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NORTH CAROLINA STATE UNIVERSITY AT RALEIGH

SCHOOL OF PHYSICAL AND MATHEMATICAL SCIENCES

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Investigation Title: Utilization of ERTS-A Data in Geological Evaluation, Regional Planning, Forest Management, and Water Management in North Carolina

Proposal No. 018

Contract No. NAS5-21732

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The period December-January was spent working with various state agencies and interested persons in attempts to develop plans for further investigations into mineral exploration and evaluation and land-use planning and land management.

Seminars about remote sensing and the ERTS program in particular were conducted for the Department of Geology, Duke University and for the Department of Biology, East Carolina University. In the former the emphasis was upon the use of ERTS imagery to study coastal processes, and in the latter the emphasis was upon the usefulness of the imagery in mapping and understanding the coastal vegetation. A cooperator at East Carolina University is collecting data on some vegetative patterns shown on imagery of Roanoke Island made in July 1973 and August 1973. In addition several meetings were held with personnel of the Department of Natural and Economic Resources concerning use of ERTS imagery, and an informal presentation of a 1:1,000,000 mosaic of the North Carolina coastal area was made at the North Carolina Land Use Congress meeting in Greensboro.

One major study was completed during the period. The U. S. Army Corps of Engineers supported a study of the distribution of Eurasian Watermilfoil in Currituck Sound. A copy of the report is attached, including a statement about the cost/benefit ratio. It should be noted that the cost of collecting the same amount of data about the distribution of the milfoil from either boats or by aircraft would have been much more than the approximately $300 that the study did cost.

The investigators have cooperated with the Triangle J Regional Planning agency (Raleigh area) in preparing and submitting to a funding agency a proposal for use of ERTS-1 imagery to study problems related to urbanization and natural resources in the Region.

An article on the use of ERTS-1 imagery has been submitted to the Journal Photo-Interpretation. A copy of the manuscript together with copies of the photographs used in the article are attached.

Large-scale agricultural developments in Washington, Beaufort and Hyde Counties can be monitored with the ERTS imagery. Color-additive viewing techniques help distinguish fields being drained, those covered with vegetation, and those with fairly high moisture contents. Groundtruth details and evaluation of the interpretations will be obtained as soon as suitable colored renditions of the imagery can be placed in the hands of agricultural extension personnel.

Work continues on the mapping of soils and various landforms in the coastal plain. The work done most recently indicates that the mapping of soils from ERTS imagery encounters the familiar problem of the interrelationships among soil bodies, geologic parent material, climate, and vegetation. It has been possible to make preliminary soils maps of the southern coastal plain of North Carolina using the categories of wet soils and dry soils; also the categories of erodible soils and resistant soils have been recognized. The mapping was done on the basis of the spectral response of the soils and on a general knowledge of the area. It appears that it will be difficult to use the Seventh Approximation soils classification in mapping as the classes are based upon vertical profiles. However, ERTS imagery combined with a minimum of groundtruth data can lead to accurate soils maps at scales of 1:250,000 to 1:125,000 especially where the distinction to be made between soils depends in large measure upon the relative moisture content of the soil as well as associated vegetative cover.

As noted in an earlier report ERTS imagery of the Chowan River area will be utilized in connection with a broad-based study of the river. Two possible uses of the imagery seem possible: (1) delineation of the swampy areas which serve as reservoirs during periods of high wind tides and high flows and (2) recognition of circulation patterns within the lower reaches of the river, north of Albemarle Sound. The first is important in defining boundary conditions for mathematical models to be constructed during the investigation, and the second is important in any possible testing of some of the models. Additionally, imagery from October, November, and December of 1972 and 1973 can be studied to see if large-scale upstream discharges of industrial waste water made in November can be recognized in some of the upper reaches of the river.

A geological study of the Triangle Region J Planning Region has commenced with the support of the Office of Earth Resources. Preliminary studies indicate that many structural features can be mapped if the imagery is enlarged to a scale of at least 1:250,000 and reproduced on film transparencies. Color additive viewing will probably aid in delineating other geologic features as well as land use patterns of interest in the study.

Attempts to have State Agencies begin to use the ERTS imagery on a routine basis are slowly bringing results. We are getting an increasing number of inquiries about possible uses, but because ERTS imagery is a new tool routine usage will be slow in coming. The daily routine must be changed and a need for this type of imagery demonstrated. The key work in transferring the technology even in its simplest form is patience. Very specific problems must be identified by the agencies themselves and inquiries made from them regarding the possible use of the ERTS-1 imagery to solve the problem. Examples of the specific problems include the question of milfoil distribution in Currituck

Sound and preliminary floodplain delineation for purposes of floodplain insurance. The measurement of open space and sources of sediment yield in a regional context are other specific problems that agencies have identified as being of use and interest to them. Direct involvement by state and regional agencies requires a commitment to change routines and to commit manpower within the context of daily needs and priorities.

The funds still remaining in the budget will enable us to continue to file the bi-monthly reports and to prepare a final report based upon the work done to date plus any additional work completed with the aid of funds generated from state agencies during the course of the project. However, we feel, as was stated in the November Type I report, that additional funding on the part of NASA to support graduate students work and a limited amount of released time for one or more of the investigators would be in the best interest of NASA.

COASTAL PROCESSES OF NORTH CAROLINA, USA AS VIEWED BY ERTS-1[1]

Monitoring of coastal processes requires a considerable amount of detailed data collected synoptically and at great expense in terms of equipment and ship time. Often the data are widely scattered and can be collected only during periods of relatively calm weather. ERTS-1 has provided the opportunity to study coastal processes in North Carolina synoptically through application of photo-interpretation techniques. Although clear weather is required for imaging by the satellite, the impress of events occurring immediately before the pass of the satellite is left upon the water masses. Detailed analyses are not easily made, but broad regional trends of which the smaller events are a part may be studied and analysed.

ERTS-1 imagery has been utilized to study the pattern of dispersal of water and suspended material at the mouth of the Cape Fear River, North Carolina, to distinguish water quality differences in a shallow estuary, and to record the shifting of the plume of suspended material extending from Cape Hatteras. Color additive viewing and density slicing techniques have been employed.

[1]The work was supported by the National Aeronautics and Space Administration, Contract No. NAS5-21732

CAPE FEAR

The varying concentrations of suspended material in the Cape Fear River estuary can be monitored with the aid of the ERTS-1 imagery. Beyond the mouth of the river the water and its accompanying suspended load theoretically respond to wind and tidal conditions as well as to the outward flow of water from the Cape Fear River.

Response of the water masses is of environmental significance not only because of the pollutants carried in the river water but also because of the construction of a nuclear power plant south of Southport which will discharge hot water about 700 meters offshore. Two images illustrate how ERTS-1 data can be used to understand plume behavior.

Image	1080-15203-4	1188-15210-5
Tide	10% toward flood; current 1.9 kt. downstream	30% toward flood; current 0.03 kt. upstream
Winds	5 to 10 kt. from northeast	10 to 20 kt. from west but up to 3 hours before imaging the winds had been from the south
River Flow	Approximately 1280 m^3/sec	between 3600 and 3900 m^3/sec

Image 1080-15203-4, 11 Oct. 1972

Suspended material is concentrated nearshore north of Cape Fear and is found in irregular patches west of the Cape. South of the Cape there is a broadly dispersed plume. Two bands of relatively clear water extend out from the near the mouth of the river (arrows). A diffuse mass of suspended material is located between the westerly clear band and an area of relatively clear water about 5 km west of the river. Wind and tidal con-

ditions have favored a broad dispersion of suspended material. Individual plumes from the several inlets are well-documented, and the plume pattern suggests a westward longshore drift in the vicinity of Lockwood's Folly Inlet.

Image 1188-15210-5, 27 Jan. 1973

Two major areas in which suspended material is concentrated are east of Cape Fear and south of the mouth of the Cape Fear River. Apparently the suspended material east of Cape Fear has been stirred up on Frying Pan Shoals and by longshore drift and dispersed eastward in an elliptical plume.

The hook-shaped plume west of Cape Fear indicates that the currents in the area have developed an eastward-trending swirl, and the tonal differences on the image suggest the presence of a higher concentration of suspended material in the eastern portion of the plume than elsewhere.

In the near future warm water from a nuclear steam-generating power plant located north of Southport will be discharged into the ocean at the position of the outfall. If this discharge had been taking place at the time Image 1188-15210-5 was made, much of the warm water would probably have moved eastward toward Cape Fear. In contrast, warm water discharged under the conditions recorded by Image 1080-15203-4 would probably have been more widely dispersed.

ALBEMARLE SOUND

Albemarle Sound is a shallow (5 to 6 m) body of water whose tides are wind-controlled. Movement of the water masses and their contained suspended material, either stirred from the bottom, brought in from the rivers, or phytoplankton living near the surface is a function of the wind. Water mass patterns are of interest for assessing the environmental quality of the sound.

Two ERTS-1 images show the response of the sound to different wind conditions and illustrate different water quality patterns. Relative concentrations of suspended material through the sound may be measured, but absolute values cannot be determined readily.

Image 1133-15150-5, 3 Dec. 1972

The water mass has been blown against the northern margin of the sound in response to a 10 to 15 knot wind from the southwest. Variations in concentration of suspended matter are emphasized by tonal differences. The lighter colored areas represent places where suspended material is more abundant. Less turbid water from the Alligator River extends northward into Albemarle Sound.

Along the coast the suspended sediment load appears to be low and restricted to a narrow band close to the shoreline.

Image 1205-15150-5, 13 Feb. 1973

This image was made two days after a major snow storm had passed through the area. The wind was blowing out of the NNE at 10 to 15 knots. Fingers of less turbid water extend southward into the sound from the rivers on the north shore, and suspended matter extends into the Alligator River.

A part of the suspended matter is phytoplankton, for a seasonal bloom of dinoflagellates was at its height when the image was made. An increased reflectance in the infrared bands of the ERTS imagery is believed to record this phenomenon.

On the ocean side of the barrier islands the currents appear to be moving sediment southward. It is suggested that erosion may have occurred at point A.

The overlays give interpretations of the two images. Of interest is the dark patch of the mouth of the Chowan River. Other images, including 1133-15150-5, show this feature. It is interpreted as an area of less turbid water, and it is present under various wind conditions. The hydrodynamic reasons for its existence is not exactly known.

Design of water sampling programs should take into account the effects of wind and surface water runoff. Distribution of nutrients in the Sound which support both phytoplankton and algal blooms is affected by wind conditions, and ERTS-1 imagery has provided a means of viewing synoptically the changing patterns.

CAPE HATTERAS

Several ERTS-1 images of the Cape Hatteras area show suspended matter carried northwestward from the Cape. Two images, one made on 2 Dec. 1972, and one made on 2 March 1973, show suspended matter distributed as a long, finger-like feature. A Jan. 1973 image does not exhibit this phenomenon.

At the time Image 1132-15092 was made the wind was blowing easterly at 10 to 12 knots and the tide was 83% toward full ebb at Oregon Inlet. The interpretation placed upon the image is that the southward-moving currents from north of Cape Hatteras are deflected northeastward north of the Cape and joining the currents moving northeastward off the Cape. About 50 km offshore the southeast side of the plume is sheared off, apparently by the Gulf Stream.

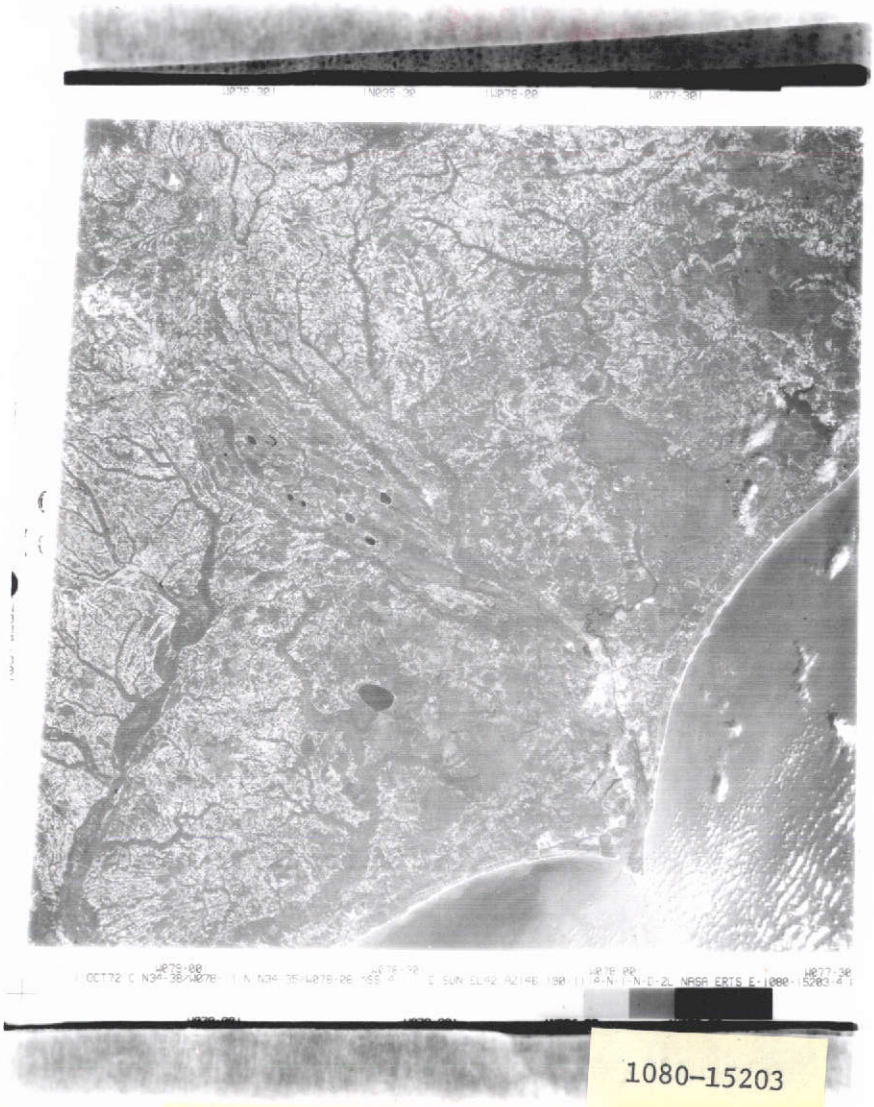
Also of interest are the four bands which extend seaward from shore. They represent higher concentrations of suspended material and reflect the internal dynamics of the coastal waters.

The overlay shows the position of the March plume (Image 1222-15093). The wind was blowing NNE at 5 to 10 knots, and the tide was halfway to full ebb.

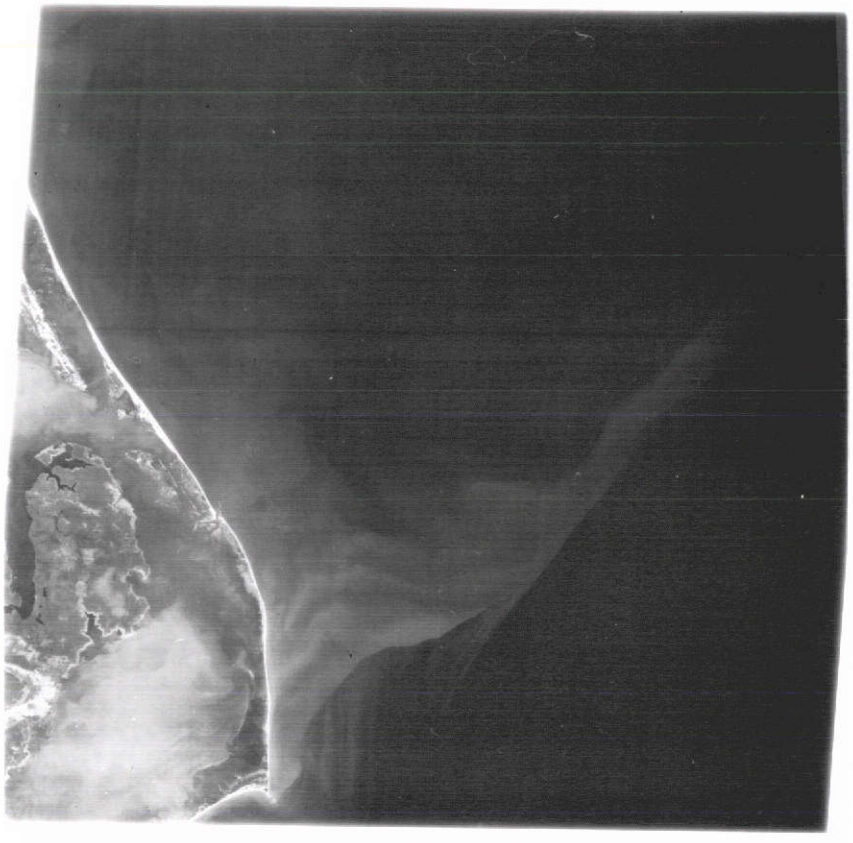
Other ERTS-1 images show different patterns of sediment dispersal within the area north of Cape Hatteras. An August 1972 image shows southerly sediment transport close to shore and northerly transport of suspended material within 2 km of the shore.

Suspended sediment in the coastal waters of North Carolina serves as an excellent marker for study of water mass movement across the shelf. ERTS-1 images give a synoptic, repetitive view that can be used to study

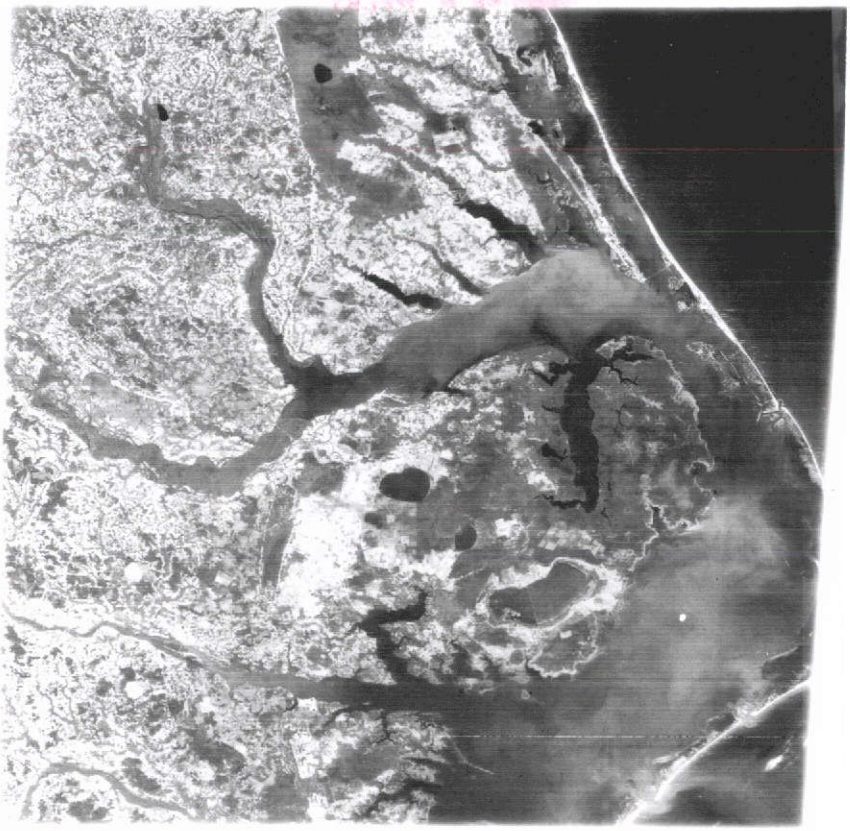
movements of the masses and so to understand better the erosional processes, the movement of nutrients, the fisheries, and transport of possible pollutants.



1080-15203



1132-15092



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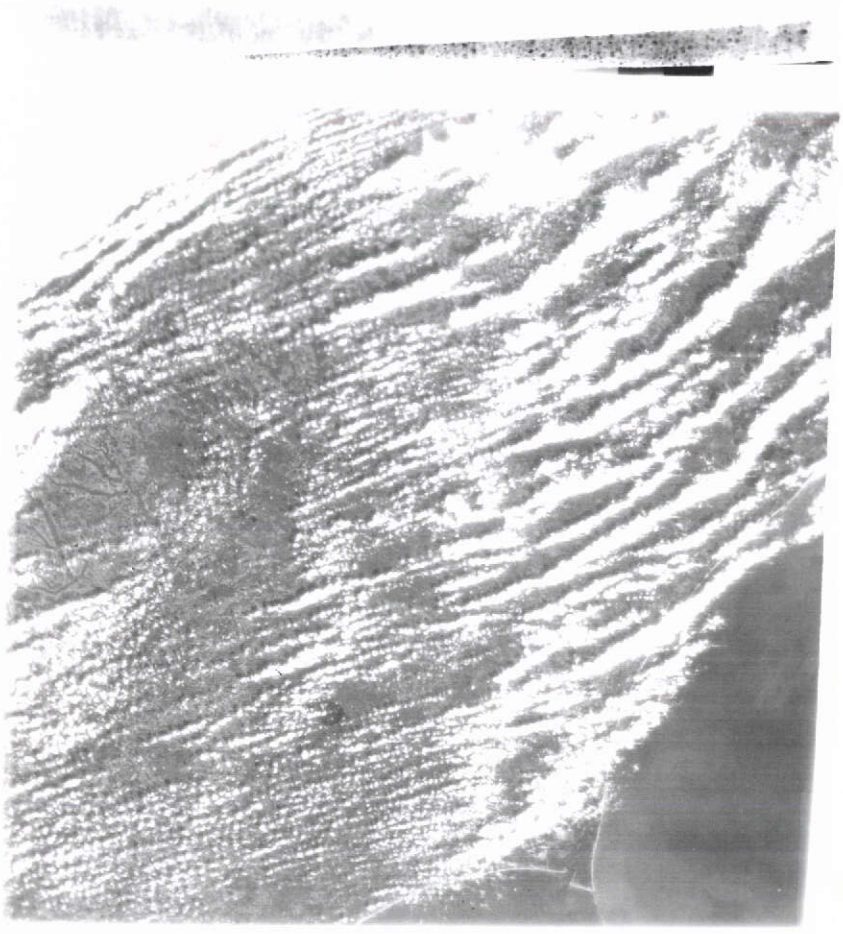
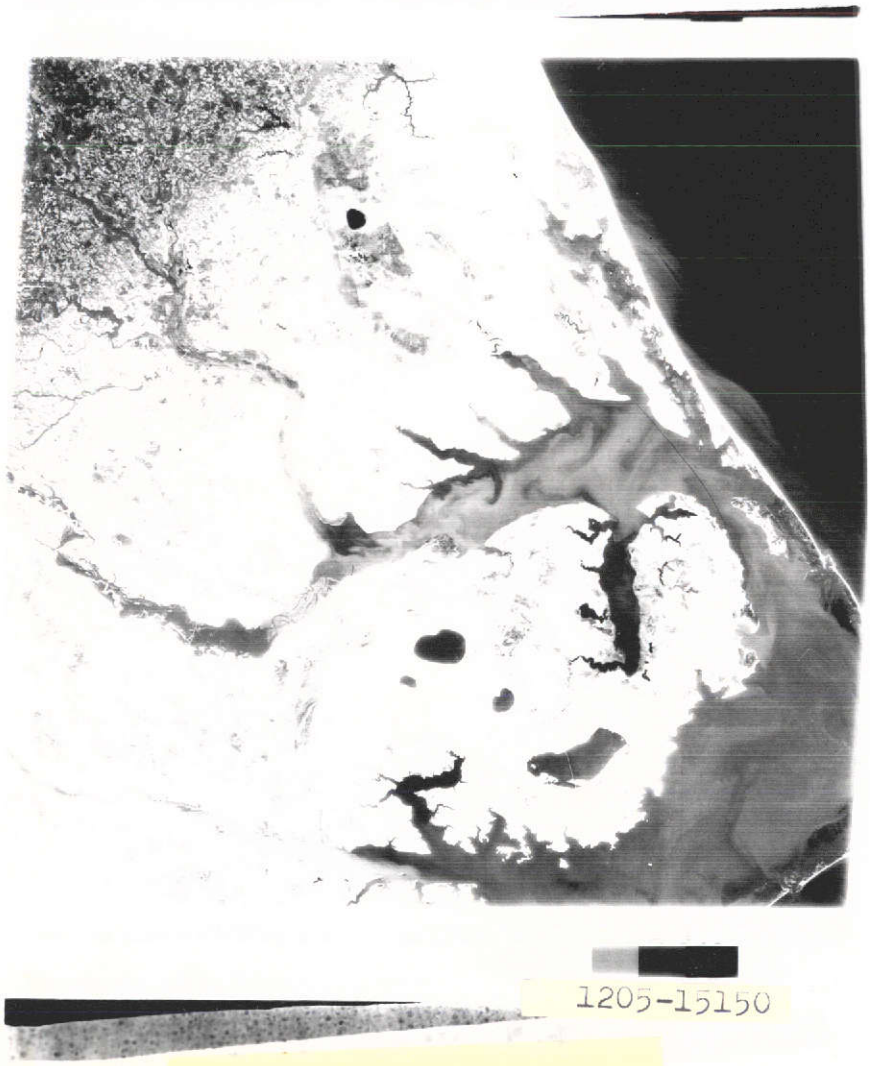


1188-15210



1205-15150

1222-15093

OCCURRENCE OF EURASIAN WATERMILFOIL (*Myriophyllum spicatum*) IN CURRITUCK SOUND AND ALLIGATOR RIVER, NORTH CAROLINA

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January 24, 1974

For the U. S. Army Corps of Engineers Wilmington District

Introduction

After discussions with Mr. R. J. B. Page, North Carolina Office of Water and Air Resources, and Mr. O. H. Johnson, U. S. Army, Corps of Engineers, Wilmington District, and under the authority of a Corps Purchase Order dated November 16, 1973, the study of the use of ERTS-1 imagery to map the distribution of Eurasian Watermilfoil (Myriophyllum spicatum) was undertaken. Since no groundtruth information was collected at the time of the ERTS-1 overpasses, locations of known concentrations of the milfoil were provided by Mr. O. H. Johnson.

Recognition of the distribution of the milfoil on the ERTS imagery requires identification of the spectral signature given off by the milfoil and recorded on the satellite. The most useful concentration of the milfoil for making this determination was that located south of Point Harbor in Currituck County. Other aquatic plants may give spectral signatures similar to those of the milfoil, but it is believed on the basis of the best information available to me that the areas mapped are chiefly milfoil and that other aquatic plants which may be present represent a minor portion of the vegetative mass indicated.

Technique

The ERTS-1 multispectral scanner records electromagnetic radiation in four wavelength bands: 0.5 to 0.6, 0.6 to 0.7, 0.7 to 0.8 to 1.1 microns, the latter two bands falling in the "near infrared" region of the electromagnetic spectrum. The data reaches the N. C. State University ERTS-1 project in the form of black and white positive and negative transparencies, the scanner data having been converted to a photographic product by NASA.

The imagery as received can be manipulated in various ways, but for this investigation positive and negative transparencies were studied in a color-additive viewer. Use was made of images taken on February 13, 1973, May 31, 1973, July 24, 1973, and August 30, 1973 together with an image made on December 3, 1972.

Vegetation reflects strongly in the 0.7 to 0.8 micron band (Band 6), particularly when it is growing vigorously. Inorganic matter suspended in the water of the North Carolina estuaries appears to reflect energy mostly in wave lengths shorter than 0.7 microns. Thus comparison of the 0.6 to 0.7 micron band and the 0.7 to 0.8 micron band should indicate whether material in the waters of the estuaries and sounds is chiefly inorganic or organic. Such a comparison was made for the images, and it was found that the July 24 image (no. 1366-15083) showed reflectances in Band 6 that were not present in the earlier images. These reflectances were located in the water areas. Comparison of the information from the milfoil location data supplied by Mr. O. H. Johnson with the locations of the Band 6 reflectances demonstrated that areas of high reflectivity on the imagery coincided with areas of known milfoil occurrence. Thus it was concluded that image 1366-15083 did record the presence of an aquatic plant growth. Study of the characteristics of the images for the areas of known milfoil infestation and comparison with characteristics of other possible areas of milfoil distribution in those areas where there was not detailed groundtruth. The Band 6 imagery shows a relatively high reflectance in an area south of Point Harbor near the confluence of Currituck Sound and Albemarle Sound, Currituck County. This locality was chosen as the chief groundtruth locality for the comparisons.

Reflectances from known areas of marsh were compared with the reflectances from the known areas of milfoil. The marshes had reflectances of lower

intensity and different hues as seen on the color additive viewer. In addition, comparison of images from December 1972 and February 1973, with the July image showed that the marshes were reflecting infrared energy at these times. The known milfoil areas were reflecting only at the time of the July 24 satellite overpass. Some reflectances were recorded on a May 31 image (1312-15091) in known milfoil areas.

Once the spectral signature of the milfoil was identified, it was then possible to map areas with similar spectral signatures. It was found that in parts of the area the spectral signature of the milfoil was much weaker than it was in others, but the hue and saturation of these areas as seen on the color additive viewer resembled closely the hue and saturation found in the areas of known milfoil growth.

In addition to the July 24 image an August 30 image (1403-15134) shows the presence of a presumed aquatic plant growth in Currituck Sound. The May 31 image (1312-15091) shows no significant increase in radiation recorded in the Point Harbor area over that found on the February 13 image (1205-15150). In fact the February and May imagery show dark areas on the positive transparencies at the Point Harbor locality. This phenomenon is interpreted as indicating an area where there is a smaller amount of suspended particulate matter in the water than there is present in the surrounding water areas. The interpretation placed upon this relationship is that it is indirect evidence of a quiet water area, perhaps held in this condition by the underwater structures of the dormant aquatic plants.

Since the resolution of the satellite imagery is about 100 meters, it is unlikely that every small patch of milfoil has been located. The density of the growth would also have some control over whether or not the reflectances from milfoil would be recorded. Thus a mass of critical size and

density of growth would have to be present for it to be recorded on the imagery, and it is presumed that there are small areas of milfoil growth with a relatively low density of plants which are not recorded on the imagery.

Aircraft imagery flown in support of the SKYLAB program flown at an altitude of approximately 10,000 feet on August 9 was used to check the presence of aquatic plant growth in two small areas in Currituck Sound. The flight line crosses the area in an east-northeasterly direction from a point about one mile north of Jarvis on U. S. 158. It crosses the 36°15' meridian about 1.2 miles east of the barrier island's oceanside shore. The color infrared photography as well as the multispectral photography show the presence of aquatic plants, presumably milfoil, in an area where they had been earlier independently mapped using the ERTS-1 imagery.

The mapping scale on the viewing screen of the color additive viewer was approximately 1:150,000. The original ERTS-1 imagery was enlarged from a 70 mm negative to an approximate scale of 1:750,000 for projection in the color additive viewer. Projection techniques were used to bring the scale to the 1 in. = 2 mi. scale of the accompanying map. North Carolina Department of Transportation county road maps served as the base maps.

Results

The accompanying map outlines the areas of milfoil occurrence which have been recognized during the course of this study. Some areas are indicated as showing possible occurrences. The imagery data for these areas suggests the presence of aquatic vegetation, but the evidence is not conclusive.

An area of apparent aquatic plant growth lies in the Powells Point area of Currituck County, along the eastern shore of the North River. The vegetation at this locality is not well developed in the May image, but its reflectance is a prominant feature on the July 24 image. Its developmental pattern resembles that of the known milfoil occurrences.

The July 24 reflectances from the East Lake area are weak, suggesting either that the vegetation here was more disperse than elsewhere or that its activity was not as vigorous as for other occurrences. The occurrence east of Durant Island conincides in general with a known area of milfoil. An area of possible occurrence is indicated along the south shore of the south arm of East Lake. It exhibits a weak reflectance on the July 24 image.

In the bay north of Second Creek Point and from Second Creek to a position about 1.5 miles south of Goose Creek on the west side of the Alligator River in Tyrrell County there appears to be a thin mass of infrared-reflecting material shown on the July 24 image. Image 1403-15134 taken on August 30, 1973, shows small patches of moderately high reflectances in Band 6 along the south side of East Lake and weaker reflections along the west shore of the Alligator River between Sandy Point and Catfish Point. Whether the August 30 data records the presence of milfoil or some other aquatic plant is not known. In the case of the occurrences along the west shore of the Alligator River the reflectances are very weak, and the data serve only to suggest that field checks are warranted.

The reflectances from the area immediately north of Catfish Point on both the July 24 and August 30 images are stronger than for the nearshore stretch to the north. It is believed that a significant mass of aquatic

vegetation is indicated for this location and in a concentration about equivalent to the density found at Long Shoal Point at the mouth of the Alligator River.

Milfoil or other aquatic plants were not recognized in the small bay north of the east end of the U. S. 158 bridge across Currituck Sound. Mr. O. H. Johnson (personal communication) indicated that milfoil at this locality had been treated chemically in 1968 and 1971. The narrowness of the bay as seen on the imagery presents problems in the interpretation of the imagery. Since any milfoil present here is apparently one of the less dense masses, the reflected energy may be obscured. Additionally, edge effects of the reflections from the adjacent land areas may contribute to the fact that the satellite did not record any aquatic plant reflectances here.

The SKYLAB-related aerial photography suggests the presence of a small patch of milfoil or other aquatic plant in the open water between the southern top of the marshes at 36°15' latitude and the barrier island. The locality is about 6 miles south of the Poyner Hill Coast Guard Station. This occurrence was not recognized on the ERTS imagery and is not shown on the map.

Acreage determinations have not been made for the milfoil infestation. Because of possible confusion over which areas are included in any acreage determination and problems associated with the resolution of the satellite imagery it is felt that the user of the map can better planimeter the areas of immediate concern to him and derive those values of most use to him.

Conclusion

With a small amount of groundtruth data to provide a key to the reflectances expected from the milfoil it has been possible to map from the

ERTS-1 imagery of the Currituck Sound and Alligator River area the extent of the major infestations of Eurasian Watermilfoil. The imagery shows not only where the milfoil occurs but also the holes and channels within the major areas of infestation. The imagery shows that the infestation within Currituck Sound and Kitty Hawk Bay is discontimuous, although there are very large areas of infestation.

The imagery should prove to be a very useful tool with which to monitor the changes in milfoil distribution within the sounds from year to year. Small patches of milfoil will have to be mapped and monitored with aircraft or by boat.

In terms of cost/benefit ratios the actual mapping required approximately three man-days, and now that the techniques have been developed, it could probably be done in about one day. Additional costs are supply costs for photographic processing of the imagery to a suitable form, including manpower costs, and the costs for preparing a final map report. The present project was completed for approximately $300, and it probably cost more than a routine monitoring of the area would because it was of an experimental nature. It is believed that on a routine basis the mapping and monitoring of the area using satellite imagery could be accomplished for no more than the cost of the imagery and the manpower costs to process it to useable form. In any event the costs should be no more than those associated with the present project. Once the areas of milfoil are outlined, a person with a good knowledge of the area could interpret the ERTS imagery using only one or two 35 mm projectors and one or two wratten filters. Sophisticated equipment would not be necessary, and a skilled interpreter would probably only need suitable black and white positive and negative transparencies and a good light table.