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FISHERIES UTILIZATION OF REMOTELY SENSED DATA

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ABSTRACT

The Fisheries Engineering Laboratory has conducted experiments in conjunction with ERTS-1 and Skylab-3 overflights, and is initiating an experiment using LANDSAT data acquisition systems. Data analyses have demonstrated relationships between remotely sensed oceanographic conditions and the distribution and abundance of specific living marine resources. These correlations have been used as the basis for predictive models which, when validated and refined, may benefit the fishing industry and the biological community.

INTRODUCTION

The advent of satellite observation systems brought with it the capability to synoptically survey vast areas in unprecedented detail. The National Marine Fisheries Service (NMFS), through its Fisheries Engineering Laboratory (FEL), and its constituent recreational and commercial fishermen and state regulatory agencies, has begun to investigate the potential value of synoptic remote sensing surveys to achieve its goals and objectives. FEL has the responsibility to develop remote sensing techniques to efficiently locate, identify and quantify living marine resources.

Available satellite-supported sensor systems lack sufficient resolution for direct fish detection. However, it appears feasible to use satellite sensors to measure selected oceanographic parameters and then to use these measurements to predict the distribution and abundance of a fish species. This feasibility is being tested. Surface vessels collect sea truth data; while low and medium altitude aircraft, using instrumentation similar to the satellite sensors, acquire data for calibration and correlation with the satellite acquired data. Finally, a data system has evolved that processes the diverse inputs, builds a user oriented data bank, and provides a capability to analyze and display selected data subsets.

SPACE EXPERIMENTS

Two experiments have been conducted by FEL--the ERTS-1 menhaden investigation and the Skylab-3 gamefish investigation--to test the validity of the precept of using remotely sensed oceanographic data as the basis for a mathematical model to predict the distribution and abundance of living marine resources. A third experiment--the LANDSAT investigation for menhaden and thread herring--is currently underway.

ERTS-1 INVESTIGATION

The primary objective of the ERTS-1 experiment, a combined Federal Government and private industry effort, was to establish the feasibility of using satellite imagery to determine the availability and distribution of the adult menhaden, Brevoortia patronus, in the Mississippi Sound. Secondary objectives were to determine the effectiveness and reliability of aircraft and ERTS-1 sensors for providing fisheries significant oceanographic information, and to ascertain the usefulness of this information for improving the harvest and management of the menhaden resource. The investigation began in July 1972 and lasted 15 months.

Menhaden were selected as the target species because of their surface schooling characteristics, making them well suited for aerospace remote sensing experiments. They also support the largest volume fishery in the United States, representing a major source of protein for animal feed, and oils and solubles for hundreds of other uses.

During the data acquisition phase of the experiment, ERTS-1, high and low altitude aircraft, and oceanographic and fishing vessels were used to simultaneously acquire oceanographic, fishery, and meteorological information on three separate occasions. ERTS provided

SEFC Contribution No. 406

MARMAP Contribution No. 83

data in digital and image form, and the aircraft acquired data for conversion to temperature, color, salinity, chlorophyll, and turbidity information. Additionally, a photographic aircraft was used to acquire fish distribution and abundance information. The oceanographic and fishing vessels acquired selected sea truth measurements.

The experimental rationale was to convert data obtained by ERTS-1 and aircraft-supported sensors into oceanographic information, attempt to derive statistically valid correlations between this information and the distribution and abundance of menhaden, and then to determine if the relationships have meaning for commercial fishing operations and resource management.

The feasibility of using satellite-supported environmental sensors to predict fish distribution was demonstrated (Kemmerer, et al., 1974). ERTS-1, MSS Band 5 imagery was shown to contain density levels which correlated with menhaden distribution. Further, these density levels were shown to correlate significantly with sea truth measurements of Secchi disc transparency and water depth--two parameters which also correlated significantly with menhaden distribution (Table 1). Additionally, surface salinity, Forel-Ule color and chlorophyll-a were found to correlate with menhaden distribution.

Several regression models predicting menhaden distribution in the study area were constructed from combinations of four oceanographic parameters: water depth, Secchi disc transparency, surface salinity and Forel-Ule color. Figure 1 depicts the results of one of these models designed to predict menhaden distribution in high, moderate and low potential distribution categories. These categories reflect the probability of finding fish in certain areas within the study area. The importance of the models is that they demonstrate a potential way that remotely-sensed oceanographic information can be used to provide fisheries information on a real-time basis. This information could be used by the commercial industry to increase fishing efficiency, and by resource managers as an aid in planning assessment surveys.

SKYLAB-3 INVESTIGATION

The Skylab-3 experiment was undertaken in the summer of 1973 to establish the feasibility of utilizing data acquired from aircraft and satellite platforms to assess and monitor the distribution of oceanic gamefish. Other objectives were to examine relationships between ocean surface conditions and gamefish distribution, and to enhance the capability for predicting the best areas for gamefishing success. The test area selected was approximately 18,000 square kilometers (5400 square nautical miles), generally triangular in shape and located off the Florida coast between Pensacola and Panama City.

Gulf Coast sportfishing clubs, NASA and NMFS participated in the experiment. As in the ERTS-1 investigation, the participants were responsible for establishing statistically valid correlations between remotely sensed data and sea truth information and the distribution of selected gamefish species. Target species for the experiment initially were: Blue marlin (Makaira nigricans), white marlin (Tetrapturus albidus), sailfish (Istiophorus platypterus), wahoo (Acanthocybium solanderi), dolphin (Coryphaena hippurus), yellowfin tuna (Thunnus albacares), and bluefin tuna (Thunnus thynnus). Sufficient biological data were only collected for white marlin; therefore the other species were not considered in the analyses.

A significant portion of the Skylab imagery has only recently been made available for analysis. The present schedule calls for this analysis to be completed in June 1975. Cloud cover and sunglint inhibited the usefulness of the previously available Skylab S190A and S190B imagery. Analytical efforts will concentrate on identifying relationships between white marlin distribution and data from S192B spectral channels. Presently, it remains uncertain if these data will supply inputs to models for predicting gamefish abundance and distribution. However, the successful identification of the fisheries significant oceanographic parameters and the demonstration of the capability of measuring most of the parameters remotely was accomplished (Savastano, et al., 1974).

Based on available data, the distribution of white marlin show significant linear correlation with several sea truth measurements as shown in Table 2. Further analyses resulted in the selection of chlorophyll-a, sea surface temperature, turbidity and water density as the set of parameters explaining the greatest amount of variation in the dependent variable. These measurements were used in developing the predictive models shown in Table 3.

Prediction results for one set of data, using Model D_5, are depicted in Figure 2. The model demonstrated a potential for increasing the probability of gamefishing success. It also demonstrated the potential for significantly reducing search time by identifying areas which have a high probability of being productive.

LANDSAT INVESTIGATION

As a logical progression to the previous experiments, a LANDSAT experiment is being conducted. The ERTS-1 experiment provided a clear definition of a viable experimental rationale for establishing the feasibility of aerospace remote sensing to enhance the management and utilization of living marine resources. A similar rationale was successfully tested during the Skylab-3 experiment. The ERTS-1 rationale consisted of four discrete experimental units that were groupings, or banks, of data; they were - Aerospace remotely sensed data, Oceanographic data, Fish distribution and abundance data, and Fishery utilization data. Aerospace remotely sensed data are used to develop oceanographic data that provide correlations with the distribution and abundance of a fish species. This information is then used to predict potential areas for harvest of the resource.

The experimental design of the current investigation is based on the rationale just described. The primary objective is to verify and refine the relationship of certain coastal environmental parameters, observable from aerospace platforms, to the availability and distribution of Gulf menhaden. A secondary objective is to establish similar relationships for a potential commercially important fish - thread herring (Opisthonema oglinum). As in the ERTS-1 Investigation, the participants are NASA, NMFS and The National Fish Meal and Oil Association.

Two test sites were selected - one in the Mississippi Sound and a second south of Morgan City, Louisiana (Figure 3). The Mississippi Sound was the test site for the previous experiment, and a question remains if the bio-environmental relationships established for the area will remain valid. Additionally, the Sound is such a dynamic and complex ecosystem that concern has been voiced that some of the data acquisition methods and interpolation procedures may have obscured subtle, yet important, relationships between the marine environment and the distribution of menhaden. The environmental complexity of the Sound led to the selection of the second site, south of Morgan City, where major oceanic features are less complex and more easily defined. This second site also supports potentially important concentrations of thread herring not found in the Mississippi Sound.

The LANDSAT experiment is being conducted in three phases. The first phase consists of continued analyses of previously acquired ERTS-type data, and planning and preparation for field operations and subsequent activities. Phase two is field operations conducted in consonance with LANDSAT overpasses to acquire oceanographic, biological and meteorological data required by the experiment's hypothesis (Table 4). Also, during this phase all collected data will be prepared and processed to facilitate storage, retrieval and analysis. The performance of data analyses required to develop, test and/or verify prediction models, and the preparation of final documentation, are phase three activities.

DATA PROCESSING

User oriented data processing based on diverse inputs and numerous output requirements has improved with each investigation. Data inputs represent remotely sensed biological, environmental and meteorological parameters, surface vessel and aircraft observations, and analyses of physical and biological samples. They are converted to digital form and formatted for input into the data bank (Figure 4); a supporting library maintains and disseminates imagery.

Software to establish, maintain and utilize the data associated with the LANDSAT Investigation consists of three major segments (Figure 5). The first was developed to reformat all incoming digital data for input to the Information Storage and Retrieval System (ISRS), the second segment. The ISRS is used to build a compressed data bank which enables users to selectively retrieve pertinent information subsets from the compressed file, print the information, or store it on magnetic tape to be utilized by analysis programs. The last segment consists of various computer programs developed to analyze and display selectively retrieved information subsets. Software is available for statistical analyses, mathematical computations, and graphical displays including land mass plots with contour and symbol plots, histogram plots and X-Y plots.

CONCLUSION

Machine processing of all data has been an integral part of each experiment and has contributed to the successes achieved to date. Kemmerer, et al. (1974) reported the principal limitation of initial ERTS data analyses was a general lack of remotely acquired synoptic oceanographic parameter measurements. Therefore, the conversion of remotely acquired oceanographic data into meaningful information proceeded slowly because of interpretation difficulties. These problems are being overcome; processing techniques have been developed that reliably interpret the remotely sensed data and provide oceanographic information used in fishery prediction models.

The ERTS-1 and Skylab-3 Investigations demonstrated that relationships exist between selected oceanographic parameters, which can be sensed remotely, and the distribution of living marine resources. Potentially these relationships will facilitate synoptic coverage of vast oceanic areas as an aid to commercial fishing and resource assessment. The LANDSAT experiment's objective is to verify and further refine some of these relationships.

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Table 1. Correlations Between Menhaden Relative Abundance and Distribution Estimates, and Selected Oceanographic Parameters.

PARAMETER	DEGREES OF FREEDOM	CORRELATION COEFFICIENT	
		RELATIVE ABUNDANCE	DISTRIBUTION
Temperature (°C)	195	0.009	0.044
Salinity (ppt)	195	-0.257***	-0.222***
Chlorophyll-a (mg/m^3)	195	0.025	0.119*
Current speed (cm/sec)	195	-0.062	0.027
Sea state (m)	195	-0.064	-0.103
Forel-Ule color (units)	113	-0.256***	-0.150*
Water depth (m)	195	-0.216***	-0.404***
Secchi disc transparency (m)	195	-0.093	-0.146**

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

Table 2. Correlations Between White Marlin (hooked) Abundance and Distribution Estimates, and Sampled Environmental Parameters.

Parameter	Degrees of Freedom	Correlation Coefficient (r)	
		Distribution	Abundance
Water Temperature (°C)	44	.407***	.310**
Salinity (ppt)	44	-.145	.001
Air Temperature (°C)	44	.113	.218*
Secchi Transparency (m)	44	.129	.269**
Sea State (m)	44	.272**	.183
Forel-Ule Color (units)	44	-.180	-.044
Chlorophyll-a (mg/m^3)	44	.200*	.054
Chlorophyll-b (mg/m^3)	44	.056	-.005
Chlorophyll-c (mg/m^3)	44	.214*	.241*
Water Depth (m)	44	.329**	.170
Distance from Shore (km)	44	.454***	.323**

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

Table 3. Empirical Regression Models Which Predict White Marlin Distribution (D) in the Skylab Test Area.

MODEL	INCLUSIVE DATES (1973)	n	REGRESSION MODEL	STANDARD ERROR OF $\bar{D}$	MODEL CORRELATION COEFFICIENT	SIGNIFICANCE LEVEL (%)
D_1	4 August	24	$\bar{D}$ = -419.5394 + 14.3929T +12.9784S + .0567C -.4461ST + .0074CA	0.3435	0.797	99.5
D_2	5 August	22	$\bar{D}$ = 164.1002 - 5.3527T -6.3246S + 0.173C +.2071ST - .0021C	0.4996	0.499	50
D_3	4 & 5 August	46	$\bar{D}$ = -25.4052 + .9301T +.3258S + .0139C -.0133ST + .0008CA	0.4751	0.436	75
D_4	4 August	24	$\bar{D}$ = -13.3676 + .6583T +.0718C - .3651B +.0043CA	0.3589	0.762	99.5
D_5	5 August	22	$\bar{D}$ = -22.4714 + .8179T +.0143C - .1035B -.0014CA	0.4879	0.489	60
D_6	4 & 5 August	46	$\bar{D}$ = -12.8553 + .4959T +.0142C - .0950B +.0007CA	0.4693	0.436	90

T = Water temperature (°C)
C = Secchi disc transparency (m)
S = Salinity (ppt)
ST, CA = Interaction formed as the product of the respective parameters
B = σ_t (measure of water density)
where $\sigma_t \times 10^{-3} + 1$ = water density (g/cm^3)
A = Chlorophyll-a (mg/m^3)

Table 4. LANDSAT Investigation Parameter Measurements

PARAMETER	SURFACE		AIRCRAFT					SATELLITE
	Fishery Vessel	Research Vessel	NP3A	NASA Twin Beach	NFMOA Spotters	NMFS Contract Photo	NMFS Contract LLLTV	ERTS
Salinity	X	X	X	-	-	-	-	-
Chlorophyl	-	X	X 1,3	X 1	-	-	-	X 1
Color	X	X	X 3	X	-	-	-	X 1
Transparency	X	X	X 1,3	X 1	-	-	-	X 1
Temperature	X	X	X	X	-	-	-	-
Depth	2	2	2	2	2	2	2	2
Fish Schools	X	-	-	X	X	X	X	-
Fishing Boat Distribution	X	-	-	X	-	X	-	-

NOTE: 1 - Inferred - High Risk NOTE: 2 - Taken from Charts NOTE: 3 - Louisiana Test Site only

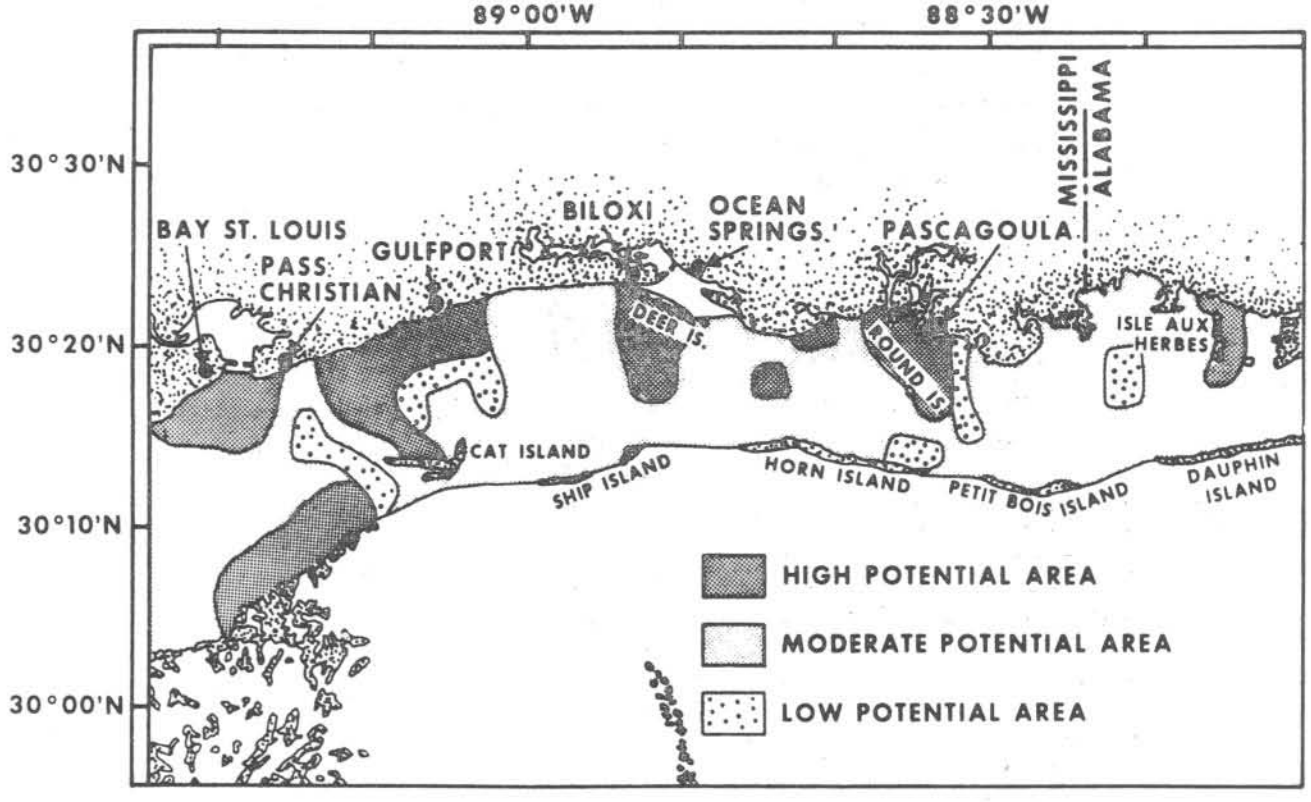

Figure 1. Predictions for Menhaden Distribution in the Mississippi Sound on 7 August 1972. (Kemmerer, et al., 1974)

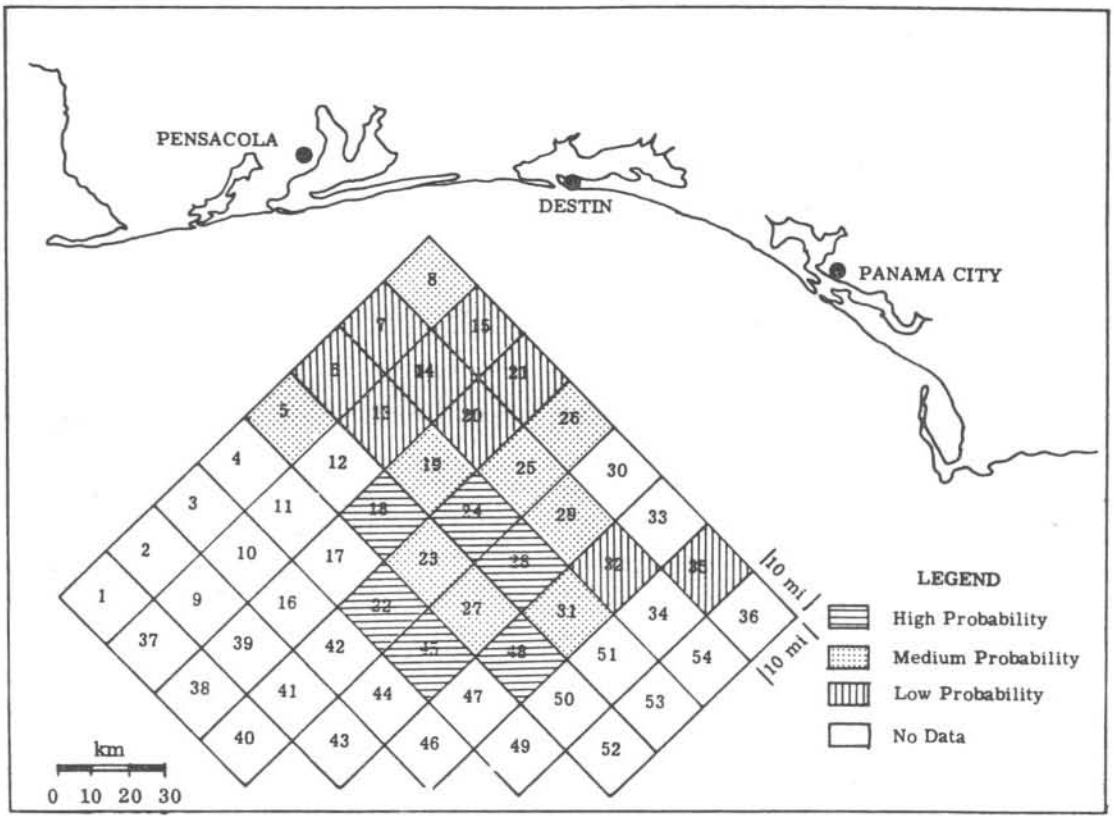

Figure 2. Prediction Results of 4 August Data for White Marlin (Savastano, et al., 1974)

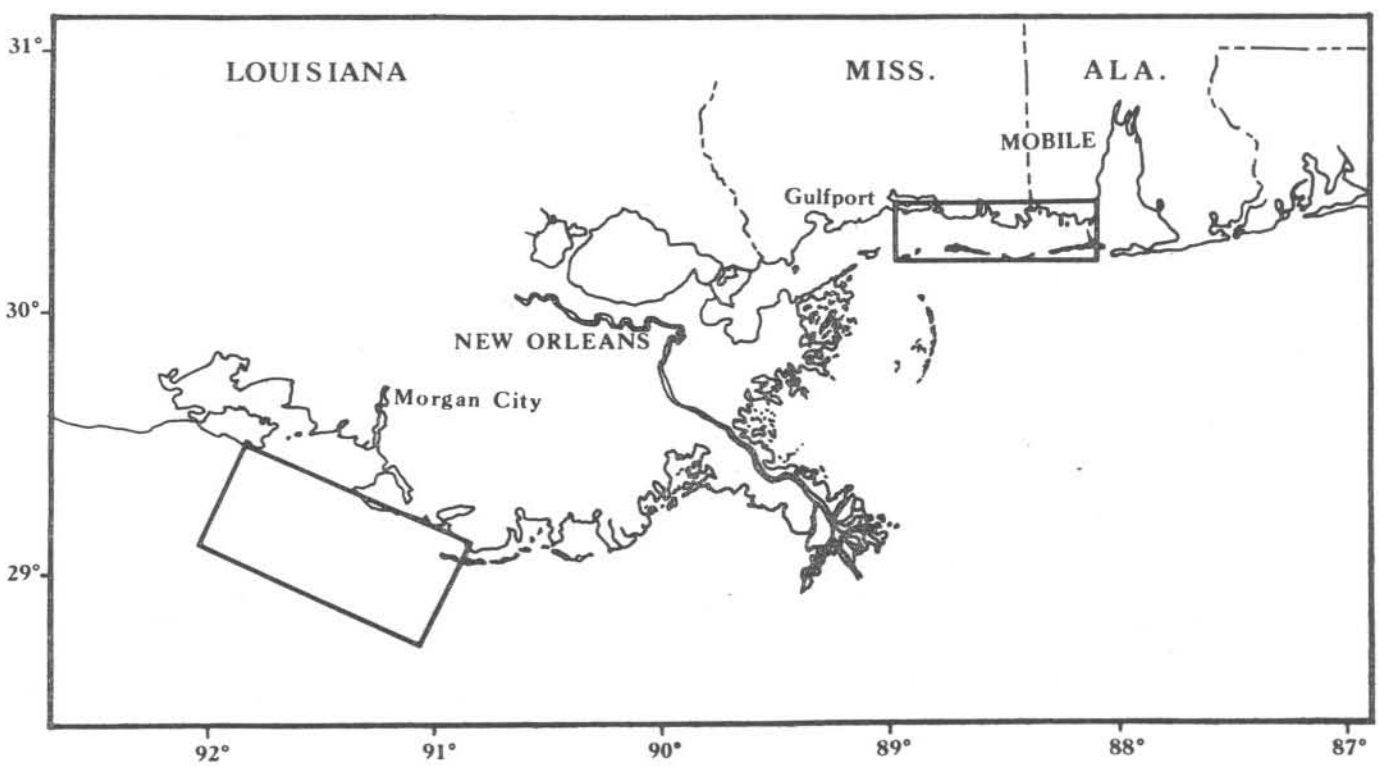

Figure 3. LANDSAT Investigation Test Sites

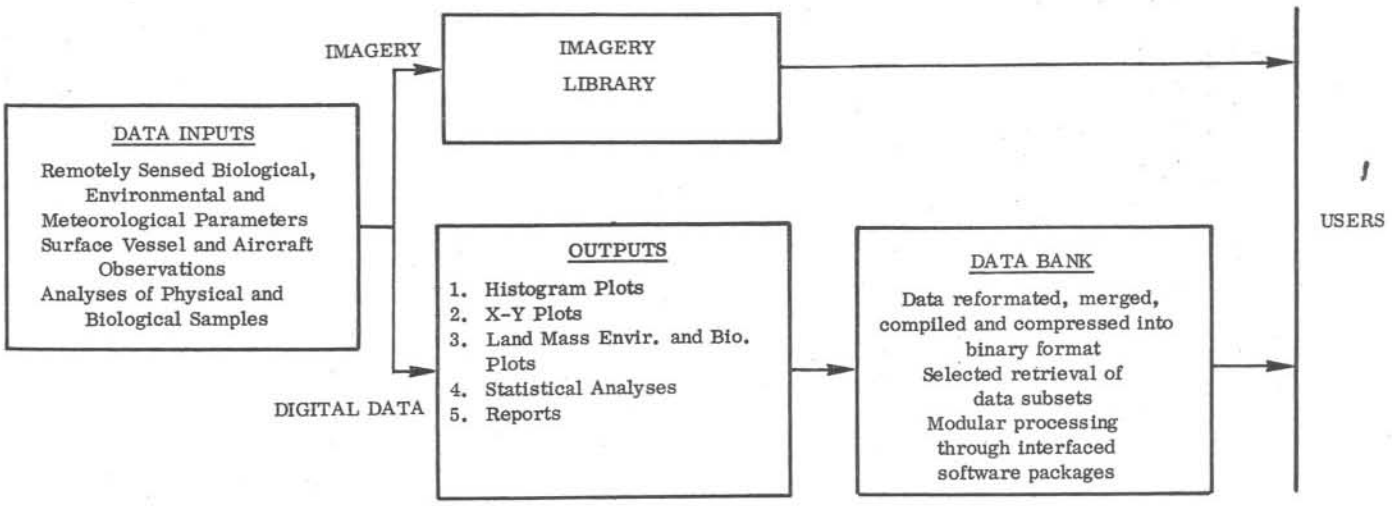

Figure 4. Establishment and Use of an Investigation's Data Bank

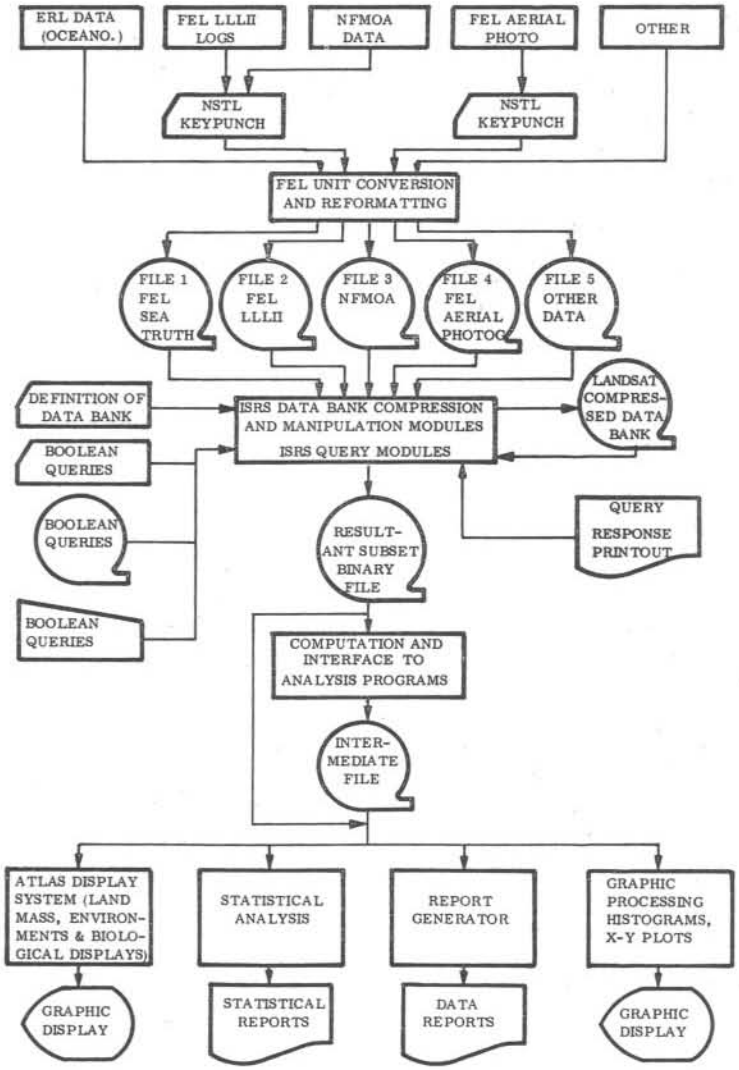

Figure 5. LANDSAT Investigation Data Management Software System