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RELATIONSHIPS BETWEEN REMOTELY SENSED FISHERIES DISTRIBUTION INFORMATION AND SELECTED OCEANOGRAPHIC PARAMETERS IN THE MISSISSIPPI SOUND

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ABSTRACT

A feasibility study to demonstrate the potential of satellites for providing fisheries significant information was conducted in the Mississippi Sound and adjacent offshore waters. Attempts were made to relate satellite acquired imagery to selected oceanographic parameters and then to relate these parameters to aircraft remotely sensed distribution patterns of resident surface schooling fishes. Initial results suggest that this approach is valid and that the satellite acquired imagery may have important fisheries resource assessment implications.

INTRODUCTION

A basic need of fishery resource managers and resource users is timely synoptic information about the resource. Resource managers need this information for effective management and use allocation, while users need it to guide their fishing and investment strategies. The tremendous costs involved in gathering adequate resource information through classical approaches, however, has hampered fulfillment of this need. All too often, resource managers are forced to base decisions on little or no information, while users must be content to base their decisions on intuition and often biased personal knowledge. In response to this need, the NMFS is attempting to identify, develop, and evaluate new resource assessment methods so that managers and users alike can be relieved of many resource related uncertainties. As a means to this end, aerial and satellite remote sensing techniques are being examined to determine if they can be utilized to provide pertinent fisheries resource information.

A 15-month study was initiated in July 1972 under NASA Projects 240 and 258 to establish the feasibility of using ERTS-1 imagery to assess, monitor, and predict the distribution and availability of a living marine resource. The study represents a combined Federal Government and private industry effort and stressed acquisition of data to:

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Sioux Falls, SD 57198

- Determine the effectiveness and reliability of ERTS-1 and high-level aircraft sensors to provide fisheries significant data about coastal waters.

- Demonstrate the feasibility of using remotely-sensed oceanographic data to predict the availability and distribution of adult menhaden in the Mississippi Sound and adjacent waters.

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

This paper presents a summary of some of the early study results with emphasis given to statistical relationships between the fishery resource and selected oceanographic parameters. Data analyses are far from complete and as such, none are considered conclusive.

SUMMARY OF EXPERIMENTAL DETAIL

The experimental approach employed is to convert satellite and aircraft remotely sensed data into oceanographic parameters, relate these parameters to the fishery resource, and then determine if the relationships have meaning in terms of the commercial fisheries and its management. At present, only a small amount of remotely sensed oceanographic data are available; consequently, the reported resource related analyses depend primarily upon sea-truth information collected with standard techniques to calibrate remote sensors.

Study Area

This study area is a 8,685 square kilometer rectangle in the north central Gulf of Mexico (Fig. 1). It encompasses all of the Mississippi Sound, the lower portion of Mobile Bay, and extends offshore to approximately the 10-fathom curve (i.e., approximately 50 kilometers offshore). The study area was selected because of the Mississippi Sound, which is a shallow (mean depth 3 meters) and turbid (secchi disc visibility varies from about 1 to 2 meters) body of water. The Sound supports a substantial commercially important menhaden population, which generally is fished from about mid-April to October.

Data Acquisition

Data acquisition activities were divided into four categories: main day, secondary and special purpose missions, and commercial fishing. Main-day missions occurred at the time of selected ERTS-1 overpasses (7 August, 25 August, and 28 September 1972) and included an intensive sea-truth sampling effort--up to 144 stations were occupied (95 stations in the Sound). Only a few sea-truth stations were occupied during secondary missions, which were conducted weekly to record temporal environmental and fishery changes. Special purpose missions were designed to meet specific limited objectives and as such, did not necessarily follow set schedules. Oceanographic and fisheries data were obtained from commercial fishing vessels in fishing areas Monday through Friday throughout most of the experimental period.

Data considered in this paper were collected during the main-day missions. Remotely sensed oceanographic data are not included, nor is much attention given to the offshore portion of the study area.

Oceanographic Data: Oceanographic or sea-truth data were collected from about 25 surface vessels, usually within a few hours of the satellite overpass. Oceanographic parameters measured included surface temperature, water transparency (secchi disc), sea state, surface current (float and impeller-type current meters), salinity (induction salinometer), surface chlorophyll-*a* (acetone extraction), water color (Forel-Ule color comparator), and water depth. Complete descriptions of methods and results can be found in NASA-ERL/MTF special reports numbers 025, 032, and 034.

Fisheries Data: Aerial photography provided all fisheries data used in this paper. Menhaden are particularly susceptible to photographic sensing because of their characteristic surface or near-surface schooling behavior. (For discussions on aerial photography as a pelagic fisheries assessment tool, see Bullis, 1967; Benigno, 1970; and Drennan, 1969.) Photographic fish sensing missions were flown to provide approximately 95 percent coverage of the study area at an altitude of 2,469 meters. A 6-inch lens and 9-inch film format aerial mapping camera, supplied with GAF blue insensitive film, constituted the sensor. Missions over the Sound were flown in the morning (0700-1000 hours) to correspond as closely as possible to ERTS-1 overpasses. Processed film was interpreted at 3X to 33X magnification and data recorded included position, number, and size (surface area) of fish schools.

DATA ANALYSIS AND DISCUSSION

Oceanographic Parameter and Fish Distribution Relationships

Initial attempts to describe relationships between menhaden school distribution and available oceanographic parameter measurements (surface sea-truth) produced interesting results. Four parameters repeatedly stood out as significantly defining fish distribution patterns (Table 1). Chlorophyll-*a*, surface current, temperature, and sea state appeared to have little influence on menhaden. The lack of significance with respect to chlorophyll-*a* was surprising in that menhaden are primarily plankton feeders; one might expect *a priori* that these fish would tend to be distributed according to phytoplankton biomass. The significant correlation between fish distribution and water color cannot be explained at this time, although presumably color served as an indicator of a condition influencing the fish--perhaps zooplankton. Secchi disc visibility did not correlate as well as was expected; commercial fish spotter pilots generally regard turbid waters as "fishy" areas. Literature sources suggest a menhaden preference for low salinity waters, which was borne out here by the significant negative correlation. Depth also appeared to be an important parameter, with menhaden apparently preferring shallow waters.

Table 1.--Simple linear correlations between the distribution of menhaden schools during the three main-day missions and selected oceanographic parameters (the dependent variable was time normalized by dividing the number of fish schools at any given location by the total population of detected schools).

Parameter	Degrees of Freedom	Correlation Coefficient	Level of Significance
Salinity	195	-0.257	99%
Color	113*	-0.283	99%
Secchi disc	195	-0.100	75%
Depth	195	-0.216	99%

* Color was not measured on the 7 August main-day mission

The lack of precise correlations between fish distribution and oceanographic parameters, as indicated by the correlation coefficients, was not discouraging; rather, the fact that the correlations had statistical significance was quite encouraging. The way the data were handled probably contributed significantly to the lack of precision. Water conditions at fish school locations generally had to be estimated based on conditions at sea-truth stations located several kilometers away. The Mississippi Sound is an extremely dynamic aquatic environment, and as such little reliance can be placed on interpolated or extrapolated values. There were other obvious sources of experimental error. The fish sensor (aerial photography) had certain limitations such as water penetration depth (roughly estimated to be about 1.5 times the secchi disc visibility depth), minimum detectable school size (about 40 square meters surface area) and minimum detectable school density (unknown). There was also doubt as to whether or not all fish schools detected were menhaden and how much commercial fishing activities influenced the distribution of schools. And finally, because aquatic organisms are influenced directly or indirectly by all conditions of their environment, there is little reason to expect that any single parameter would explain all of the experimental variation.

Multiple regression techniques were employed to determine if significantly more experimental variation could be explained by combining the parameters listed in Table 1. Data used in this analysis were taken from the last two main-day missions (25 August and 28 September), as no water truth color information was obtained on 7 August. The dependent variable was number of fish schools (normalized for time) and the independent variables were salinity, secchi disc visibility, color, and the two factor interactions between these variables (i.e., salinity x secchi disc visibility, salinity x color, and secchi disc visibility x color). The resultant equation (Table 2) was highly significant (99.95 percent) and explained about 30 percent of the experimental variation (Table 3). Water depth erroneously was not included in the analysis; subsequent analyses suggest that this parameter might have significantly increased its precision.

Table 2.--Components of a multiple regression equation where the normalized number of menhaden fish schools is predicted based on oceanographic parameters.

Parameter	Coefficient	Standard Error of Coefficient
Salinity (S)	-0.04565	0.01087
Secchi disc (D)	-0.06599	0.02785
Color (C)	-0.07368	0.01664
S x D	0.00207	0.00079
S x C	0.00237	0.00065
D x C	0.00004	0.00091

Constant = 1.42682
Standard error of Y = 0.03881

Table 3.--Analysis of variance for a multiple regression analysis of menhaden distribution versus selected oceanographic parameters (Table 2).

Source Variation	Degrees of Freedom	Mean Square	F-Value
Total	114	0.00200	
Regression	6	0.01086	7.192***
Error	108	0.00151	

Correlation coefficient = 0.535

A tentative conclusion from the foregoing analyses is that menhaden appear to be distributed according to environmental conditions in the water mass. Notably, all of the parameters significantly correlated with fish distribution, except for depth, can be measured remotely. Future analyses will emphasize remote, synoptically acquired oceanographic parameter information which should substantially increase experimental precision.

ERTS-1 Imagery and Fish Distribution Relationships

A preliminary analysis of the 7 August ERTS-1 multispectral scanner (MSS) imagery was performed to determine if the imagery contained readily apparent fisheries significant information. August 7 was selected because it was the only day where four MSS channels (i.e., 4, 5, 6, and 7) were available and there was no significant cloud coverage over the study area. Channels 6 and 7, representing spectral ranges 0.7 to 0.8 and 0.8 to 1.1 microns, respectively, appeared to have little water mass information (e.g., boundaries, turbid areas, etc.), while channel 4, covering a spectral range of 0.5 to 0.6 microns, appeared to have too much density detail for this type of analysis. Channel 5, representing 0.6 to 0.7 microns, for reasons not clearly understood at this time, did appear to provide fisheries significant information.

Figure 2a shows a portion of the ERTS-1, channel 5 imagery for the west end of the Mississippi Sound and adjacent offshore waters as displayed on a I^2S DIGICOL video screen. Superimposed on the image are locations of 23 photographically-detected fish schools (the four closely grouped fish school locations shown in the middle left portion of the photograph actually should be 10 positions). The water imagery densities were divided into two density ranges and color enhanced. All of the fish school locations were found to lie in the less dense range of the two ranges (Fig. 2b). The characteristics of the I^2S permitted further division of the density range containing the fish schools into four narrower discrete ranges. When this was done, all of the fish school locations were found to either lie in or immediately adjacent to a single narrow image density range (Fig. 2c).

Although it may be too soon to draw conclusions from the foregoing analysis, it does suggest that ERTS-1 remotely sensed data may have significant fisheries meaning.

ERTS-1 Imagery and Oceanographic Parameter Relationships

A preliminary analysis was performed on the ERTS-1, MSS, channel 5 imagery for 7 August to determine if image densities could be explained based on selected oceanographic parameter information. An isodensity tracing was made of the image as a first step to provide quantitative density data. The tracing was not particularly satisfactory because of instrument limitations which caused more than one density to be represented by the same color trace. Nevertheless, the density measurements probably were reasonably accurate.

Water depth, secchi disc visibility, and the interaction between these two parameters, were regressed against image density (Tables 4 and 5). These particular parameters were selected because of their significant correlation with fish distribution (Table 1) and because the ERTS-1 image seemed to describe turbidity and depth patterns in the water. The analysis was highly significant (99.95 percent) and explained 59 percent of the experimental variation. Unfortunately, color data were not available for 7 August and as such, there is no way to determine if color would have significantly reduced the error term.

Table 4.--Analysis of variance for the relationship between ERTS-1 image density and two oceanographic parameters.

Variation	Degrees of Freedom	Mean Square	F-Value
Total	47	0.00508	
Regression	3	0.04692	21.040***
Error	44	0.00223	

Correlation coefficient = 0.768

Table 5.--Components of a multiple regression equation where levels of ERTS-1, MSS, channel 5, image density are predicted.

Parameter	Coefficient	Standard Error of Coefficient
Water depth	0.00677	0.00294
Secchi disc visibility	0.02324	0.00677
Interaction	-0.00047	0.00036

Constant = 0.57763
Standard error of Y = 0.04717

TENTATIVE CONCLUSIONS

1. The distribution of photographically detected adult menhaden in the Mississippi Sound was significantly correlated with secchi disc visibility, surface salinity, water color, and water depth.

2. ERTS-1, 7 August, channel 5 imagery appeared to contain fishery significant information; all detected menhaden schools were located in areas of lowest image density.

3. Image density patterns could be explained statistically with good precision based on water depth and secchi disc visibility measurements, parameters which correlated significantly with the distribution of menhaden.

LITERATURE CITED

Benigno, Joseph A. 1970. Fish detection through aerial surveillance. Technical Conference on Fish Finding, Purse Seining, and Aimed Trawling; Reykjavik, May 1970, FAO, FII:FF 70/78, 13 pp.

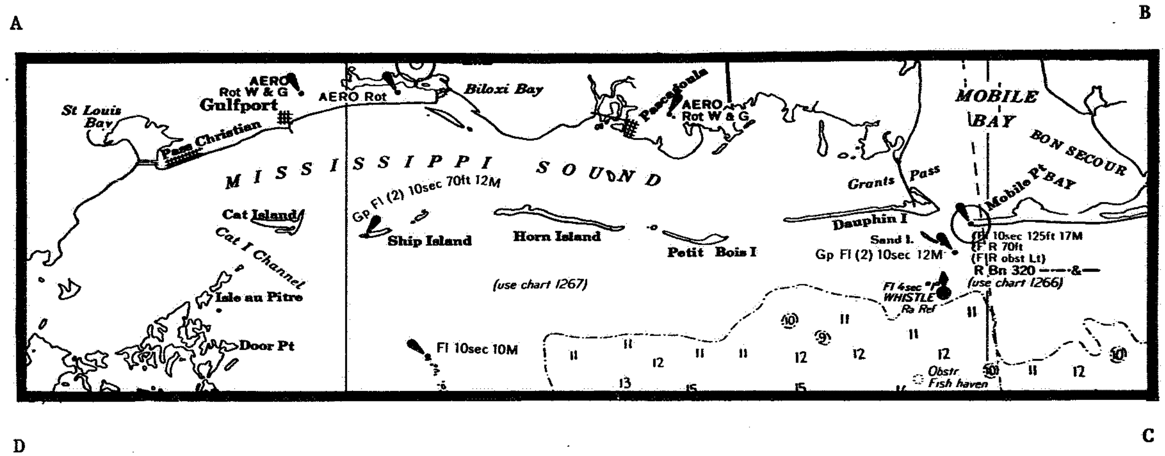
Bullis, Jr., Harvey R. 1967. A program to develop aerial photo technology for assessment of surface fish schools. Proceedings of the Gulf and Caribbean Fisheries Institute, 20th Annual Session: 40-43.

Drennan, Kirby L. 1969. Fishery oceanography from space. Proceedings of the Sixth Space Congress; Space, Technology, and Society. Canaveral Council of Technical Societies, Cocoa Beach, Florida: 9.1-9.6.

NASA-ERL/MTF. 1972. Sea remote sensing program, Mississippi Sound remote sensing study, August 7, 1972. Report No. 025; 18 October 1972.

____________. 1972. Sea remote sensing program, Mississippi Sound remote sensing study, August 25, 1972. Report No. 032; 30 November 1972.

____________. 1973. Sea remote sensing program, Mississippi Sound remote sensing study, September 28, 1972. Report No. 034; 9 January 1973.



<u>TEST SITE COORDINATES</u>

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

SCALE 1:875,000

N.MI. 10 20

KM. 10 20 30 40

<u>TEST SITE DIMENSIONS</u>

LENGTH: 170 KM.

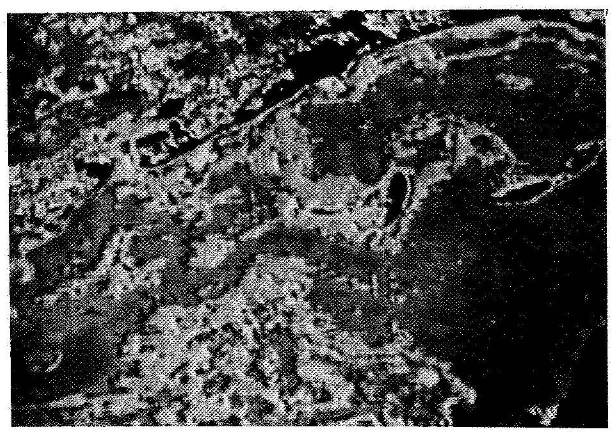
WIDTH: 51 KM.

AREA: 8685 SQ.KM.

Figure 1.--ERTS-1 study area

a

b



c

Figure 2. ERTS-1, channel 5, August 7 image of western portion of study area (Fish school locations are shown as black dots):

a. I^2S DIGICOL television screen image.

b. Image water densities divided into two ranges and enhanced. Instability of the television image caused fish locations on the extreme left of the figure to appear on the beach.

c. Enhancement of a narrow density range within the range containing the fish school locations--note how the fish schools either fall adjacent to or within this narrow range.

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