

COLOR ILLUSTRATIONS  
CONTAINS

SECTION 47

Hydrology

DETECTION AND IDENTIFICATION OF BENTHIC COMMUNITIES  
AND SHORELINE FEATURES IN BISCAYNE BAY  
USING MULTIBAND IMAGERY<sup>1/</sup>

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INTRODUCTION

Progress has been made in the development of a technique for identifying and delineating benthic and shoreline communities using multispectral imagery. Heretofore, manual mapping from aerial photographs or on-site surveys were the only feasible methods to inventory benthic features in large, shallow bodies of water (refs. 1, 2 and 3). Images were collected on March 10, 1970, with the University of Michigan's multispectral scanner systems mounted in a C-47 aircraft. The overflight covered south Biscayne Bay, Florida and adjacent shoreline (fig. 1), including a region affected by heated water from an electrical power plant. Concurrent with the overflight, ecological ground-and sea-truth information was collected at 19 sites in the bay and on the shore (fig. 2). South Biscayne Bay is a study area within the Florida Regional Ecological Test Site (fig. 3).

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Also, the authors express appreciation to the scientists and engineers that assisted in the sea-truth operations and experiments conducted in south Biscayne Bay during March 2-13, 1970. Although many persons contributed their efforts, the following individuals and agencies deserve special credit: U.S. Environmental Protection Agency - John Hagan, Sanitary Engineer; Lee Purkerson, Microbiologist; Reginald Rogers, Aquatic Biologist; Douglas Lair, Operation Engineer; Michael Polito, Chemist;

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Biscayne Bay, along the Atlantic shoreline, is a shallow semi-enclosed estuary that includes the Biscayne National Monument (fig. 4). The detailed interpretation of the character of the bottom is important for species identification in ecological studies. The bottom flora provides shelter and food for juvenile sport and game fish, shrimp, and other commercial species. The occurrence and distribution of plants can serve as an index of pollution by indicating the state of biological well-being of the estuary. The pollutants range from pesticides to heated water. Increased water temperature caused by the heated effluent from electric generating plants, especially those powered by nuclear energy, are a potential problem in Florida and other states. One such plant is under construction in south Biscayne Bay. Another problem in the bay results from turbidity caused by dredge and fill operations. Either excessive temperature or turbidity can destroy plankton, attached vegetation, and sessile animals. It may even diminish or destroy natural communities and the commercial and sport fisheries of an area.

Fresh water enters the bay by runoff and ground-water discharge. In places, the discharge emerges in sufficient strength to form springs, subcircular depressions a few feet in diameter. Thermal contrasts between the upwelling water and the surrounding bay water were sensed remotely.

In many instances, the zonation of plants in the coastal marshes and forests of south Biscayne Bay indicates the extent and duration of tidal inundation. The typical zonation pattern is red mangrove (Rhizophora mangle) through the intertidal zone, black mangrove (Avicennia nitida) in the upper tidal reaches, and buttonwood (Conocarpus erectus) in the supratidal region. The delineation and mapping of these species can be valuable to those concerned in planning and in settling problems relating to the legal definitions of shorelines or mean high-water lines that concern ownership or the seaward limit allowable for landfill and bulkhead lines.

## DESCRIPTION OF APARATUS AND METHOD OF ANALYSIS

The multispectral data collector consists of an optical-mechanical scanner mounted in an aircraft. As the aircraft flies over the terrain to be mapped, a rotating mirror scans the field of view of a parabolic-mirror telescope across the ground perpendicular to the direction of flight. This action, in conjunction with the aircraft motion, covers a strip of terrain centered under the aircraft with a continuous scan (fig. 5). Two telescopes and one double-sided rotating mirror (the two sides are rotated  $90^\circ$  with respect to each other) constitute the scanner. Two scanners are employed in the C-47 aircraft operated by the University of Michigan. Filtered detectors convert the radiation from the ground into electrical signals, which are amplified and recorded on magnetic tape along with synchronizing signals necessary to reconstruct the images (ref. 4).

The processing of scanner data depends upon the automatic recognition of objects by their spectral signatures (fig. 6). Essentially, the processing procedure consists of four steps:

- (1) Selection of a decision rule which states in mathematical terms the criteria to be used in determining the nature of the scanned objects.
- (2) Training of the digital computer by presenting it with a sample of data from the object (biological community) to be mapped - a training set. The parameters of the decision rule are adjusted to this set to optimize the detection process.
- (3) Presenting the analog computer with unknown data and asking it to recognize all objects similar to those in the training sets.
- (4) Preparing a community recognition map with a film-strip printer.

A detailed theoretical discussion of data processing is presented by Higer and others, 1970 (ref. 4) Voss and others, 1969 (ref. 5). Two new digital programs (F. Thomson, University of Michigan, oral communication, 1970) were developed for processing the Biscayne Bay data; one corrects for sun glint, and the other corrects for geometric distortion of features induced by the scanner (fig. 6).

## Results and Discussion

Preliminary processing of the scanner imagery with a CDC 1604 digital computer provided the optimum channels for discernment among different underwater and coastal objects. The following six spectrometer bands were used for discrimination of underwater features:

Multispectral data Channel <u>Number in Figure 7</u>	Wavelength Interval, <u>Micrometers</u>	Approximate Subjective <u>Color</u>
2	0.430-0.455	Violet
4	0.485-0.500	Blue-Green
5	0.500-0.520	Blue-Green
6	0.520-0.545	Green
8	0.580-0.630	Light Red
9	0.630-0.680	Deep Red

Recognition maps of benthic community types were provided by electronically processing combinations of video signals in the six spectral bands. The computer was trained to identify each community type from the intertidal zone to a depth of 3 meters to compensate for variations of reflectivity due to such factors as light scattering and extinction as a function of water depth.

Computer maps were printed in different colors and superposed to provide a color-composite map of recognized community types in the study area (fig. 8). The plant and animal communities in south Biscayne Bay and Card Sound are varied and rich in species; a list for Biscayne National Monument contains about 1,400 different marine species (ref. 5). Several pertinent reports contain detailed discussions of the communities in south Biscayne Bay and neighboring areas (refs. 6, 7, 8 and 9). The identification of benthic communities using remote sensing techniques shows them to be large, sessile, and common. Communities are characterized from the air by species composition, organism density, and nature of substrata or bottom. Bottom composition is a major factor in the reflectivity from a benthic community, especially where attached organisms are sparse. Two distinct composition types occur in the bay: soft bottom that is dark in color and contains sand, calcitic mud, and organic sediments ranging from 0.5 to about 4 meters deep; and hard bottom that is light in color and contains materials such as carbonate and quartz sand and shell hash that have accumulated in shallow layers as thick as a few centimeters. Sea grasses characterize the soft bottom community; macro-algae and sponges characterize the hard bottom community (fig. 9).

The dominant plants of the soft bottom community (color coded red in fig. 8) are turtle grass (Thalassia testudinum), manatee grass (Syringodium filiforme), and Diplanthera wrightii. These grasses often form dense mats on the bottom. In some regions the grasses are sparse and are invaded by algae such as Laurencia, Penicillus, Canlespa, and Halimeda. In a few small regions of the bay the soft bottom lacks attached vegetation. The bare soft bottom adjacent to West Arsenicker Key and mapped in figure 8 (color coded dark yellow) becomes emergent at low tide.

Hard bottom community (color coded green in fig. 8) covers much of the deeper part of the bay. The largest common forms within this community designation are sponges, notably the vase sponge (Ircinia campana) and the loggerhead sponge (Spheciospongia vesparia). Also abundant are sponges of the genera Hippiospongia and Spongia. The formerly mentioned algae that invade the soft-bottom community are common in the hard-bottom community. Corals of the genera Porites, Solenastrea and Siderastrea and sea feathers of the genera Plexaurella and Pterogoria occur regularly in the hard-bottom sites.

The hard- and soft-bottom communities are intermixed over large parts of the study area (color coded dark blue in fig. 8). In these regions the biological components and substrate of both communities are present. The recognition map was color coded light blue for regions where the mixed hard- and soft-bottom community is sparsely inhabited by grasses, algae, corals, and sea feathers. White areas on the color-composite recognition map are those that failed to receive a community designation during computer processing. Additional training sets would need to be established for these areas.

The accuracy of the boundaries of the delineated communities has not yet been established, but detailed spot checks indicate excellent agreement between mapped and observed community types.

A computer map of surface-water temperatures overlying the mapped bay-bottom communities was produced in which temperature intervals of 2 and 3° F are assigned different roles (fig. 10). The mapped temperatures ranged from 64.9 to 83.8° F. The accuracy of the temperature profiles lies within ±1.5° F (F. Thomson, oral commun., 1970).

Automatic mapping of the benthic plants by multiband imagery and the mapping of isotherms and hydrodynamic parameters by digital model coupled together can become an effective predictive ecological tool. Using the two systems, it appears possible to predict conditions that could adversely affect the benthic communities. With the advent of the ERTS satellites and space platforms, imagery data of south Biscayne Bay could be obtained which, when used in conjunction with water-level and meteorological data, would provide for continuous ecological monitoring.

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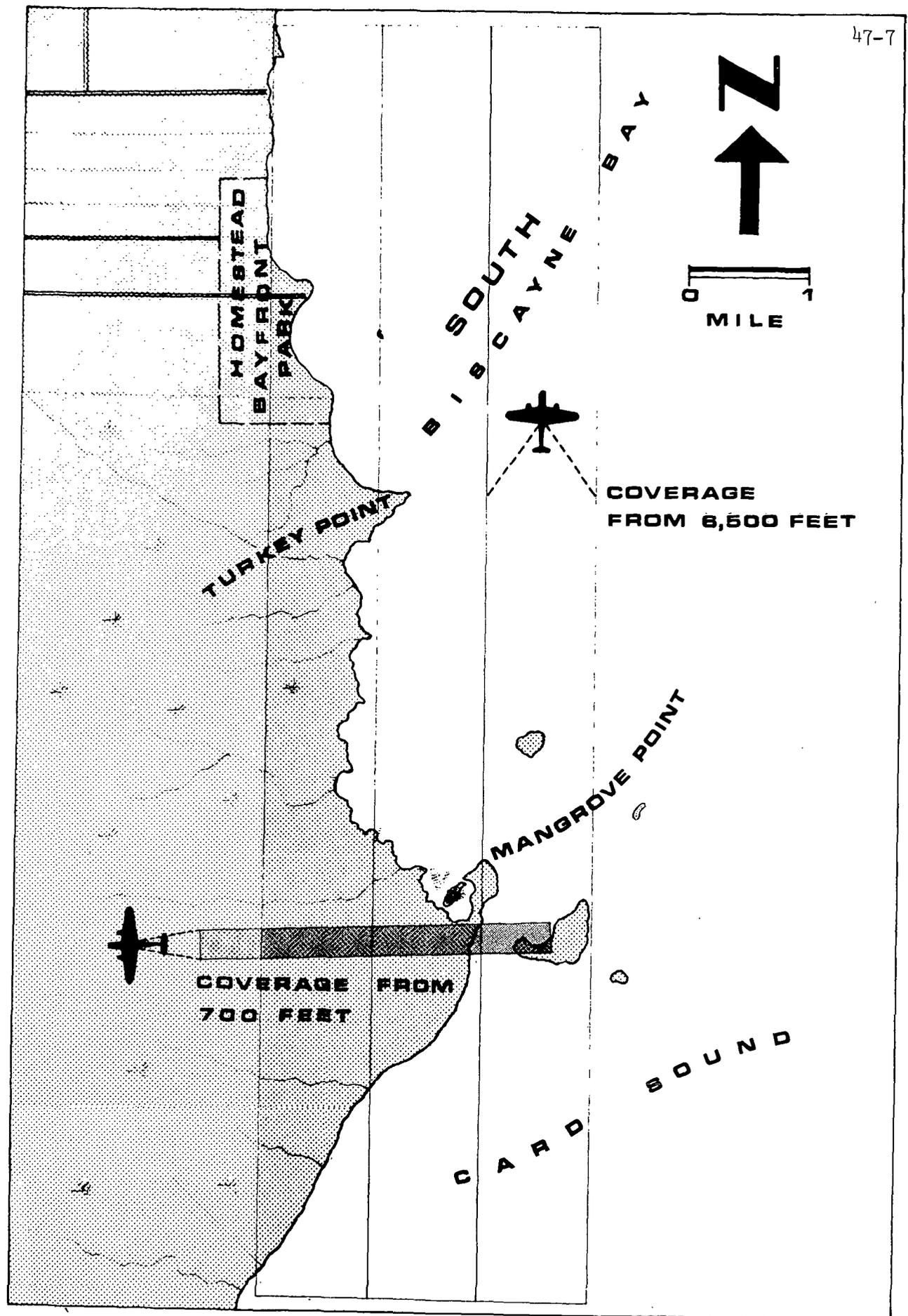
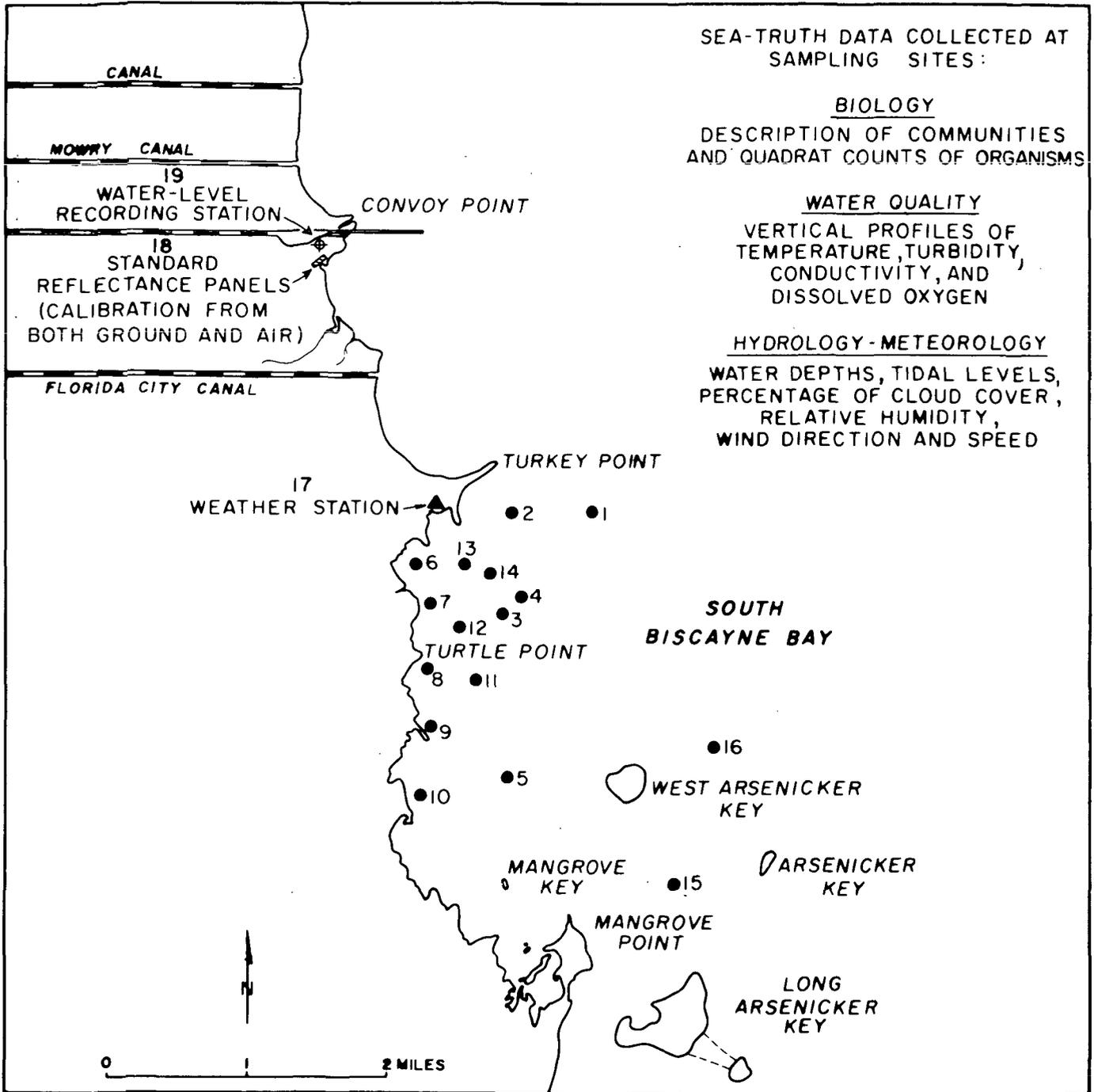


Figure 1.- Location map of areas covered by optical-mechanical scanner from an overflight on March 10, 1970.



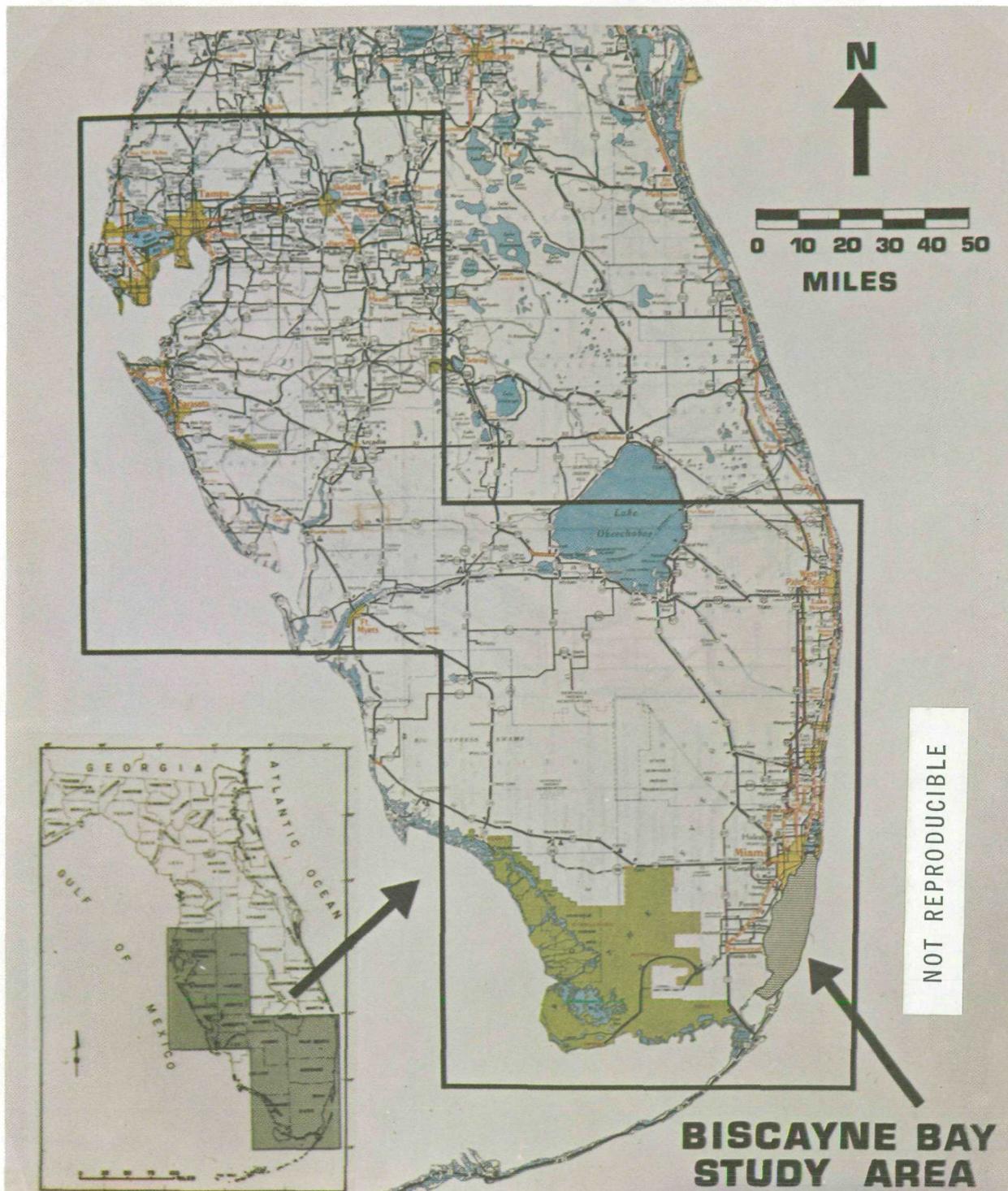


Figure 3.- The Florida Regional Ecological Test Site is a multidisciplinary experiment, established to test and evaluate remote sensor applications to resource problems from space, aircraft and ground platforms.

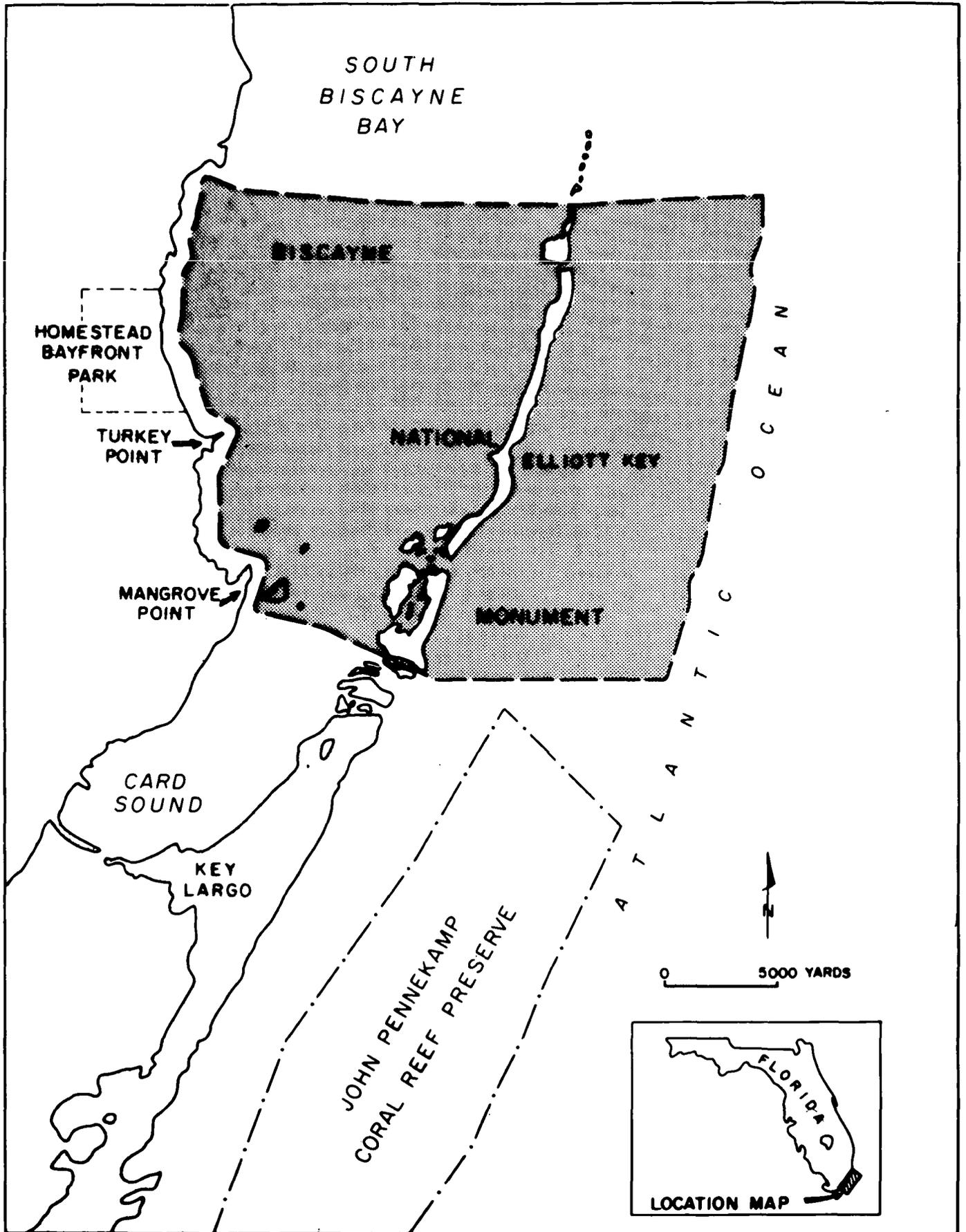


Figure 4.- Location map of Biscayne National Monument in south Biscayne Bay.

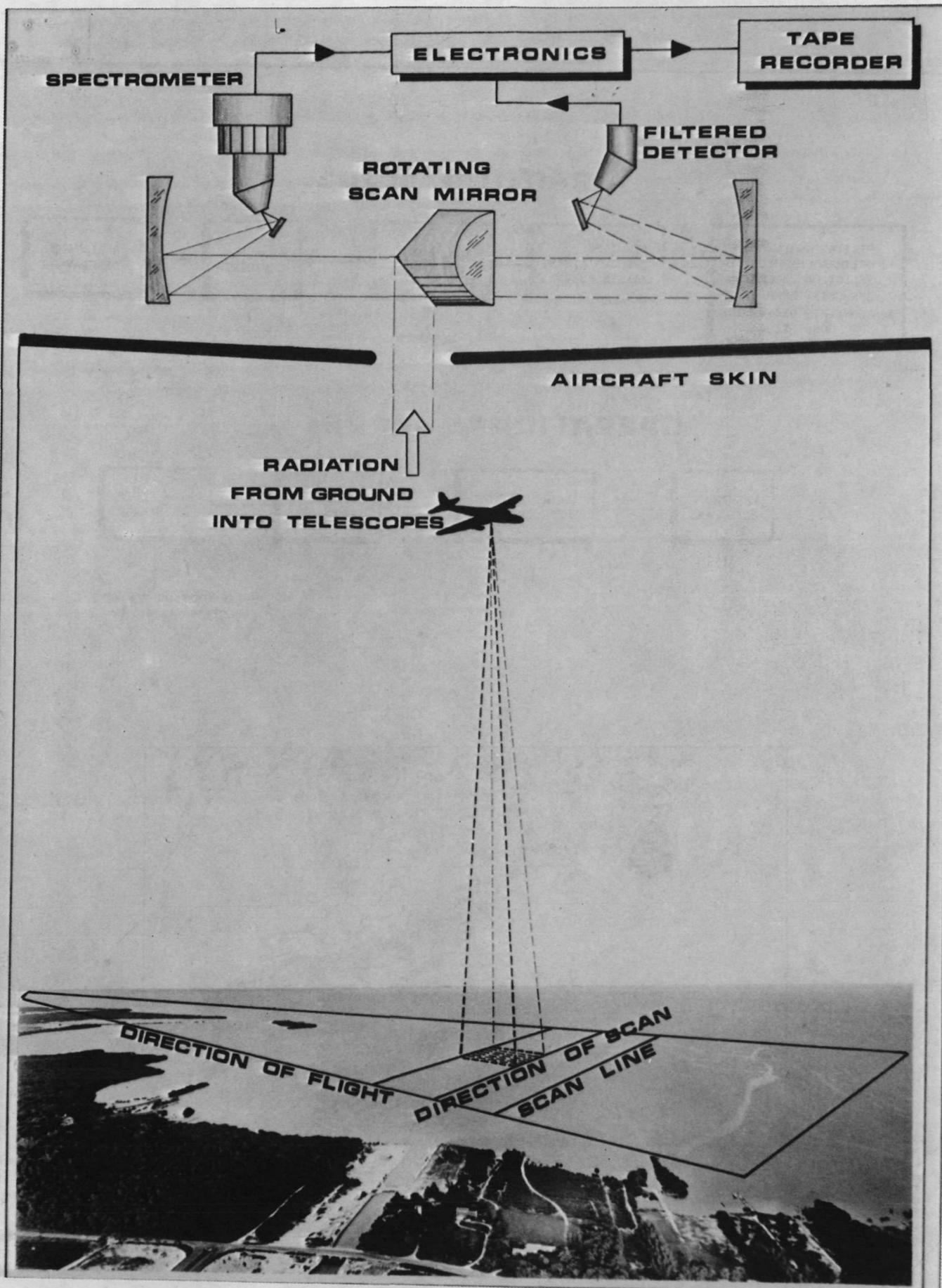
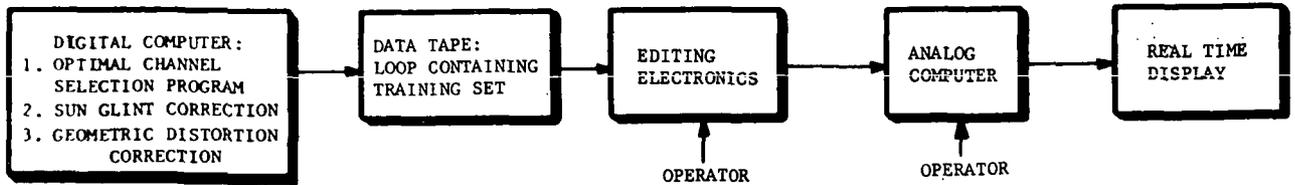


Figure 5.- Schematic of multispectral scanner operation over study area in south Biscayne Bay.

## TRAINING MODE



## OPERATIONAL MODE

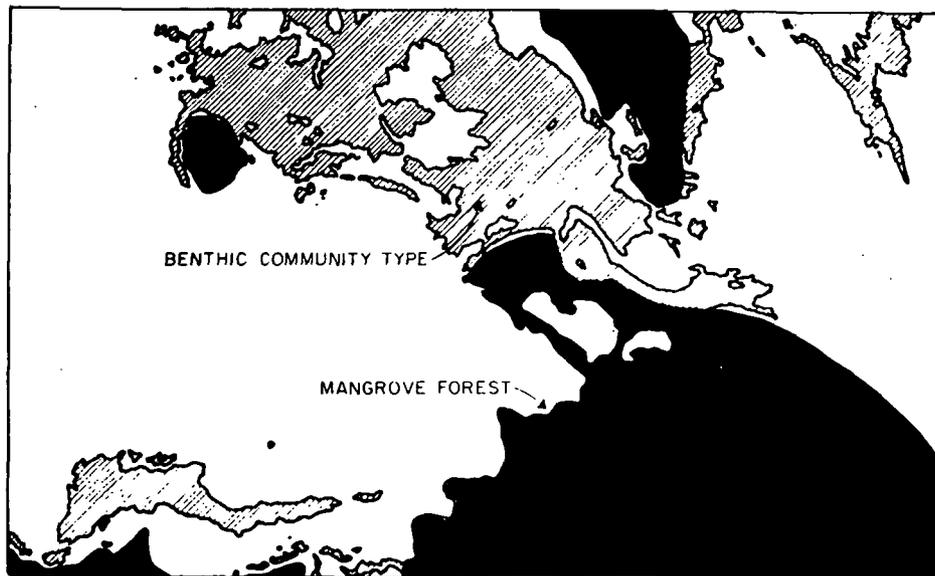
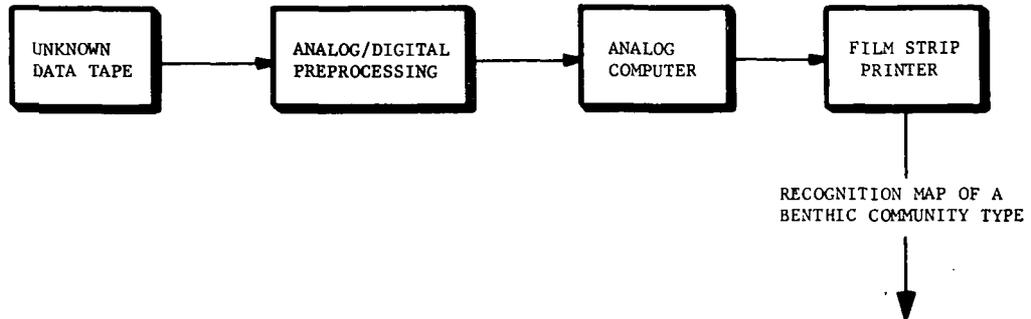


Figure 6.- Block diagram of multispectral-scanner-imagery processing operations for benthic communities. The spectral characteristics of targets and background objects are analyzed to determine how to electronically process spectral information from a scene using both digital and analog techniques. Each recognition map with its assigned color is superposed to provide an imagery mosaic of the benthic communities of the study area.

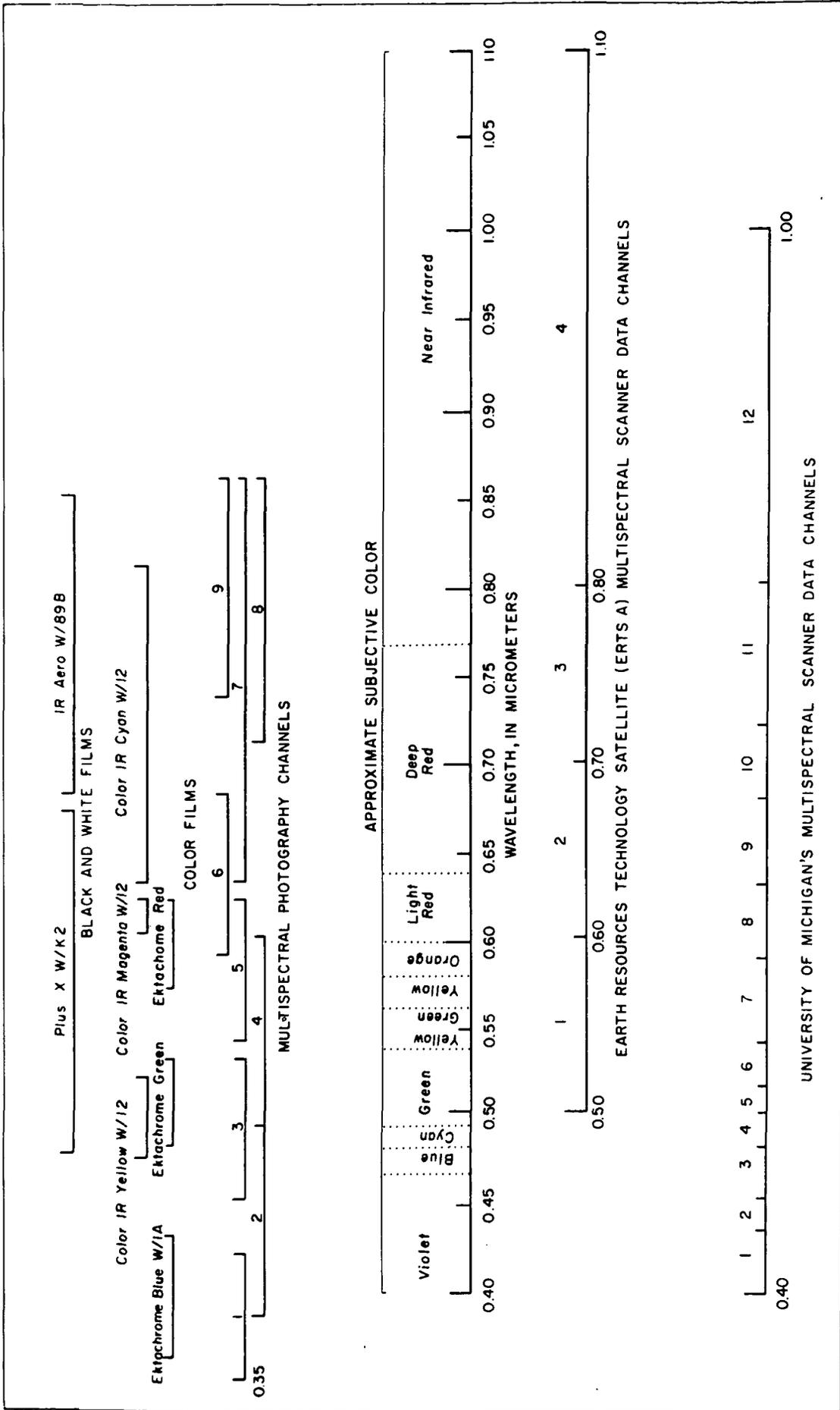


Figure 7.- Comparison of spectral ranges of various film-filter combinations with ERTS-A imagery bands and an optical-mechanical-scanner system.

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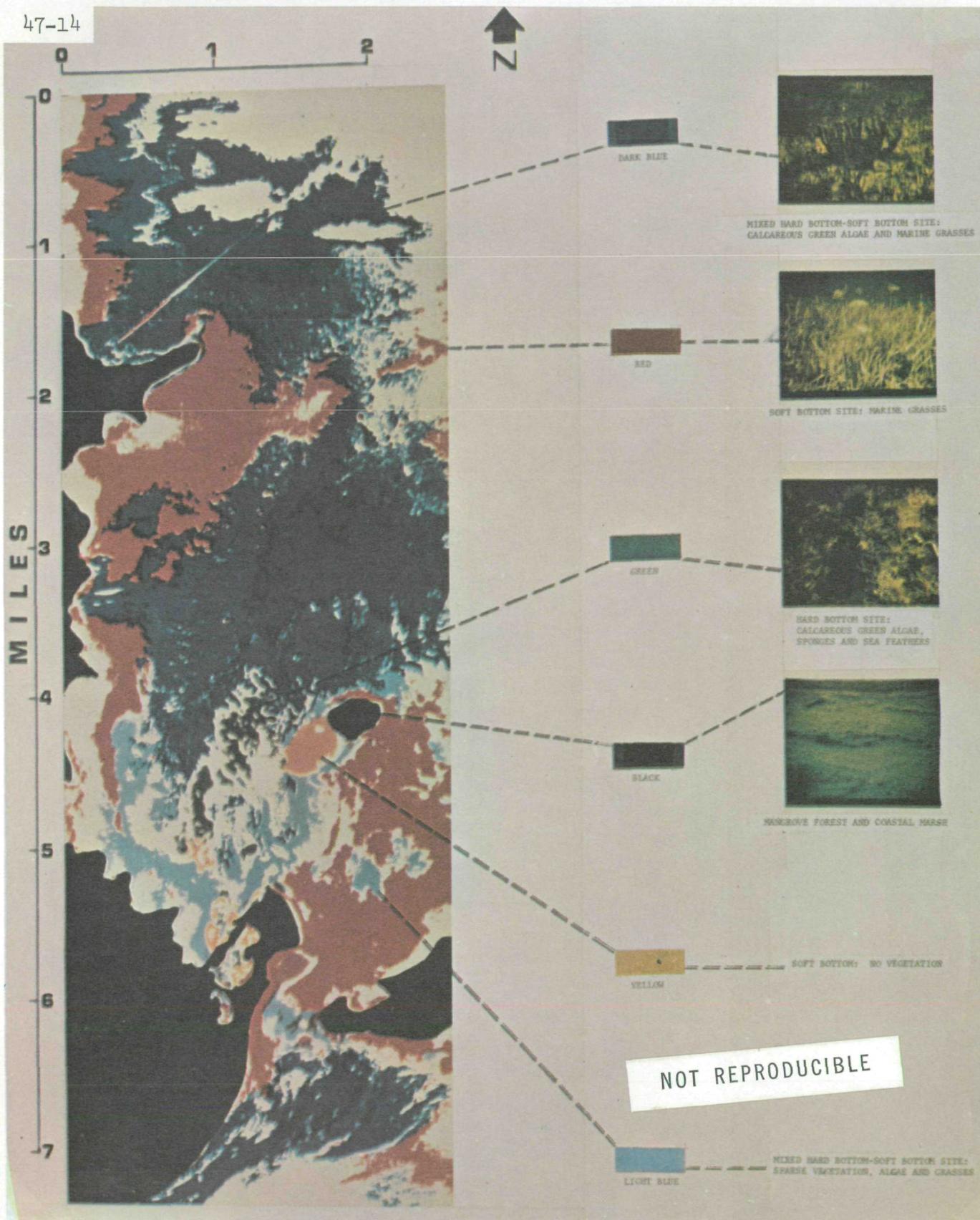


Figure 8.- Color-composite recognition map of benthic communities in south Biscayne Bay. Underwater photographs illustrate dominant community types. Water depths in the mapped area ranged from 0 to 3 meters during the overflight.

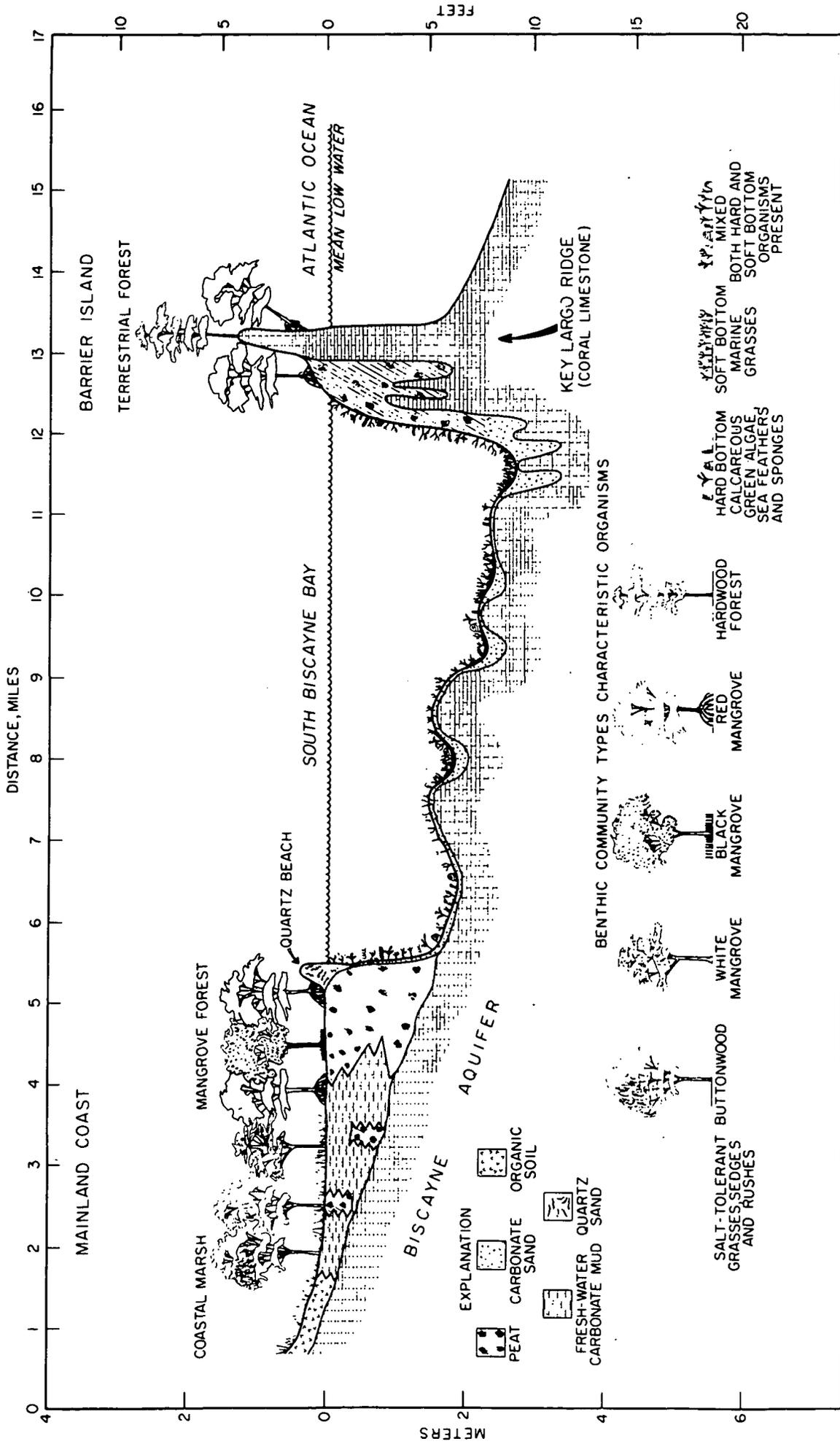


Figure 9.- Generalized cross section through south Biscayne Bay showing biogeologic features. Adapted from Wanless, 1969, (ref. 3). Vertical scale exaggerated 1000x.

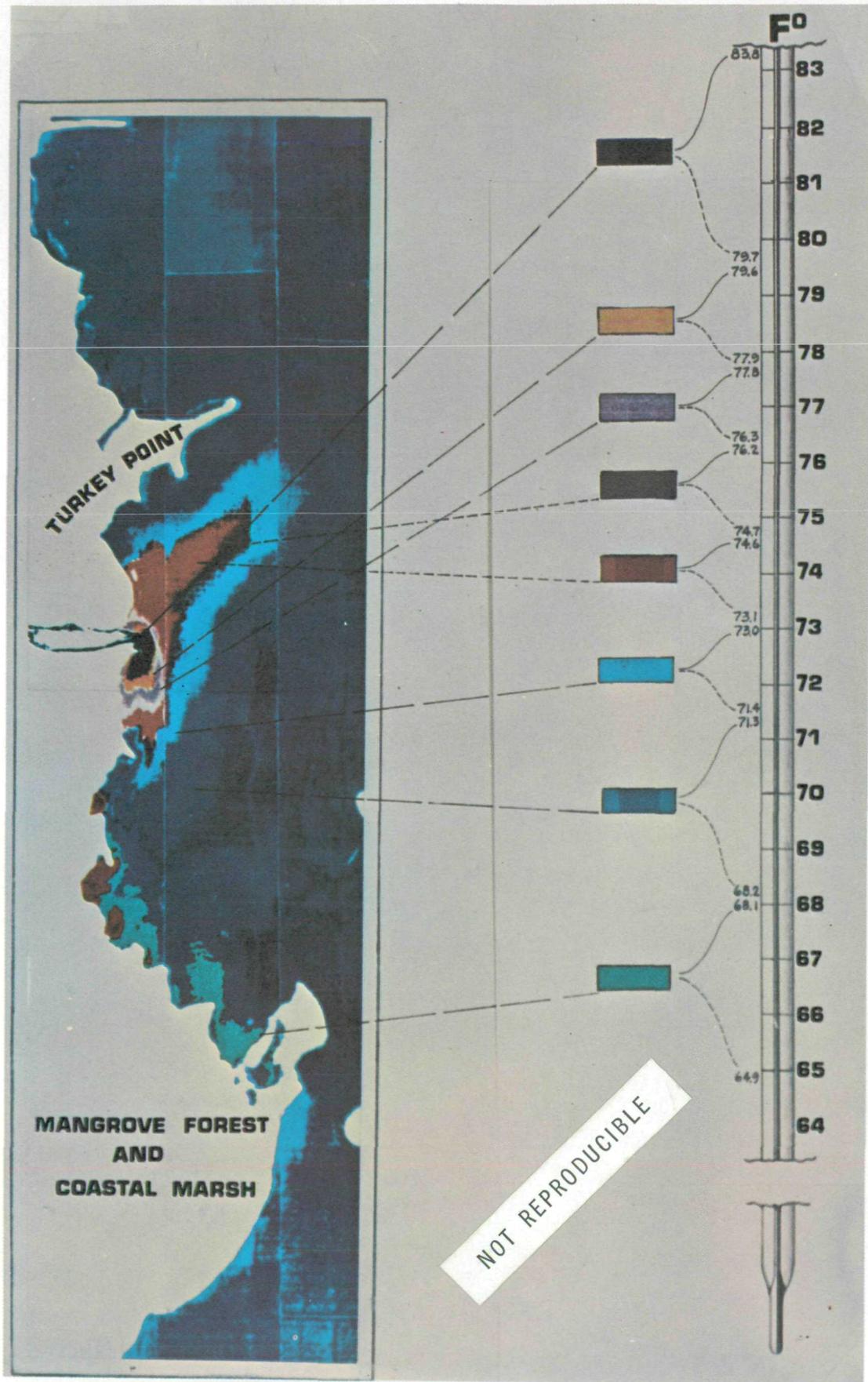


Figure 10.- Color composite recognition-map of surface water temperatures in south Biscayne Bay on March 10, 1970, between 10:08 and 10:56 a.m. Temperature distributions were derived from scanner imagery (8-13.5  $\mu$ m) that was calibrated with a network of manual thermometers and recording thermographs.