Date (MMDDYY)
3. Roll Number
4. Photograph Number
5. Section Number
6. Fish Species (Code)
7. Fish School Surface Area (000100 = 100 M^2)
8. Fish School Shape
9. Fish School Density

Repeated for each school

AERIAL PHOTOGRAPHIC DATA FORMAT INSTRUCTIONS

(Card No. 1)

COLUMN	ITEM	INSTRUCTIONS
1 - 2	Project ID	Numeric Code: 01 = June 1971 Experiment 02 = June 1972 Experiment 03 = ERTS-A (NOTE: Column 1 must be punched)
3 - 8	Date	Numeric Month - Day - Year; e.g., Jan. 1, 1975 = 0 1 0 1 7 5
9 - 10	Mission	Mission Number within a project. A mission can be composed of one or more flights.
11 - 12	Film Type	Numeric Code: 01 = Kodak Ektachrome IR 02 = GAF minus blue
12 - 14	Film Roll Number	Film Roll Number within a project
15 - 17	Aircraft Altitude	Expressed in hundreds of feet; e.g., 8100 feet expressed as 081
18 - 22	Photographic Scale	Expressed in dimensionless units as 1:16200 = 16200 (NOTE: "1" omitted)
23 - 26	Section Size	Square nautical miles (xx.xx); e.g., 6 = 0600 and 1/4 = 0025
27 - 28	Sea State	Expressed in whole feet
29 - 30	Flight Number	Flight Number within a mission, e.g., 02
31 - 32	Flight Line Number	Flight Line Number; e.g., Line 1 shown as 01
33 - 35	Photograph Number	Photograph Number on a given roll of film
36 - 39	Time of Photograph	Expressed on the basis of a 24-hr. clock, e.g., 1:00 p.m. = 1300
40 41	Forward Overalp on West End of Photograph	Expressed as a whole percentage, e.g., 10 percent = 10
42 - 43	Forward Overlap on East End of Photograph	Numeric, ditto
44 - 45	Side Overlap on North Side of Photograph	Numeric, ditto

COLUMN	ITEM	INSTRUCTIONS
46 - 47	Side Overlap on South Side of Photograph	Numeric, ditto
48	Exposure Quality	Coded subjective assessment of exposure quality: 1 = very underexposed; not usable 2 = underexposed, usable 3 = proper exposure 4 = overexposed; usable 5 = very overexposed; not usable
49	Film Developing Quality	Coded subjective assessment of film developing quality: 1 = poor; not usable 2 = fair; usable 3 = good
50 - 51	Section Number	Photograph will be divided into 0, 4, 16, etc., equal sections. Sections are numbered from NW to NE and then SW to SE ("0" indicates photograph not sectioned)
52 - 56	Section Center Latitude	Record to nearest tenth of minute, e.g.: 07°45'30" = 07455
57 - 61	Section Center Longitude	Ditto
62 - 64	Land Mass Photographed	Expressed as a whole percentage, e.g.: 99% = 099
65 - 57	Cloud Coverage	Ditto
68 - 70	Cloud Shadow Coverage	Ditto
71 - 72	Sun Glare Coverage	Ditto, except 99% = 99, not 099
73 - 74	Menhaden Boats	Total number within a section
75 - 76	Trawlers	Ditto
77 - 78	Sport Boats	Ditto
79 - 80	Oil Slicks	Ditto

GENERAL INSTRUCTIONS FOR CARD NO. 2

Card No. 2 contains information on fish schools detected within a section. The first 18 columns contain key information derived from Card No. 1; thereafter, school information is contained in blocks of 11 columns, with a maximum of 5 schools being contained on each card. If the total number of observed schools per section exceeds 5, then additional No. 2 cards will be generated, each having identical key information. Thus, Columns 19-29, 30-40, 41-53, 54-62, and 63-73 contain information on individual schools. Columns 74-80 are left blank ( ) at this time. Column 1 is left blank by the recorder, being reserved for data processing.

The following should provide sufficient instructions for completing the data form from which Card No. 2 will be punched. Neatness and accuracy are emphasized. Please include zeros where columns are not used.

GENERAL INSTRUCTIONS FOR CARD NO. 2

COLUMN	ITEM	INSTRUCTIONS
1		Leave blank
2 - 4	Project ID	Numeric Code: 001 = June 1971 Experiment 002 = June 1972 Experiment 003 = ERTS-A
5 - 10	Date	Numeric Month - Day - Year; e.g., Jan. 1, 1975 = 0 1 0 1 7 5
11 - 13	Roll Number	Film Roll Number within a project
14 - 16	Photograph Number	Photograph Number within a roll
17 - 18	Station Number	Section Number within a photograph. Photographs will be divided into 0, 2, 4, 16, etc., equal sections. Sections are numbered from top left to right. "0" indicates photograph is not sectional.
19 - 20	Fish Species	Numeric Code: 01 = unidentified 02 = menhaden
21 - 26	Fish School Surface Area	Square Meters (whole numbers)
27 - 28	Fish School Shape	Numerical Code: 01 = round 02 = ameboid 03 = crescent 04 = elliptical 05 = string
29	Fish School Density	Numerical Code: 1 = homogeneous density throughout school 2 = heterogeneous density throughout school

Card No. 1 - Section Information

Pro-ject	Month Day Year	Mis-sion	Film	Roll	Altitude	Scale
1 2	3 4 5 6 7 8	9 10	11 12	13 14	15 16 17	18 19 20 21 22

Section Size	Sea	Flight	Line	Photo	Time	West Ovlap	East Ovlap
23 24 25 26	27 28	29 30	31 32	33 34 35	36 37 38 39	40 41	42 43

North Ovlap	South Ovlap	Exp	Dev	Sec-tion	Latitude	Longitude
44 45	46 47	48	49	50 51	52 53 54 55 56	57 58 59 60 61

Land	Clouds	Shadow	Glare	Sein-ers	Trawl	Sport	Oil
62 63 64	65 66 67	68 69 70	71 72	73 74	75 76	77 78	79 80

Card No. 2 - Reference Information

△	Project	Month Day Year	Roll	Photo	Sect.
1	2 3 4	5 6 7 8 9 10	11 12 13	14 15 16	17 18

COMMENTS:

PROJECT ____________ DATE ____________ RECORDED BY: ____________

APPENDIX J

AVAILABLE STATISTICAL ROUTINES

DESCRIPTIVE STATISTICS

Frequency Polygun
Histogram
Multivariate Histogram
Grouping of Data

INVERSE DISTRIBUTION FUNCTIONS

Inverse Normal Distribution
Inverse Student's Distribution
Inverse Fisher's Distribution
Inverse Chi-Square Distribution

CONFIDENCE INTERVALS

Confidence Interval for the Mean: Known Variance
Confidence Interval for the Mean: Unknown Variance
Confidence Interval for the Difference Between Two Means
Confidence Interval for Variance
Tolerance Intervals

MULTI-VARIATE ANALYSIS

Generalized Variance
Hotelling's Distribution
Mahalanobois' Disbribution
Significance of a Set of Means
Discriminant Analysis
Factor and Principal Component Analysis

TIME SERIES ANALYSIS

Moving Averages
Shiskin's Seasonality Factors
Weighted Moving Averages
Trend Analysis by Lease Squares
Variate Difference Method
Autoregressive Model
Generalized Exponential Smoothing
Auto-Correlation and Cross-Correlation Analysis
Power Density Functions
Residual Probabilities

REGRESSION ANALYSIS

Stepwise Multiple Regression
Back Solution Multiple Regression
Correlation Analysis

MISCELLANEOUS SUBROUTINES

Plot of One Line
Matrix Inversion
Left Multiplication of a Matrix by Its Transpose

ELEMENTARY POPULATION STATISTICS

Arithmetic Mean
Geometric Mean
Harmonic Mean
Median
Mode
Quantities
Distribution Curve
Interpercentile Range
Range
Mean Deviation
Standard Deviation
Coefficient of Variation
Order and Rank Statistics
Central Moments
Absolute Moments
Cumulants
Sheppard's Corrections
Skewness and Kurtosis

CHI-SQUARE TESTS

Chi-Square Test of Sample Proportion - One Sample
Chi-Square Test of Sample Proportion - J Samples
Chi-Square Test of Fit to Poisson Distribution
Chi-Square Test of Normality
Chi-Square Test of Homogeniety
Chi-Square Test for Independence
Chi-Square Test for General Goodness of Fit

DISTRIBUTION, FITTING AND PLOTTING

Binomial Distribution
Poisson Distribution
Hypergeometric Distribution
Normal Distribution
Arne Fisher Series

SIGNIFICANCE TESTS

Test of Significance of Proportion of Successes
Test of Significance of a Mean
Test of Significance of the Difference Between Two Means
Test of Significance of the Ratio Between Two Variances

DISTRIBUTION FUNCTIONS

Normal Distribution
Chi-Square Distribution
Student's Distribution
Fisher's Distribution
Poisson Distribution
Binomial Distribution
Hypergeometric Distribution
Incomplete Gamma Distribution
Incomplete Beta Distribution

ANALYSIS OF VARIANCE

One-Way Cross Classification
Two-Way Cross Classification
Three-Way Cross Classification
Missing Data
Variable Transformations
Randomized Blocks
Latin Squares
Split-Plot Design
Split-Split Plot Design
Two-Way Nested Design
Three-Way Nested Design
Analysis of Covariance
General Linear Hypotheses

APPENDIX K

WATER COLOR INVESTIGATION

SEA TRUTH DATA

I. Mission - Water measurement for Goddard Space Flight Center Spectrometer Water Color Study, Mississippi Sound Area, July 24, 1972. Earth Resources Laboratory, Report No. 19.

Mission Area - Middle of Mississippi Sound from Bay St. Louis to west tip of Dauphin Island.

Sea Truth - 24 sample stations along flight lines. Four sea truth boats utilized. Two measurements obtained at each station except only one measurement from stations A6, B6, C6, and D6.

Meteorological Data - Sky clear; however, considerable haze and smoke.

Measurement Summary (July 24)

	SECCHI VISIBILITY (FT.)				CHLOROPHYLL (mg/m^3)				WATER DEPTH (FT.)			
Station	A	B	C	D	A	B	C	D	A	B	C	D
1	5.5	5.5	4.5	5.5	1.999	2.552	2.504	7.880	12	18	18	12
2	6.0	5.5	4.0	3.5	2.955	2.002	4.034	16.978	10	16	16	13
3	5.0	8.0	7.0	4.0	3.339	1.271	2.857	4.932	15	16	16	16
4	5.0	8.0	5.5	5.5	3.218	1.247	2.793	1.510	14	14	15	10
5	5.0	8.5	5.5	8.5	3.930	1.810	2.737	1.160	14	16	11	12
6	5.5	10.0	6.0	8.0	3.009	1.563	3.388	1.197	16	14	16	15

II. Mission - Multispectral Line Scanner (M^2S) Evaluation, Mississippi Sound Area Surface Measurements, August 4, 1972, Earth Resources Laboratory Report No. 028.

Mission Area - Middle of Mississippi Sound from Bay Saint Louis to west tip of Dauphin Island.

Sea Truth - 24 sample stations along flight line. One sea truth boat utilized. One measurement obtained at each station.

Meteorological Data - Sky clear of clouds and visibility was seven miles.

Measurement Summary (August 4)

	SECCHI VISIBILITY (FT.)				CHLOROPHYLL+ (mg/m^3)				WATER DEPTH (FT.)			
Station	A	B	C	D	A	B	C	D	A	B	C	D
1	3.5	4.0	10.0	4.0	2.9	3.0	1.0	3.9	6	16	15	14
1	4.0	6.0	8.0	6.5	1.5	2.1	2.9	3.2	7	16	15	12
2	4.5	6.0	8.0	6.0	2.5	-	1.6	1.7	7	16	13	15
2	4.0	6.5	8.0	6.0	0.2	0.8	1.1	3.6	7	16	18	16
3	4.0	6.0	8.5	6.0	2.5	2.1	1.7	3.9	13	16	12	16
3	4.5	8.0	6.0	6.0	2.0	1.6	1.3	2.3	13	16	15	15
4	4.5	6.5	8.0	8.0	1.8	1.2	2.1	4.4	13	14	15	10
4	4.0	10.0	6.5	6.5	1.5	1.1	1.6	4.3	13	18	15	14
5	4.5	9.0	8.0	10.0	2.5	1.0	1.2	2.2	14	17	20	15
5	4.0	10.0	5.5	6.0	2.2	1.3	1.9	8.7	14	19	12	16
6	4.0	11.0	6.5	12.0	2.6	1.3	1.7	1.0	15	20	10	18

III. Mission - Mississippi Sound Remote Sensing Study, August 7, 1972, ERL Report No. 025.

Mission Area - Mississippi Sound from east of Bay St. Louis to the middle of Dauphin Island and extending south ten miles outside of the Mississippi Sound Barrier Islands.

Sea Truth - Sampling stations were based on a 3-mile grid system throughout the test area.

Meteorological Data - Sky clear of clouds.

Measurement Summary (August 7)

NOTE: *indicates two sea truth measurements at the same station but at different times.

STATION NUMBER	SECCHI VISIBILITY (FEET)	CHLOROPHYLL (mg/m^3)	WATER DEPTH (FEET)
A8*	5/1.5	2.4/3.7	12/6*
A9	6	6.1	8
A10	6	2.6	8
A15	1.5	3.9	25
A16	1.5	3.5	10
A17	2.5	2.4	11
A23	2.5	2.2	14
A25	2.5	2.6	.2
B1	3	3.6	8.5
B7*	3.5/4	4.4/4.1	9/9
B9*	4.5/5.6	3.4/2.5	9/9
B11	5.3	1.4	25
B17	6	2.5	12
B21	5	2.5	13
B22	4.5	1.7	16
C2	7	1.9	13
C3	8.5	2	17
C4	14	1.1	43
C5	12	2.2	35
C6	14	1.4	30
C7*	8.5/-	1.4/6.5	13/18
C8*	5.5/-	2.2/4.5	13/16
C9*	5/-	3.2/4	11/12
C16	10.5	1.4	24
C17	7	1.4	12
C21*	10/8.5	1/1.9	10.5/11

STATION NUMBER	SECCHI VISIBILITY (FEET)	CHLOROPHYLL (mg/m^3)	WATER DEPTH (FEET)
C26	5	3	12
C27	1.5	8.8	6.5
D1	3	10	8
D2	3.5	5.3	14
D3	7	1.9	17
D7*	5/7	2.1/2.4	14/13
D8*	2.5/4	4.5/2.4	12/11
D9*	2.5/2	4.7/7.2	7/6
D10	2	2.9	6
D11	4	2.2	8
D17	7.5	2.0	15
D18	3.5	6.9	7
D19*	4/3.5	6.8/11.4	11/11
D20*	8/5	3.1/5.1	20/16

STATION NUMBER	SECCHI VISIBILITY (FEET)	CHLOROPHYLL (mg/m^3)	WATER DEPTH (FEET)
D26	7	1.3	16
D27	3	11.1	5
E1*	6/5	-/3.7	12/12
E2*	6/6	-/.2	12/18
E9*	8/-	-/-	14/16
E10*	1/1.5	5.1/3.1	11/11
E11*	8/8.5	2.5/1.4	17/17
E12*	10/10	1/5.2	18/18
E16*	4/-	5.2/-	16/16
E17*	.7/7.5	2.3/1.9	15/15
E20*	5.5/6	10.7/3.8	12/12
E21*	6/5.5	3.7/2.4	11/11
E25	3.5	8.4	6

IV. Mission - Biloxi Bay Study, October 18, 1972.

Mission Area - Middle of Back Bay of Biloxi, Biloxi Bay and between Deer Island and Biloxi Beach.

Sea Truth - Fourteen sample stations were located along the three flight lines.

Meteorological Data - 20% cloud cover below flight line, heavy haze.

Measurement Summary - Unavailable.

APPENDIX L

RS-18 DATA PRODUCT INFORMATION

FOR 7 AUGUST 1972

RS-18 SCANNING RADIOMETER

Section A - INFRARED SCANNER IMAGERY

In this section information is given for the collected RS-18 Scanner data which has been processed by "standard" methods from analog tape to infrared imagery.

Section B - RADIOMETRIC TEMPERATURE

In this section additional information is given for the RS-18 data discussed under A to explain the special processing into this digital thermal format.

A. INFRARED SCANNER IMAGERY

1. Program or Project: Mississippi Sound Remote Sensing Study/Fisheries Resource Assessment

2. Sensor: RS-18 Scanning Radiometer

3. Product: Infrared Scanner Imagery

4. Site: Mississippi Sound (with emphasis on area C and E)

5. Date: 7 August 1972

6. Mission Number: 039 (34-5)

7. Roll Number: N/A (initial data recorded on magnetic tape (airborne), subsequent film and paper products are produced in laboratory)

8. Flight Lines On This Product: 5, 4, 3, E-6, E-5, E-4, C-2, 16

9. Data Start Time: 08:32:01 CDT

10. Data Stop Time: 15:33:10 CDT

11. Format: Original Film Data - Film Negative - Continuous strip of imagery, coincident with flight path - N-S flight lines 70mm x approximately 20 inches - E-W flight lines 70mm x approximately 80 inches.

    Product as presented - positive contact prints of original film data.

12. Altitude: 10,000 feet for lines 5, 4, 3, E-6, E-5, E-4, C-2, 2,000 feet for line 16.

13. Scale Of Imagery: Approximately 1:100,000 across flight path (format) - variable along strip for each flight line.

14. Coverage/Frame: ~23,000 feet across flight path (format)
length of N-S line ~15 miles
length of E-W lines ~100 miles

15. Number Of Frames: 1 strip of imagery per flight line.

16. Overlap (Forward): Continuous

17. Overlap (Side): 20% to 60% for lines E-4, E-5 and E-6; none for remaining lines.

18. Film: 2749 RAR-used for initial data recording from tape to film

19. Filter/Spectral Range: 8-14 microns nominal (sensor response function available at ERL Data Lab)

20. Transparency: Positive: 0 - Negative: 0

21. Paper: Positive: 0 - Negative: 0

22. Footage: Initial film record, ~23 feet x 70mm.

23. List Of Frames/Times:

Line Number	Altitude (K-Feet)	Time CDT Start/Stop	Aircraft Heading	Approximate Ground Speed (Kts.)
5	10K	0832/0859	090°	165
4	10K	0911/0943	270°	160
3	10K	0955/1032	090°	165
E-6	10K	1427/1432	000°	160
E-5	10K	1435/1442	180°	160
E-4	10K	1443/1449	000°	160
C-2	10K	1503/2012	180°	160
16	2K	1533	000°	140

24. Processing: The data recorded on magnetic tape during flight was transscribed in the laboratory to film producing a film negative. Positive paper products were produced from this film photographically (contact printing).

25. Atmospheric Corrections: No atmospheric corrections were applied to the infrared imagery.

26. Quality Assessment And Anomalies:

a. Sensor Performance:

1. RS-18 Scanner failed after flying lines 3, 4, and 5. Repairs were made on ground and remainder of mission was flown (see item 23 - frames/times).

2. Before and after repairs, the scanner performance was classified as normal - only slight modulation (added noise) to RS-18 video signal by the DC/AC converter.

b. Magnetic Tape Data Verification:

1. RS-18 sync. pulse: Calibration quality - good
Data signal quality - good

2. RS-18 video signal: Calibration quality - good
Data signal quality - good

c. Quality Of Infrared Imagery:

1. Flight Alignment: The center line (nadir track) of the infrared imagery had the same orientation as the flight lines for the Hasselblad photography, as indicated on the actual flight line maps. Average heading deviations of the actual flight lines differ less than 5 degrees from the flight request. Locations of flight lines are within 0.25 to 0.75 n.mi. from flight request.

2. Positional Errors: These were difficult to define in this imagery since they are a function of two different recording scales; across flight and along flight. Scales in direction across track were relatively constant. Scales in directions parallel to the flight track may have varied from the cross tract scale in one imagery strip due to velocity to height ratio of the aircraft. Ideally, these scales were matched during processing, which required exact application of ground speeds. The RS-18 data for this mission has been processed with the ground speed as estimated during flight. No special corrections have been applied. Therefore, the strips of infrared imagery vary considerably in their scales in the direction of flight. (See below).

Imagery scale in direction perpendicular to flight - approximately 1:115,000.

Imagery scales in directions parallel to flight directions as follows -

Line E-4 -	92,000
Line E-5 -	94,000
Line E-6 -	90,000
Line C-2 -	94,000
Line 3 -	94,000
Line 4 -	100,000
Line 5 -	102,000

3. Image Quality: Water areas of the imagery were lacking in density contrasts for thorough interpretation of cooler (darker tones) and warmer (lighter tones) surface water patterns. The edges of the strips show in general higher densities due to atmospheric attenuation. The lighter and darker density bands parallel to scan direction are thought to be due to recording signal modulation. No special processing for either data recording signals or photographic tone matching was applied.

B. RADIOMETRIC TEMPERATURE

(For basic information as project, date, flight lines, altitudes, etc. see Section A.)

1. Product:

A computer generated gray level thermal map, (Figures 13 and 14) based on the RS-18 radiometric temperatures, was prepared showing the surface water temperature distribution in 0.5°C increments. Processing was performed to express eight (8) shades of gray or a total of 4°C (greater variations in surface water temperatures were not observed during any one mission). Gray levels over land areas should be ignored since the data has been processed for conditions and temperature ranges over water areas only. Superimposed on the gray levels at regular intervals, are printed values of radiometric temperatures to the nearest 0.1°C. Since quality control (photographic) did not allow exact gray level tone matching between flight strips, or portions of a strip, the gray levels were not identified in the legends. Temperature values should be obtained from the superimposed values.

2. Format:

The original of the digitally processed infrared scanner data was produced as successive frames on 35mm film (negatives), depicting the ground coverage in shades of gray.

Original data product was comprised of continuous assembled strips of positive prints (enlarded 35,, film frames) depicting collected data by flight line.

Original print dimensions were approximately:

Line E-4 - not processed
Line E-5 - 3.5 x 15 inches
Line E-6 - 3.5 x 13 inches
Line C-2 - 3.5 x 23 inches
Line 3 - 3.5 x 100 inches
Line 4 - 3.5 x 80 inches
Line 5 - 3.5 x 50 inches

3. Scale Of Imagery:

In direction across line of flight: approximately 1:80,000

In directions parallel to line of flight:

Line C-2 - 1:80,000
Line E-5 - 1:85,000
Line E-6 - 1:84,000
Line 3 - 1:80,000
Line 4 - 1:80,000
Line 5 - 1:76,000

4. Coverage/Flight Strip: Across line of flight - 3.75 n.mi.
Length of strip (Approx.) -

C-2	- 25 n. mi.
E-4, E-5, E-6	- 18 n.mi.
3	- 100 n.mi.
4	- 90 n.mi.
5	- 83 n.mi.

5. Number Of Strips: 6 (one strip/flight line)
(Strip E-4 not processed)

6. Overlap (Forward): Continuous

7. Overlap (Side): Approximately 45% between lines E-5 and E-6. None for remaining lines.

8. Transparency: Positive: 0 - Negative: 0

9. Paper: Positive: 0 - Negative : 0

10. Processing:

a. A/D conversion was accomplished on a SDS-930 computer.

b. A UNIVAC 1108 computer was used for processing and correction of data, and for transformation into the gray level thermal map.

c. Necessary high quality control of microfilm production and succesive photographic enlargement are not available at this time. Therefore, on occasion, gray levels show different densities for similar water temperature zones.

11. Atmospheric Corrections:

The total scanning angle of this sensor is 100° across track which leads to marked differences in path lengths between nadir, and the left and right extremes of the field of view. Corrections for atmospheric effects are included in the processing of the data for the gray level map to result in a temperature field consistent with the observed temperatures provided by the boats. Item 12C lists actual corrections applied.

12. Quality Assessment And Anomalies:

a. Sensor Performance:

Modulation of signal by DC/AC converter has been mentioned in Section A, Item 26.

b. Quality Of Radiometric Temperature Map:

1. Flight alignment - see comments Section A, Item 26, C1

2. Positional accuracies within the airborne radiometric temperature strips were estimated to be within 0.25 n.m.i (when scale factors under Item 3 are applied). The positional errors were primarily due to the following factors:

- Differences in scale of the imagery across track and along flight track. The overall scale was generally constant across track for any one flight line, but may have varied along the line of flight with respect to the cross track scale, due to changes in velocity to height ratio of the aircraft.

- Difficulties in determining the correct ground speed of the aircraft. Correct ground speed was needed to equalize the two scales mentioned under (a) during processing.

- RS-18 infrared data for this mission has been processed with an average ground speed per flight line as estimated during flight.

- The initial gray level images were produced on microfilm, which were enlarged to a suitable size. Establishing the correct enlargement factors, and assembling the images were sources of error.

- Aircraft deviations in flight headings.

- Possible errors due to yaw.

- All surface features in this product were averaged during digital processing. Therefore, their definition, as compared with the standard infrared imagery, was reduced. Spatial resolution at nadir was approximately 125 feet and degraded as scan angle increased.

3. Image Quality

- Gray levels between many portions (enlarged microfilm frames) of each strip of imagery show marked tonal differences creating the false impression of a shift to another level.

- Many streaks, generally white, parallel with the scan direction are present in the images. Their exact origin has not been determined, but were apparently caused during the digital transformations of the data. Their interference with interpretation of surface water temperature patterns was, however, negligible.

c. Corrections:

1. The temperature corrections applied during the processing of the data to reduce the effects of differences in the atmospheric path lengths between nadir and the extremes of the field of view of the scanner plus the temperature off-set applied to make the scanner temperatures compatible with the temperatures as measured on the boats are given below:

		Correction °C	
	Left	Nadir	Right
Line 5	4.38	2.93	4.51
Line 4	2.47	1.17	2.49
Line 3	2.47	1.17	2.53
Line E-4, E-5, E-6	2.47	1.17	2.47
Line C-2	4.38	2.93	4.53

2. Positional corrections were applied in across scan directions for image rectification.

APPENDIX M

LIST OF VARIATIONS BETWEEN SEA
TRUTH STATION SURFACE TEMPERATURES
AND RADIOMETRIC TEMPERATURE GRID
VALUES WITH TIME

NOTE: * - Means flyover occurred before station temperature measurement
+ Means flyover occurred after station temperature measurement

STATION NUMBER	RADIOMETRIC TEMPERATURE	TEMPERATURE VARIATION (RADIOMETRIC-STATION	TIME VARIANCE FROM FLYOVER HRS.: MIN.*
C1	31.9	+ .6	-1:52
C2	32.0	+1.1	-2:13
C3	32.1	+1.4	-2:35
C9	31.7	+ .8	-0:54
C8	31.8	+ .8	-0:42
C7	31.7	+ .9	-0:20
C6	31.9	+1.3	-4:00
C5	31.8	+1.2	-4:00
E18	31.4	+ .4	-0:18
E17	31.3	+ .4	+0:07
E16	31.5	+1.0	-0:03
E15	31.5	+2.0	-3:28
E19	31.8	+0.7	+0:07
E20	31.6	+0.6	+0:52
E21	31.5	+1.2	+1:17
E26	31.3	-0.1	-0:14
E25	31.5	+0.4	-1:06
E24	31.3	+0.9	-1:37
A9	31.1	+0.8	+5:00
A16	30.4	+0.9	-0:07
A17	30.3	-0.7	+2:38
A23	30.1	+0.1	+0:23
B1	29.9	-0.3	-0:07
B9	29.9	-0.9	+3:37
B11	29.7	-1.2	+4:00
B18	30.4	+0.4	+0:18
B21	30.3	-0.2	+1:40
C2	30.2	-0.7	+4:08
C8	30.1	-0.6	+3:05
C17	29.9	+0.4	+0.33
C19	29.8	-0.8	+2:48
C20	29.7	-0.8	+2:08
C26	29.8	-1.1	+3:53
C27	29.9	-1.0	+3:28
D1	29.9	+0.4	+1:10
D2	29.8	-0.2	0:00
D8	29.9	-0.1	+0:55
D9	30.1	-0.3	+1:10
D11	29.6	-0.7	+1:40
D10	29.9	-0.6	+1:22
D17	29.7	+0.5	0:00
D18	29.6	+1.2	-0:20
D19	29.8	+0.3	+1:25
D27	29.8	+1.3	+1:40

STATION NUMBER	RADIOMETRIC TEMPERATURE	TEMPERATURE VARIATION (RADIOMETRIC-STATION)	TIME VARIANCE FROM FLYOVER HRS.: MIN.*
E1	30.3	+0.2	-0:20
E9	30.1	-0.4	+2:15
A3	31.5	+0.6	0:0
A6	31.1	-0.4	+1:15
A12	30.8	-0.8	+5:05
A13	30.7	+0.7	+0:30
A21	30.3	-0.5	-1:00
B24	30.3	-0.7	-1:10
C5	30.3	-0.1	+0:30
C14	29.7	-0.6	+1:35
C23	30.1	+0.6	-1:00
D5	30.1	-0.4	+3:35
D29	30.1	-0.4	+2:20
D14	30.3	-0.7	+2:50
D23	30.1	+0.1	-0:50
E5	29.8	0.0	+0:10
E23	29.6	-0.2	+2:10
E14	29.3	-0.3	+1:00
A1	31.3	+0.8	-1:10
A8	30.7	-0.1	+3:20
A10	31.0	+0.4	+4:50
A15	29.8	+0.3	-0:10
B3	29.7	-0.9	-0:15
B7	29.8	-0.8	+1:00
B12	29.8	-0.9	+3:33
B17	29.6	-0.2	-0:15
B22	29.7	-0.8	+0:17
C3	30.6	-0.1	+3:00
C7	30.4	-0.4	+2:45
C28	30.0	-0.5	+4:25
C16	30.2	+0.8	+0:30
C21	30.2	+0.7	+0:53
C25	30.2	-0.2	+3:35
D3	30.3	+0.8	-0:18
D7	30.2	-0.6	-0:00
D12	30.3	-0.4	+1:20
D16	30.2	+1.1	-0:08
D11	30.5	+0.2	+1:05
D17	30.2	+1.0	-0:35
D20	30.0	+1.0	+0:30
D26	30.0	+2.2	+1:25
E2	30.1	+0.1	-0:05
E8	30.2	0.0	+1:20
E12	30.0	-0.1	+2:10
E22	30.1	-0.2	+3:40
E16	29.8	0.0	+1:40
E21	29.7	-0.3	+3:00
E24	29.7	-0.6	-0:15

REFERENCES

1. W. H. Stevenson. Investigation Using Data From ERTS To Develop And Implement Utilization Of Living Marine Resources. NOAA/NMFS/FEL, NASA Project No. 240 Type I Progress Report, Contract No. S-70246-AG, September 1972. p.7

2. W. H. Stevenson. Investigation Using Data From ERTS To Develop And Implement Utilization Of Living Marine Resources. NOAA/NMFS/FEL, NASA Project No. 240 Type I Progress Report, Contract No. S-70246-AG. NASA-CR-129249. Also: National Technical Information Service MF No. #72-10279. December 1972. p.24

3. W. H. Stevenson. Investigation Using Data From ERTS To Develop And Implement Utilization Of Living Marine Resources. NOAA/NMFS/FEL, NASA Project No. 240 Type I Progress Report, Contract No. S-70246-AG, June 1973. p.4

4. W. H. Stevenson and E. J. Pastula, Jr. Investigation Using Data From ERTS To Develop And Implement Utilization Of Living Marine Resources. NOAA/NMFS/FEL, NASA Project No. 240 Type I Progress Report, Contract No. S-70246-AG, September 1973. p.4

5. W. H. Stevenson and E. J. Pastula, Jr. Investigation Using Data From ERTS To Develop And Implement Utilization Of Living Marine Resources. NOAA/NMFS/FEL, NASA Project No. 240 Combined Type I and Type II Progress Report, Contract No. S-70246-AG. NASA-CR-132035. National Technical Services MF No. E73-10624. June 1973. p.19

6. W. H. Stevenson and E. J. Pastula, Jr. Investigation Using Data From ERTS To Develop And Implement Utilization Of Living Marine Resources. NOAA/NMFS/FEL, NASA Project No. 240 Type II Progress Report, Contract No. S-70246-AG, July 1973. p.12

7. Fisheries Engineering Laboratory. Project Plan: ERTS-A Experiment. NOAA/NMFS/Southeast Fisheries Center, July 1972 (Internal Publication). p.238

8. E. G. Simmons and J. P. Breuer. The Texas Menhaden Fishery. Texas Parks And Wildlife Department, Bulletin No. 45, Series No. II - Coastal Fisheries, GFC-813-3-64-5M, 1964. p.16

9. J. W. Reintjes and A. L. Pacheco. The Relation Of Menhaden To Estuaries. U. S. Department of Interior, Bureau of Commercial Fisheries, Beaufort, N. C., 1966. p.8

10. J. Y. Christmas and G. Gunter. Distribution of Menhaden, Genus *Brevoortia*, In The Gulf Of Mexico. Trans. Amer. Fish. Soc., Vol. 89, No. 4, 1960. p.338-343

11. R. D. Suttkus. Early Life History Of The Gulf Menhaden, Brevoortia patronus, In Louisiana. Trans. 21st N. Amer. Wildlife Conf., 1956. p.391-413

12. G. Gunter and J. Y. Christmas. A Review Of Literature On Menhaden With Special Reference To The Gulf Of Mexico Menhaden, Brevoortia patronus Goode. U. S. Fish and Wildlife Service, Spec. Sci. Report - Fish. No. 363, 1960. p.31

13. W. R. Turner. Life History Of Menhadens In The Eastern Gulf Of Mexico. U. S. Dept. Of Interior, Bureau Of Commercial Fisheries, Beaufort, N. C., 1968. p.26

14. W. H. Stevenson and T. M. Vanselous. Remote Sensing Data Management From A User's Viewpoint. Amer. Astro. Soc. 19th Ann. Mtg., Internat. Cong. Space Benefits, AAS Paper No. 73-152, June 1973. Also: NASA-CR-133220, and National Technical Information Service MF No. E-73-10720. May 1973. p.12

15. NASA Earth Resources Technology Satellite Data Users Handbook. Goddard Space Flight Center, Greenbelt, Md. Document No. 71SD4249. Sept. 1971 (with update revisions). p.(var.)

16. A. Schwalb. Modified Version Of The Improved TIROS Operational Satellite (ITOS D-G). U. S. Dept. Comm., NOAA/NESS Tech. Mem. 35, April 1972. p.49

17. NASA Aircraft Remote Sensing Systems. Johnson Space Center, Houston, Tex. Document No. MSC-04162, May 1971. p.(var.)

18. NASA Skylab/EREP Investigators' Data Book. Johnson Space Center, Houston, Texas. (No Control No.), October 1972. p.(var.)

19. NASA. NASA Earth Resources Program, JSC Earth Resources Aircraft Plan, And Data Facilities Plan. Johnson Space Center, Houston, Texas. (No Control No.), rev. ed. April 1972. p.(var.)

20. C. M. Roithmayr and F. P. Wittmann. Low Light Sensor Developments For Marine Resource Assessment. Marine Tech. Soc. 8th Ann. Conf. Preprints, Washington, D. C., 1972. p.277-288

21. UNESCO. Determination Of Photosynthetic Pigments In Sea Water. SCOR-UNESCO Working Group 17, Paris, 1969

22. J. W. Weldon. Remote Measurement Of Water Color In Coastal Waters. NASA/Earth Resources Lab./MTF Internal Report No. 083, August 1973. p.47

23. Lockheed Electronics Co., Inc. User Documentation Phase II, IR Spectral Radiometer Program. 22-1-22-38. 1973

24. R. Boudreau. NASA/ERL Atmospheric Group, MTF. Personal Communication to J. W. Weldon

25. G. L. Clark, G. Ewing, and C. Lorenzen. Spectra Of Backscattered Light From The Sea Obtained From Aircraft As A Measure Of Chlorophyll Concentration. Science, Vol. 167, 1972. p.3921

26. J. C. Arvesen, E. C. Weaver, and I. P. Millard. Rapid Assessment Of Water Pollution By Airborne Measurement Of Chlorophyll (TBC)

27. C. S. Yentsch. The Influence Of Phytoplankton Pigments On The Color Of Sea Water. Deep-sea Research, Vol. 7, 1960. p.1-9

28. T. Worthington. NASA, Earth Resources Laboratory, Mississippi Test Facility, Bay Saint Louis, Mississippi. Personal Communication

29. NASA/Earth Resources Laboratory. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study August 7, 1972. Remote Measurements - Light Aircraft. Report No. 045, March 22, 1973. (Internal Report p.26

30. R. Chapoton. NMFS, Atlantic Estuarine Fisheries Center, Beaufort, N. C. Personal Communication

31. NMFS, Fisheries Engineering Laboratory. Low Light Level Image Intensifier System Final Report. Prepared by the MTF Data Services Laboratory. October, 1973. p.40

32. A. J. Kemmerer and J. A. Benigno. Relationships Between Remotely Sensed Fisheries Distribution Information And Selected Oceanographic Parameters In The Mississippi Sound. NASA-CR-131884. Also: National Technical Information Service MF. No. E73-10580. March 1973. p.11

33. A. J. Kemmerer, J. A. Benigno, G. B. Reese, and F. C. Minkler. A Summary Of Selected Early Results From The ERTS-1 Menhaden Experiment. NASA-CR-133152. Also: National Technical Information Service MF No. E73-10785. June 1973. p.37

34. B. Ostle. Statistics In Research. 2nd ed., Iowa State University Press, Ames, Iowa. 1963

35. J. A. Benigno and A. J. Kemmerer. Aerial Photographic Sensing Of Pelagic Fish Schools: A Comparison Of Two Films. Proc. Amer. Soc. Photo Part II. Oct. 2-5, 1973. p.1032-1040

36. D. G. Mott. The Analysis Of Determination In Population Systems. In: K.E.F. Watt (ed.), Systems Analyses In Ecology. Academic Press, New York. 1967

ILLUSTRATION CREDITS

FIGURE	SOURCE
1, 4, 9, 19, 20	NMFS/FEL/MTF. Bay Saint Louis, Mississippi
2	The Menhaden Advisory Committee. New Orleans, Louisiana
3	J. A. Benigno. NMFS/Pascagoula Lab, Pascagoula, Miss.
5, 12	Stevenson and Vanselous (ref. 14). Modified from original
6	Roithmayr and Wittmann (ref. 20)
7, 13, 14	NASA/ERL/MTF (ref. 30). Modified from originals
8	Kemmerer and Benigno. NMFS/Pascagoula Lab., Pascagoula, Miss.
10	NASA/GSFC (ref. 15)
11	NASA/MTF, Slidell Computer Complex, Annual ADP Planning Document. 1971. (Internal Publication)
15, 16, 17, 18	NASA/ERL/MTF. Sea RS Progress, Mississippi Sound RS Study, 7 August 1972. Surface Meas. Report No. 025. 1972. (Internal Publication). Modified from originals
21, 22, 23, 24	Weldon (ref. 22). Modified from originals
25, 27, 28, 29, 30, 31	Kemmerer, et al (ref. 33, 34)
26	NASA/GSFC. Greenbelt, Maryland. Modified from original ERTS-1 Image (1015-16013-5)

BIBLIOGRAPHY

Atwell, B. H. Mississippi Sound Remote Sensing Study. NASA, Earth Resources Lab. Internal Report No. 048. Mississippi Test Facility, Bay Saint Louis, Miss. 1973. p.70

Benigno, J. A. Fish Detection Through Aerial Surveillance. Tech. Conf. On Fish Finding, Purse Seining, And Aimed Traveling. FAO, FIL FF 70/78. Reykjavik, Iceland. May, 1970. p.13

Bullis, H. R. A Program To Develop Aerial Photo-Technology For Assessment Of Surface Fish Schools. Proc. Gulf Carib. Fish Inst. 20th Ann. Sess. 1967. p.40-43

Christmas, J. Y. Cooperative Gulf Of Mexico Estuarine Inventory And Study, Mississippi. Phase I - Area Description. Spec. Rept. To Miss. Conser. Comm. (Gulf Coast Res. Lab., Ocean Springs, Ms.). 1973. p.450

Drennan, K. L. Fishery Oceanography From Space. Proc. 6th Space Cong., Space Tech. Soc. Canaveral Council of Tech. Soc., Cocoa Beach, Fla. 1969. p.9.1-9.6

Earth Satellite Corp. Investigation To Improve Menhaden Fishery Prediction. NASA-CR-127743, GSFC-1D-PR507. Also: Nat. Tech. Info. Serv. MF No. E72-10019. Aug. 1972. p.2

Freden, S. C. Performance Of Sensors And Systems. In: Introduction ERTS-1 Symp. Proc., GSFC, Greenbelt, Md. NASA. Sept. 1972. p.1-6

Hanson, J. J. Remote Sensing Of The Ocean. In: Remote Sensing Of The Troposphere. U. S. Dept. of Commerce, Nat. Oceanic & Atmos. Admin. p. 1-56.

Hutchinson, G. E. A Treatise On Limnology. Geography, Physics, and Chemistry. Vol. 1. John Wiley & Sons, New York. 1957

Maughan, P. M. An Investigation to Improve The Menhaden Fishery Prediction And Detection Model Through The Application Of ERTS-A Data. NASA-CR-133637. Also: Nat. Tech. Info. Serv. MF. No. E73-10961/WR. Sept. 1973. p.17

Maughan, P. M. An Investigation To Improve The Menhaden Fishery Prediction And Detection Model Through The Application of ERTS-A Data. Interim Rept. NASA-CR-129654. Also: Nat. Tech. Info. Serv. MF No. E72-10340. Dec. 1972. p.29

Maughan, P. M. Investigation to Improve Menhaden Fishery. Prog. Rept. 1 August - 31 Oct. 1972. NASA-CR-12828. Also: Nat. Tech. Info. Serv. MF No. E72-10152. Oct. 1972. p.4

Maughan, P. M. Investigation To Improve Menhaden Fishery Prediction Prog. Rept. 1 Dec. 1972 - 31 Jan. 1973. NASA-CR-130374. Also: Nat. Tech. Info. Serv. MF No. N73-17291. Feb. 1973. p.4

Maughan, P. M. Investigation To Improve Menhaden Fishery Prediction. NASA-CR-131300. Also: Nat. Tech. Info. Serv. MF No. E73-10480. Apr. 1973. p.3

NASA. Aircraft Remote Sensing Systems. Johnson Space Center, MSC-04162. Houston, Texas. May, 1971. p. 131

NASA. Earth Resources Program, Johnson Space Center Earth Resources Aircraft Plan and Data Facilities Plan. Johnson Space Center, Houston, Texas. Rev. ed., April, 1973. p.114

NASA. Program Management, Michoud Assembly Facility, Slidell Computer Complex, Annual ADP Planning Document. Miss. Test. Fac., Bay Saint Louis, Ms. August, 1971. p. (var.)

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 6 July 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 022. Miss. Test Fac., Bay Saint Louis, Miss. Sept. 1972. p.23

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 6 July 1972 - Surface Measurements. Earth Res. Lab. Internal Rept. No. 021. Miss. Test Fac., Bay St. Louis, Ms. Sept. 1972. p.32

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 11 July 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 042, Miss. Test Fac., Bay St. Louis, Ms. Feb. 1973. p.26

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 11, 19, 25 July and 1 August 1972 - Surface Measurements. Earth Res. Lab. Internal Rept. No. 023. Miss. Test Fac., Bay St. Louis, Ms. Sept. 1972. p. 32

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 19 July 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 060. May 1973. p.14

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 25 July 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 044, Miss. Test Fac., Bay St. Louis, Ms. Mar. 1973. p.26

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 1 August 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 046, Mar. 1973. p. 26

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 7 August 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 045. Miss. Test Fac., Bay St. Louis, Ms. Mar. 1973. p.26

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study. 7 August 1972 - Surface Measurements. Earth Res. Lab. Internal Rept. No. 025. Oct. 1972. p.25

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 15, 19 August and 7 September 1972. Earth Res. Lab. Internal Rept. No. 033. Nov. 1972. p.28

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 25 August 1972. Earth Res. Lab. Internal Rept. No. 032. Nov. 1972. p.36

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 29 August 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 064. Miss. Test Fac., Bay St. Louis, Ms. May 1973. p. 25

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 7 September 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 063. May 1973. p. 24

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 19 September 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 070. Miss. Test Fac., Bay St. Louis, Ms. June, 1973. p. 34

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study. 19 September, 4 and 8 October 1972 - Surface Measurements. Earth Res. Lab. Internal Rept. No. 037. Jan. 1973. p.29

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 28 September 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 073. Miss. Test Fac., Bay St. Louis, Ms. June 1973. p. 33

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 28 September 1972 - Surface Measurements. Earth Res. Lab. Internal Rept. No. 034. Jan. 1973. p. 31.

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 4 October 1972, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 071. Miss. Test Fac., Bay St. Louis, Miss. June, 1973. p.34

NASA. Sea Remote Sensing Program, Mississippi Sound Remote Sensing Study, 18 October 1973, Remote Measurements - Light Aircraft. Earth Res. Lab. Internal Rept. No. 072. Miss. Test Fac., Bay St. Louis, Ms. June, 1973. p. 35

NASA. Skylab/EREP Investigators' Data Book. Johnson Space Center, Houston, Texas. October, 1972. p. 106

Reese, G. B.; Minkler, F. C.; Kemmerer, A. J., and Benigno, J. A. Fishing With Film. Miss. Game and Fish, Vol. 36, No. 4, Jul.-Aug. 1973. p.10-12

Reintjes, J. W. Synopsis Of Biological Data On The Atlantic Menhaden, Brevoortia tyrannus. FAO Species Synopsis No. 42. U. S. Fish Wildl. Serv. Cir. No. 320. 1969. p.1-30

Reintjes, J. W.; Christmas, J. Y.; and Collins, R. Annotated Bibliography Of The American Menhaden. U. S. Fish & Wildlife Serv., p. 297-322.

Rounsefell, G. A. Biology Of The Commercial Fishes Of The Gulf Of Mexico. In: Gulf Of Mexico. Its Origin, Waters, and Marine Life. U. S. Fish & Wildl. Serv., Fish Bull. No. 89, Vol. 55. 1954. p.507-512

Stevenson, W. H. Application Of Remote Sensing For Fishery Resource Assessment And Monitoring. NASA-CR-132249. Also: Nat. Tech. Info. Serv. MF No. E73-10658

Stevenson, W. H.; Atwell, B. H.; and Maughan, P. M. Application Of ERTS-1 For Fishery Resource Assessment And Harvest. 8th Internat. Symp. On Rem. Sens. Environ. Willow Run Lab., Ann Arbor, Mich. Oct. 1972. Also: Nat. Tech. Info. Serv. MF No. N73-11309, and NASA-CR-128486. Oct. 1972. p.8.

Vary, W. E. A New Non-blue Sensitive Aerial Color Film. Sem. Proc. - New Horizons In Color Aerial Photography. Amer. Soc. Photo & Soc. Photo. Sci. & Eng. June 1969. p.127-130