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

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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.

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PREFACE

This progress report covers the investigative period from January 31, 1976 to April 30, 1976. It represents the fourth 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 one summarized initial analytical efforts. This report emphasizes results from analyses of LANDSAT MSS data.

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 fourth 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 January 31, 1976 to April 30, 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. This fourth in a series of type II progress reports emphasizes the analytical efforts of the investigation.

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.

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)

Nicholls State University

Four Oil Companies

3. SUMMARY OF EARLIER REPORTS

As the first three 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. 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.

Figure 3.1 Main Day Mission Data Acquisition Platforms and Parameters

Parameter	SURFACE				AIRCRAFT					SATELLITES	
	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.

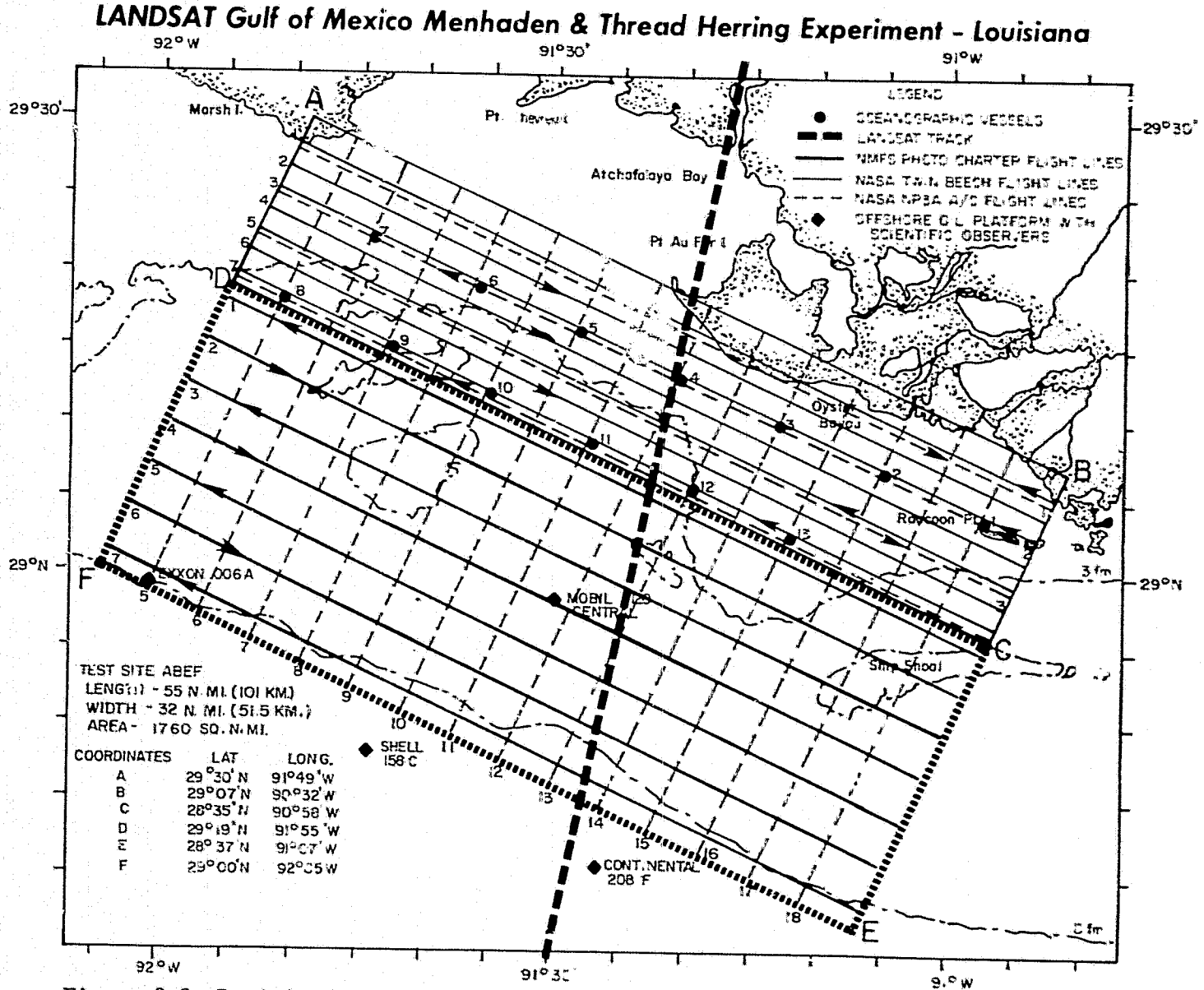

Figure 3.2 Louisiana Study Area Showing the LANDSAT Track, Aircraft Flight Lines, Oceanographic Stations, and Oil Platform Locations

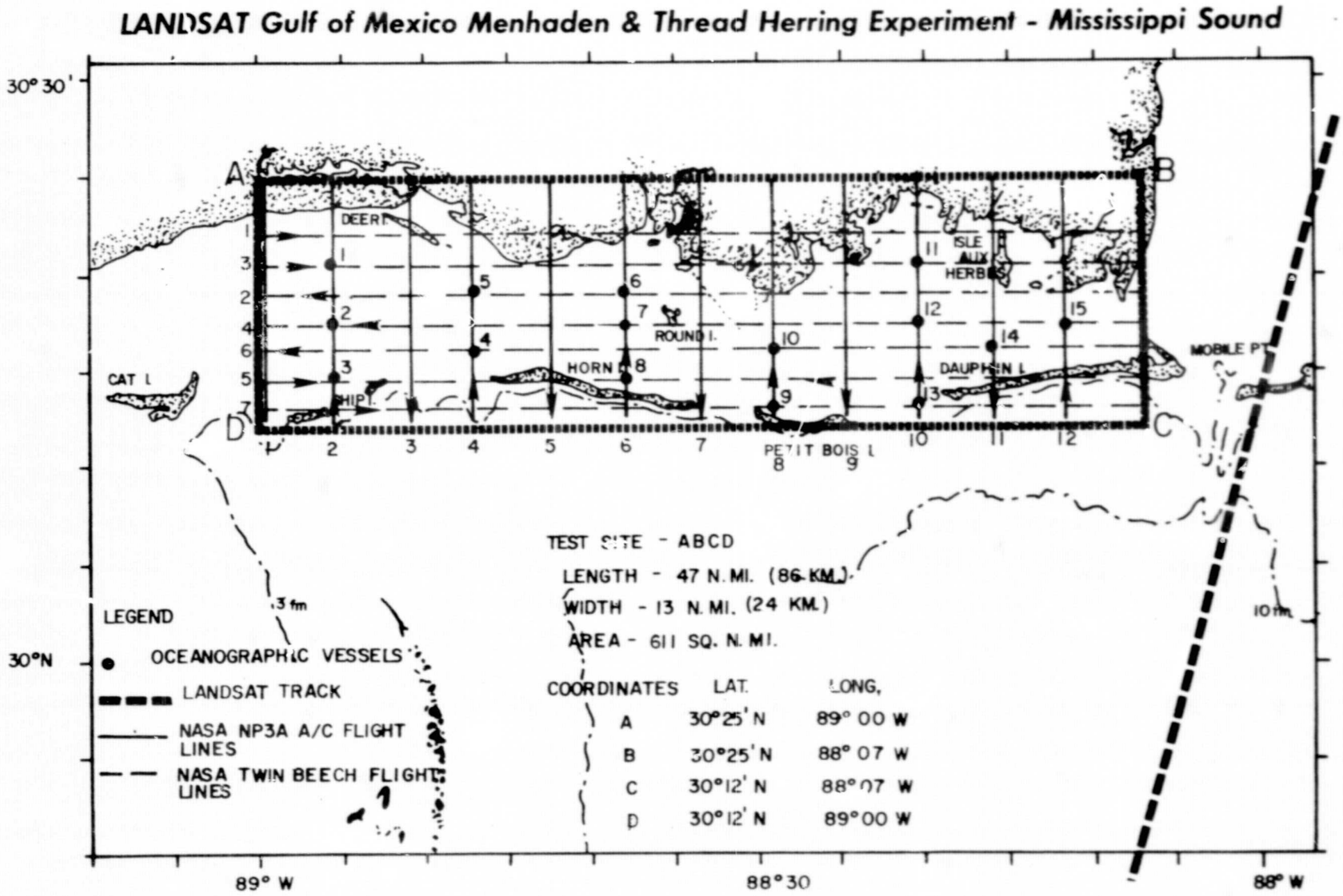

Figure 3.3 Mississippi Sound Study Area Showing the LANDSAT Track, Aircraft Flight Lines, and Oceanographic Stations

SUMMARY OF LOUISIANA LANDSAT MISSIONS (1975)

PLATFORM	MISSION DATE	MAIN APR 25	MAIN MAY 13	SUPPLE-MENTARY JUN 18	ABORTED MAIN [1] JUL 24	SUPPLE-MENTARY AUG 11	RESCHED-ULED MAIN AUG 20	SUPPLE-MENTARY AUG 29	SUPPLE-MENTARY 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

SUMMARY OF MISSISSIPPI SOUND LANDSAT MISSIONS (1975)

PLATFORM	MISSION / DATE	MAIN MAY 2	MAIN MAY 20	SUPPLE-MENTARY JUN 25	ABORTED MAIN 1 JUL 31	SUPPLE-MENTARY AUG 18	MAIN[2] SEP 5	SUPPLE-MENTARY 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

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.

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.

A major feature of the initial analytical efforts is they emphasized May 20, 1975, a main mission day for the Mississippi Sound. The rationale was to select one mission for emphasis such that all remotely acquired data (temperature, salinity, and LANDSAT MSS) could be processed for analysis along with the sea truth and fishing data. LANDSAT MSS data from the May 20 mission were classified into low and high probability fishing areas using a parallelepiped classifier. The results indicated accuracies of 85 to 90 percent. The MSS data from the 1972-1973 ERTS-1 menhaden experiment also were classified with acceptable accuracies. Linear and non-linear multiple regression models for menhaden distribution were developed for the May 20 data set using LANDSAT MSS data. The results were good indicating statistically significant relationships between radiance values and menhaden distribution (correlation coefficients ranged from 0.54 to 0.64)

4. ACCOMPLISHMENTS

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

Recent data processing efforts have concentrated on preparation of the surface truth and fisheries data for correlation analyses. This is now about 50 percent complete. Computer generated composite point plots for all main day missions (3 in the Mississippi Sound and 3 off the coast of Louisiana) have been prepared for surface water temperature, Forel-Ule color, secchi disc transparency, salinity, and menhaden locations. These data came from observers aboard fishing vessels, fishing vessel captains, spotter pilots, aerial photography, and 3 research vessels. Contour maps for each of the above oceanographic parameters have been prepared for 3 main mission days: April 25 (Louisiana), May 13 (Louisiana), and May 20 (Mississippi Sound), 1975. Data sets for with and without menhaden areas have been developed from the contour maps for statistical analysis.

4.2 DATA ANALYSIS

4.2.1 Salinity Measurements: With the receipt of the PRT-5 data acquired by the NP3A aircraft, determination of salinities from the microwave radiometer data has progressed well. Data from April 25, 1975 (Louisiana) have been processed to the point of developing a listing of sea surface salinity at half mile intervals along each flight line. There were no serious difficulties encountered with this data set.

The data set from the May 2, 1975 (Mississippi Sound) mission is presenting significant problems. There appears to be a large noise component having a period of approximately 80 seconds superimposed on the microwave signal. This noise component is being removed using digital filtering techniques. A more serious problem, however, has resulted from the mission being flown several hours later than scheduled. At the time the mission was flown, the central point of the solar specular reflection pattern was well within the field of view of the L-band antenna for the flight lines flown west to east and north to south, resulting in microwave energy emitted by the sun being reflected from the water directly into the antenna. This causes the apparent microwave radiometric temperature of the sea surface to increase drastically. Efforts are currently underway to compensate for this problem.

The data acquired during the May 13, 1975 mission (Louisiana) have been processed and are currently being geographically referenced so that listings of salinity by latitude and longitude along the flight lines can be developed. The data appear to be of good quality.

LANDSAT DATA FLOW

Mission No. 1
Date 25 April
Site Louisiana

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

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					
	M^2S	No										
	PRT-5	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

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				
	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

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	
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	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

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							
	M^2S	X	X	X								
	PRT-5	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

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					
	M^2S	No										
	PRT-5	X	X	X	X	X	X					
LANDSAT	Imagery	X										
	CCT	X	not ordered									

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

The data from the September 5, 1975 mission (Mississippi Sound) are currently being analyzed, and appear to be of acceptable quality. There is, however, an unsolved problem concerning the calibration of these data, but this is expected to be resolved shortly. Specular reflection of the sun again appears to be a problem, although fairly minor. The problem manifests itself in significantly higher radiometric microwave temperatures on the southbound flight lines.

The microwave data from the August 20, 1975 mission (Louisiana) have been run only through the first stages of processing. No serious problems have been noted at this time.

Salinity processing for data from all 6 main day missions is expected to be completed by the end of May 1976.

4.2.2 Surface Truth Analysis: Correlation and multiple regression analyses were applied to surface truth data from 3 main missions: April 25 (Louisiana), May 13 (Louisiana), and May 20 (Mississippi Sound). Correlation coefficients for each of the parameters tested are given in Table 4.1.

Table 4.1 Correlation Coefficients for the Relationship of Menhaden Distribution to Selected Oceanographic Parameters

	Louisiana Test Site		Mississippi Sound
Parameter	April 25	May 13	May 20
Temperature	0.289**	0.234*	0.184*
Forel-Ule Color	0.286**	0.477**	0.434**
Salinity	0.211*	-0.050	0.048
Secchi Disc	-0.068	-0.329*	-0.202*
Chlorophyll-a	0.027	0.544*	Not avail.
Sample Size	70	40	80

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

A summary of the step-wise multiple regression analyses is shown in Table 4.2. 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.

Regression model correlation coefficients averaged about 0.55 for the three missions indicating fairly low levels of statistical precision. Several non-linear combinations of the parameters were also analyzed to try to increase precision without realizing much success (not presented). The models were, however, about 75 percent accurate in

classifying the study areas into with and without menhaden areas. Accuracy was computed from the sample areas used to develop the models.

Water color as inferred from Forel-Ule color measurements generally correlated the best with menhaden distribution (Table 4.1) and dominated the regression models (Table 4.2; see order of selection). Surface water temperature also correlated significantly with menhaden distribution which is contrary to earlier conclusions developed from an analysis of samples from the fishing vessels.

The relatively low level of precision associated with the secchi disc measurements was disappointing especially since the same measurements at sites of menhaden capture did suggest a good relationship between water clarity and menhaden distribution. The relatively low level of precision associated with the salinity measurements was not unexpected.

Table 4.2 Summary of Step-wise Multiple Regression Analyses

Parameters and Regression Statistics	Regression Coefficients Louisiana Test Site April 25	May 13	Mississippi Sound May 20
Temperature	0.0565	-0.0569	0.1527
Forel-Ule Color	0.0762	0.0337	0.0876
Salinity	0.0467	0.0230	0.0543
Secchi Disc	-0.0566	-0.0219	-0.0938
Chlorophyll-a	-0.0319	0.0471	not avail.
Intercept	-2.2793	1.1051	-5.3546
Correlation Coefficient	0.516	0.589	0.542
F-value	4.633	3.609	7.781
Degrees of Freedom	5/64	5/34	4/75
Significance Level	99.5	97.5	99.9
Order of Selection	T,F,Sa,C,Se	C,F,Sa,Se,T	F,T,Sa,Se

4.2.3 LANDSAT Analyses: Three distinct methods have been applied to LANDSAT MSS data for classifications of the study areas into high and low probability fishing areas. These methods include a parallelepiped, multiple regression, and discriminant function classifications. In addition, an attempt was made to combine LANDSAT MSS and surface truth data into a single predictive algorithm (Section 4.2.4).

Handling of the LANDSAT MSS data was similar for all classifiers. Initial preprocessing was done with original CCT's to identify land, water, and cloud pixels. Following this preprocessing, each MSS channel

was averaged over a six scan line by seven element wide matrix across the data set. The averages were multiplied by 4. Land and cloud pixel radiance values were not included in this averaging. The range of radiometric resolution was thus increased from 0 to 63 to 0-252 since only integers were used. The sacrifice in spatial resolution probably is not critical.

Locations of menhaden schools used in classifier analyses were determined from aerial photography, spotter aircraft reports, and fishing vessel reports, and translated into the LANDSAT coordinate reference system. Radiance data were extracted from the CCT's for each of the school locations where clouds did not obscure the sea surface. Areas where fish schools were not observed during the entire mission day were also identified and their radiance values extracted. These areas represent the with and without menhaden training samples used in most of the subsequent analyses.

4.2.3.1 Parallelepiped Classifier - Classifications based on the parallelepiped technique were partially reported on in the last progress report and as such only a brief review will be presented here.

The classifier was given limits of plus and minus one standard deviation of the means of the training samples. Figure 4.7 shows how the classifier was used to separate the Mississippi Sound into low and high probability fishing areas. In general, the classifier worked well for this mission except for several school locations in the right-center portion of the figure. These exceptions probably were due to cloud contamination of pixels which was not discriminated in the preprocessing.

The second attempt at using the parallelepiped method was for a June 25th supplementary mission in the Mississippi Sound. This mission was selected because of relatively little cloud coverage. Twelve fish school locations were used to develop the classifier algorithm and 18 to test it. Twenty-six of the total (30) classified correctly (87%).

Interestingly, most fish school locations from the following day (June 26, 1975) also fell into the high probability fishing areas (21 out of 24) developed from June 25th data suggesting persistence in the classified fishing areas.

An initial attempt to apply the parallelepiped classifier technique to July 24, 1975 data from the Louisiana Test Site was relatively unsuccessful. Most of the menhaden school locations failed to fall into high probability fishing areas. A further check of the data suggests that there may be three or four unique spectral signatures associated with the fish school areas which will have to be considered in classification algorithms. The data are now being reprocessed through standard pattern recognition software (ELLTABX - a high speed table look-up classifier) to classify the multiple categories of high probability fishing areas. In addition, two other classification approaches were used which are reviewed in the next two sections.

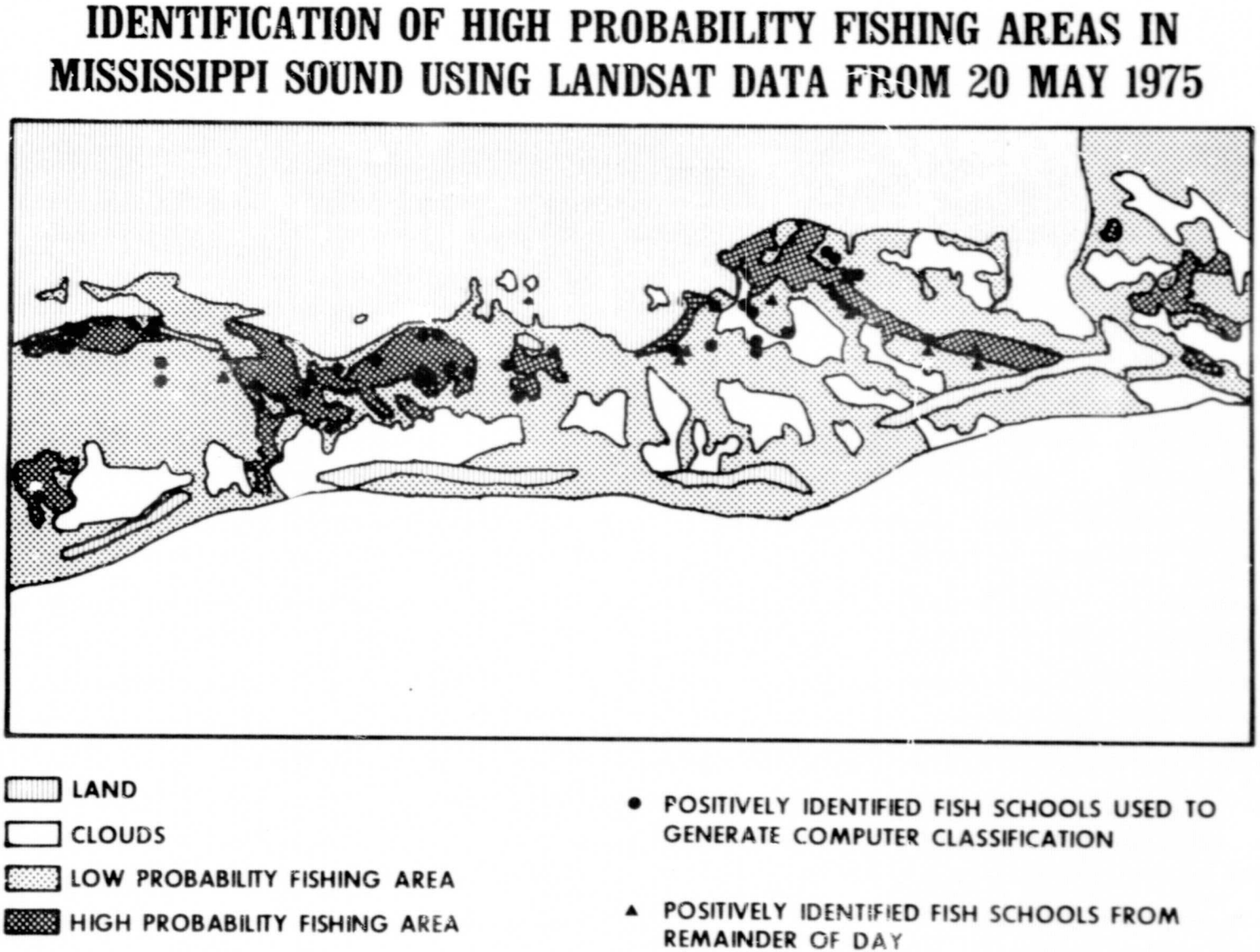

Figure 4.7 Example of a Parallelepiped Classification of LANDSAT MSS Data

4.2.3.2 Correlation and Multiple Regression Analyses - Preprocessed LANDSAT data for each spectral channel were compared to with and without menhaden sample areas through correlation analysis (Table 4.3). In general, channel 5 correlated more precisely than the other channels (exception July 24). Channel 6 also appeared to correlate well with menhaden distribution. Interestingly, channel 4 edged out the other channels in precision in the Louisiana Test Site. Whether or not significance should be given to this is unclear; however, intuitively channel 4's more precise correlation seems reasonable due to the relatively clearer waters in this test site. In addition, menhaden were generally caught in deeper waters off Louisiana than in the Mississippi Sound. Not shown are results from several power transformations of the spectral data which indicated that these transformations did not significantly increase precision.

Table 4.3 Correlation Coefficients for the Relationship of Menhaden Distribution to LANDSAT Spectral Data

	Louisiana Test Site		Mississippi Sound
MSS Channel	July 24	May 20	June 25
C4	0.540**	0.647**	0.461*
C5	0.521**	0.741**	0.822**
C6	0.448**	0.666**	0.685**
C7	0.379*	0.607**	0.300*
Sample Size	28	36	18

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

Multiple regression models were developed from MSS spectral data for the three missions (Table 4.4). 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%.

Table 4.4 Summary of Step-wise Multiple Regression Analyses of LANDSAT MSS Spectral Data

	Regression Coefficients		
MSS Channel and	Louisiana Test Site		Mississippi Sound
Regression Parameters	July 24	May 20	June 25
C4	-0.1087	-0.0287	-0.2082
C5	0.3035	0.3116	0.3729
C6	-0.4231	0.2888	-0.1382
C7	0.2580	0.5545	0.1902

Table 4.4 Summary of Step-wise Multiple Regression Analyses of LANDSAT MSS Spectral Data (Continued)

MSS Channel and Regression Parameters	Regression Coefficients: Louisiana Test Site July 24	Mississippi Sound May 20	Mississippi Sound June 25
Intercept	1.2710	-2.7863	-0.3123
Correlation Coefficient	0.736	0.762	0.8939
F-value	6.775	10.719	12.921
Degrees of Freedom	4/23	4/31	4/13
Significance Level	99.5	99.95	99.95
Order of Selection	C_4, C_7, C_5, C_6	C_5, C_6, C_7, C_4	C_5, C_4, C_6, C_7

The regression models were used to classify LANDSAT data into low and high probability fishing areas for each of the respective missions. The May 20th Mississippi Sound model classified 31 out of 36 training fields correctly or 86 percent. The June 25th Mississippi Sound model classified 18 out of 18 training fields correctly or 100 percent. The July 24th Louisiana model classified 26 out of 28 training fields correctly or 93 percent.

4.2.3.3 Discriminant Function Analysis - As previously mentioned (Section 4.2.3.1), the parallelepiped classifier was not successful in classifying MSS data from July 24, 1975 (Louisiana Test Site) into low and high probability fishing areas. This was probably due to the greater range of water conditions associated with menhaden schools compared to those in the Mississippi Sound. For this reason, a discriminant function classifier was developed for menhaden schools in three classes of water and three without fish areas. The function classified 27 of 33 training samples (with fish) correctly for an accuracy of 82 percent.

Additional work has been done with the discriminant function technique on Mississippi Sound MSS data for the June 25th mission. The technique classified 18 out of the total 18 training fields correctly for an accuracy of 100 percent. A discriminant function algorithm is being developed for May 20th MSS data.

4.2.4 Combination of LANDSAT and Surface Truth Data Analysis: Correlation and multiple regression analyses were done on May 20th data from the Mississippi Sound to determine if an improved classifier could be developed. Table 4.5 provides a comparison or correlation coefficients for the two data sets and demonstrates that MSS data correlate more precisely with menhaden distribution than the classical oceanographic parameters.

Table 4.5 Comparison of Correlation Coefficients for the Relationship of Menhaden Distribution to LANDSAT MSS and Surface Truth Data (May 20, 1975, Mississippi Sound)

Parameters	Correlation Coefficient
MSS Channel 4	0.643**
MSS Channel 5	0.746**
MSS Channel 6	0.676**
MSS Channel 7	0.638**
Temperature	-0.101
Forel-Ule Color	0.353*
Salinity	0.097
Secchi Disc	-0.289*
Sample Size	34

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

A multiple regression model was also developed from the two data sets (Table 4.6). A slight improvement in model precision was noted over an earlier model developed solely for MSS data (Table 4.4; correlation coefficient 0.762), but probably not enough to warrant the additional parameters.

Table 4.6 Summary of a Step-wise Multiple Regression Analysis of LANDSAT MSS and Surface Truth Data from the May 20th Mississippi Sound Mission

Parameter	Regression Coefficient
MSS Channel 4	0.0060
MSS Channel 5	0.2642
MSS Channel 6	-0.3335
MSS Channel 7	0.7481
Temperature	-0.0133
Forel-Ule Color	0.0475
Salinity	0.0361
Secchi Disc	-0.0287
Intercept	-3.2169
Correlation Coefficient	0.812
F-value	6.056
Degrees of Freedom	8/25
Significance Level	99.95
Order of Selection	C_5,F,Sa,C_7,C_6,Se,T,C_4

4.4 FUTURE PLANS. Emphasis for the next few months will continue to be given to analyses of LANDSAT MSS data for low and high probability fishing areas.

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

Analytical work will be initiated shortly on thread herring. Unfortunately, the scarcity of fishing data on these fish may preclude any but very general conclusions.

5. SIGNIFICANT RESULTS

The most significant achievement realized by this investigation thus far is the successful charting of high probability fishing areas from LANDSAT MSS data.

6. REPORTS, PUBLICATIONS, AND MEETINGS

An internal report was prepared specifically for vessel captains and crews, spotter pilots, and fleet managers who have been participating in the investigation entitled:

> "Can Satellites Help Fishermen Find Fish? A Special Report on the LANDSAT Menhaden and Thread Herring Resources Investigation", April 1976.

On May 4, 1976, a review of the operational phase of the investigation was presented at the Offshore Technology Conference in Houston, Texas. This presentation was entitled "An Operational Overview of the LANDSAT Menhaden and Thread Herring Investigation". An abstract was included in the last progress report.

Several meetings were attended since the submission of the last progress report where reviews of the investigation were presented.

February: A series of informal meetings were held with representatives of menhaden fishing companies to discuss the investigation in New Orleans, Dulac, Houma, and Empire, Louisiana, and Pascagoula, Mississippi.

March 15: A briefing on the investigation was given to NMFS Headquarters personnel in Washington, D.C.

March 15: A review of the investigation was given to NFMOA cooperators in Washington, D.C.

March 16: A review of the investigation was given at the Annual Meeting of the NFMOA in Washington, D.C.

March 17: A review of the investigation was presented to NASA Goddard personnel (including Dr. Freden) at NASA Goddard.

March 17: A review of the investigation was presented at the Gulf States Marine Fisheries Commission meeting in Brownsville, Texas.

April 5: A requested review of the investigation was given to four officials of the USSR at NSTL, Bay St. Louis, Mississippi.

April 25: A progress report was presented at the Annual NFMOA Spotter Pilot Safety Meeting in Houma, Louisiana.

April 29: A review of the investigation was presented to personnel of the NMFS Pascagoula Laboratory.

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.

8. RECOMMENDATIONS

No recommendations are presented at this time

9. FUNDS EXPENDED

Purchase orders and other expenditures directly attributable to this investigation total $183,986.00.

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 are primarily being 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	-
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	-
		TOTALS		300	360	1,000
			GRAND TOTAL			1,660

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