

By M. Kristine Butera, NASA/JSC, Earth Resources Laboratory
Bay St. Louis, Mississippi

ABSTRACT

A test was conducted to determine if salinity regimes in coastal marshland could be mapped and monitored by the identification and classification of marsh vegetative species from aircraft multispectral scanner data. The data was acquired at 6.1 km (20,000 ft.) on October 2, 1974, over a test area in the coastal marshland of southern Louisiana including fresh, intermediate, brackish and saline zones. The data was classified by vegetational species using a supervised, spectral pattern recognition procedure. Accuracies of training sites ranged from 67% to 96%. Marsh zones based on free soil water salinity were determined from the species classification to demonstrate a practical use for mapping marsh vegetation.

INTRODUCTION

The United States can claim 30 million acres of marsh, or non-forested wetland, among its 26 coastal states and territories (1). The marsh includes such aquatic areas as fresh water lagoons and sloughs, estuaries, and the generally more saline coastal interfaces.

The coastal zone not only offers residence to approximately one-third of the nation's population, but also contains vast marshlands which represent an economically valuable, renewable resource. Non-forested wetland provides breeding grounds for commercial fish, shellfish, and fur-bearing animals. It also provides recreational activities such as boating, hunting and fishing, and represents a natural purification and drainage system for water flowing to the coast from more congested areas. Any environmental change within the marsh may impact the benefits derived from it, and thus monitoring the marsh becomes necessary for proper management.

One method of monitoring the marsh is the recording of marsh vegetation, as any type of vegetation growing in an area is an indicator of its environment. This paper deals with the utilization of multispectral remote-sensing by the modular multiband scanner (MMS) as a means of mapping expanses of marsh vegetation for use in the environmental monitoring of salinity intrusion.

Description of Study Area

A 72.5 km transect through the marsh of Louisiana, which alone claims seven million acres of marsh, was selected for the study described in this paper (Fig. 1). The study area is a representative sample of the Louisiana marshes, which originated from the old delta of the Mississippi River as it shifted course with time along the coast. The area is of interest because it is believed to be undergoing salt water penetration from the coast due to the introduction of man-made canals (2). Further, the same area is experiencing a reduction of fresh water flow from the Mississippi River and its tributaries due to the imposition of levee systems that prevent natural flooding of the marsh (3).

Changes in salinity levels give rise to environmental change, affecting marine productivity. The Louisiana marsh serves as a nursery for such commercially valuable animal life as menhaden, crab, oyster, shrimp, nutria, mink and muskrat, each depending on the status quo of a given salinity range to survive, where the brackish marsh, between fresh and salt water regimes, is the most productive (1). The study area includes a transitional zone of brackish marsh, grading into fresher inland marsh in one direction and more saline coastal marsh in the other.

In a more general sense, the study area may be representative of most marshes, because though geographically dispersed across the continent, the marsh maintains a uniformity in type and succession from Nova Scotia to Mexico, where water is the common factor and sodium chloride is the limiter (4). Thus, such uniformity of marsh suggests a general applicability of the results of this localized study to other areas.

Concept

The establishment of particular vegetative species in the marsh is dependent on such environmental factors as tidal phenomena, soil type, rainfall, temperature, and both horizontal and vertical gradients of soil salinity (5).

Comprehensive studies of the Louisiana coastal marsh vegetation have arranged dominant marsh species into groups based on soil water salinity alone (2, 6). Typical marsh types are shown in Figs. 2-23. The most recent work, premised on the salinity groups mentioned above, has divided the Louisiana marsh into four types: fresh, intermediate, brackish, and saline, each type being characterized by a given soil salinity range and association of plant species (Tab I) (7). Chabreck's 1968 marsh zonation of Louisiana, the work mentioned above, was accomplished by the recording of vegetation types from a helicopter following transect lines approximately 12 km (7.5' in latitude) apart, with interpolation of the salinity zones between the lines (Fig. 24).

The objective of this paper is to demonstrate that the same task of identification of marsh vegetation and the determination of marsh salinity zones can be accomplished by an aircraft multispectral remote-sensor with the advantages of greater efficiency and the accuracy associated with total area coverage. This investigation is preliminary to the classification of satellite multispectral data for marsh salinity zone determination.

EXPERIMENT DESIGN

The area described in this paper represents flight line #3 of the 15 flight-line design set of NASA Mission 287, from which MMS data and color IR imagery were acquired in the Louisiana marsh on October 2, 1974. Associated information for flight line #3 follows:

| <u>Aircraft</u> | <u>Ground Speed</u> | <u>Altitude</u> | <u>Time (CST)</u> | <u>Sensors</u> | <u>Scan Rate</u> |
|-----------------|---------------------|-----------------|---------------------------------|---------------------------|------------------|
| NP3A | 6.5 km/hr | 6.1 km | Start 11:20:00 Stop 11:26:00 | Zeiss MMS ¹ | 12 rev./sec. |

¹The MMS has an instantaneous field of view of 2.5 milliradians, a full scan angle of 100° ± 20° and a scan rate range of 10-100 revolutions/sec.

Possible training sites, for use in the supervised pattern recognition system of classification, were selected from color IR imagery acquired over the area in 1973, based on variations in texture and color that would lead to sites representative of dominant marsh vegetative species. Expanded chronopaques of the color IR imagery were produced on which the training sites were marked to use as "maps" for the ground truth expedition.

Ground truth of the training sites was accomplished almost exclusively by helicopter July-August 1974, since the marsh was generally inaccessible by car and often even by boat. While the helicopter hovered over a training site located on the chronopaque map, several overhead photographs were taken between 61m to 15m (200' to 50') and observations were recorded regarding the % barren and/or water in the site and the total % vegetation in the site. The percent of each observed species and dead plant material was also noted. Species not immediately identifiable were collected for laboratory study and herbarium mounts.

The field description of each training site was reviewed and the training site rejected for further use in the classification process if it did not represent a dominant marsh species or typical association of species.

The original pulse-code-modulated tape which recorded the MMS Mission 287 data was decommutated and made computer-compatible on the data analysis station (DAS) at the Earth Resources Laboratory at the National Space Technology Laboratory, Bay St. Louis, Mississippi. MMS channels 5, 7, 8 and 10, representing wavelengths .58-.62, .66-.70, .70-.74 and .97-1.06 μm , respectively, were used in the pattern recognition classification (8). Salinity zones were interpreted from the resultant marsh vegetational classification and compared with those derived by Chabreck (7).

RESULTS

The observed composition of each training site used in the classification of the study area is listed in Table II. Usually, one species dominated a training site, with one or more subdominant species occurring in association with the dominant. Some sites included a given percentage of water and/or sediment. The locations of training sites are indicated on the color IR imagery acquired from NASA Mission 287 (Fig. 25).

The marsh vegetation of the study area was classified from the MMS data using water and six different vegetative classes (Fig. 26). The unclassified areas probably represent agricultural fields, barren, and/or urban areas for which no training sites were included. Only the area covered by 90° of the total 120° scan is shown in the classified map.

Classification accuracies of the training sites, a function of class versus class-name percent occurrences, ranged from 68.7% to 96.0%, with an average of 88.2% (Table III).

Salinity zone lines within the study area were defined associations where *Sagittaria falcata*, *Panicum hemitomon*, and *Myrica cerifera* as dominants indicated a fresh zone; *Spartina patens* as a dominant indicated a brackish zone; *Spartina alterniflora* and *Avicennia nitida* as dominants indicated a saline zone; and the transitional area where *Spartina patens* appeared with other fresh marsh vegetative types indicated an intermediate zone (Fig. 27b). The salinity zone delineation derived from this remotely-sensed classification differed from the delineation derived by line-transect method in 1968 (Fig. 27a). The latter indicated a broader area of intermediate zone, but not extending as far south as in the former, and a larger area of saline zone extending more inland.

DISCUSSION

A September-October time frame for data acquisition was chosen based on the fact that the majority of marsh species are mature at that time, many of them flowering in the fall (6). The multispectral signatures of mature plants were assumed they would be more distinct, producing better separation and less misclassification, although this point may not be true in certain cases. Since the data was collected in a north-south direction, a flight time when the sun would be directly overhead was stipulated to minimize the illumination of one side of the flight line more than the other. Ground truth field work for identification of training site vegetation was timed to coincide, at least in the same season, with MMS data acquisition to avoid misrepresentation of training site location and vegetative type input to the pattern recognition system.

Analysis of the processed data led to some interesting observations. At an altitude of 6.1 km, the MMS instantaneous field of view (resolution cell size) is 15 m. Training sites large enough to include at least 25 resolution cells were considered statistically significant samples. Standard deviations of the mean reflected radiation in each channel for a given

training site seem to be indirectly proportional to resolution cell size, the multispectral response of a site becoming less integrated and the responses of different elements within a site more discrete with lower altitude and consequent greater resolution, based on this author's experience of MMS data from 3.05 km.

Of a possible 11 channels with a wavelength range of .38 μm to 14 μm , only channels 2, 5, 7, 8, 9 and 10 were able to be decommutated from the original MMS tape. Analysis of the obtained channels indicated that the recorded reflected radiation was not a function of ground elements alone. As the scan angle increased from nadir, so did reflected radiation due to the atmospheric interference associated with longer path length. Data from the shorter wavelength channel 2, .44-.49 μm , seemed most affected by the greater amount of light scattering related to the atmosphere. Therefore, channel 2 data was dropped and the combined signal of channels 5, 7, 8 and 10 improved. Homogeneous training sites were desired, but in an extensive area of uncultivated vegetation, one or more species may grow naturally in association with another. Thus, the multispectral signature of a training site may represent in some cases the integrated response of a mixture. The question of the degree to which a mixture may vary in composition and still be represented by the same signature needs to be addressed, as it probably affected the classification accuracy of this investigation. Similarly, the amount of water tolerated in a marsh training site without producing an unacceptably high standard deviation of the mean reflectivity for a given channel should be studied as it relates to this classification.

In comparing color IR imagery to classified scanner data, more marsh vegetative types could be identified by the MMS data (Fig. 26) than by photo-interpretation of color IR imagery (Fig. 25). The relatively high accuracies of the training site classifications, except for that of the *Spartina patens/Cyperus* spp. which probably was affected by the presence of water, indicated good separation of the vegetative classes.

Once the remotely-sensed identification of vegetation in the marsh study area was accomplished, delineation of the area into salinity zones depended on definition alone. Chabreck's similar delineation of salinity zones of the same area (Fig. 27a) is the only basis for comparison with the results of this investigation. However, the variable introduced by the two different methods of data acquisition and salinity zone interpretation does not make the comparison direct. Nevertheless, the salinity zones determined by this investigation follow the same trend as those determined by the work mentioned above. Variations between the 1968 determination and the one represented by this investigation may be explained by the natural phenomena of salinity intrusion, fluctuations in rainfall and spring floods that have occurred since the earlier work.

CONCLUSION

Results of this investigation demonstrate that vegetational species can be identified and mapped with a good degree of accuracy over a large area of the Louisiana marsh by using aircraft multispectral scanner data. The same technique can probably be applied to mapping marsh vegetation in other areas, as well.

This capability can be applied to determine salinity zones within the marsh for monitoring salinity intrusion, a factor influencing the growth and ultimate harvesting of fish, shellfish, and fur-bearing animals for commercial use.

Further, the remote-sensing capability of marsh species identification can be applied to monitor the distribution of one or more plant species as it may affect: (1) navigation, as in the case with the water hyacinth, (2) marine productivity estimates, as in the case with oystergrass, (3) wild life foraging, as in the case with 3-cornered grass, and (4) coastal zone definition.

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TABLE I. MARSH SPECIES ASSOCIATION FOR
SALINITY ZONE DEFINITIONS

[from Ref 7]

| MARSH ZONE | FREE SOIL WATER SALINITY AVE. (PPT) | MAJOR INDICATOR SPECIES |
|--------------|-------------------------------------|---|
| Fresh | 1 | MAIDEN CANE (<i>Panicum hemitomon</i>), <i>Hydrocotyl</i> sp., WATER HYACINTH (<i>Eichornia crassipes</i>), PICKEREL WEED, (<i>Pontederia cordata</i>), ALLIGATOR WEED, (<i>Alternanthera philoxeroides</i>), BULLTONGUE (<i>Sagittaria</i> sp.) |
| Intermediate | 3.3 | WIREGRASS, (<i>Spartina patens</i>), DEER PEA (<i>Vigna repens</i>), BULL TONGUE WILD MILLET (<i>Echinochloa walteri</i>), BULLWHIP (<i>Scirpus californicus</i>), SAWGRASS (<i>Cladium jamaicense</i>) |
| Brackish | 8.1 | WIREGRASS, THREE CORNERED GRASS (<i>Scirpus olneyi</i>), COCO (<i>Scirpus robustus</i>), WIDGEONGRASS (<i>Ruppia maritima</i>) |
| Saline | 15.9 | OYSTERGRASS (<i>Spartina alterniflora</i>), <i>Salicornia</i> sp., BLACK RUSH, (<i>Juncus roemerianus</i>), <i>Batis maritima</i> , BLACK MANGROVE <i>Avicennia nitida</i> , SALTGRASS (<i>Distichlis spicata</i>) |

TABLE II. COMPOSITION OF TRAINING SITES FOR
LINE 3-2, MISSION 287^a

| Training Site Field Number | Composition |
|-------------------------------|--|
| 3 | <i>Sagittaria falcata</i> 40%, <i>Panicum hemitomon</i> 40%, <i>Typha</i> sp. 5%, <i>Eleocharis microcarpa</i> 5% |
| 5 | <i>Spartina patens</i> 70%, <i>Cyperus</i> sp. 10%, <i>Bacopa monnieri</i> 5%, water 15% |
| 9 | <i>Myrica cerifera</i> 40% <i>Panicum hemitomon</i> 50% |
| 11 | <i>Spartina patens</i> 50%, water and sediment 50% |
| 75 | <i>Spartina alterniflora</i> 80%, water and sediment 20% |
| 78 | <i>Avicennia nitida</i> 70%, <i>Spartina alterniflora</i> 15%, Water 10% |
| 178 | <i>Spartina patens</i> 95%, <i>Scirpus</i> sp. 3% |
| 179 | <i>Spartina patens</i> 90%. water 10% |
| 198, 200-209 | water (varying depths and turbidity) |

^{a/} determined by field observations July-Aug. 1974

TABLE III. ACCURACY CHECK OF TRAINING SITES FOR MARSH CLASSIFICATION
OF FLIGHT LINE 3-2, MX. 287

| CLASS | CLASS-NAME % OCCURRENCES | | | | | | | | | |
|--------------------|--------------------------|-----------|------------|------------|------------|-----------------------|------------|-----------|-------------|----------------|
| | 1 3SFPA | 2 11SP | 3 178SP | 4 9MCPA | 5 5SPCY | 6 H ₂ O | 7 179SP | 8 75SA | 9 78ANSA | 27 UNCLASS. |
| 1.- 3SFPA | 91.67 | 2.63 | | .44 | | | | | .22 | 5.04 |
| 2 - 11SP | 2.63 | 89.25 | 1.97 | 1.10 | | | | | 1.10 | 3.95 |
| 3 - 178SP | | 2.80 | 89.32 | | .53 | | 1.23 | | | 6.13 |
| 4 - 9MCPA | .51 | .25 | | 95.96 | | | | | | 3.28 |
| 5 - 5SPCY | .29 | 2.30 | 1.01 | | 68.68 | 3.16 | .14 | | | 24.43 |
| 6 H ₂ O | | | | | | 95.25 | | .56 | | 4.19 |
| 7 - 179SP | .26 | | | | | | 76.30 | | .26 | 23.18 |
| 8 - 75SA | | | | | .16 | .49 | 1.79 | 92.67 | | 4.89 |
| 9 78ANSA | | 1.79 | | | | | | | 94.64 | 3.57 |

SFPA = *Sagittaria falcata/Panicum hemitomon*
 SP = *Spartina patens*
 MCPA = *Myrica cerifera/Panicum hemitomon*
 SPCY = *Spartina patens/Cyperus sp.*

H₂O = WATER
 SA = *Spartina alterniflora*
 ANSA = *Avicennia nitida/Spartina alterniflora*

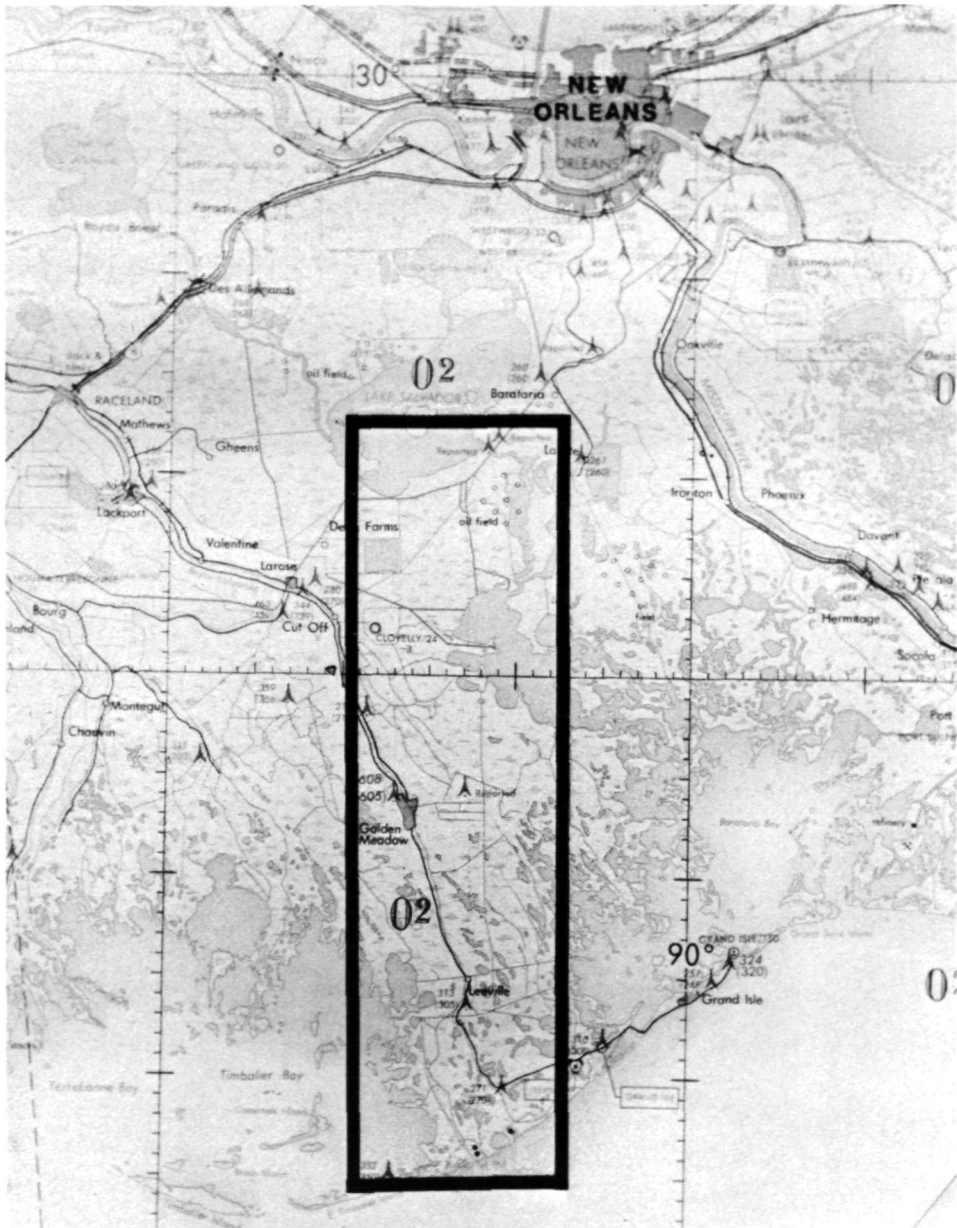


Fig. 1 Test site location MMS mission 287
flight line 3-2, Oct 2, 1974



Fig. 2 Black willow, Salix nigra, commonly borders fresh marsh areas along spoil banks and newly accreted land.



Fig. 3 The interface between fresh marsh (left), and cypress swamp (right) indicates an ecotone. Dead standing trees in the marsh represent a changing environment

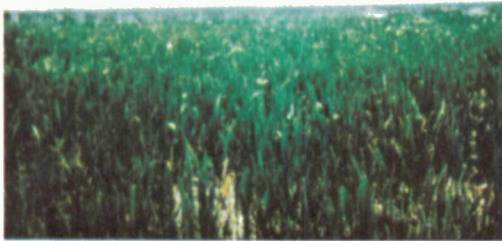


Fig. 4 Bulltongue, Sagittaria falcata, is a common fresh marsh plant.



Fig. 5 Low shrubs (background) commonly border spoil banks, giving way to fresh marsh plants such as bulltongue (foreground).

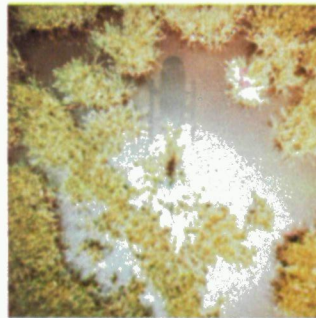


Fig. 6 Helicopter view of bulltongue indicates standing water is a common element of fresh marsh.



Fig. 7 Cat - tail, Typha latifolia, is a typical marsh species.

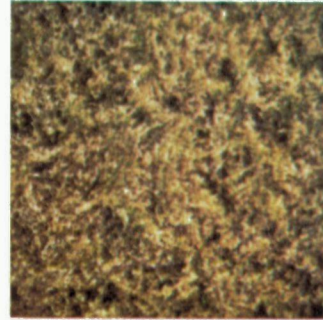


Fig. 8 Helicopter view of maidencane, Panicum hemitomon, dominating the Louisiana fresh marsh.



Fig. 10 Water hyacinth, Eichhornia crassipes, forms floating vegetative mats in the fresh marsh.

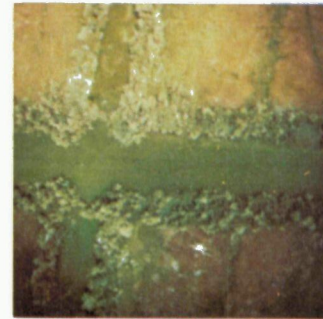


Fig. 9 Helicopter view shows water hyacinth choking waterways bordered by buckbrush, Baccharis halimifolia, a fresh to brackish shrub.



Fig. 11 Roseau cane, Phragmites communis, is a 2-1/2 to 4 m grass usually found along elevated areas in the fresh marsh.



Fig. 12 Standing roseau cane stalks from the previous growing season are shown at the back slope of a spoil bank, indicated by the growth of wax myrtle, Myrica cerifera, in the fresh marsh.

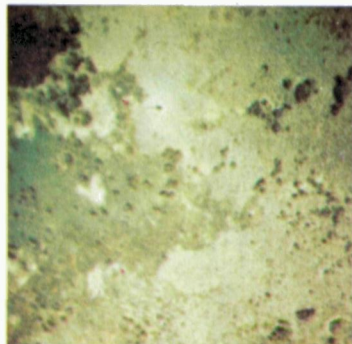


Fig. 13 Helicopter view at 155m shows variation in color and texture pattern produced by the association of buckbrush and roseau cane in the fresh marsh.



Fig. 14 Helicopter view at 30 m showing dioecious nature of buckbrush where the lighter colored plant is in flower.



Fig. 15 An association of wiregrass, Spartina patens, (foreground) three - cornered grass, Scirpus olneyi, and blackrush, Juncus roemerianus, indicates a brackish marsh.

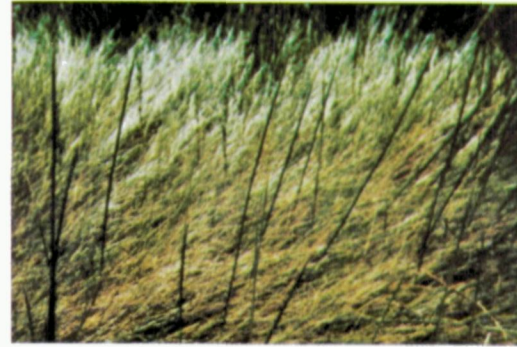


Fig. 16 A mixture of wiregrass and three - cornered grass: wiregrass dominates this area with dispersed areas of three - cornered grass.



Fig. 17 Helicopter view at 15 m shows homogenous stand of wiregrass.



Fig. 18 Oyster grass, Spartina alterniflora, is a 1-2 m grass dominating the saline marsh.

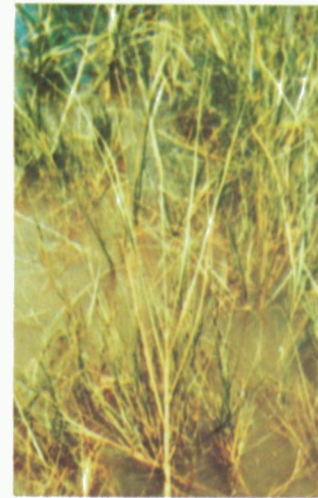


Fig. 19 Salt grass, Distichlis spicata, a plant 15 to 50 cm, commonly grows in association with the taller oyster grass.

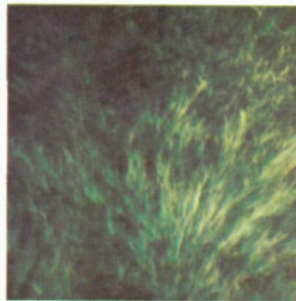


Fig. 20 Helicopter view of homogenous stand of flowering oyster grass found in the saline marsh.

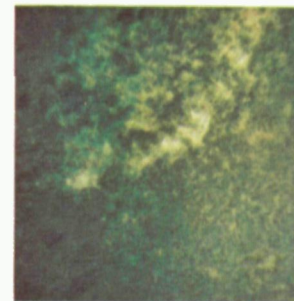


Fig. 21 A mixture of salt grass (foreground), oyster grass (light green area) and wiregrass, is a common saline type association as viewed from 60 m.



Fig. 22 Extensive blackrush occurs in a brackish to saline area, interfacing an oak-pine chenier background.



Fig. 23 Helicopter view of black mangrove, Avicennia nitida, a 1-2 m shrub growing along the most saline areas of the Louisiana coast.

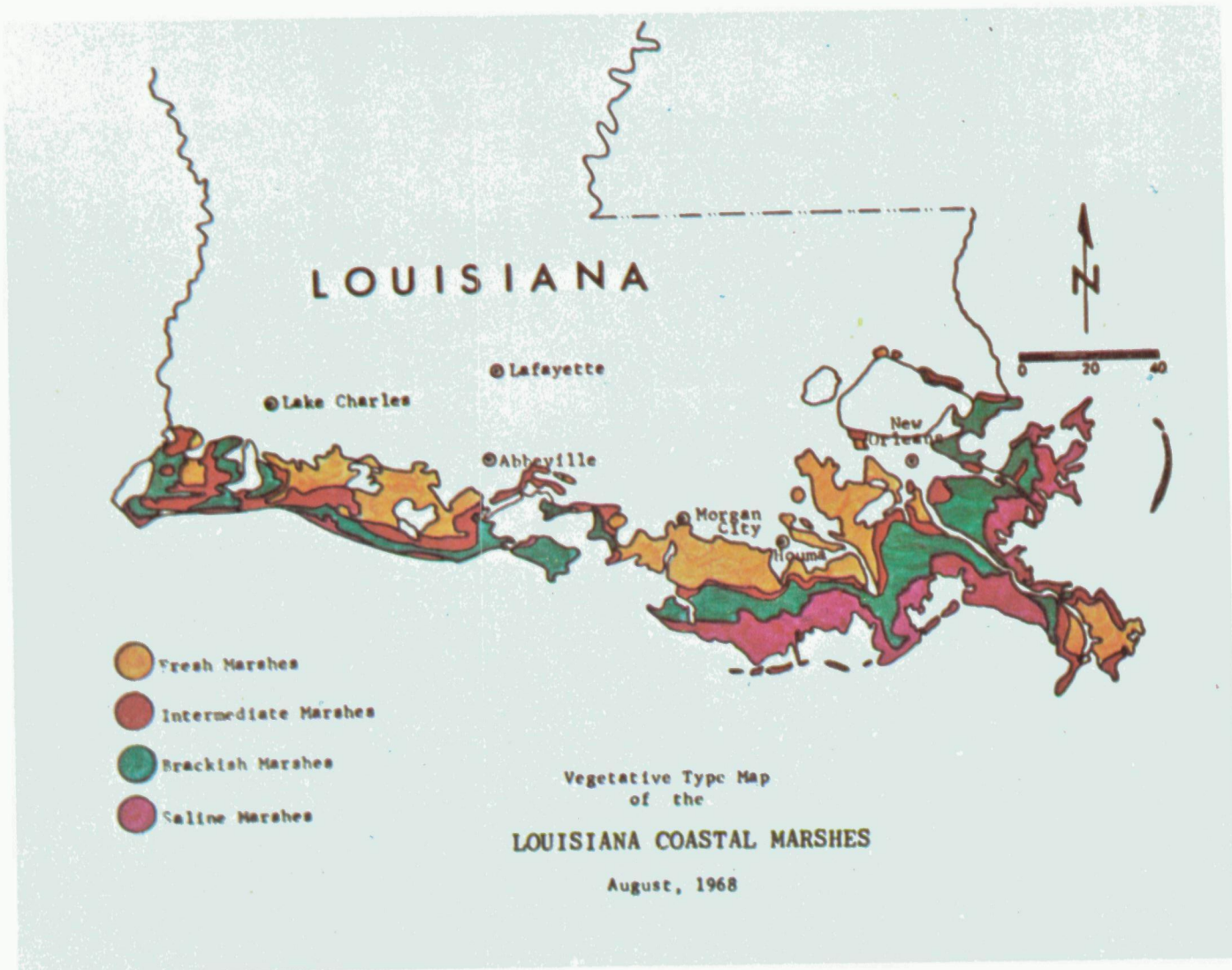


Fig. 24

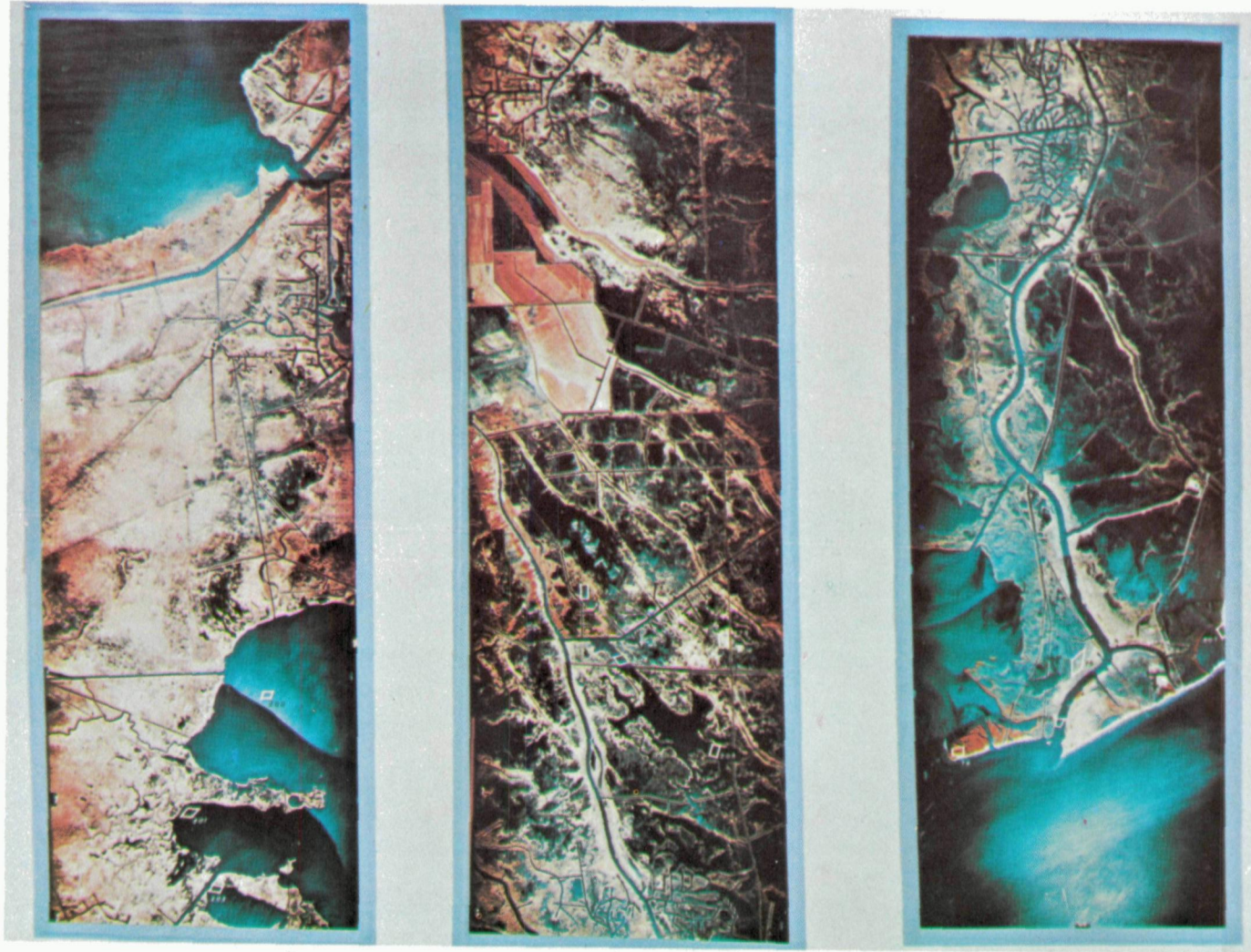


Fig. 25 Training site locations on color IR photography of south Louisiana marsh flight line 3, MX 287.

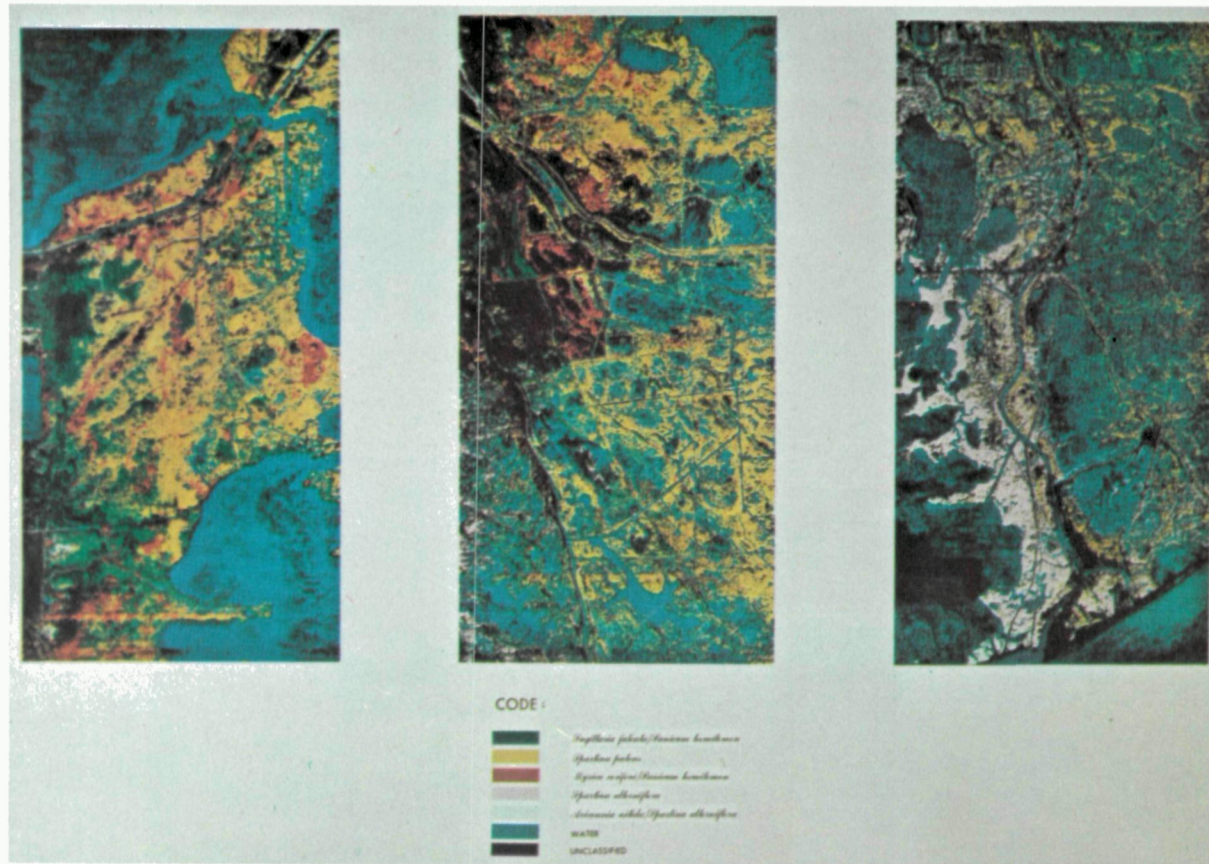


Fig. 26 MMS classification of major species associations of marsh vegetation Oct 2, 1974.

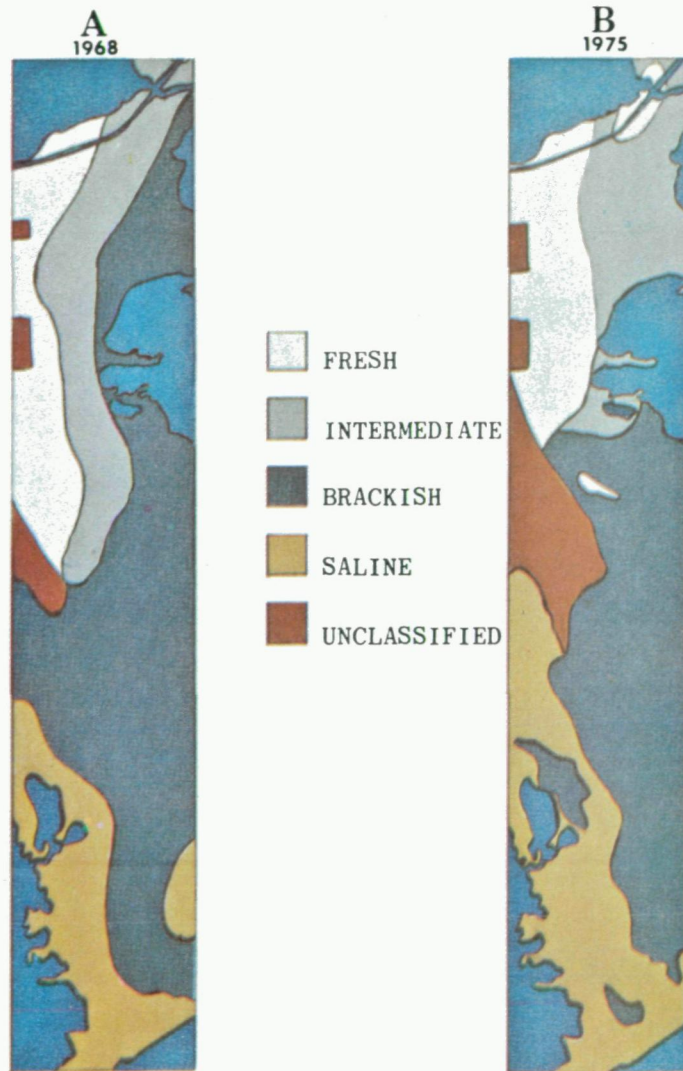


Fig. 27 Thematic maps of marsh salinity zones

A Marsh zones determined by line-transect method (R.H. Chabreck)

B Marsh zones determined from multispectral scanner data 20'K