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COASTAL WETLANDS: PROSPECTS FOR SATELLITE INVENTORY*

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ABSTRACT

Wise management of coastal resources depends in part on the maintenance and preservation of healthy wetland ecosystems. The water storage and purification function of wetlands as well as the nutrient contribution to aquatic organisms is well documented. Wetland management decisions are dependent upon timely, accurate information such as location, size and value of major wetlands and identification of areas significantly affected by man's activities. ERTS-1 (Earth Resources Technology Satellite) data provides repetitive synoptic coverage for analysis of wetland ecology, detection of change, and mapping or inventory of wetland boundaries and plant communities. ERTS-1 positive transparencies of Atlantic Coastal Wetlands were enlarged to different scales and maps were made using a variety of methods. Results of analysis of imagery and digital data indicate: (1) mapping of wetland boundaries and vegetative communities from imagery at a scale of 1:1,000,000 is impractical because small details are difficult to illustrate; (2) mapping to a scale of 1:250,000 is practical for defining land-water interface, upper wetland boundary, gross vegetative communities, and soil disposal/dredge and fill operations; (3) 1:125,000 enlargements provide additional information on transition zones, smaller plant communities, and drainage or mosquito ditching; (4) ERTS digital data can be used for mapping at a scale of approximately 1:20,000.

Analysis of Skylab data has just begun. Preliminary information indicates that small acreages and fresh water wetlands with complex species associations may be better delineated than with ERTS-1 data.

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INTRODUCTION

Coastal wetlands are among the nation's most valuable natural resources. Atlantic coastal areas are receiving increasing pressure for industrial, residential, recreational and agricultural development, largely as a result of population growth. Dredge and fill operations have already altered many portions of the coastline. The northeastern coast is under the most pressure at the present time and laws regulating development have been passed in several of the states. The southeastern coastline (except Florida) has had less developmental pressure, derived mainly from agriculture and some industry. The prognosis is for a tremendous increase in development pressure in the southern coast during the next decade. Laws regulating development usually require costly mapping of coastal resources. A relatively low cost and moderately accurate method for mapping these areas including wetlands, mud flats, drainage patterns, impact of man and vegetation productivity would be very attractive to states and assure that at least a portion of this valuable ecosystem would be preserved and managed.

Investigators such as Anderson (1) and Reimold (3) have shown the reliability of using aircraft remote sensing techniques to do a variety of wetlands studies, including species mapping and vegetation productivity. Ground based ecological studies in wetlands have produced maps of relatively small areas with a high degree of accuracy. These have been valuable in developing remote sensing techniques but the process is too slow and costly for large areas. Low altitude (2,000 meters) aerial photography has been applied in New Jersey by Anderson and Earth Satellite Corporation to produce wetland maps which meet national map accuracy standards. This is a relatively rapid method, but the cost may be prohibitive for some states. In order to decrease the time and cost involved in wetland mapping, it will be necessary to reduce the accuracy somewhat. It appears from this research that ERTS-1 data may

be applied to rapid, relatively low cost wetland mapping on broad regional scales.

ERTS-1 data provide repetitive synoptic coverage of the earth's surface. This is the first time that information of this nature has been available to investigators on a routine basis. The satellite is in a near polar, sun-synchronous orbit, making about 14 revolutions around the earth each day with complete global coverage every 18 days. The altitude is 912 kilometers with equatorial crossing about 9:45 local time. ERTS-1 is equipped with two sensing systems. The Multi-spectral Scanner System (MSS) scans the earth, simultaneously detecting energy in four spectral bands: band 4, 0.5-0.6 micrometers (visible green); band 5, 0.6-0.7 micrometers (visible red); band 6, 0.7-0.8 micrometers (infrared), and band 7, 0.8-1.1 micrometers (infrared). The Return Beam Vidicon (RBV) system consists of three co-aligned cameras, each viewing the same scene but in different spectral bands: 0.475-0.575, 0.580-0.680, and 0.690-0.830 micrometers. Information is either transmitted directly to ground stations or stored in on-board tape recorders for later transmission.

The MSS digital data is stored on computer compatible tapes (CCT). Images, 185 kilometers square, of the earth's surface, are prepared from the digital data at Goddard Space Flight Center, Maryland. One pixel or resolution element represents the average reflectance level (radiance level) over an 80 x 80 meter field of view, but because of overlap in the horizontal scan, the unique instantaneous field of view (IFOV) is approximately 57 x 79 meters. Maximum spatial and grey-level resolution is available from the ERTS digital data.

CHARACTERISTICS OF THE TEST SITES

The test region for the ERTS research extends from Delaware Bay to Georgia. Two smaller test sites were chosen for intensive study. Figure 1 is a map of the Chesapeake Bay showing the location of the northern test site and indicating two test areas examined in detail in the following pages. Area 1 is a salt marsh complex located at the mouth of the Chincoteague Bay in Virginia. Area 2 is a large, near-saline marsh at the mouth of the Nanticoke River in Dorchester County, Maryland. Maryland has approximately 300,000 acres of wetlands, 250,000 of which lie on the Eastern Shore, or what is commonly called the Delmarva Peninsula. Virginia has approximately 330,000 acres of wetlands, over half of which also lie on the Delmarva Peninsula.

The southern test site (Figure 2) is bordered on the south by Saint Catherine's Island, Georgia, and on the north by Charleston, South Carolina. The coastal marshes from North Carolina southward represent the best development of saline marshes in the United States. Those in South Carolina and Georgia are particularly well developed. Cooper (2) has summarized the current knowledge of eastern coastal areas. Vegetational composition is quite similar along most of the coast but grades to mangrove swamps in Florida. Tidal amplitudes vary from two feet in some portions of North Carolina to eight feet in South Carolina and Georgia.

The major community types which dominate the frequently inundated saline and near-saline marshes of the east coast are *Spartina alterniflora* (salt marsh cordgrass) and *Juncus roemerianus* (needle rush). *S. alterniflora* occurs as at least two and in some areas three growth forms. This is apparently related to tidal inundation and soil aeration. High growth (to 3 meters) is found along the banks of creeks where the substratum is very soft and tidal inundation is for the longest period of time. The next growth form (to 1 meter) grows at slightly higher elevations in a more firm substrate. The third growth type (less than 1 meter) is at the highest elevation for *S. alterniflora* in a firm substrate where other species may mix with it occasionally. *Juncus roemerianus* occurs as small to large zones mostly at the next highest elevation and where the water is somewhat fresher.

Vegetative composition in the high marsh varies from north to south. Higher, less frequently inundated parts of the northern test site are characterized by pure stands of *Spartina patens* (saltmeadow cord grass) or mixtures of *S. patens* and *Distichlis spicata* (spike grass). Other species which grow as mixed communities include *Spartina cynosuroides* (giant cordgrass), *Baccharis halimifolia* (groundsel bush), and *Iva frutescens* (marsh elder). The higher elevations in the southern test site contain mixed communities of *Salicornia* sp. (glasswort), *Iva frutescens*, *Batis maritima* (saltwort), *Borrhchia frutescens* (sea oxeye), and *Distichlis spicata*. Large stands of *Spartina patens* are relatively rare. *Spartina cynosuroides* is common in near-saline areas.

RESULTS

A. General

Interpretation of grey-levels imaged on the four ERTS bands is facilitated by knowledge of the spectral reflectance characteristics of earth surface features. A considerable amount of spectroradiometric data has been collected by the authors in wetland areas, using an ISCO spectroradiometer. Table 1 is a summary of the average spectral reflectances, in percent, of a number of major wetland plant species and other wetland components. The reflectance values listed in this table are representative values, or ranges of values, chosen to illustrate the general relationship between wetlands reflectances during the growing season. Actual reflectance of marsh plant associations can be expected to vary depending on percentage composition of species, density, tidal inundation and season.

ERTS positive transparencies at a scale of 1:1,000,000 have high resolution and excellent contrast. The coastal marshes generally appear as a dark grey tone near the dense end of the scale on bands 6 and 7 images, and as a dark red-grey in a color infrared simulation (color composite). This is largely because of the high moisture content of the background and because the spectral reflectance of the dominant marsh species, or species associations, is also generally low in bands 6 and 7. Processing procedures at Goddard Space Flight Center favor the more highly reflective, upland features. For this reason, special processing is sometimes required to bring out detail in coastal features. Detail in uplands is lost when optimum processing techniques for coastal areas are used.

The marsh-water interface and the upper wetland boundary are clearly seen on MSS bands 6 and 7. Large plant associations or communities can also be detected on either MSS band 7 or on color composites made using Diazo subtractive color technique. In bands 4 and 5 (visible: green and red), saline marsh species have a relatively low overall average reflectance but appear less dark in tone than adjacent dryland forest vegetation. As the coastal marshes become fresher, the spectral reflectance of the species composing these marshes is higher in the IR (bands 6 and 7) and approaches that of dryland vegetation, making the wetland/upland boundary less clear. It may be necessary to develop special processing techniques where wetland grades to dryland in order to clearly define this boundary.

B. Northern Test Site

Use of a Bausch and Lomb Transfer Scope in combination with 1:1,000,000 scale ERTS format permits enlargement of the image and construction of maps and overlays to a scale of 1:250,000. Figure 3 is a 1:250,000 enlargement of an ERTS MSS 7 image (1079-15140, Sept. 7, 1972) of the Chincoteague salt marsh complex, and a 1:250,000 map of the same area showing four categories; (1) upland vegetation and beach, (2) water, (3) Spartina alterniflora/Salicornia sp. association, and (4) Spartina patens/Distichlis spicata/Iva frutescens association. The spectral reflectance of the Spartina alterniflora/Salicornia sp. association is generally low, in part because of the wet mud or peat background below the vertically oriented vegetated layer. The relatively high reflectance of Spartina patens permits sufficiently large areas of the Spartina patens/Distichlis spicata/Iva frutescens association to be delineated. The upper wetland boundary is generally sharp except where broad transition zones exist. The marsh-water interface is sometimes difficult to determine in areas interlaced with numerous small tributaries or sparse patches of vegetation. Sand and marsh at the mouth of Chincoteague Bay are not shown on the USGS 1:250,000 map published in 1946. Spoil areas may be easily separated from reflective vegetation by referring to bands 4 and 5 or by using a color composite since they are highly reflective in all four bands.

ERTS-MSS digital data from the Chincoteague test area was analyzed using the ERTS-Analysis System at Goddard Space Flight Center (4). A wetland vegetation signature analysis algorithm was developed using ISCO field-determined spectral signatures and ground truth data. A computer-generated vegetation map of a small marsh island within the test area has been produced. The output identifies 8 categories of marsh vegetation and marsh features at an approximate scale of 1:20,000. These categories are:

- . - water
- - sandy mudflat
- / - organic mudflat, sparsely vegetated
- - spoil
- I - Iva frutescens
- P - Spartina patens
- A - Spartina alterniflora
- ? - unidentified

Refinement of the algorithm should improve the mapping capability in similar

Table 1: Average or Range of Average Spectral Reflectance, in Percent, for Wetland Species and Components in ERTS MSS Bands 4-7

Wetland Species or Component	MSS Band			
	4	5	6	7
<u>Spartina alterniflora</u> (salt marsh cordgrass)	3.6- 5.2	3.9- 5.3	12.7- 17.4	16.0- 23.5
<u>Salicornia sp.</u> (glass wort)	4.7	5.2	13.8	18.7
<u>Spartina patens</u> (salt meadow cordgrass)	3.7- 7.1	4.2- 7.7	18.3- 27.9	21.4- 41.1
<u>Juncus roemerianus</u> (needlerush)	2.4	3.1	7.5	10.9
<u>Spartina cynosuroides</u> (glauk cordgrass)	4.2	3.7	20.9	28.1
mudflat	3.9- 6.0	4.4- 7.7	6.1- 11.5	7.0- 11.6
sandy fill	12.9- 13.7	17.0- 20.0	22.8- 26.1	25.8
water (turbid)	9.5	10.4	7.8	4.1
The American University	The U.S. Geological Survey			

marshes.

C. Southern Test Sites

Two sites in the southern portion of the test region were selected for intensive study. These were the Charleston, S.C., area for marsh categorization and the Ossabaw Island, Ga., for general wetland mapping. Figure 4 is a map of the Charleston, S.C., area made from ERTS images 1081-15264-5,7 and 1243-15274-7 using a Bausch and Lomb Zoom Transfer Scope to compile at a scale near 1:250,000. Three categories of wetlands were identified:

Category 1. Salt marsh containing predominantly Spartina alterniflora with the following subdominants present in varying amounts, usually at or near the upper wetland boundary: Juncus roemerianus, Salicornia sp. (glass wort), Distichlis spicata (spike grass), Spartina patens (salt meadow cordgrass), Borrchia frutescens, and Iva frutescens (marsh elder).

Category 2. Near-saline to brackish marsh containing predominantly Juncus roemerianus with stream channels bordered by Spartina alterniflora at the more saline and Spartina cynosuroides at the fresher end. Subdominants in this area may include Distichlis spicata, Salicornia sp., Spartina patens, Scirpus sp., and Iva frutescens.

Category 3. Brackish to fresh marsh containing large stands of Spartina cynosuroides along stream margins with Scirpus americanus or olneyi (three-square) or Juncus roemerianus often filling in the remaining area. Subdominants include Scirpus sp., Zizania aquatica (wild rice), Juncus sp. As the water becomes fresher, Sagittaria sp. (arrowhead), Nuphar advena (yellow water lily), Pontedaria cordata (pickerelweed), Peltandra virginica (arrow arum), Lilaeopsis chinensis, and Typha sp. (cattail), become co-dominants with Spartina cynosuroides.

As the water becomes fresher, the species mixture becomes more complex and the vegetative cover more reflective in the IR. The upper wetland boundary becomes increasingly difficult to identify in band 7 with distance inland during the growing season. Supplementing the interpretation with band 5 imagery aids delineation since the marsh shows a grey-level reflectance distinguishable from spoil and agricultural fields (lighter) and water or woods (darker). However, the best method using B/W imagery is to

delineate upper wetland boundaries on band 7 of winter or early spring imagery (3/23/73) and to attempt species discrimination using band 7 and 5 imagery taken midway to late in the growing season. Band 5 can be used to separate disturbed or spoil areas from other wetland features and to separate trees from fresher tidal marshes.

Figure 5 is a 1:250,000 scale enlargement of MSS band 7 (no. 1046-15324, Sept. 7, 1972) of the Ossabaw Island test area. Note the good tonal differentiation in the coastal marshland but loss of detail in the upland. The upper wetland boundary (F) is clearly seen in most of the image although patchy clouds may be mistaken for upland or tree islands in the marsh. Lagooning for water-side home development (A) is visible near Burnside, Georgia, in the Vernon River. Of possible greater significance is the marshland ditching visible in the Fort McAllister area of the Ogeechee River (B). Ditching causes drying out and accelerates vegetational succession to dryland species and is therefore undesirable as currently practiced for mosquito control and agriculture in many areas. It has been assumed that the resolutional limitation of ERTS imagery would not allow definition of ditching practices. At least in this area that assumption was incorrect.

Various vegetational features are also clearly shown. Tonal characteristics of marshland vegetation in Ogeechee River are considerably different from the nearby Medway River. On the ground investigations have shown that Juncus roemerianus (C) is the dominant vegetation in the Red Bird Creek area. The lighter tones of this species contrast nicely with the darker tones of flooded areas of Spartina alterniflora (D) which makes up the bulk of the vegetation in Medway River. The lightest tones in these marshes are at the "loop" in the Ogeechee River (Spartina cynosuroides) and off Kilkenny Creek near Belle Island (mixed populations of Borrchia frutescens and Spartina alterniflora on slightly elevated mudflats).

Tonal structure in the Bear River marshes indicate that separation of at least two growth forms of S. alterniflora will be possible. The tall form along the creeks images lighter than the shorter forms. It appears that gross productivity estimates may be made from the imagery.

D. Effect of Tidal Stage on ERTS Image Interpretation

Images taken over the Georgia coast, Ossabaw Island area on different dates were analyzed for effects of tidal height on imagery interpretation in wetlands. In addition, ERTS images and U-2 photography from different dates over Charleston, S.C., area were examined to check the interpretation of the Georgia images and to examine tidal effects in the upper reaches of tidal rivers. The approximate time of imagery relative to high or low tide, tidal height above mean low water and tidal range were calculated using the Tide Table, High and Low Water Predictions for Each Coast of North and South America, 1972 and 1973, published by NOS (NOAA).

ERTS images 1010-15322-7 (8/2/72) taken at low tide and 1046-15324-7 (9/7/72) taken at high tide were used for determining effect of tide stage on image interpretation. Conclusions were that drainage patterns and berms or levees can be delineated using the low tide image. The high tide image shows good differentiation between low growth and high growth forms of Spartina alterniflora. Low growth forms of Spartina alterniflora occur on higher ground, but grow so sparsely that the water background affects scene reflectance. Areas containing predominantly Juncus roemerianus can be separated from those containing predominantly Spartina alterniflora at this tidal stage since an overall light reflectance is characteristic of Juncus roemerianus in band 7 whereas a mottled, dark-light appearance is characteristic of Spartina alterniflora areas where large amounts of background water may be present. Fresher marshes containing Spartina cynosuroides and associated species have a higher reflectance than the more brackish Juncus marshes and may also be separated on this image.

SKYLAB DATA ANALYSIS

Preliminary analysis of the Skylab-2 data has been directed toward comparing resolution of wetlands with that of the ERTS images. Negatives have been made of the northern (Nanticoke) test site from the following ERTS images: 1062-15190-5,7; 1079-15133-5,7; 1170-15193-5,7; 1205-15141-5,7; 1295-15142-5,7; and 1313-15141-5,7; and from all four of the black and white Skylab-2 photographs frame #166. Figure 6 is the B/W IR (.8-.9 u) Skylab-2 photograph and the June 1, 1973, ERTS image 1313-15141-7, both enlarged to a scale approximating

1:170,000. First look analysis indicates that increased resolution in the Skylab photograph enables separation of a greater number of discrete grey levels within the marsh areas. Also small rivers and creeks, drainage patterns, and upper wetland boundaries are seen in sharper detail.

CONCLUSIONS

Mapping at a scale of 1:250,000 is adequate for the general delineation of large marshes and for rather gross plant species associations. Enlargement of the imagery to a scale of 1:125,000 provides additional information when processing is done to enhance the contrast in the denser part of the image. Overlays can be made directly from the prints which show the marsh-water interface and upper wetland boundary clearly. Where broad successional zones exist, these can also be mapped. Smaller plant communities, occasionally less than 25 meters in diameter in high contrast areas, can be identified. In addition, open and vegetated ditches dug for drainage or agriculture can be recognized and indicated on the map. If states can sacrifice some accuracy (amount unknown at this time) in placing of boundary lines, the technique may be used to do the following:

- (1) Estimate extent of man's impact on marshes by ditching and lagooning.
- (2) Place boundaries between wetland and upland and hence estimate amount of coastal marshland remaining in the state.
- (3) Distinguish among relatively large zones of various plant species including high and low growth S. alterniflora, J. roemerianus, and S. cynosuroides.
- (4) Roughly determine the areal extent of major plant species and hence estimate potential productivity of each.
- (5) ERTS-1 digital data provides maximum grey-level resolution for mapping of wetland species and features.

Tidal stage affects imagery interpretation and must be considered when analyzing wetlands from ERTS-1 data.

Preliminary analysis of Skylab-2 data has shown increased resolution of grey-levels in freshwater marshes where level of detail in ERTS data has been

unsatisfactory. Processing techniques must be refined to obtain optimum use of data.

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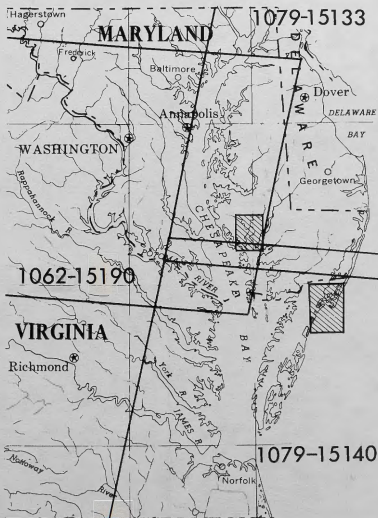


Figure 1

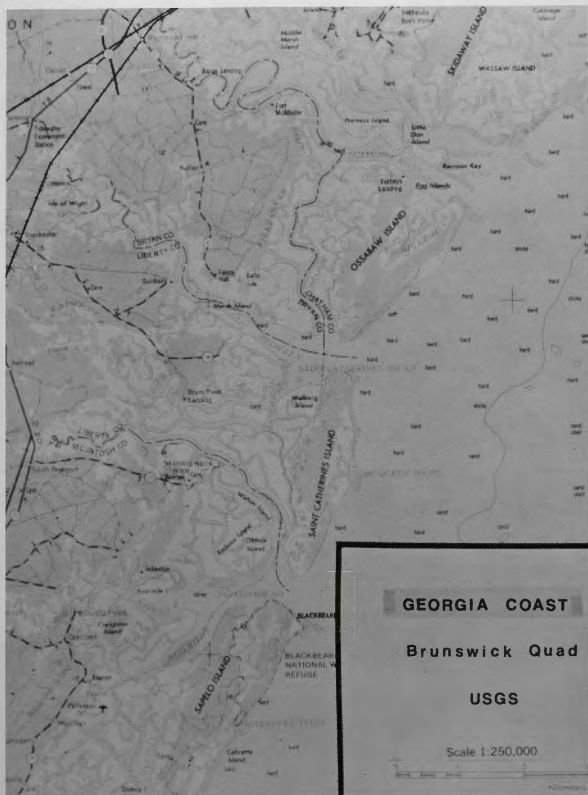
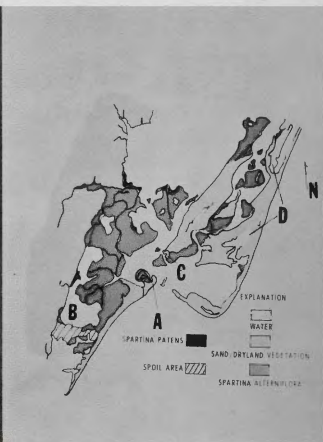
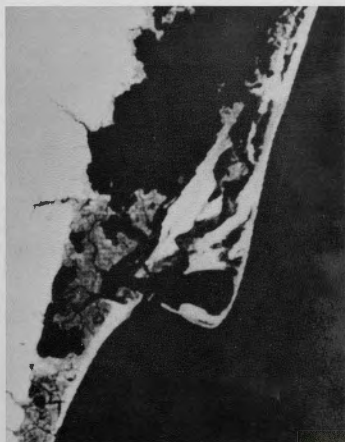


Figure 2



1079-15140-7

1: 250,000 ENLARGEMENT

ERTS WETLAND MAP

- A Sand/Marsh Area**
- B Old Spoil Area**
- C Recent Spoil Fill**
- D Fresh Water Impoundment**



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Figure 3

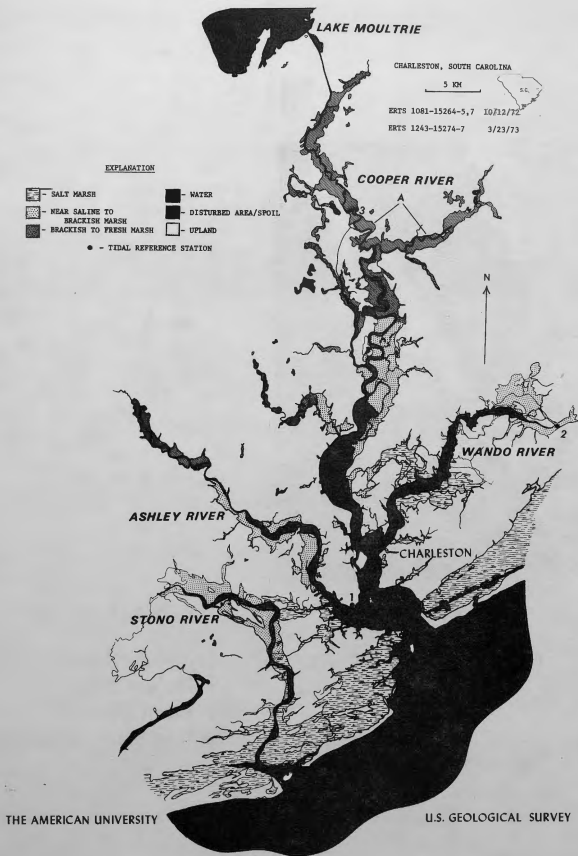


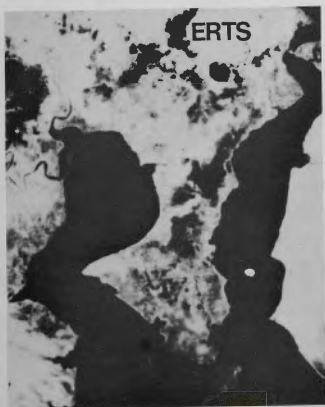
Figure 4



GEORGIA COASTLINE

- A Lagooning
- B Ditching
- C Juncus
- D Spartina
- E Berm
- F Wetland boundary

Figure 5



1349-15134-7 July 73



SL-2 167 RL13 June 73

Figure 6