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LANDSAT FOLLOW-ON EXPERIMENT - GULF OF MEXICO MENHADEN AND THREAD HERRING RESOURCES INVESTIGATION

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Andrew J. Kemmerer, Kenneth Savastano, Thomas Leming, and Hillman Holley
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
Fisheries Engineering Laboratory
NSTL, Bay Saint Louis, Mississippi 39520

Kenneth Faller
National Aeronautics and Space Administration
Johnson Space Center
Earth Resources Laboratory
Slidell Computer Complex
Slidell, Louisiana 70458

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7. Author(s) A. J. Kemmerer, K. J. Savastano, H. J. Holley, T. D. Leming and K. H. Faller*

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*National Aeronautics and Space Administration
JSC, Earth Resources Laboratory
Slidell Computer Complex, Slidell, Louisiana 70458

16. Abstract

An investigation is being conducted cooperatively by Federal and State Government agencies and private industry to demonstrate the feasibility of using satellite data for enhancing the management and utilization of coastal fishery resources in the northern Gulf of Mexico. Classification algorithms have been developed for LANDSAT MSS data which divide the study areas into high and low probability fishing areas. These classifications are in excess of 80 percent accurate demonstrating the value of satellite derived data for enhancing the harvest and management of coastal fishes in the northern Gulf of Mexico.

A successful two-week field operation was completed in July 1976 to simulate an operational satellite system for providing tactical fishing information and to examine the temporal persistence of high probability fishing areas derived from LANDSAT MSS data. LANDSAT data were processed and classified into high and low probability fishing areas for dissemination to the fishing fleet in less than 21 hours after satellite coverage. Reports from the fishing fleet indicate that the high probability fishing areas produced good fish catches the day following satellite coverage.

17. Key Words (Selected by Author(s))
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PREFACE

This progress report covers the investigative period from May 1, 1976 to July 31, 1976. It represents the fifth report since the investigation was formally initiated on April 29, 1975. The first two reports emphasized organization, experimental design and rationale, and field operations. The third and fourth summarized analytical efforts. This report emphasizes parent project data processing and analysis, planning, field operations, and initial analysis of the extension of the LANDSAT Menhaden and Thread Herring Resource Investigation. This report was prepared to give readers a concise overview of the investigation prior to reviewing accomplishments since the last progress report. In addition, it summarizes the status of all data collected in support of the study in the event that someone would like copies for their own use.

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ABBREVIATIONS AND SYMBOLS

NASA	National Aeronautics and Space Administration
NMFS	National Marine Fisheries Service
NFMOA	National Fish Meal and Oil Association
LANDSAT-1	Land Satellite (No. 1)
LANDSAT-2	Land Satellite (No. 2)
JSC	Johnson Space Center
ERL	Earth Resources Laboratory
FEL	Fisheries Engineering Laboratory
NOAA	National Oceanic and Atmospheric Administration
NESS	National Environmental Satellite Service
NWS	National Weather Service
AOML	Atlantic Oceanographic and Meteorological Laboratory
GSFC	Goddard Space Flight Center
NSTL	National Space Technology Laboratories
USGS	United States Geological Survey
EROS	Earth Resources Observation Systems
OCSO	Outer Continental Shelf Operations
USCG	United States Coast Guard
NP3A	NASA Medium Altitude Remote Sensing Aircraft
SMS/GOES	Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite
LLLTV	Low Light Level Television
ISRS	Information Storage and Retrieval Systems
PRT-5	Precision Radiation Thermometer-5
MSS	Multispectral Scanner System
ERTS	Earth Resources Technology Satellite
MFMR	Multifrequency Microwave Radiometer
M^2S	Modular Multispectral Scanner
CCT	Computer Compatible Tape
A/D	Analog to Digital
PCM	Pulse Code Modulated

LANDSAT MENHADEN AND THREAD HERRING
RESOURCES INVESTIGATION

1. INTRODUCTION

1.1 REPORTING. This progress report is the fifth in a series under NASA Agreement Number S-54114, ID #20770, sponsored by the NASA Goddard Space Flight Center. It is a type II report covering the investigative period from May 1, 1976 to July 31, 1976.

1.2 OVERVIEW. This investigation is being conducted in two test sites off the coasts of Mississippi and Louisiana. The primary target species is the Gulf menhaden (Brevoortia patronus); the secondary target species is the thread herring (Opisthonema oglinum). Both species form large schools with numbers frequently exceeding one hundred thousand per school. The schools are considered near-surface pelagics which suggests an immediate application of remote sensing techniques. Both species are harvested for conversion into high protein fish meal and oils. Approximately 600,000 tons of menhaden are taken from the Gulf annually representing almost 26 percent of the entire domestic harvest of all fish. While the standing stock of thread herring in the Gulf is believed to exceed that of the menhaden, the catch averages less than 1 percent of the average menhaden landings. The thread herring is truly a latent resource and one which is beginning to receive increased attention from several fishing companies.

The investigation was formally initiated on April 29, 1975. Unofficially, however, the investigation began back as early as November 1974 when a series of meetings began with representatives of the National Fish Meal and Oil Association. These meetings were designed to formulate a plan with the industry for the investigation and in particular to acquire their interest and support.

The investigation was designed to extend over an 18-month period with the first 6 months dedicated primarily to planning and data acquisition (field operations), and the remaining 12 months used for data analysis and report preparation. During this reporting period, the LANDSAT Menhaden and Thread Herring Resource Investigation was extended an additional 6 months to pursue two objectives related to the definition and development of satellite remote sensing system for fishery harvest and management. The extension was based on preliminary findings which indicated that water color measured by LANDSAT multispectral scanner (MSS) could be used to predict menhaden distribution in the northern Gulf of Mexico.

This fifth in a series of type II progress reports emphasizes the analytical efforts of the parent investigation and the planning, field operational, data processing and analysis for the LANDSAT Extension.

1.3 OBJECTIVES. The primary objective is to verify the relationship of certain coastal environmental parameters which are observable from aerospace platforms to the distribution and abundance of Gulf menhaden, a commercially important fish in the northern Gulf of Mexico. A secondary objective is to establish relationships of remotely sensed environmental parameters to a fish with potential commercial importance, thread herring.

Sub-objectives of the multi-phased investigation are:

- Confirm utilization of aerospace data as inputs for a distribution prediction model for adult menhaden in the Mississippi Sound.
- Test utilization of aerospace data as inputs for a distribution prediction model for adult menhaden over the entire season of menhaden availability in the Mississippi Sound.
- Test utilization of aerospace data as inputs for a distribution prediction model for adult menhaden throughout the commercial fishery range in the northern Gulf of Mexico.
- Test utilization of aerospace data as inputs for a distribution prediction model for adult thread herring off the coast of Louisiana.
- Continue development of techniques for the application of remote sensing data to living marine resource assessment and utilization.

Objectives of the contract extension are:

- Simulate the use of an operational satellite system to provide tactical information for the commercial harvest of menhaden.
- Define the persistence of LANDSAT-predicted high probability fishing areas over a 24-hour period.

2. INVESTIGATION PARTICIPANTS

2.1 PRINCIPAL AND CO-INVESTIGATIVE PARTICIPANTS. This experiment is a cooperative venture whose principal participants originate from various Federal agencies and commercial fishing companies. They are as follows:

National Oceanic and Atmospheric Administration (NOAA)
    National Marine Fisheries Service (NMFS)
        Southeast Fisheries Center
            Fisheries Engineering Laboratory
            Pascagoula Laboratory

National Aeronautics and Space Administration (NASA)
    Earth Resources Laboratory (JSC/ERL)

National Fish Meal and Oil Association (NFMOA)

2.2 ASSOCIATED GROUPS AND AGENCIES. Various groups and agencies who have and are providing assistance in one form or another to the Principal and Co-Investigative elements within the experiment are as follows:

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

National Aeronautics and Space Administration (NASA)
- Johnson Space Center (JSC)
- Goddard Space Flight Center (GSFC)
- National Space Technology Laboratories (NSTL)

Department of the Interior
- United States Geological Survey (USGS)
  - Earth Resources Observation Systems (EROS)
  - Outer Continental Shelf Operations (OCSO)

United States Coast Guard (USCG)

Mississippi State University

Nicholls State University

Four Oil Companies

3. SUMMARY OF EARLIER REPORTS

As the first four progress reports emphasized organization, responsibilities, experimental rationale, methodology, field operations, and initial analytical efforts, these subjects only will be reviewed in this one. The reader is encouraged to refer to these reports if this summary does not provide enough detail for his particular purpose.

3.1 ORGANIZATION AND RESPONSIBILITIES. The organization consists of a principal investigator who provides overall guidance to the investigation, and the three principal participants (ERL,NFMOA, and SEFC). Responsibilities of ERL include acquisition of aerospace remotely sensed data and conversion of these data into measurements of selected oceanographic parameters. The NFMOA is responsible for the acquisition of fishing data (spotter pilots and vessel captains reports) and review and evaluation of all aspects of the investigation. The SEFC responsibilities include program management and coordination, acquisition of fisheries data, and the development of models for predicting fish distribution from remote measurements of selected oceanographic parameters.

3.2 EXPERIMENTAL RATIONALE AND DESIGN. The rationale is based on the assumption that fish distribution is governed by certain measurable oceanographic parameters. The investigation was designed to identify these parameters and then to determine if they could be measured with sufficient accuracy remotely for fish distribution predictions. The parameters considered were limited to those that could be or had the potential of being remotely measured.

3.3 FIELD OPERATIONS (1975). Field operations were organized and conducted to satisfy data requirements of the basic units of the experimental design. These operations functioned to provide aerospace remotely sensed data (LANDSAT and aircraft), oceanographic data (research vessels), fish distribution and abundance data (photographic and spotter pilot aircraft), and utilization data (fishing vessels). The primary parameters considered and the platforms from which measurements were made are presented in Figure 3.1.

Two classes of missions were conducted to satisfy the experimental design: main and supplementary. The main missions included all of the platforms shown in Figure 3.1 while the supplementary missions involved only fishing and LANDSAT data. The latter missions were designed to provide data for testing and expanding upon the oceanographic and fishery models developed from data acquired during the main missions.

The two study areas used in the investigation together with superimposed locations of LANDSAT tracks, NP3A, ERL Twin Beech, and NMFS charter aircraft flight lines, oceanographic sampling stations, and oil platforms are shown in Figures 3.2 and 3.3. Both study areas support an active menhaden fishery. Thread herring are primarily found in the offshore portions of the Louisiana study area although infrequently they are caught in the Mississippi Sound.

Figures 3.4 and 3.5 summarize the main and supplementary missions conducted in support of the investigation. The first two main missions in the Louisiana Test Site (Figure 3.4) operated as planned with all platforms acquiring data. The third scheduled mission, however, was aborted due to a reported LANDSAT-1 malfunction. It was rescheduled to coincide with a LANDSAT-2 orbit. The first two Mississippi Sound main missions also operated as planned while the third main mission had to be rescheduled due to inclement weather and unavailability of the NP3A aircraft (Figure 3.5). Unfortunately, even though the main and supplementary missions went smoothly from an operational standpoint, all LANDSAT MSS data are of marginal quality due to excessive cloud cover.

3.4 DATA PROCESSING AND ANALYSIS. Emphasis for data processing has been given to reviewing available data for quality determinations and preparing it for insertion into a single LANDSAT data management system. The single system was developed to insure a complete data file for analytical purposes by current as well as future investigators.

Figure 3.1 Main Day Mission Data Acquisition Platforms and Parameters

	SURFACE				AIRCRAFT					SATELLITES	
Parameter	Fish. Vess. without Observer	Fish. Vess. with Observer	Oceano-graphic Vessel	Oil Platform	NP3A	NASA ERL Aircraft	NFMOA Spotters	NMFS Photo	NMFS LLLTV*	LANDSAT	SMS/GOES
Salinity		X	X	X	X						
Chlorophyll		X	X	X	X*	X				X	
Color		X	X	X	X*	X				X	
Transparency		X	X	X	X*	X				X	
Temperature		X	X	X	X	X					
Water Depth		X	X	X							
Fish School Locations			X			X	X	X	X		
Location of Fish Catches	X	X				X		X			
Meteorology			X				X				X

*Louisiana study area only.

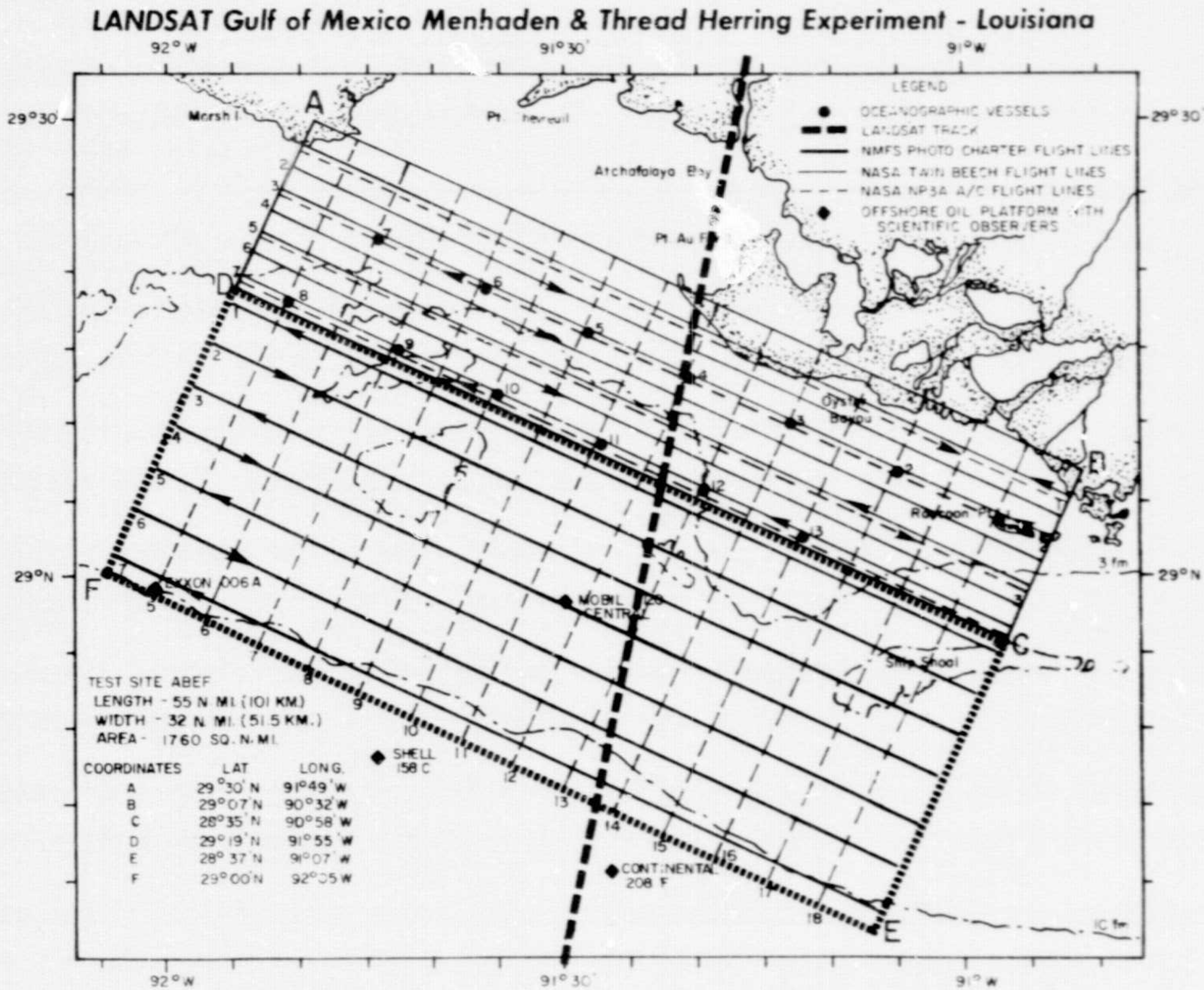

Figure 3.2 Louisiana Study Area Showing the LANDSAT Track, Aircraft Flight Lines, Oceanographic Stations, and Oil Platform Locations

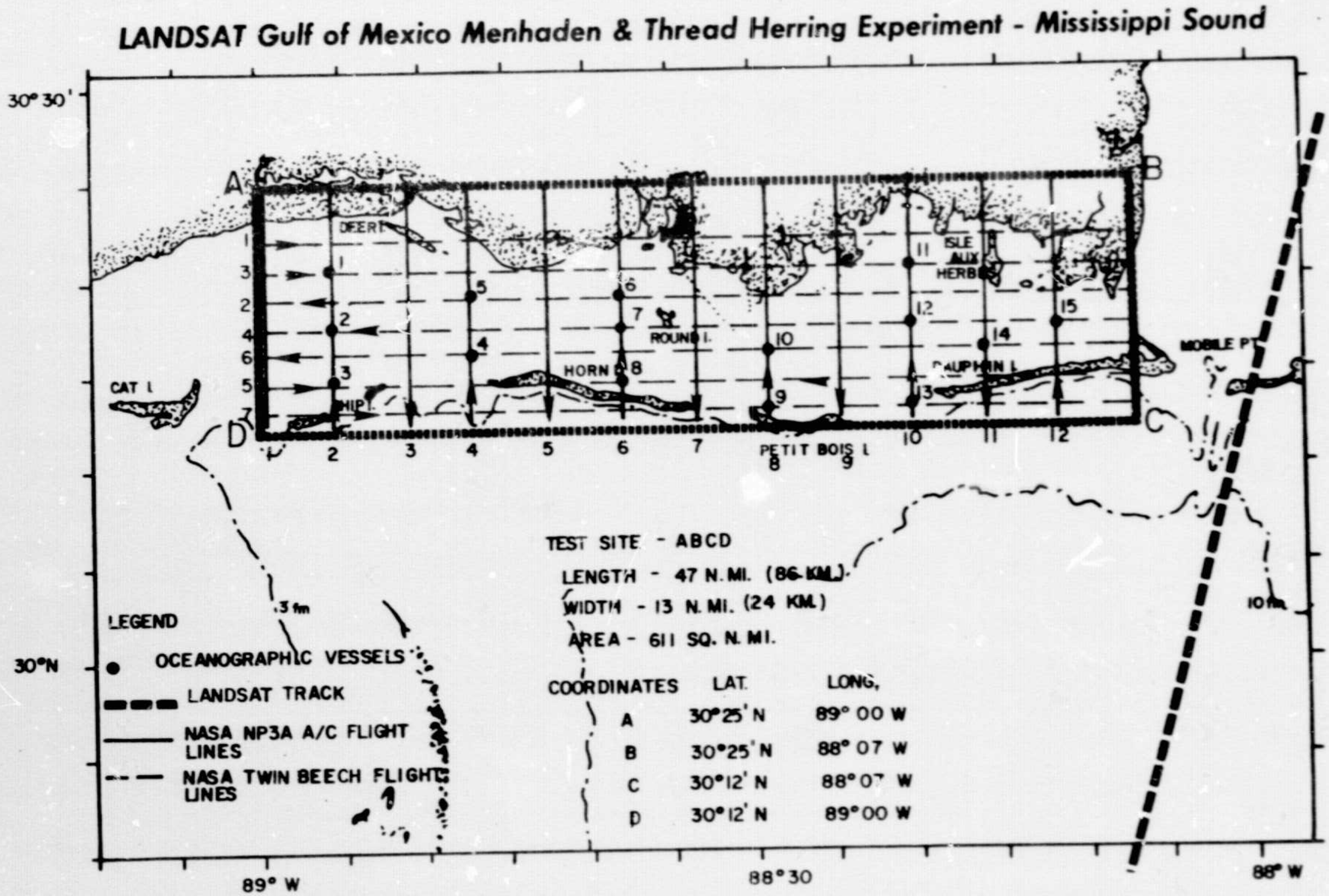

Figure 3.3 Mississippi Sound Study Area Showing the LANDSAT Track, Aircraft Flight Lines, and Oceanographic Stations

SUMMARY OF LOUISIANA LANDSAT MISSIONS (1975)

PLATFORM	MISSION	MAIN	MAIN	SUPPLE-MENTARY	ABORTED MAIN [1]	SUPPLE-MENTARY	RESCHED-ULED MAIN	SUPPLE-MENTARY	SUPPLE-MENTARY
	DATE	APR 25	MAY 13	JUN 18	JUL 24	AUG 11	AUG 20	AUG 29	SEP 16
FISHING VESSELS		X	X	X	X	X	X	X	X
SPOTTER AIRCRAFT		X	X	X	X	X	X	X	X
FISHING VESSEL OBSERVERS		X	X		X		X		
RESEARCH VESSELS		X	X				X		
OIL PLATFORMS		X	X				X		
ERL AIRCRAFT		X	X				X		
NP3A AIRCRAFT		X	X				X		
PHOTO-GRAPHIC AIRCRAFT		X	X				X		
LANDSAT I		X	X	X	X	X	X [2]	X	X

1 Mission aborted due to mechanical failure reported aboard LANDSAT I

2 LANDSAT II

Figure 3.4 Summary of Louisiana Test Site Missions (1975)

SUMMARY OF MISSISSIPPI SOUND LANDSAT MISSIONS (1975)

PLATFORM	MISSION	MAIN	MAIN	SUPPLE-MENTARY	ABORTED MAIN 1	SUPPLE-MENTARY	MAIN[2]	SUPPLE-MENTARY
	DATE	MAY 2	MAY 20	JUN 25	JUL 31	AUG 18	SEP 5	SEP 23
FISHING VESSELS		X	X	X	X	X	X	X
SPOTTER AIRCRAFT		X	X	X	X	X	X	X
FISHING VESSEL OBSERVERS		X	X		X		X	
RESEARCH VESSELS		X	X				X	
ERL AIRCRAFT		X	X					
NP3A AIRCRAFT		X	X				X	
LANDSAT II		X	X	X	X	X	X	X

1 Mission aborted due to inclement weather and unavailability of NP3A.

2 ERL Aircraft unable to complete mission due to inclement weather and mechanical failure.

Figure 3.5 Summary of Mississippi Sound Missions (1975)

Analytical emphasis initially was given to the sea truth data collected from fishing and research vessels. The objectives of these analyses were to identify those parameters and analytical techniques which offered the greatest potential for satisfying the objectives of the investigation. The analytical rationale was to compare oceanographic measurements at sites of menhaden capture with those taken from the research vessels over time and between test sites. This was done to determine if menhaden appeared to prefer a relatively constant range of environmental conditions. The assumption was that those parameters remaining relatively constant in magnitude, but demonstrating differences from those measured from the research vessels could be used to predict fish distribution.

The parameters which appeared to have significant direct effects on menhaden distribution are water turbidity (secchi disc) and color (Forel-Ule). Surface water temperature and salinity appeared to have little direct effect. Chlorophyll-a also did not appear to be a very good indicator of menhaden distribution.

Surface truth and fisheries data sets for three main missions (April 25, May 13, and May 20, 1975) were prepared for correlation analyses. Data sets for with and without menhaden areas were developed from contour maps of surface water temperature, Forel-Ule color, secchi disc transparency, salinity, and chlorophyll-a.

Remotely sensed salinity data from April 25 and May 13, 1975 were processed to listings of sea surface salinity at half mile intervals along each flight line. Processing problems were encountered for May 2 and September 5 remotely sensed salinity data sets and work has been initiated to resolve these problems. The first stages of processing of the August 20 remotely sensed salinity data set are complete.

Correlation and multiple regression analysis were applied to surface truth data (temperature, Forel-Ule color, salinity, secchi disc, and chlorophyll-a) for three missions: April 25 (Louisiana), May 13 (Louisiana), and May 20 (Mississippi Sound). Water color as inferred from Forel-Ule color measurements generally correlated well with menhaden distribution. Regression model correlation coefficients averaged about 0.55 for the three missions indicating fairly low levels of statistical precision. The models were about 75 percent accurate in predicting menhaden distribution.

Three distinct methods were applied to LANDSAT MSS data for classification of the study areas into high and low probability fishing areas. These methods include parallelepiped, multiple regression, and discriminant function classifications. In addition, LANDSAT MSS and surface truth data were combined into a single precictive algorithm.

The parallelepiped classifier worked well on the May 20 and June 25 (Mississippi Sound) MSS data, but performed poorly for the July 24 (Louisiana) MSS data set. Multiple regression models were developed from MSS spectral data for May 20, June 25, and July 24. The precision of the resultant models was reasonably good with correlation coefficients ranging from 0.736 to 0.894. All were significant at confidence levels exceeding 99%. Results from classification of training samples indicate accuracies of approximately 90%. Discriminant function models were developed from MSS spectral data from June 25 and July 24. Training sample classification accuracy was approximately 90%.

Correlation and multiple regression analyses were performed using a combination of LANDSAT and surface truth data from May 20. MSS data correlated more precisely with menhaden distribution than the classical oceanographic parameters such as temperature, Forel-Ule color, salinity, and secchi disc transparency. A multiple regression model was developed from the two data sets. A slight improvement in model precision was noted over an earlier model developed solely fro MSS data, but not enough to warrant the additional parameters.

4. ACCOMPLISHMENTS

This section will describe progress made during the last three months in data processing, data analysis, and the extension of the investigation to cover simulation of the use of an operational satellite system to provide tactical information for the commercial harvest of menhaden.

4.1 DATA PROCESSING. The status of data flow is shown in Figures 4.1 through 4.6.

Computer generated composite point plots for all main missions (three in Mississippi Sound and three off Louisiana) were prepared for chlorophyll-a. Chlorophyll contour maps were prepared for April 25, May 13, and May 20 missions. Similar plots and contour maps were prepared for remotely sensed salinity and temperature measurements. With and without menhaden area data sets were developed from the contour maps for statistical analysis.

Microwave radiometer measurements together with PRT-5 measurements of surface thermodynamic temperature were used to generate remotely sensed salinity measurements, which were mapped for the test areas for each of the main missions except one. Microwave data acquired on May 2, 1975 could not be used to develop acceptable salinity measurements because of an instability in the signal, possibly due to the center of the sun glint pattern moving into the central lobe of the antenna pattern as the automatic guidance system on the aircraft maintained headings on the east-west line, and severe sun glint contamination on southbound lines.

4.2 DATA ANALYSIS

4.2.1. Salinity Analysis. Table 4.1 was compiled from surface truth data and remote salinity measurements. A comparison of remote measurements with surface truth salinity measurements was performed by extracting salinity measurements from a 10 second average of the microwave signal centered at the point of closest approach to the surface station. All sampling stations were intended to be directly under at least one flight

LANDSAT DATA FLOW

Mission No. 1

Date 25 April

Site Louisiana

X Completed

▼ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	X
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	X
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Oil Platform	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
NMFS A/C Charter (photo)	Fish Loc. Data	X	X	X	▼							
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	X	▼				

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refo.	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract.	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	▼							
	PRT-5	No										
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X			
	M^2S	Yes	X	X	▼							
	PRT-5	X	X	X	X	X	X	X	X			
LANDSAT	Imagery	X	X	X	NA	X	▼					
	CCT	X	X	X	X	X	▼					

Figure 4.1 Platform and Data Flow Status Summary for the April 25, 1975 Louisiana Main Day Mission

LANDSAT DATA FLOW

Mission No. 2

Date 2 May

Site Mississippi Sound

X Completed

▼ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	▼					

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refor	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	Partial	X	▼					
	PRT-5	X	X	X	X	X	X	X	X	X	X	
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	▼			
	M^2S	No										
	PRT-5	X	X	X	X	X	X	X	▼			
LANDSAT	Imagery	X	X	X	NA	X	▼					
	CCT	X	Not Ordered									

Figure 4.2 Platform and Data Flow Status Summary for the May 2, 1975 Mississippi Sound Main Day Mission

LANDSAT DATA FLOW

Mission No. 3

Date 13 May

Site Louisiana

X Completed

▼ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	X
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	X
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Oil Platform	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
NMFS A/C Charter (photo)	Fish Loc. Data	X	X	X	▼							
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	▼					

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refo.	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract.	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	▼							
	PRT-5	X	X	X	X	X	X	X	X	X	X	
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X			
	M^2S	X	X	X	▼							
	PRT-5	X		X	X	X	X	X	▼			
LANDSAT	Imagery	X	X	X	NA	X	▼					
	CCT	X	X	X	X	X	▼					

Figure 4.3 Platform and Data Flow Status Summary for the May 13, 1975 Louisiana Main Day Mission

LANDSAT DATA FLOW

Mission No. 4

Date 20 May

Site Mississippi Sound

X Completed

▼ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	X
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	X
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	X
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	X	X	X	X	X	▼	▼	X

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refor	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	X	X	▼					
	PRT-5	X	X	X	X	X	X	X	X	X	X	X
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X	X	X	X
	M^2S	No										
	PRT-5	X	X	X	X	X	X	X	▼			
LANDSAT	Imagery	X	X	X	NA	X	X	X	X	NA	NA	X
	CCT	X	X	X	X	X	X	X	X	X	X	X

Figure 4.4 Platform and Data Flow Status Summary for the May 20, 1975 Mississippi Sound Main Day Mission

LANDSAT DATA FLOW

Mission No. 5
Date 20 August
Site Louisiana

X Completed
▼ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Oil Platform	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
NMFS A/C Charter (photo)	Fish Loc. Data	X	X	X	▼							
NASA Twin Beech	Fish Photo Data, KC1B	X	X	X	▼							

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refo.	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract.	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	X	X	X	▼							
	PRT-5	X	X	X	X	X	X	X	X	X	X	
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X			
	M^2S	X	X	X	▼							
	PRT-5	X	X	X	X	X	X	X	▼			
LANDSAT	Imagery	X	X	X	NA	X	▼					
	CCT	X	X	X	X	X	▼					

Figure 4.5 Platform and Data Flow Status Summary for the August 20, 1975 Louisiana Test Site Main Day Mission

LANDSAT DATA FLOW

Mission No. 6

Date 5 September

Site Mississippi Sound

X Completed

▼ Terminated

SURFACE TRUTH

Platform	Data Type	Data Acq.	Data Rec.	Data Veri.	Data Trans.	Data Veri.	Key Punched	Data Ret.	Data Veri.	Data to Comp.	Data Ret.	Data Anal.
Fishing Vessel	Fish Data	X	X	X	X	X	X	X	X	X	X	
	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
Spotter Pilot	Fish Data	X	X	X	X	X	X	X	X	X	X	
Oceano. Vessel	Oceano. Data	X	X	X	X	X	X	X	X	X	X	
NASA Twin Beech	Fish Photo Data, KC1B	X	X									

REMOTE SENSING

Platform	Data Type	Data Acq.	Data Rec.	Quick Look	A/D, Decom. or Refor	Raw Product	Correl. w/ Surf. Truth	Final Data Prod.	Sample Extract	Data to Comp.	Data Ret.	Data Anal.
NASA Twin Beech	RS-18	No										
	PRT-5	No										
NASA NP3A A/C	MFMR	X	X	X	X	X	X	X	X			
	M^2S	No										
	PRT-5	X	X	X	X	X	X	X	X			
LANDSAT	Imagery	X	X	X	▼							
	CCT	X	not ordered									

Figure 4.6 Platform and Data Flow Status for the September 5, 1975 Mississippi Sound Main Day Mission

line. Unfortunately, the NP3A with its inertial navigation system was unable to navigate all flight lines without position errors at times exceeding 3 miles, so not all stations were directly overflown.

Table 4.1. Salinity Error Analysis[1]

MISSION	SURFACE TRUTH[2]	INTERSECTING FLIGHT LINES[3]
4/25/75	1.58	1.95
5/13/75	1.78	1.71
5/20/75	1.46	1.53
8/20/75	2.56	2.58
9/05/75	1.09	0.48

1 $\left(\frac{1}{n-1} \quad (X_i - X_k)^2\right)^{1/2}$

2 RMS deviation between surface truth and remote measurements.

3 RMS deviation between remote measurements at intersections of flight lines.

The flight lines were laid out such that two measurements were made at a large number of points. This was accomplished by having one east-west flight line in the Mississippi Sound test area, with 11 short north-south lines crossing it. For the Louisiana test area, four lines were flown parallel to the coast and seven perpendicular to it. The 10-second average microwave signal centered at the intersection of flight lines was used to develop the two salinity measurements for the point on the sea surface. These two measurements were compared in exactly the same manner as that used for the comparison of surface and remote measurements. The second column in the table contains these deviations.

Interpretation of the deviations in Table 4.1 is not as simple as might be assumed at first. There are three basic causes for discrepancy in the measurements. The first and most obvious is the error in remote measurement, since the surface measurements are made with precision to 0.01 parts per thousand. The other two causes of deviation are spatial and temporal variation of salinity. As noted above, the remote and surface measurements were not always made in exactly the same location. In addition, unknown errors in positioning the aircraft and surface vessels could lead to major discrepancies. The time differences between most of the surface measurements and the overflight and between successive passes over the same point on different flight lines also probably contributed to the errors.

4.2.2 Surface Truth Analysis. Correlation and multiple regression analyses were applied to surface truth data collected by scientific observers aboard the commercial fishing vessels. The surface truth data for temperature, secchi disc transparency, Forel-Ule color, salinity, and chlorophyll-a were extracted for each day of the six main and the two aborted main mission periods (July 24 (Louisiana) and July 31 (Mississippi)). The number of sample sets collected at menhaden, thread herring, and no fish areas are listed in Table 4.2.

Several days out of the menhaden data set as well as the entire thread herring data set were excluded from individual analyses due to the small number of collected samples or the small number of samples remaining after the imbalance in the number of fish and no-fish samples had been removed.

Individual days, days grouped by mission, days grouped by area (Louisiana or Mississippi) and all data were analyzed using correlation and multiple regression techniques. Correlation coefficients for each of the parameters by date, are given in Table 4.3. The dependent variable was presence or absence of fish (i.e. 0 = no fish and 1 = fish).

Analysis of the correlation coefficients of each parameter shows inconsistency in both magnitude and range as can be seen in Table 4.4.

A summary of the step-wise multiple regression analyses is shown in Table 4.5. Menhaden distribution was the dependent variable in each case and was established by assigning sample areas with and without menhaden values of 1 and 0, respectively.

The number and percentage classified incorrectly were computed from the samples used to develop the models. As shown in Table 4.5, the models were inaccurate in classifying no-fish areas. This was expected, since the no-fish samples were taken from fishing vessels which presumably try to remain in or close to areas containing fish. Therefore, there were probably many instances where the no-fish samples were truly indicative of fish samples, thus creating significant problems in the development of predictive models.

The order of selection of the parameters (secchi disc, salinity, temperature, chlorophyll-a and Forel-Ule color) in developing each model is also shown in Table 4.5. The confusion factor created by the inaccurate no-fish samples probably accounts for the lack of consistent selection of Forel-Ule color and secchi as the main indicator parameters. This inconsistency in parameter selection is shown in Table 4.6.

From the data analyzed, it is evident that collection of true no-fish data samples can not be done from commercial menhaden fishing vessels under normal fishing conditions. This information was utilized during the July 1976 field operation, during which all no-fish oceanographic sampling was eliminated.

Table 4.2. Fishing Vessel Data Sets

SEQUENCE #	DATE	DATE ANALYZED	MENHADEN SAMPLES	THREAD-HERRING SAMPLES	NO-FISH SAMPLES	TOTAL SAMPLES
1	4/21		0	0	0	0
2	4/22	*	15	0	5	20
3	4/23	*	19	0	22	41
4	4/24	*	18	0	14	32
5	4/25	*	24	0	30	54
6	4/28		0	0	0	0
7	4/29		1	0	0	1
8	4/30	*	6	0	2	8
9	5/01		23	0	2	25
10	5/02	*	12	0	7	19
11	5/12	*	26	1	5	32
12	5/13		2	0	50	52
13	5/14	*	8	0	9	17
14	5/15	*	10	0	12	22
15	5/16	*	9	0	5	14
16	5/17		1	0	0	1
17	5/19	*	14	1	12	27
18	5/20	*	36	0	5	41
19	5/21		38	0	0	38
20	5/22		18	0	1	19
21	5/23		11	0	2	13
22	7/21		29	0	0	29
23	7/22	*	14	0	5	19
24	7/23	*	18	0	3	21
25	7/24	*	16	0	10	26
26	7/25	*	15	1	6	22
27	7/28	*	11	0	5	16
28	7/29		1	0	7	8
29	7/30	*	4	0	2	6
30	7/31		0	0	0	0
31	8/18	*	18	0	7	25
32	8/19	*	12	4	11	27
33	8/20		2	2	25	29
34	8/21	*	6	2	8	16
35	8/22		1	0	3	4
36	9/03		10	0	2	12
37	9/04		11	0	2	13
38	9/05		1	0	2	3
39	4/21 - 4/25	*	76	0	71	147
40	4/28 - 5/02	*	42	0	11	53
41	5/12 - 5/17	*	56	1	81	138
42	5/19 - 5/23	*	117	1	20	138
43	7/21 - 7/25	*	92	1	24	117
44	7/28 - 7/31	*	16	0	14	30
45	8/18 - 8/22	*	39	8	54	101
46	8/03 - 9/05	*	22	0	6	28
47	La. (39,41,43,45)	*	263	10	230	503
48	Miss. (40,42,44,46)	*	197	1	51	249
49	All	*	460	11	281	752

Table 4.3. Correlation Coefficients for the Relationship of Menhaden Distribution to Selected Oceanographic Parameters

DATE	SAMPLE SIZE	TEMP.	SECCHI DISC	FOREL-ULE COLOR	SALINITY	CHLOROPHYLL-a
4/22	20	.209	-.053	-.023	.213	.109
4/23	41	.122	-.133	-.218	-.119	-.131
4/24	32	.204	.060	-.216	-.085	-.055
4/25	54	.442	-.462	.330	-.522	.176
4/21 - 4/25	147	.108	-.303	.196	-.271	.096
4/30	8	.345	-.556	.421	-.280	.405
5/02	19	.248	-.400	.102	-.107	-.467
4/28 - 5/02	53	.139	-.217	-.021	.025	-.197
5/12	31	-.154	-.105	.356	-.221	.142
5/14	17	.275	.051	-.017	-.506	.420
5/15	22	.002	.427	-.557	.425	-.141
5/16	14	-.054	.375	-.109	.553	-.129
5/12 - 5/17	137	.214	-.340	.279	-.251	.084
5/19	26	.603	.151	.067	.203	-.208
5/20	41	.193	.142	-.220	.323	-.058
5/19 - 5/23	137	.360	.206	-.152	.297	-.016
7/22	19	-.377	-.507	-.086	-.576	-.247
7/23	21	.158	-.269	.078	-.269	.008
7/24	26	.350	.405	-.306	.657	-.378
7/25	21	.287	.333	-.139	.241	-.498
7/21 - 7/25	116	.063	.126	-.063	.159	-.307
7/28	16	-.031	.269	-.316	.221	-.289
7/30	6	-.202	-.757	.948	-.600	.481
7/28 - 7/31	30	-.084	-.251	.237	-.145	-.042
8/18	25	.090	-.171	-.130	-.081	.215
8/19	23	-.229	-.239	-.180	-.233	.166
8/21	14	-.500	.053	.147	.303	.132
8/18 - 8/22	93	.005	-.305	.220	-.283	.271
9/03 - 9/05	28	.283	-.497	.083	-.143	-.091
La.	493	.131	-.205	.240	-.214	.061
Miss.	248	.012	-.088	-.052	.066	-.082
All	741	.103	-.285	.229	-.143	-.008

Table 4.4. Correlation Coefficient Frequency in Percent within Indicated Ranges

RANGE	TEMPERATURE	SECCHI DISC	FOREL-ULE	SALINITY	CHLOROPHYLL-a
-.7 to -.8	0	3	0	0	0
-.6 to -.7	0	0	0	3	0
-.5 to -.6	3	6	3	10	0
-.4 to -.5	0	6	0	0	6
-.3 to -.4	3	13	6	0	6
-.2 to -.3	6	19	9	25	6
-.1 to -.2	3	[illegible]	16	16	13
.0 to -.1	10	6	16	6	22
TOTAL	25	63	50	60	53
.0 to .1	16	10	13	6	13
.1 to .2	22	9	9	3	16
.2 to .3	22	6	16	16	9
.3 to .4	9	6	6	6	0
.4 to .5	3	6	3	3	9
.5 to .6	0	0	0	3	0
.6 to .7	3	0	0	3	0
.7 to .8	0	0	0	0	0
.8 to .9	0	0	0	0	0
.9 to 1.0	0	0	3	0	0
TOTAL	75	37	50	40	47

Table 4.5. Summary of Step-Wise Multiple Regression

DATE	TOTAL NUMBER OF SAMPLES	NUMBER OF FISH SAMPLES	NUMBER OF NO-FISH SAMPLES	INCORRECTLY CLASSIFIED FISH N	INCORRECTLY CLASSIFIED FISH %	INCORRECTLY CLASSIFIED NO-FISH N	INCORRECTLY CLASSIFIED NO-FISH %	ORDER OF SELECTION	DEGREES OF FREEDOM	CORRELATION COEFFICIENT
4/22	20	15	5	1	7	4	80	Sa,Se,C,T,F	5/14	.432
4/23	41	19	22	11	58	6	27	F,Se,C,Sa,T	5/35	.345
4/24	32	18	14	4	22	8	57	F,Sa,T,C,Se	5/26	.373
4/25	54	24	30	6	25	7	23	Sa,F,T,Se,C	5/48	.618[1]
4/21-4/25	147	76	71	20	26	30	42	Se,T,F,C,Sa	5/141	.361[1]
4/30	8	6	2	0	0	0	0	Se,C,T,Sa,F	5/2	.915
5/02	19	12	7	1	8	1	14	C,Se,F,T,Sa	5/13	.746[1]
4/28-5/02	53	42	11	0	0	8	87	Se,C,F,T,Sa	5/47	.463
5/12	31	26	5	1	4	4	80	F,T,C,Se,Sa	5/25	.437
5/14	17	8	9	1	13	2	22	Sa,T,C,Se,F	5/11	.780[1]
5/15	22	10	12	4	40	2	17	F,Sa,T,C,Se	5/16	.641
5/16	14	9	5	1	11	2	40	Sa,Se,F,T,C	5/8	.599
5/12-5/17	137	56	81	34	61	17	21	Se,F,T,Sa,C	5/131	.362[1]
5/19	26	14	12	4	29	3	25	T,Sa,F,C,Se	5/20	.677[1]
5/20	41	36	5	0	0	5	100	Sa,T,F,Se,C	5/35	.443
5/19-5/23	137	117	20	0	0	11	55	T,Sa,F,Se,C	5/131	.573[2]
7/22	19	14	5	0	0	2	40	Sa,T,Se,F,C	5/13	.735
7/23	21	18	3	0	0	3	100	Sa,F,T,C,Se	5/15	.346
7/24	26	16	10	2	13	2	20	Sa,F,C,T,Se	5/20	.715[1]
7/25	21	15	6	2	13	2	33	C,Sa,Se,T,F	5/15	.612
7/21-7/25	116	92	24	3	3	22	92	C,Sa,T,F,Se	5/110	.315
7/28	16	11	5	0	0	2	40	F,C,Sa,Se,T	5/10	.643
7/28-7/31	30	16	14	6	37	6	43	Se,C,F,Sa,T	5/24	.326
8/18	25	18	7	0	0	5	71	C,T,Sa,Se,F	5/19	.393
8/19	23	12	11	4	33	3	27	Se,T,F,Sa,C	5/17	.376
8/21	14	6	8	3	50	1	13	T,Se,F,Sa,C	5/8	.557
8/18-8/22	93	39	54	21	54	10	19	Se,C,F,T,Sa	5/87	.379
9/03-9/05	28	22	6	1	5	3	50	Se,T,F,C,Sa	5/22	.592
La.	493	263	230	22	8	153	67	Se,T,F,Sa,C	5/487	.314[2]
Miss.	248	197	51	0	0	51	100	Se,Sa,C,F,T	5/242	.197
All	741	460	281	0	0	245	87	Se,T,C,Sa,F	5/735	.302[2]

Se = Secchi disc
Sa = Salinity
T = Temperature
C = Chlorophyll-a
F = Forel-Ule color

1. Significant at 90%
2. Significant at 99%

Table 4.6. Parameter Selection Frequency

ORDER	Number of times parameter selected at indicated order. TEMPERATURE	SECCHI DISC	FOREL-ULE	SALINITY	CHLOROPHYLL-a
1st	3	11	6	8	4
2nd	10	6	4	7	5
3rd	8	2	13	2	7
4th	7	7	3	9	6
5th	4	6	6	6	9

4.2.3. LANDSAT Analyses. Analytical emphasis was given to two areas: simulate SMS-GOES broad band visible spectrum data from LANDSAT MSS data for menhaden distribution predictions and apply standard ERL pattern recognition classifier to July 24, 1975, and July 19, 1976 MSS data. The rationale behind the GOES simulation was to determine if this system might be considered as an operational tool for providing tactical fishing information. GOES provides repeat coverage every 30 minutes compared to the 18-day LANDSAT coverage cycle.

4.2.3.1. GOES Simulation. Preprocessed LANDSAT data for each spectral band and the sum of bands 4 and 5 radiance values were compared to with and without menhaden sample areas through correlation analysis (Table 4.7). The sum of the two bands was used to approximate the spectral response of the GOES system for comparison with LANDSAT. It should be understood, however, that the summation does not truly simulate GOES data; it only provides a rough approximation. This is due to a number of factors including (1) LANDSAT bands 4 and 5 do not cover the exact spectral range of GOES, (2) spectral response curves were not used to adjust the radiance values before summing, and (3) spatial resolution of the LANDSAT was degraded only to about 1/3 of that provided by GOES.

As can be seen from Table 4.7, the sum of bands 4 and 5 generally correlated well with menhaden distribution. This area of analysis clearly warrants additional investigation.

Table 4.7. Correlation Coefficients for the Relationship of Menhaden Distribution to LANDSAT Spectral Data

MSS BAND	LOUISIANA TEST SITE JULY 24	MAY 20	MISSISSIPPI SOUND JUNE 25
B4	0.416**	0.647**	0.461*
B5	0.356*	0.741**	0.822**
B6	0.282*	0.666**	0.685**
B7	0.200	0.607**	0.300*
B4 & B5	0.382*	0.703**	0.708**
SAMPLE SIZE	33	36	18

*Significant at the 90% confidence level
**Significant at the 99% confidence level

Multiple regression models were developed from MSS spectral data for three missions (Table 4.8 to Table 4.10), using all four bands and the sum of bands 4 and 5. The regression models were used to classify LANDSAT data into low and high probability fishing areas for each of the respective missions. The regression models using the sum of bands 4 and 5 compared favorably with the four band models, as can be seen in the tables. The models were about 85% accurate in classifying the study areas into high and low probability menhaden areas. Accuracy was computed from the sample areas used to develop the models.

Table 4.8. Summary of Step-Wise Multiple Regression Analyses of LANDSAT MSS Spectral Data for July 24.

MSS BAND AND REGRESSION PARAMETER	REGRESSION COEFFICIENTS 4 BAND MODEL	BAND 4 & 5 MODEL
B4	0.0384	
B5	0.1398	
B6	-0.3059	
B7	0.2422	
B4 & B5		0.1090
Intercept	-0.7134	-0.1813
Correlation Coefficient	0.5941	0.3815
F-Value	3.8835	5.28123
Degrees of Freedom	4/28	1/31
Significance Level	90	60
Order of Selection	B4,B6,B5, B7	B4 & 5
Percent classified correctly	73%	70%

Table 4.9. Summary of Step-Wise Multiple Regression Analyses of LANDSAT MSS Spectral Data for May 20.

MSS BAND AND REGRESSION PARAMETER	REGRESSION COEFFICIENTS 4 BAND MODEL	BAND 4 & 5 MODEL
B4	-0.0287	
B5	0.3116	
B6	0.2888	
B7	0.5545	
B4 & B5		0.9147
Intercept	-2.7863	-3.6410
Correlation Coefficient	0.762	0.703
F-Value	10.719	33.184
Degrees of Freedom	4/31	1/34
Significance Level	97.5	80
Order of Selection	B5,B6,B7,B4	B4 & 5
Percent classified correctly	86%	81%

Table 4.10. Summary of Step-Wise Multiple Regression Analyses of LANDSAT MSS Spectral Data for June 25.

MSS BAND AND REGRESSION PARAMETER	REGRESSION COEFFICIENTS 4 BAND MODEL	BAND 4 & 5 MODEL
B4	-0.2082	
B5	0.3729	
B6	-0.1382	
B7	0.1902	
B4 & B5		.10781
Intercept	-0.3123	-3.8573
Correlation Coefficient	0.8939	0.7085
F-Value	12.921	16.123
Degrees of Freedom	4/13	1/16
Significance Level	97.5	75
Order of Selection	B5,B4,B6,B7	B4 & B5
Percent Classified correctly	100%	83%

4.2.3.2 Standard ERL Pattern Recognition. The standard pattern recognition technique at ERL is a table look-up implementation of a maximum likelihood classifier known as ELLTAB (See Clay Jones, "Implementation of an Advanced Table Look-up Classifier for Large Area Land-Use Classification", Proceedings of the Ninth International Symposium on Remote Sensing of Environment, 1974). Data from July 24 were processed with this classifier and the results were compared to those obtained with the discriminant function classification. There appeared to be more area classified as with fish with the ELLTAB classification, but manipulation of a priori probabilities and thresholds permitted reduction of the with fish areas to approximately 15% of the total water scene.

Because the ELLTAB computer program has very rigid input requirements and sometimes requires several iterations to get a good product, a simpler likelihood classifier was also investigated. While the results of applying this classifier to the July 24 data are not complete, they appear to be almost identical to those provided by ELLTAB. This classifier was also used for processing July 19, 1976 data for the rapid turn-around experiment. Again, the results were very comparable to the classification achieved with the discriminant function analysis.

4.3 LANDSAT MENHADEN AND THREAD HERRING RESOURCE INVESTIGATION EXTENSION (1976)

The extension of the LANDSAT Menhaden and Thread Herring Resources Investigation (LANDSAT Proposal No. 20770) pursued two objectives related to the definition and development of a satellite remote sensing system for fishery harvest and management. The extension was based on preliminary findings from the parent investigation which indicate that water color measured with the LANDSAT multispectral scanner (MSS) could be used to predict menhaden distribution in the northern Gulf of Mexico.

The test area for the extension included the Louisiana study area (south of Atchafalaya Bay) used in the parent investigation but extended westward to encompass three adjacent LANDSAT ground tracks (Figure 4.7). LANDSAT overflights occurred on three consecutive days.

As in the parent investigation, the primary test species was Gulf Menhaden (Brevoortia patronus). Thread herring (Opisthonema oglinum) was a secondary test species.

A detailed description of the experiment extension can be found in a document entitled "Extension of the LANDSAT Menhaden and Thread Herring Resources Investigation - Field Operations Plan", July 15, 1976, Rev. 1.

4.3.1 Data Processing Preparations. The initial data processing plans were developed and documented in a field operations report. Special attention was given to the operational system simulation because of the critical nature of time in acquiring data at the Goddard Space Flight Center (GSFC) one day and providing fishing predictions the next. This was to be the "acid test". Hardware or personnel failures in terms of time could have disastrous effects on the concept of satellite applications to fisheries.

The first data processing plan is shown in Figure 4.8. It identifies events, data flow, and schedules for the operational system simulation. Fishing data collected from vessels and aircraft would be used at GSFC to determine if the simulation should be aborted to another day. The fishing data would also be used to identify training samples for LANDSAT MSS data classification into high and low probability fishing areas.

In preparation for the simulation experiment, "dry runs" were made to determine if the initial timing schedules for GSFC and Slidell data processing could be attained. The first dry run at GSFC on a test data set took about 5 hours to complete, which was within the alloted 6-hour period. A second dry run at GSFC reduced processing time to 3 hours. While this was an excellent reduction in time, the lack of earlier commercial airline flights to New Orleans prevented its application to the overall schedule. It did, however, serve to ensure that GSFC processing could be completed easily within the alloted 6 hours.

On July 10, 1976, the first dry run of the Slidell portion of the operation was attempted. After 16 hours of processing, only about 65% of the work was completed. The remaining portion had to be delayed for 3 days due to other hardware commitments. The dry run took about 25 hours to complete which was greatly in excess of the alloted 8-hour period. The single most significant problem encountered during this dry run was image registration (i.e. geographically referencing the pixels). Based on this information, a second processing sequence was developed which even though more complex should reduce processing time (Figure 4.9).

TEST AREAS FOR LANDSAT OVERPASSES

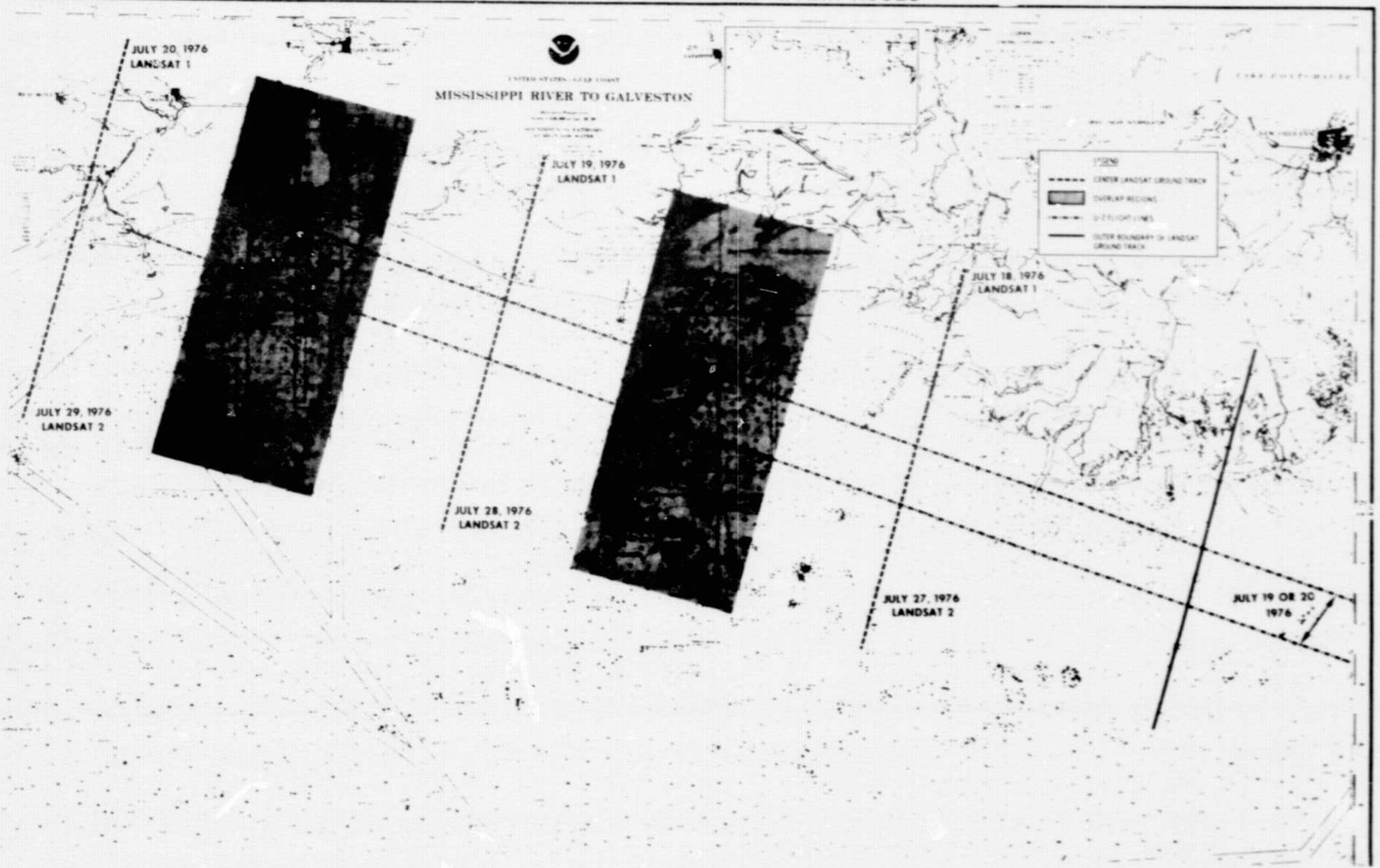

Figure 4. 7. Test Areas for LANDSAT Overpasses

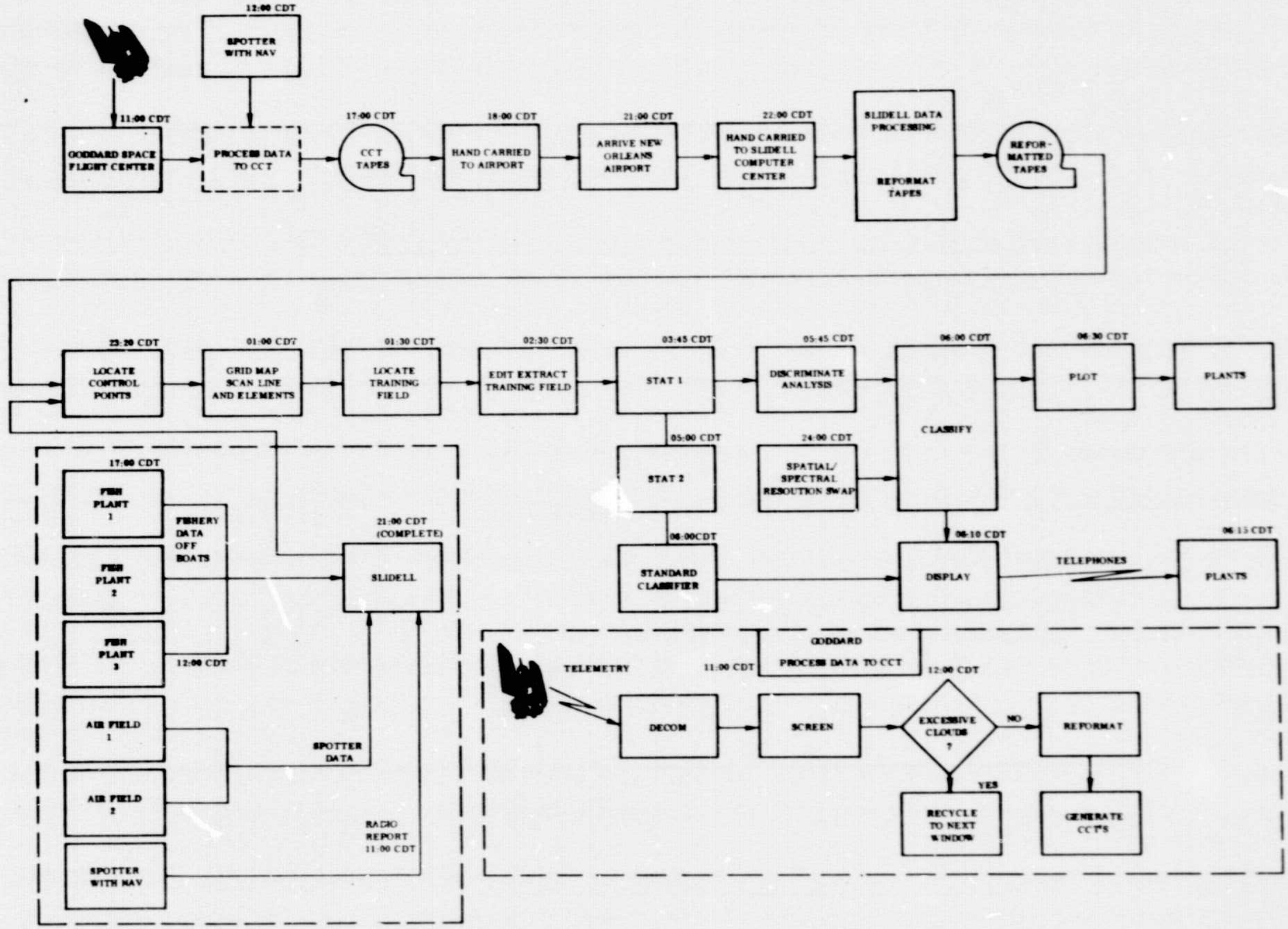

Figure 4.8. Events and Data Flow for Operational System Simulation

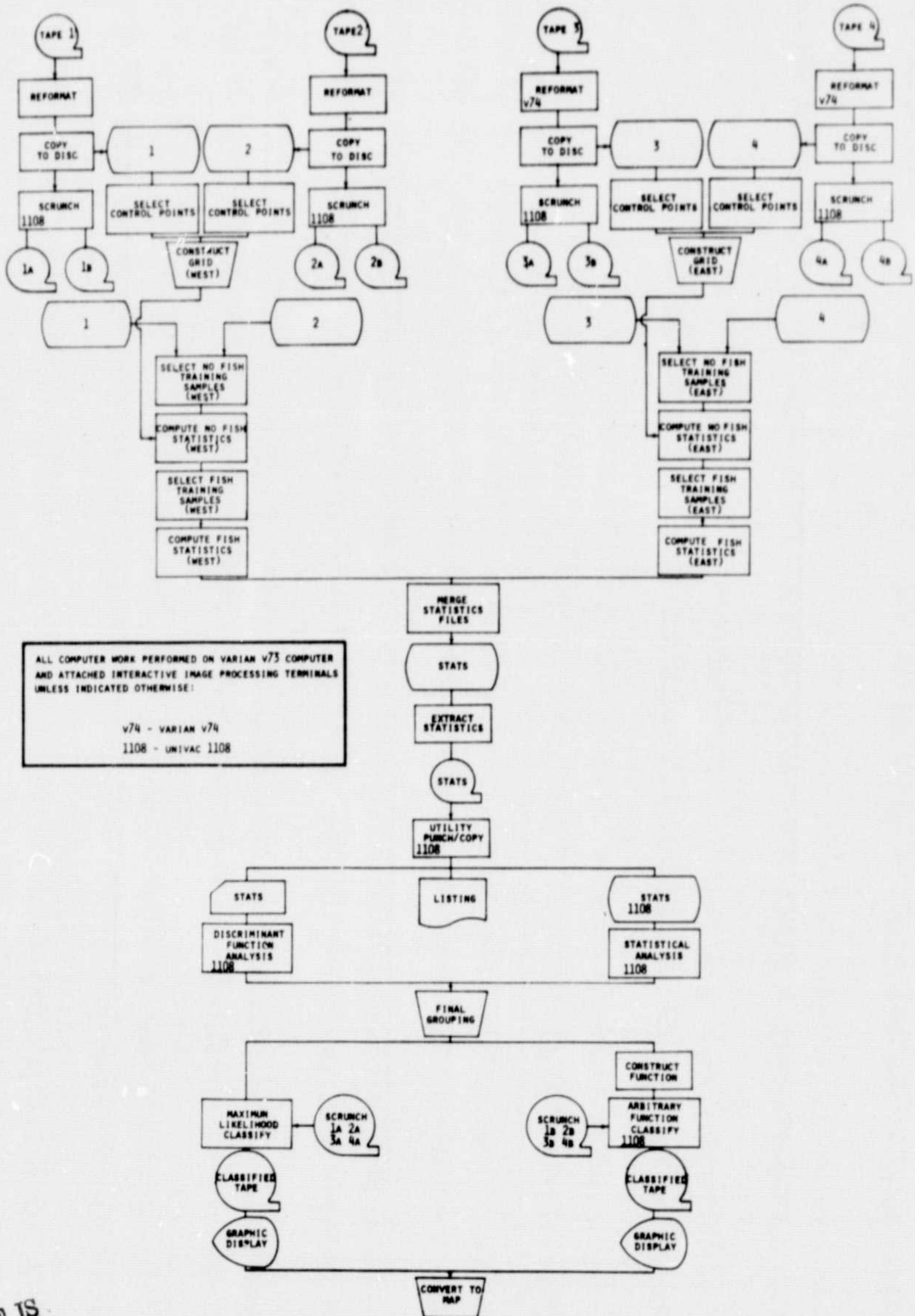

Figure 4.9. Slidell Data Processing Flow Diagram

On July 16, 1976, a second attempt was initiated to process a set of test data within the allotted time period at Slidell. This second dry run required 14 hours to complete. Thus, the new procedure reduced processing time by 11 hours; unfortunately, this was still not enough. The dry run, however, did highlight some problems which, if eliminated, could bring the processing operation down into the allotted time period.

4.3.2 Field Operations. Figure 4.10 presents a summary of planned data acquisition by platform and day. Fishing vessels without observers were to acquire set information (time, location, species, and number) on 5 days of the field operations. The fishing vessels with scientific observers aboard were scheduled to acquire fishing and oceanographic data everyday (fishing generally does not occur on Saturday and Sunday). These latter vessels also were equipped with Loran-C navigation system for improved location information. Spotter aircraft were scheduled to collect fish location, identification, and abundance information on three days of each fishing week. One aircraft was equipped with a Loran-C unit. Two oceanographic vessels were used to collect sea truth information on the 19th or 20th of July.

A summary of data actually acquired during the two-week operation period is given in Figure 4.11. While not all of the platforms provided data as planned for a variety of reasons, enough redundancy had been constructed in the plan to ensure a successful operation.

While the U-2 ocean scanner flight was not a contractual part of the extension, it is reported on here for completeness. Both flight lines were flown during the morning of July 20, 1976. The pilot reported 60% cloud cover over the eastern portion of the flight lines and about 20% over the western end. Color scanner data have been sent to Goddard for processing and delivery is expected in September 1976. These data will be used to optimize spectral regions and bandwidths for fishery applications.

Color scanner data test tapes were provided by GSFC and programs to reformat the data are being prepared. Final processing of the scanner data is expected next summer (1977). Photographs from the 4-band 70mm camera aboard the U-2 were received and are of good quality. These photographs probably will be used to establish the accuracies of some of the menhaden catch information.

Figure 4.12 shows the number of fishery data sets taken by day during the field operations period. A total of 365 fish school locations were recorded.

The most critical days of the field operation period were July 19 and 20, 1976, because of the operational system simulation objective. The information given in Figure 4.12 (92 and 44 fish locations for the 19th and 20th, respectively), however, is somewhat misleading for these two days. Less than half of the fish school locations were usable for training or test samples as many were located under a heavy cloud bank which obscured about 20% of the coverage area. Additionally, some of the data are questionable insofar as position accuracy. More data may be forthcoming as some pilots and vessel captains may not have mailed in their data sheets prior to the writing of this report.

SUMMARY OF PLANNED LOUISIANA LANDSAT MISSION (1976)

PLATFORM		MAIN	DATE (JULY 1976)							MAIN [2]			
	18 SUN	19 MON	20 TUE	21 WED	22 THU	23 FRI	24 SAT	25 SUN	26 MON	27 TUE	28 WED	29 THU	30 FRI
FISHING VESSELS		X	X							X	X	X	
FISHING VESSELS WITH OBSERVERS (8)		X	X	X	X	X			X	X	X	X	X
SPOTTER AIRCRAFT	X	X	X							X	X	X	
SPOTTER AIRCRAFT WITH LORAN-C	X	X	X							X	X	X	
RESEARCH VESSELS (2)		X	X										
U-2 AIRCRAFT		X	X[1]										
LANDSAT I	X	X	X										
LANDSAT II										X	X	X	

1. Planned as back-up mission
2. Rescheduled as supplementary upon successful July 19 mission

Figure 4.10. Summary of Louisiana Test Site Missions (1976)

SUMMARY OF ACQUIRED DATA FOR LOUISIANA LANDSAT MISSION (1976)

PLATFORM		MAIN	DATE (JULY 1976)										
	18 SUN	19 MON	20 TUE	21 WED	22 THU	23 FRI	24 SAT	25 SUN	26 MON	27 TUE	28 WED	29 THU	30 FRI
FISHING VESSELS		X	X	X	X	X							
FISHING VESSELS WITH OBSERVERS (8)		X	X	X	X	X			X	X	X	X	X
SPOTTER AIRCRAFT	X	X	X	X						X			
SPOTTER AIRCRAFT WITH LORAN-C		X									X		
RESEARCH VESSELS (2)			X										
U-2 AIRCRAFT			X										
LANDSAT I	X	X	X										
LANDSAT II										X	X	X	

Figure 4.11. Summary of Acquired Data for Louisiana Test Site Missions (1976)

DAY	VESSELS WITH OBSERVERS								CAPTAINS	SPOTTERS	SPOTTER	TOTALS
	1	2	3	4	5	6	7	8	NO. OBSERVERS	OMNI	LORAN-C	
7/18	-	-	-	-	-	-	-	-	-	15	-	15
7/19	7	4	2	8	7	5	3	7	3	29	17	92
7/20	6	6	3	2	-	3	1	4	3	16	-	44
7/21	5	-	4	3	7	3	2	7	2	4	-	37
7/22	2	5	-	6	-	1	2	5	5	-	-	26
7/23	-	-	-	1	3	-	2	3	2	-	-	11
7/26	5	2	3	7	7	4	3	7	-	-	-	38
7/27	3	1	2	4	1	4	3	5	-	3	-	26
7/28	5	2	4	4	6	4	3	6	-	-	13	47
7/29	2	4	2	8	3	3	2	-	-	-	-	24
7/30	1	2	-	1	-	-	-	1	-	-	-	5
TOTALS	36	26	20	44	34	27	21	45	15	67	30	365

Figure 4.12. Number of Reported Fish School Locations

4.3.3 Data Processing, Analysis, and Preliminary Results. Data processing and analysis to date has concentrated on the operational satellite system simulation objective of the experiment. From previous analyses, water color data acquired by the LANDSAT multispectral scanner indicated that the particular types of water in which the fish were most often found could be identified and discriminated from water which did not typically contain commercially significant numbers of the menhaden.

Current satellite systems capable of providing the multispectral data are not designed for real-time applications, and it is difficult to assess the significance of the resource distribution prediction without near real-time dissemination of the distribution data to the field. Consequently, special arrangements were made with GSFC to preprocess LANDSAT multispectral data immediately upon receipt from the satellite and supply it to the ERL and FEL for near real-time analysis. Calibration data were provided on the same basis from industry spotter pilots working in the study area and scientific observers placed on commercial menhaden vessels by FEL.

The day prior to the principal satellite pass (July 19, 1976), scientific observers boarded eight menhaden vessels at ports across western and central Louisiana. The satellite was due to pass over west-central Louisiana, covering the area from Sabine to Marsh Island, so vessels expected to be fishing in that area were selected. Two menhaden spotters were made available to the investigation the day before the main pass to determine the prime areas for the study and to provide precise fish school locations in the zone of overlap between that day's LANDSAT pass and the pass of the principal day. An abundance of fish were present in the study area.

The satellite passed over the area at 10:25:50 CDT, a time at which the entire western portion of the test area was completely free of clouds and the eastern part was approximately 50% cloud covered. The transmission of the data from the satellite to the GSFC was completed successfully.

Representatives from FEL and NFMOA were situated at GSFC on July 19, 1976 to review the satellite data shortly after reception. Information pertaining to fish school locations was telephoned to them at about 1100 hrs. (CDT) so that they could evaluate the significance of clouds in the coverage area.

The LANDSAT data were received at GSFC at 1027 CDT. The first quick-look at the imagery was at 1115 CDT. At that stage, the recording process introduced severe scan line dropout in the data. The input data were re-recorded three times until the scan line problem was eliminated. The image was then framed such that it contained approximately 50% land and 50% water.

The early fishing reports placed most of the school locations in the easternmost portion of the image which was heavily cloud covered. The go/no-go decision was postponed until further fishing reports could be received. Personnel at GSFC, however, continued to process the data to CCT format. A decision to go was finally reached at about 1330 CDT. Two complete sets of CCT's were delivered to the FEL representative at 1500 CDT. The tapes were then hand-carried via commercial airliner to Slidell. Arrival was at 2045 CDT. By the time of the arrival of the tapes, locations of fish schools set on by the fleet or identified by the spotter pilots had been plotted on navigation charts. Locations were made using Loran-C or VHF omnidirectional VOR navigation.

The first step in processing the LANDSAT imagery at ERL was to reformat the four image tapes into a format compatible with ERL software. This was performed simultaneously on Tapes 1 and 3 and then on 2 and 4 using ERL's Varian V-73 and V-75 computers (Figure 4.9). As soon as a tape was reformatted, it was read into disc storage to facilitate access by the two Comtal 8100 Image Processing Systems (IPS). The original data tapes were received by ERL at 2045 CDT in the evening on July 19. The first two tapes (1 and 3) were ready for analysis by 2130 CDT.

One difficult phase of the processing was to correlate the LANDSAT image to the existing map base. To accomplish this, control points were identified in the image and on 1:250,000 scale U.S.G.S. maps. A grid of scan lines and elements was constructed on the map from the control points. These points had been previously identified using earlier satellite data, and the selection of points to use at this time was quickly accomplished, requiring about 10 to 15 minutes per tape, doing two tapes at a time. The grid was transferred to the navigation charts on which the schools had been plotted. The first tape was gridded on the map by 2345 CDT, the last tape by 0145 CDT, July 20. While the gridding was being done, training samples for areas where no fish were found were selected. Areas where no fish were caught either the day before or the day of the principal satellite pass were identified for "no fish" statistical analysis. The training samples were all selected by 0040CDT. Statistics for the "no fish" samples were computed using the Comtal systems at 2340 CDT for Tapes 3 and 4, but were not computed for Tapes 1 and 2 until later. Training data at the fish school locations were taken from 2345 to 0045 CDT on the IPS, after which the statistics were computed. All statistics for the individual fish and no fish training samples were complete by 0230 CDT. The data files containing the statistics for the two IPS's were merged and extracted onto magnetic tape in card image format, then taken to the Univac 1108 computer system which was used to simultaneously punch cards for each of the training samples and create a FASTRAN file for further analysis. The cards and new file were available at 0315 CDT.

A graphical display of the individual training samples was prepared which showed each sample as a function of the mean in the green and red channels. Preliminary grouping was performed using this display. The no fish data were divided into five groups, the fish data into two groups. At this point, FEL continued analysis of the grouped data using a discriminant function analysis technique while ERL conducted a detailed study of the distribution of the values and the separability of the groups. Two very similar groupings of training samples resulted and were ready for classification by 0455 CDT.

While the other analyses were underway, special tapes were prepared on the 1108 system which reduced the spatial resolution of the LANDSAT data to improve radiometric resolution. The final data had a distribution of 0 to 254 counts to represent the range of light intensities detected by the sensor, as opposed to 0 to 63 in the original data. Land and clouds were preclassified and set to a value of 255 in each spectral channel. These tapes were ready at 0200 CDT. A maximum likelihood classifier was applied to the tapes generated for use on the Varian system, but the tapes could not be read. After considerable difficulty determining the nature of the problem, new tapes were generated. This tape problem delayed the final product approximately one hour. Meanwhile, another computer program was written which generated the same type tapes on the V-73 system rather than the 1108 system, since it appeared that the problem was from use of the 1108's 9-track tape units as opposed to the standard 7-track units. The V-73 has only a 9-track capability. The newly generated tapes were classified using the maximum likelihood classifier by 0800 CDT July 20. Later analyses determined that the problem was an error in the program set up on the 1108 rather than a system malfunction.

The results of the discriminant function analysis were in the form of a function for each of the water classes (two fish and five no fish) These were programmed into the ERL software and implemented on the 1108 for Arbitrary Function Classification. The classifier was run four times on the radiometric resolution expanded tapes with a limitation that a point must fall within one, one-and-a-half, two, and three standard deviations of the mean of a particular class for it to be placed in that class. These classifications were complete by 0715 CDT July 20. At this time they were viewed on the PIDS and high probability fishing areas were marked on navigation charts. These results were transmitted to the commercial fleet. A further refinement of the classifications was made and at 0830 CDT the improved prediction was disseminated (Figure 4.13).

The commercial fleet reported that fish were concentrated in the high probability areas indicated by the analysis of the satellite data, and that they were having one of the best days of the season to date. A quantitative verification of this opinion was attempted by plotting the location of menhaden capture and observation on the prediction chart (also shown in Figure 4.13). If the school location areas which could not be classified due to cloud cover are ignored, one can see that the majority of the observations were in or adjacent to the high probability areas predicted from LANDSAT data.

While the commercial fisherman recognizes the LANDSAT did not put fish into the water, almost everyone contacted agrees that their fishing operations benefited tactically from the satellite predictions.

4.4 FUTURE PLANS. Emphasis for the next few months will continue to be given to the completion of analyses of LANDSAT MSS data for low and high probability fishing areas. Continued effort will be expended in the analysis of the July 19, 1976 LANDSAT MSS data in an attempt to remove possible training sample location errors created by positioning errors in the Loran-C instrumentation aboard a key spotter aircraft.

The analysis of remotely acquired temperature and salinity data should be completed within the next reporting period. These data will be combined with those from LANDSAT to determine if they will improve statistical precision of the classification algorithms.

5. SIGNIFICANT RESULTS

The most significant achievements realized by this investigation thus far include the successful charting of high probability fishing areas from LANDSAT MSS data and the successful simulation of an operational satellite system to provide tactical information for the commercial harvest of menhaden.

6. REPORTS, PUBLICATIONS, AND MEETINGS

Two manuscripts were proposed for publication which directly or indirectly related to the LANDSAT Investigation. Abstracts follow:

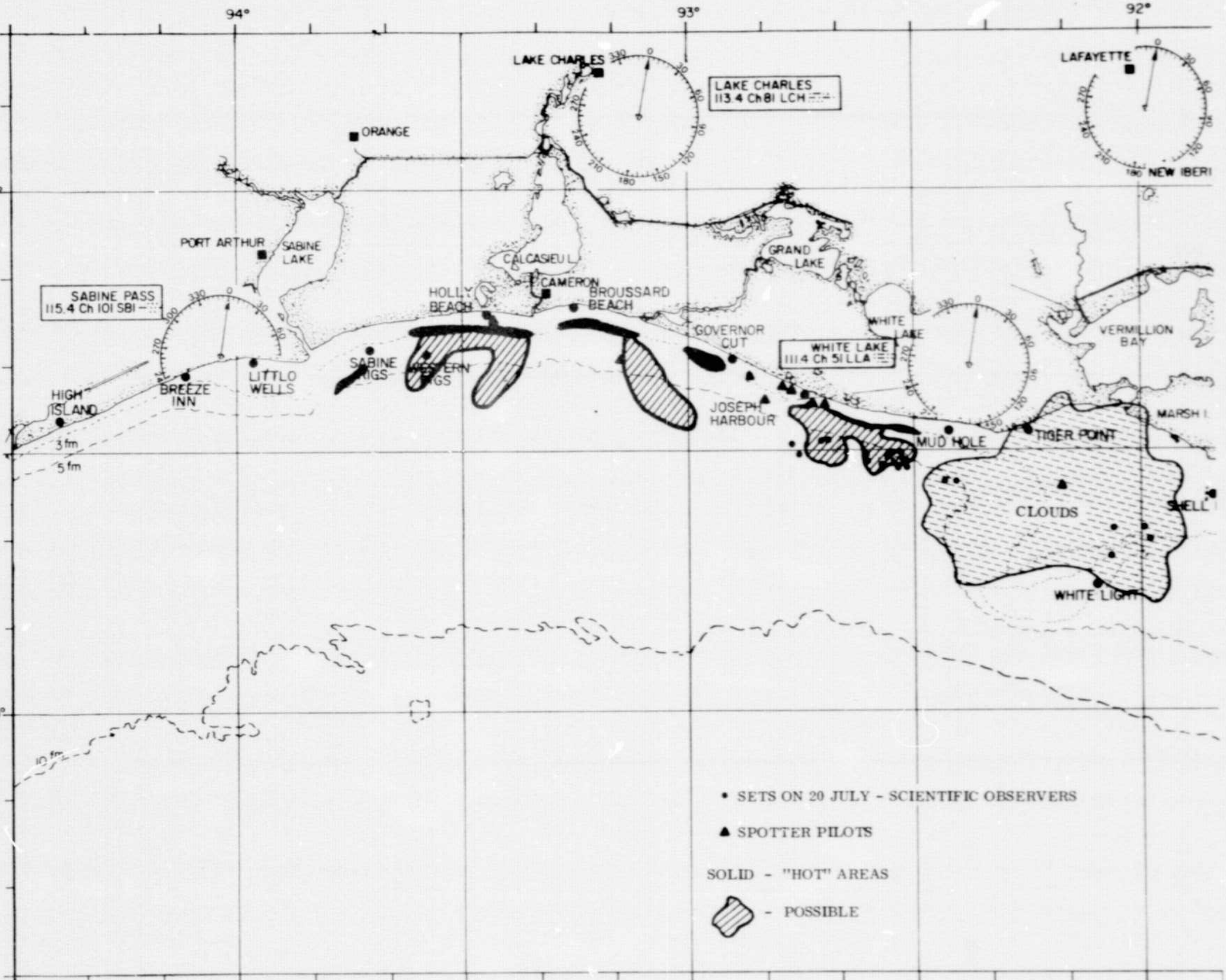

Figure 4.13. Predicted High Probability Fishing Areas for July 20, 1976 using July 19, 1976 LANDSAT MSS Data.

Faller, K. H., T. D. Leming, and J. T. Brucks. 1976. Synoptic Oceanographic Measurements in a Coastal Environment. Paper presented at the 39th Annual Meeting of the American Society of Limnology and Oceanography, Savannah, Georgia, 21-24 June 1976.

Coastal waters are frequently typified by rapidly varying conditions. When surveys are conducted using surface vessels sampling along transect lines, the observations reflect not only the spatial variation of the oceanographic parameters under study, but the time-dependent variation as well. Techniques for the remote measurement of oceanographic parameters from aircraft and satellite provide a means for surveying wide areas in a very brief period of time, during which conditions at any given point can be considered relatively constant. This permits the oceanographer to gain a synoptic view of an area under study. Techniques are available for remote measurement of surface temperature, salinity, and turbidity from aircraft, and of temperature and turbidity from satellite. Techniques are currently being developed for the remote measurement of chlorophyll content. Mappings of salinity, temperature, and turbidity based on surface and remote measurements are compared for the Mississippi Sound and an area of the Gulf of Mexico off the Louisiana Coast.

Kemmerer, A. J. and J. Butler, 1976. Finding Fish with Satellites. Marine Fisheries Review (In Press).

The LANDSAT Investigation began in April 1975 to determine if satellites can be used to help fishermen find fish. The cooperative government, industry, and academic study uses a multispectral scanner in LANDSAT satellites to measure certain ocean features for determination of good fishing areas for menhaden and thread herring. Two study areas were selected for field operations during the 1975 menhaden fishing season; the eastern portion of Mississippi Sound and 5200 square km area off the Louisiana Coast. Aircraft sensors, fishing vessels, spotter pilots, research vessels, and offshore oil platforms were used to collect supplementary and corrobrative data for the satellites on chlorophyll, surface water temperature, salinity, color, turbidity, and fish school location and size. The data are computer processed and analyzed to determine if and which of the environmental ocean features measurable by aerospace remote sensors can be used to predict best fishing areas for menhaden and thread herring. Data analyses so far indicate that water color and turbidity are strong factors affecting the presence of menhaden. Surface temperature and salinity do not appear to be decisive factors. The impact of chlorophyll has not yet been determined pending completion of analysis. The study will be completed and a final report prepared by February 1977.

A joint NOAA and NASA press release coordinated with NFMOA was prepared during the reporting period which emphasized the operational system simulation effort:

SPACE TECHNOLOGY APPLIED TO FISHERIES RESEARCH

A team of fishermen, engineers, physicists, oceanographers, biologists and computer specialists have "found" fish with a satellite in a unique experiment off the Louisiana coast. This exercise represents the culmination of a larger effort -- the LANDSAT Menhaden and Thread Herring Investigation -- which began last year.

Investigating the feasibility of using satellite data for assessing fisheries resources in the northern Gulf of Mexico, and thereby enhancing management of them, has been a cooperative industry-Federal Government project. Working together have been personnel from the Earth Resources Laboratory of the National Aeronautics and Space Administration (NASA), and Southeast Fisheries Center of the National Marine Fisheries Service (NMFS), and boats, planes, and their crews from member companies of the National Fish Meal and Oil Association.

Their work has shown that there are relationships between the distribution of menhaden and water turbidity--which the LANDSAT sensor measures as water color. From the water colorations sensed by LANDSAT, scientists can infer the probable presence or absence of menhaden. The satellite cannot sense, or "see" fish directly. Menhaden vessels, fishing under the direction of their spotter pilots, confirmed the presence of menhaden in most, though not all, of the high probability concentration areas predicted by analysis of LANDSAT data, while special navigation systems plotted the locations of the fish precisely and scientific observers on board several vessels collected water samples.

Thus they validated a technique for locating fish concentrations from space which may lead to a greatly improved understanding of coastal fishery ecology and to better methods for resource assessment.

The analysis of LANDSAT data in near "real-time" began when LANDSAT I passed over the selected study area in the late morning hours of July 19, 1976, sending electromagnetic multispectral scanner data to a receiving station at the Goddard Space Flight Center in Greenbelt, Maryland. At the receiving station, NASA, NMFS, and NFMOA investigators reviewed the data prior to storing it on four large magnetic tapes. The tapes were then hand-carried to the NASA Earth Resources Laboratory in Slidell, Louisiana, where another team of scientists further processed the satellite's information, geographically referenced it, and analyzed it for high probability menhaden areas. At approximately 7:15 a.m. on July 20th, less than 21 hours after the satellites began viewing the study area, the first telephone calls were made to inform spotter pilots and vessel captains of the probable locations for menhaden so that they could compare and check their vessel findings with the scientific predictions as an experimental control. Early reports from the fishing industry indicate that the satellite did its job well.

While the test was a success, considerably more work will be required before an operational satellite system can be made available for application to fishery problems. At best, three to five years must pass before such a system could become operational. Other coastal, and perhaps oceanic, species will have to be considered and additional investigations may be required. Special computer programs and facilities will have to be developed. The concept, however, has been demonstrated and that should make future efforts easier.

A series of informal meetings were held with NFMOA representatives during the reporting period primarily to prepare for the July 1976 field operations. Other meetings included:

<u>July 9, 1976</u>: Briefing of contractor personnel at GSFC on the LANDSAT Investigation with emphasis on the simulation objective.

<u>July 11, 1976</u>: Briefing of vessel captains and spotter pilots on the parent and extension portions of the LANDSAT Investigation in Cameron, Louisiana.

<u>July 18, 1976</u>: Briefing of vessel captains and spotter pilots on the parent and extension portions of the LANDSAT Investigation.

7. PROBLEMS

Clouds continue to interfere with the analyses of LANDSAT MSS data. This is particularly frustrating because of the apparent strong relationship between these data and menhaden distribution. Fortunately, only one main mission out of the attempted six is a total loss.

Potential errors in positioning some of the menhaden training samples used in the classification of the July 19, 1976 data have been identified. This problem is presently being investigated and will be corrected if possible.

8. RECOMMENDATIONS

No recommendations are presented at this time.

9. FUNDS EXPENDED

Purchase orders and other expenditures directly attributable to this investigation total $201,171.

10. LANDSAT DATA

Table 10.1 summarizes LANDSAT 1 and 2 ordered in support of this investigation. These data are being used to establish relationships between the distribution of menhaden and thread herring and their ocean environment as manifested in the LANDSAT spectral channels.

11. AIRCRAFT DATA

Table 11.1 summarizes the status of data acquired with sensors aboard the NP3A. These data were primarily used for computing salinity conditions in the two test sites.

Table 10.1 Summary of LANDSAT Data Status

Mission Date	Satellite	Ident. Code	Data Quality	Value of Data Ordered ($) 9"X9" Transparency Pos.	Neg.	CCT
April 25	I	5006 - 15485	Fair	20	24	200
May 2	II	2100 - 15445	Poor	20	24	-
May 13	I	5024 - 15480	Fair	20	24	-
May 20	II	2118 - 15448	Good	20	24	200
May 21	II	5024 - 15473	Good	20	24	200
June 18	I	?	Not recieved	20	24	-
June 25	II	2154 - 15450	Excellent	20	24	200
July 24	I	5096 - 15435	Good	20	24	200
July 31	II	1290 - 15442	Not received	20	24	-
August 11	I	?	Not received	20	24	-
August 18	II	2208 - 15435	Excellent	20	24	-
August 20	II	2210 - 15554	Poor	20	24	200
Sept 5	II	?	Not received	20	24	-
Sept 16	I	?	Not received	20	24	-
Sept 23	II	?	Not received	20	24	-
July 19 '76	I	5457 - 15255	Excellent	-	-	-
July 27 '76	II	2552 - 15485		-	-	-
July 28 '76	II	2553 - 15543		-	-	-
July 29 '76	II	2554 - 16001		-	-	-
		TOTALS		300	360	1860

Table 11.1 Aircraft Data (NP3A) Status

Mission Date 1975	Microwave		PRT-5		M^2S		Photography (Boresight)	
	Status	Quality	Status	Quality	Status	Quality	Status	Quality
April 25	In lab	Good	In Lab	Good	In lab	Good	In lab	Poor
May 2	In lab	Adequate	In Lab	Adequate	NA	NA	In lab	Poor
May 13	In Lab	Good	In Lab	Good	In lab		In lab	Poor
May 20	In lab	Good	In Lab	Good	NA	NA	In lab	Poor
July 24	NA	NA	NA	NA	NA	NA	NA	NA
July 31	NA	NA	NA	NA	NA	NA	NA	NA
August 20	In Lab	Good	In Lab	Good	In lab	Good	In Lab	Poor
Sept 5	In Lab	Good	In Lab	Good	NA	NA	In Lab	Poor