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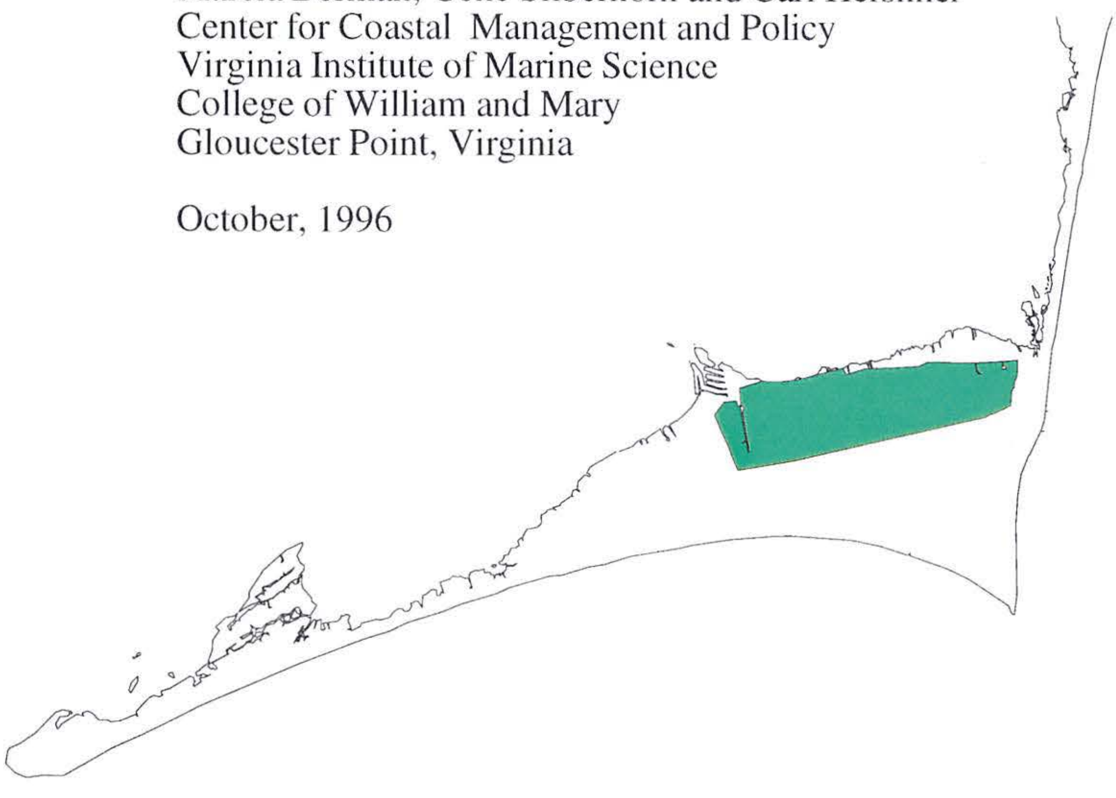

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Final Report

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by
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Introduction

Residential development and growth along private lands bordering the southern portion of Cape Hatteras may be increasing at a rate inconsistent with the current water supply and demand. In the late 1960's and again in the late 1970's a series of wells were drilled to supply area residences and businesses with potable water from the local shallow water aquifer. Today, additional wells are being considered to serve the expanding community of Buxton Woods.

At the same time, the National Park Service maintains a series of ditches for both mosquito and flood control management. A large ditch which trends approximately northeast/southwest through the Buxton Woods Campground and discharges approximately 1.5 miles west of Cape Hatteras into the Atlantic Ocean has been the subject of some controversy. This system was installed in the 1930's prior to conversion of these lands to park ownership. The history surrounding the purpose and development of the system is not well documented. The ditch serves to drain the low lying area of the park campground which is subject to flooding during northeasters, hurricanes, and periods of torrential rains. It has become a quasi-effective method of flood control for the campground which provides an important recreational resource for the park and attracts a number of visitors each year.

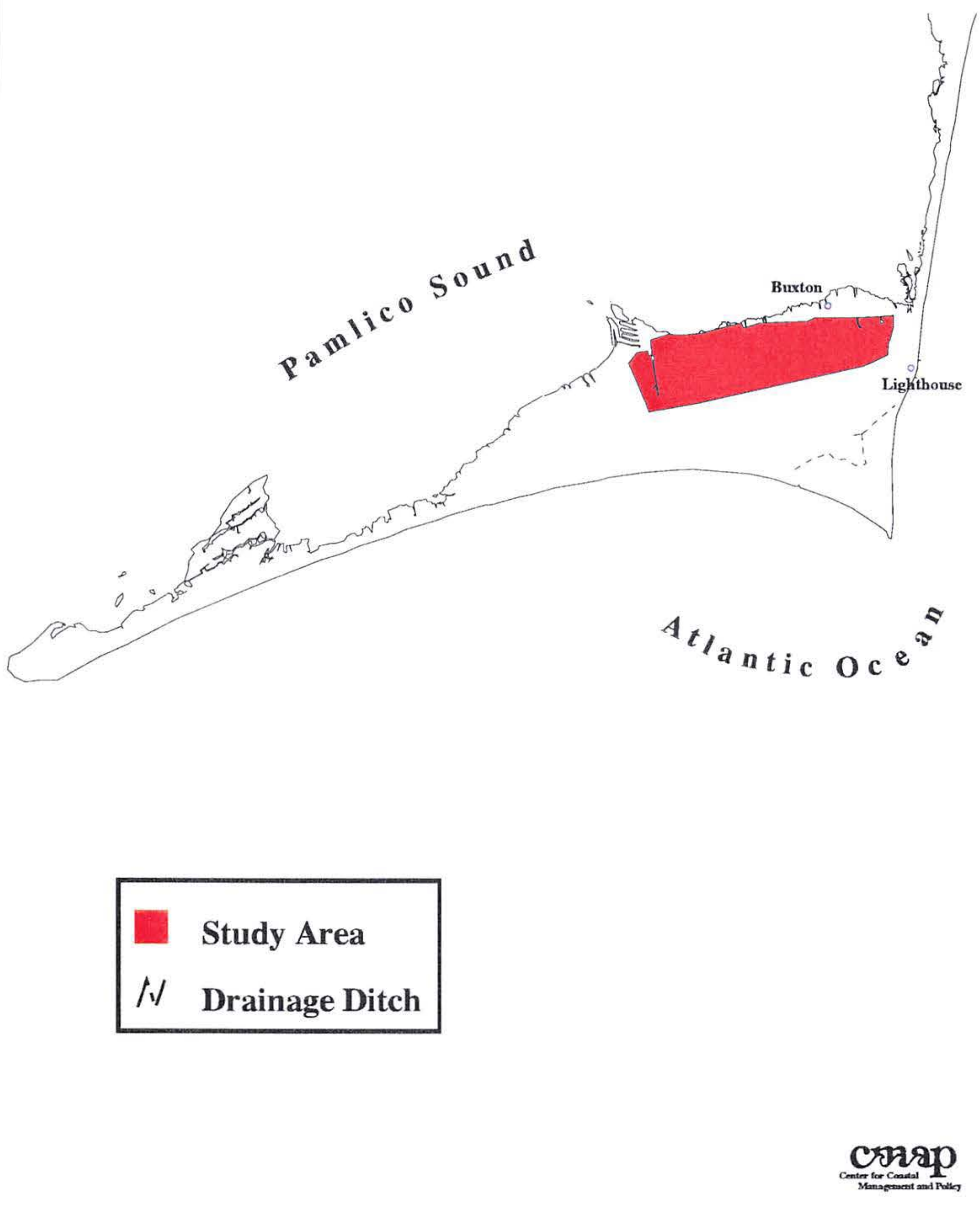
Both the construction of ditches and the withdrawal of water from shallow aquifers has the potential to disturb or alter the natural vegetation communities. The National Park Service has a vested interest in the protection and preservation of these vegetative resources. Therefore, an understanding of how the natural vegetation assemblages have responded to these stressors overtime better prepares the Service to implement responsible management actions.

Objectives

The objective of this study is to determine the variation in vegetation communities for this region of Cape Hatteras (Figure 1) through a temporal and spatial analysis of changes in vegetation patterns. Basic remote sensing techniques were combined with Geographic Information Systems (GIS) to delineate and map vegetation patterns for three different decades (1950, 1970, and 1990). Earlier attempts in the project history to acquire imagery from the 1930's and 1940's were unsuccessful.

These data have been prepared to assist in current activities within the National Park. Park Service staff and scientists will explore the historical development of the local water authority's activities regarding water withdrawal from the shallow water aquifers as well as the construction and utilization of the drainage ditches on park lands. This project is one step in determining if spatial changes in vegetation patterns can be associated with alterations in the hydrologic system as they have occurred through time. Consideration

Figure 1. Study Area: Buxton Woods
Cape Hatteras National Seashore



will have to be given to natural pressures exerted on these habitats as well such as: flooding, hurricanes, drought, and fire.

Methods

A. Vegetation Mapping

The vegetation mapping combines GIS and photo interpretation techniques for delineating vegetation patterns. Six (6) different vegetation communities were targeted for the delineation. Beginning with the driest regimes they include: maritime forest, maritime forest/harvested, scrub/shrub, maritime swamp, scrub shrub/emergent, and emergent herbaceous. The maritime forest/harvested class was identified to trace regrowth in the maritime forest after clear cutting some time prior to 1955. Ponded or aqueous areas were also delineated (water), but the vegetation composition of these systems were not analyzed.

Panchromatic (black and white) vertical photography was acquired from the National Coast and Geodetic Survey for 1955, and the North Carolina Department of Transportation for 1970. Photographic scale equals 1:24,000 (1"=2,000') for both data sets. Depending upon the year, seven (7) or eight (8) different photographs covered the study site. The photographs were enlarged by the agency three (3) times their original size and printed on contact paper at a scale of 1:8,000 (1"= 667').

The 1990 survey used color infra-red photography flown and printed at a scale of 1:32,000 (1" = 2,667'). These images were acquired by the National Park Service through the National Aerial Photography Program (NAPP). In the planning stages of this project, a land use and land cover classification developed from the photographs for an earlier project with the Park Service was expected to be integrated into this study. However, the vegetation classes differed enough from the classes to be identified in the 1955 and 1970 surveys that it would have been difficult to make accurate comparisons between years studied with any degree of confidence. Therefore, using the original NAPP photography the vegetation communities for 1990 were re-delineated using the same methods and classes applied for the 1955 and 1970.

There are few hard and fast rules in photo interpretation. A combination of expert knowledge of the study area and experience in photo interpretation helps to build confidence in the mapping effort. A solid understanding about the limitations of the medium and the potential errors which will be incurred is also important. Two notable differences in the imagery which might be impacting the accuracy of the photo interpretation here do exist. First, the 1955 and 1970 prints are at an enlarged scale of 1:8,000 compared with the 1990 print at 1:32,000. Therefore, the detection limits in the 1990 survey are reduced. Second, the 1955 and 1970 flyover was conducted during leaf-off conditions where the 1990 occurred during leaf-on. There are advantages and disadvantages to both; depending on what is being analyzed. Tree canopy during leaf-on conditions can obscure the presence of standing water indicative of emergent wetlands and swamps. Leaf-off conditions generally occur during dorment stages of plant growth. This will decrease the ability to distinguish different vegetation types.

Photographic indicators for delineating the targeted classes differ for the two photographic mediums (i.e. panchromatic vs. color infra-red). Standards to insure quality control and consistency were established for this study. To enable future vegetation surveys to follow similar guidelines some of the indicators employed in this study are listed below:

For Color Infra-red (1990)

Water: black, smooth;

Scrub/shrub: small clustered pink canopies;

Scrub/shrub-emergent: small clustered pink canopies within light grey;

Emergent: light grey, usually associated with water;

Maritime swamp: mottled large canopied trees, deciduous and coniferous pink to bright red, water is often visible under the canopy;

Maritime Forest: mainly closed canopied pines mixed with deciduous trees uniform pink to red;

For Black and White (1955/1970)

Water: black to dark grey or reflective;

Scrub/shrub: small dark clusters (canopies) that are short and do not cast shadows;

Scrub/shrub - emergent: small dark clusters (shrub canopies) mixed with light grey texture sometimes the black texture indicative of water;

Emergent: light grey to off white ranging from the smooth texture of dense stands to small clumps or tuffs, often associated with water (black to dark grey);

Maritime Forest: a.) Immature Pines - usually closed canopies, individual canopies indistinct, nearly uniform dark grey; b.) Mature Pines - foliated open canopies, large individual canopies, shadows evident at edges of emergent vegetation; c.) Deciduous canopies - lacking foliage, frequently distinct;

Maritime Swamp: similar to maritime forests but lack the dense canopies of immature pines, water often visible under open canopies.

Typical species for each of the vegetation classes include:

emergent: saw grass (*Cladium spp.)*, cattails (*Typha spp.)*
scrub/shrub: wax myrtle (*Myrica.*), evergreen
scrub/shrub - emergent: combinations of saw grass, cattails, and wax myrtle
maritime forest: Loblolly pine (*Pinus spp.)*, Live oak (*Quercus spp.)*
maritime swamp: Loblolly pine. Red Bay (*Persea borbonia)*, Sweet Bay (*Magnolia virginica*)

The mapping began only after these photographic indicators were finalized. To preserve the photographs a sheet of stable-base acetate was placed over the print and the boundaries of the vegetation communities were delineated using an ultra-fine drafting marker. Color markers and a coding sequence was used. The use of acetate is preferred among other mediums for digitizing since it is a material resistant to shrinking and stretching. Therefore, the acetate not only preserves the photographs, but also provides a more accurate medium for digitizing.

When the drafting was complete, the boundaries were digitized on a Numonics 2200 digitizing tablet interfaced with a Unix workstation running Arc/Info. A fine line digitizing cursor was used and standard digitizing practices were followed. The images were rectified using either ground control points collected with a Global Positioning System (GPS) in the area as part of another project, or NAD27 control points selected off a USGS topographic maps. The topographic control was necessary when no GPS points were available in the area.

For 1955 and 1970 each of the images were rectified separately. After rectification, the digital files were pieced together to form one composite image for each year. This step had to consider the 40-60% overlap in the images, the sections of the image with the best rectification points (i.e. GPS), and the fact that the center of the photograph would be the least distorted and therefore most accurate. Sometimes it was necessary to accept some distortion and move away from the central portion of an image in exchange for a section where a number of GPS points were available. Figure 2 is an example of this process for 1970 images.

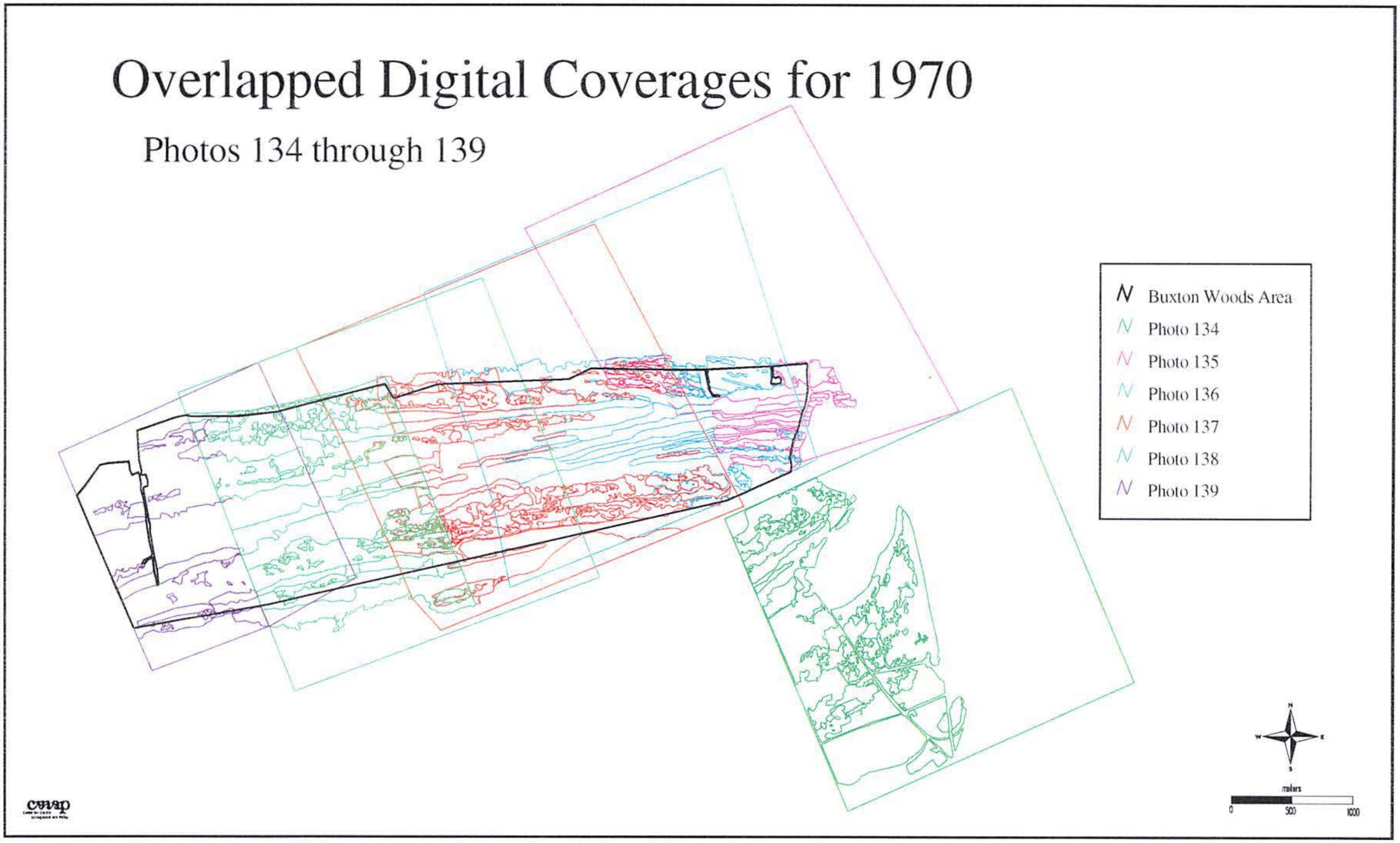

Overlapped Digital Coverages for 1970
Photos 134 through 139
Buxton Woods Area
Photo 134
Photo 135
Photo 136
Photo 137
Photo 138
Photo 139
meters
0
500
1000

Figure 2.

When the digital records were complete a site visit to the study area for ground-truthing was made. Since the nature of historic vegetation analysis eliminates real opportunities for ground-truthing, this field effort was most valuable for reconnaissance of the 1990 digital survey. The 1990 survey was mapped from imagery with leaf-on conditions and a reduced scale. Some interpretation and delineation errors can be expected. Ground-truthing occurred under the assumption that in the five (5) years since the imagery was flown there has been little changes in the general vegetation patterns that existed in 1990.

Since the purpose of this project is to quantitatively compare the vegetation communities through time, a framework for comparison had to be established. This required that the study area analyzed for each time period be the same. Obviously, the amount of aerial coverage differs for each year studied since the different agencies are attempting to capture different features in their flyover missions. The 1990 photography had the greatest coverage, while the 1970 photography was most limited. Sponsored by the North Carolina Department of Transportation, the 1970 photography focuses on the interior regions of the proposed study area where transportation planning around the developing communities is of greatest interest to them. Since it is the limiting coverage, 1970 determined the quantitative study boundary within which the mapped vegetation patterns were compared over time. Unfortunately this required that the eastern and southern coastal reaches be eliminated from the analysis. These areas contain the large drainage ditches which were digitized from topographic maps as a reference to interpret vegetation changes in their vicinity. This analysis will have to be conducted as a separate study using a photographic source with more vegetation coverage closer to the land/water margin.

Large format color maps were produced to illustrate the distribution of the vegetation patterns mapped and quantified for each year studied (Appendix 1). Tabular data reporting the total acres of each vegetation community mapped within the common boundary have been prepared for this report (Table 1). A matrix analysis was conducted in Arc/Info to quantify the transition of vegetation polygons from one community type to the next (Tables 2a-2c). This analysis should be used in conjunction with the maps which display where these transitions are occurring.

B. Transect Surveys

Much later in the study period a request to incorporate the vegetation monitoring being conducted by East Carolina State University (ECU) was initiated. The purpose of this activity was to provide a mechanism by which the ECU scientists could compare the composition of their survey transects today with the vegetation present in 1955, 1970 and 1990. To do this, the location of their transects were digitally plotted on the vegetation maps prepared here using GPS coordinate data, survey measurements and compass bearings (Appendix 1). Transects 1A, 1B, and 2B fall outside the study boundary. The remaining transect pairs included were enlarged to visually interpret the vegetation communities present in 1955, 1970, and 1990. The amount of vegetation present for each class was computed in ArcInfo and tabulated. The transect diagrams illustrating the vegetation composition along each transect in 1955, 1970, and 1990 are enlarged and attached in Appendix 2. The tabular data (Appendix 3) report the amount of each vegetation class comprising the transect in 1955, 1970, and 1990. Since a discussion on these data will be presented in a report from ECU, no results or conclusions are drawn here.

Results

Considering only the total acreage of each vegetation class there appears to be no overwhelming trends in the data (Table 1). There is a decline over the entire study period in the amount of emergent herbaceous vegetation present. Also there is a dramatic increase in the amount of scrub shrub/ emergent communities present after 1970 (i.e. reported for 1990).

Table 1. Distribution of vegetation types in hectares for 1955, 1970, and 1990.

Vegetation Type	**1955**	**1970**	**1990**
scrub shrub	9.87	17.27	-0-
emergent herbaceous	191.03	106.92	81.81
maritime swamp	274.76	365.25	262.05
maritime forest	264.92	290.68	337.04
maritime forest/harvested	53.26	-0-	-0-
scrub shrub/emergent	2.63	0.69	83.63
water	2.98	17.33	8.67
Total	799.45	798.35	773.20

The distribution maps for each year (Appendix 1) illustrate that since 1970 scrub shrub/emergents have invaded the emergent communities along the northern boundary of the study area. From 1955 to 1970 the maritime forest which was harvested along the central portion some time prior to 1955 has recovered. Both maritime forest and maritime swamp have come in along the southeast section of the study area since 1955. The transition from maritime swamp to maritime forest by 1990 might be a detection limitation rather than a real conversion because of the canopy masking the presence of standing water in 1990; thus yielding the apparent presence of a maritime forest rather than a maritime swamp.. In all areas where emergent vegetation once dominated in 1955 there is clear evidence to conclude that these habitats have been invaded by other communities. However there is no definitive transition to one particular community type.

The matrix analysis performed in Arc/Info looked at the transition of each community type from 1955 to 1970, from 1970 to 1990, and finally over the entire study period (1955-1990). Tables 2a through 2c report the percent change of one vegetation type to another. Figures 3a and 3b illustrate the conversion of vegetation communities between 1955 and 1970, and again between 1970 and 1990. The trends suggest a shift in the hydrologic regime to drier conditions. In fact 50% or more of nearly every vegetation type either remained the same or was replaced by one of the other communities less tolerant of wet conditions (Tables 2a-c).

Discussion

The resolution and image quality of the aerial photographs of all three years in general was satisfactory. The black and white imagery of 1955 and 1970 was taken after leaf off. Therefore, the under story and ground cover vegetation that would be otherwise obscured during leaf out could be observed. Empty canopy silhouettes also reduced shading and shadows that would have obscured features.

Table 2a. Matrix analysis to quantify percent change in composition from 1955 (y-axis) to 1970 (x-axis).

	DEV	MF	MFH	SS	MS	SS/EM	EM	W
DEV	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
MF	0.001	56.58	-0-	1.81	37.87	0.07	2.81	0.85
MFH	-0-	80.32	-0-	-0-	19.55	-0-	0.13	-0-
SS	-0-	11.26	-0-	3.55	68.46	-0-	6.60	10.14
MS	.002	26.06	-0-	1.45	62.83	0.036	8.83	0.60
SS/EM	-0-	14.07	-0-	4.18	75.67	-0-	6.08	-0-
EM	0.49	12.94	-0-	3.95	37.77	0.15	38.63	6.07
W	-0-	2.68	-0-	16.39	31.10	4.35	17.39	28.09

Table 2b. Matrix analysis to quantify percent change in composition from 1970 (y-axis) to 1990 (x-axis).

	DEV	MF	MFH	SS	MS	SS/EM	EM	W
DEV	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
MF	10.73	34.86	-0-	-0-	31.26	15.04	6.31	1.79
MFH	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
SS	31.52	23.93	-0-	-0-	22.71	15.01	6.84	-0-
MS	14.71	39.33	-0-	-0-	31.26	7.53	6.46	0.71
SS/EM	57.1	14.64	-0-	-0-	0.44	27.82	-0-	-0-
EM	38.82	32.38	-0-	-0-	15.86	6.54	6.26	0.14
W	9.12	53.55	-0-	-0-	16.56	3.81	16.10	0.87

Table 2c. Matrix analysis to quantify percent change in composition over the entire study period: 1955 (y-axis) to 1990 (x-axis).

	DEV	MF	MFH	SS	MS	SS/EM	EM	W
DEV	-0-		-0-	-0-	-0-	-0-	-0-	-0-
MF	9.88	35.48	-0-	-0-	34.59	12.02	6.59	1.44
MFH	7.19	49.22	-0-	-0-	28.02	13.39	1.37	0.81
SS	2.63	60.99	-0-	-0-	25.73	0.20	9.22	1.21
MS	17.69	34.33	-0-	-0-	31.22	9.93	5.73	1.09
SS/EM	22.14	62.21	-0-	-0-	15.65	-0-	-0-	-0-
EM	29.06	36.22	-0-	-0-	17.35	8.07	8.91	0.38
W	5.69	57.19	-0-	-0-	8.69	5.02	23.08	0.33

DEV = developed
MF = maritime forest
MFH = maritime forest (harvested)
SS = scrub shrub
MS = maritime swamp
SS/EM = scrub shrub/emergent
EM = emergent
W = water

Vegetation Transition 1955-1970

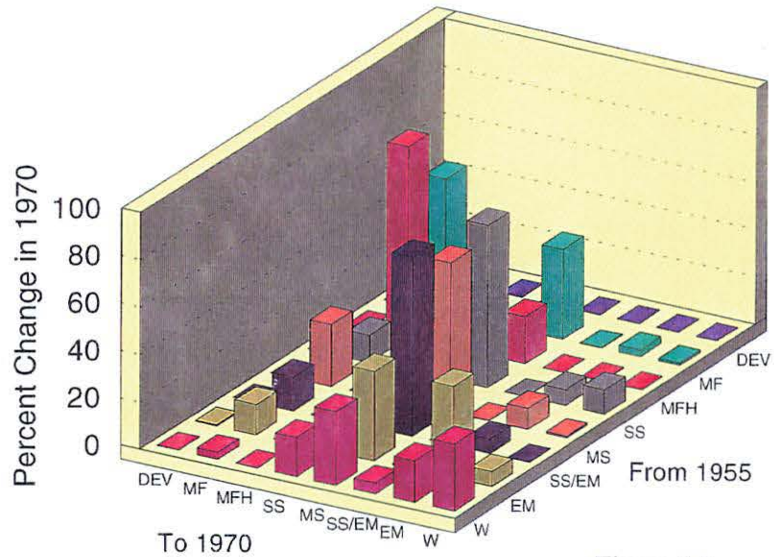


Figure 3A

Vegetation Transition 1970-1990

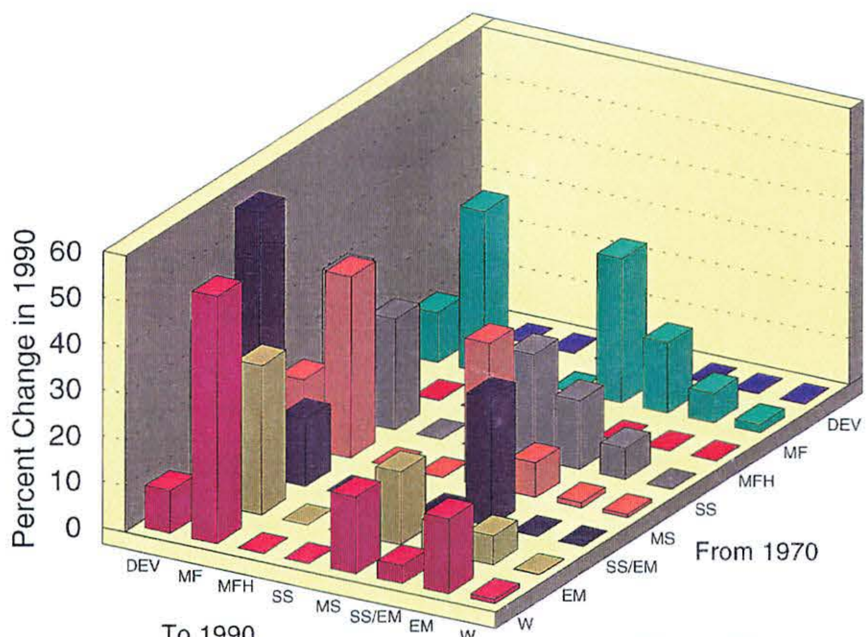


Figure 3B

The 1990 color infra-red imagery of reduced scale was taken in July during full foliage which made interpretation more difficult. Probably the most difficult distinction to make was the difference between maritime forest and maritime swamp. This interpretation was impaired by a thick tree canopy which obliterated the presence of standing water. In some cases, water could be seen beneath the canopy and these areas were classified as maritime swamps. In most situations, maritime swamps appeared in narrow, elongated swales or lowland between narrow sandy ridges. Maritime forests appeared to occupy the sandy ridges. The differentiation was more revealing in the 1955 imagery where clear cutting was obvious on the higher ridges while trees were left uncut in the narrow swales; likely because of difficulty in extraction.

Emergent herbaceous vegetation was the most obvious classification type to distinguish in all years. This vegetation type was of a lighter contrast and finer texture than forested or scrub/shrub types. In the 1990 scene, herbaceous and scrub/shrub/herbaceous appeared lighter in color (pink) than the surrounding forested areas. *Typha* spp. (cattails), *Cladium jamaicense* (saw grass) and various other species of sedges and grasses appear to be the dominant vegetation in this wetland type. Open water areas associated with emergent vegetation was also easy to detect because it was always dark black in the 1955 and 1970 photography and dark blue in the 1990 aerials.

Scrub/shrub was also quite distinct because the individual canopy size was smaller and more scattered than individual tree canopies. Scrub vegetation was small trees or saplings (less than 7 m tall) and largely small pines. Scrub/shrub often appeared to be associated with an emergent herbaceous ground cover. Scrub/shrub/emergent vegetation appeared to be more abundant in 1990 and is described as emergent vegetation mixed with scrub/shrub species.

The primary area of concern in this study is the Jeanette's Sedge area, clearly indicted on USGS Topographic Quadrangle, Buxton,NC with marsh symbols. The area could be readily delineated on the 1955 photos but was less distinct on the 1970 and 1990 imagery. Nevertheless, it is evident that scrub/shrub vegetation and trees have invaded the area and the maps provided indicate an evolution from emergent herbaceous vegetation to maritime forest. This evidence of succession could be attributed to hydrologic changes.

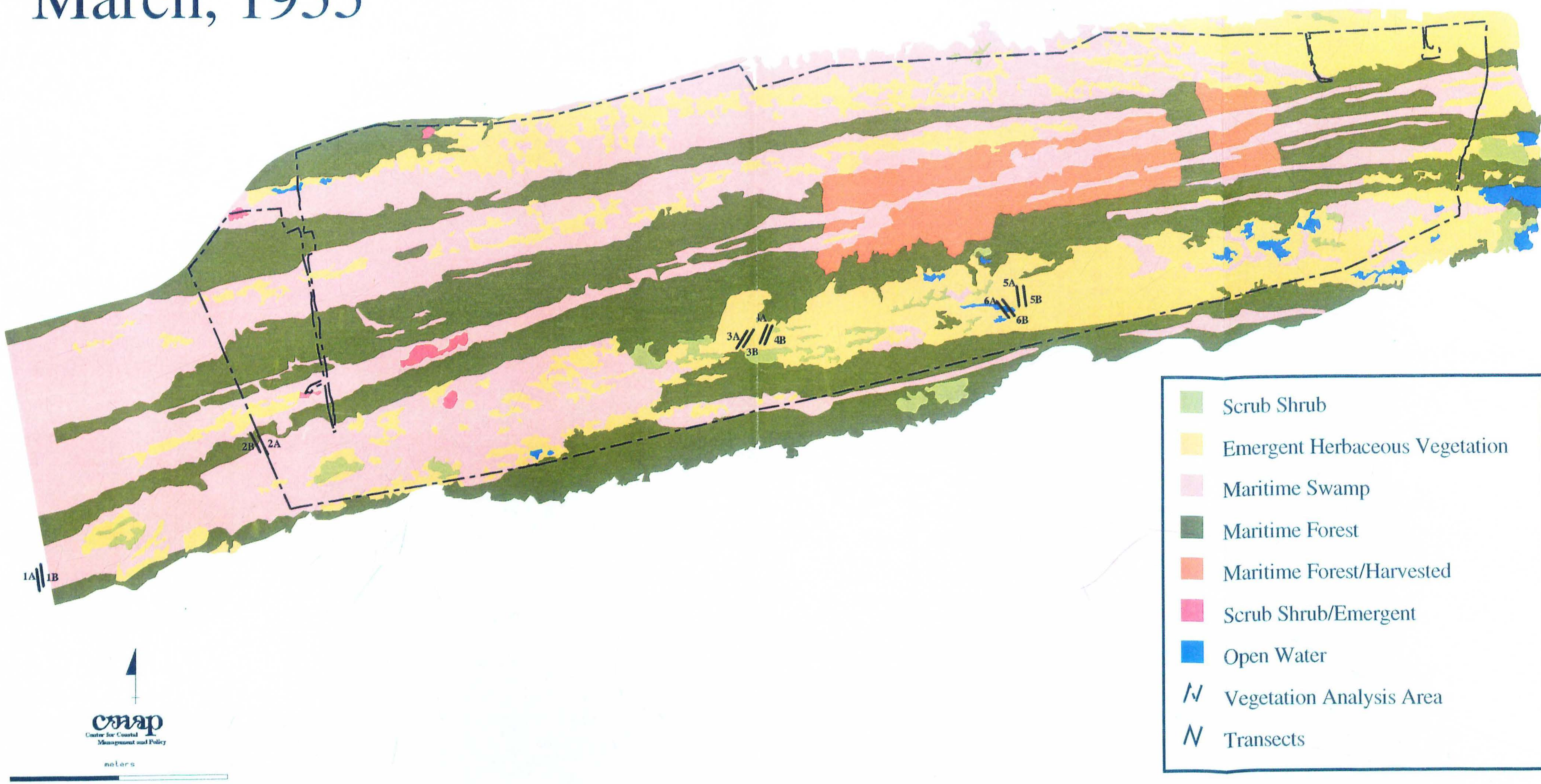
The information gained in this study has certainly improved our understanding of relatively recent changes in the vegetation patterns along this portion of the National Seashore. There is an apparent transition to a drier hydrologic regime, but the evidence is not strong enough to be conclusive. Nor can the patterns of change detected be related to any one existing anthropogenic activity which might alter the natural hydrologic cycle.

This study would have benefitted from additional data years for a broader and more detailed historic perspective. The research being conducted at East Carolina State University should provide some important attributes to the preliminary findings here. The on-going hydrologic studies conducted by North Carolina State University are certainly critical. Through a combination of these research efforts, more conclusive data should be derived.

APPENDIX 1

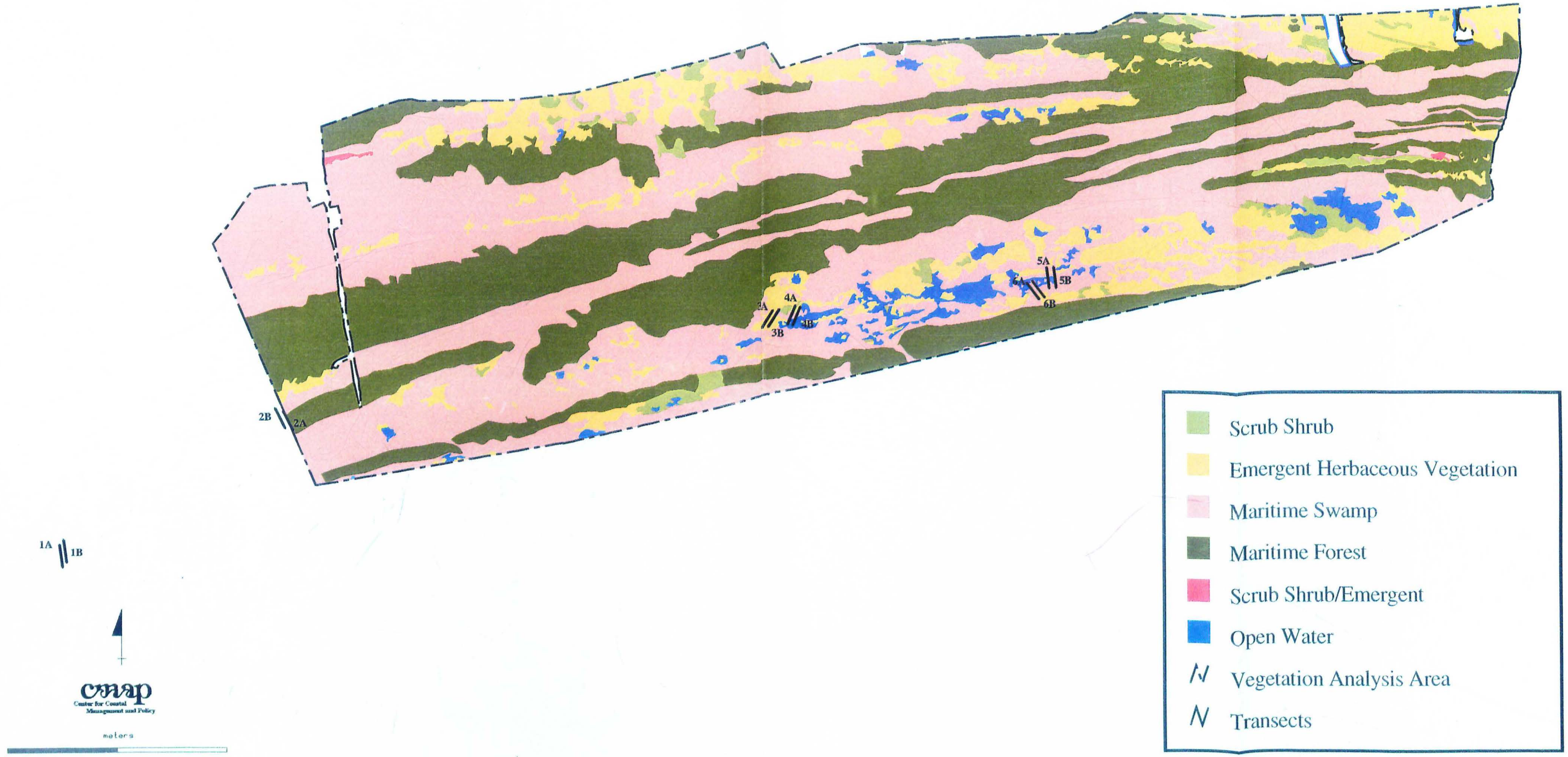
Buxton Woods Vegetation

March, 1955



Source: North Carolina Department of Transportation

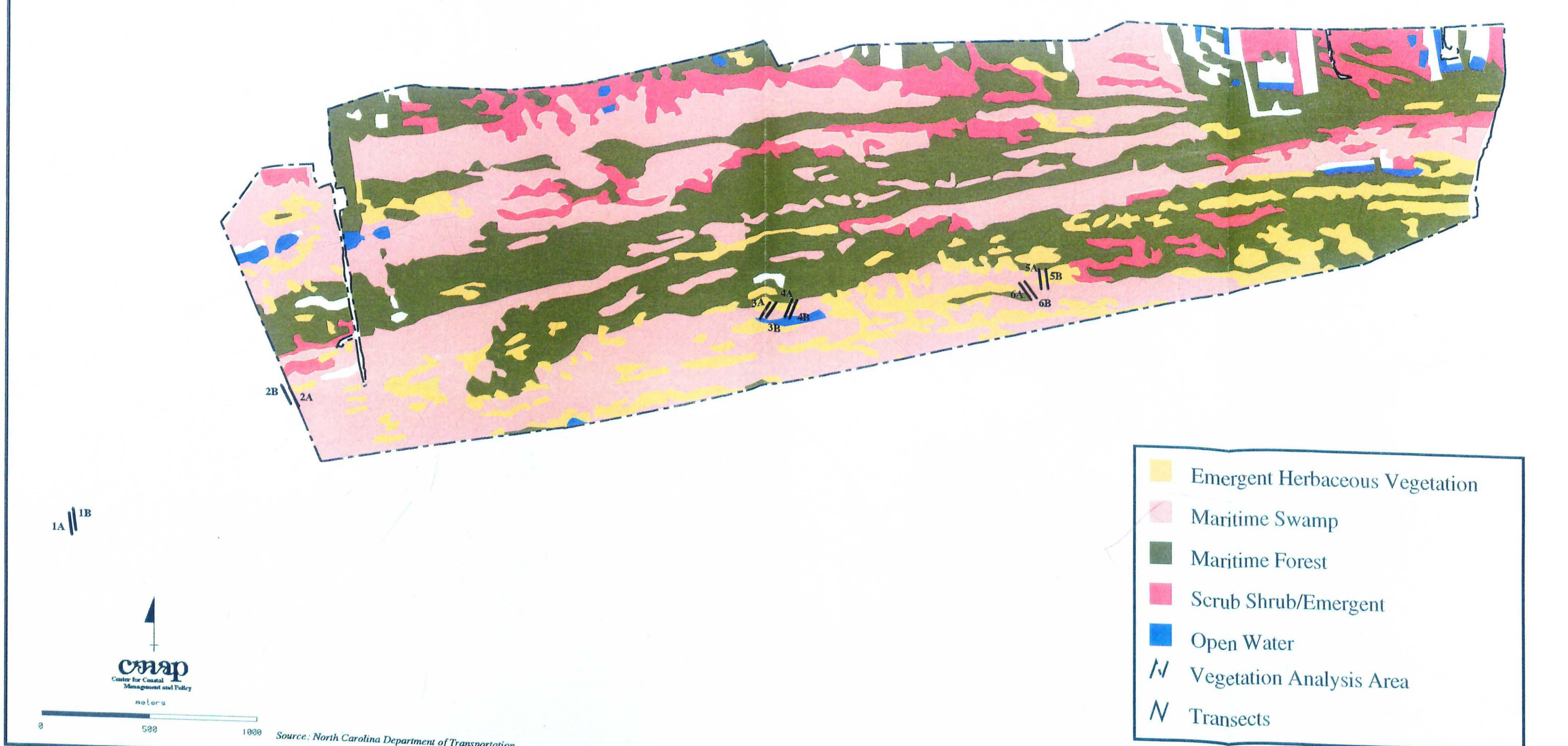
Buxton Woods Vegetation
November, 1970



Source: North Carolina Department of Transportation

Buxton Woods Vegetation

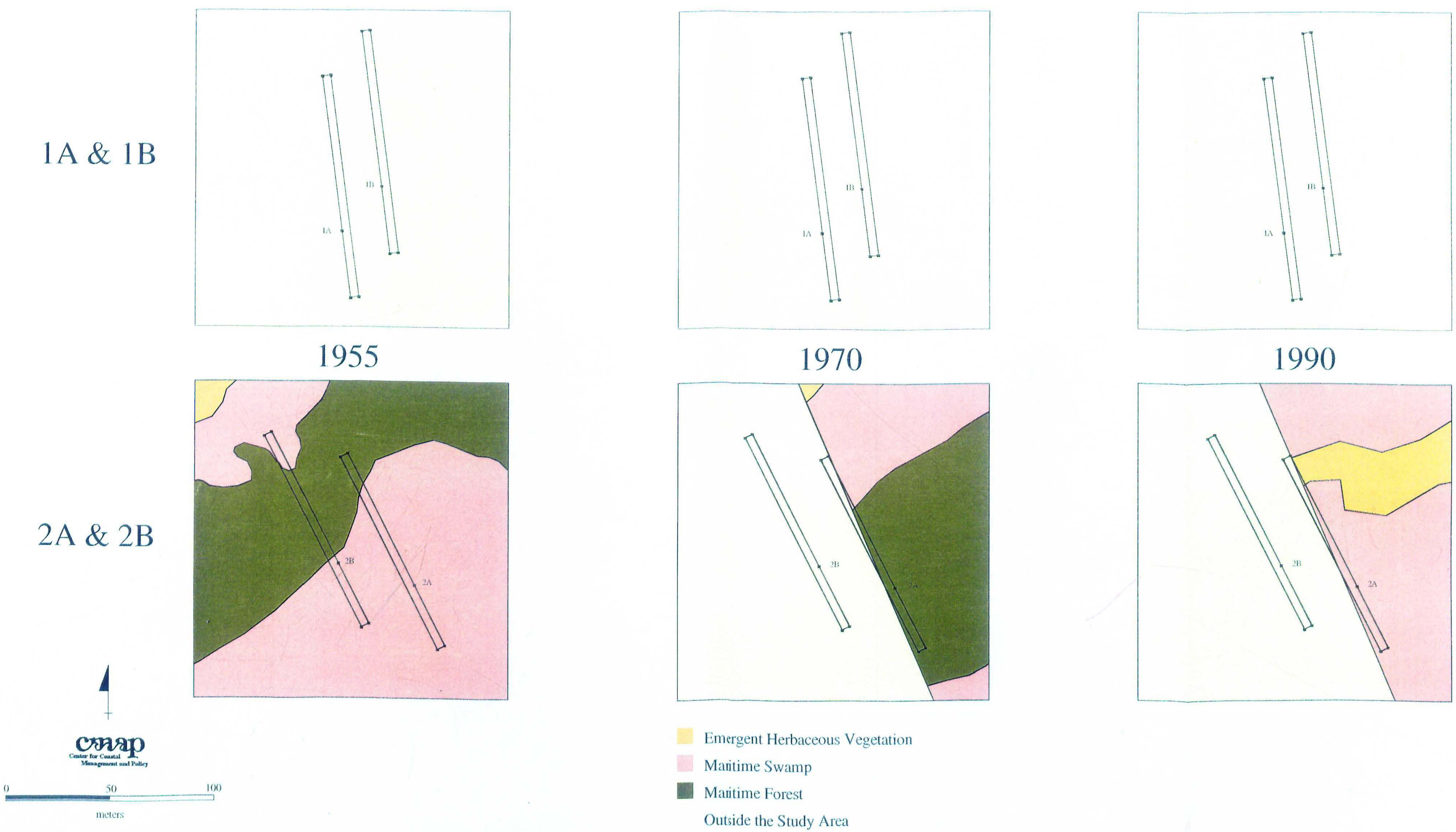
1990



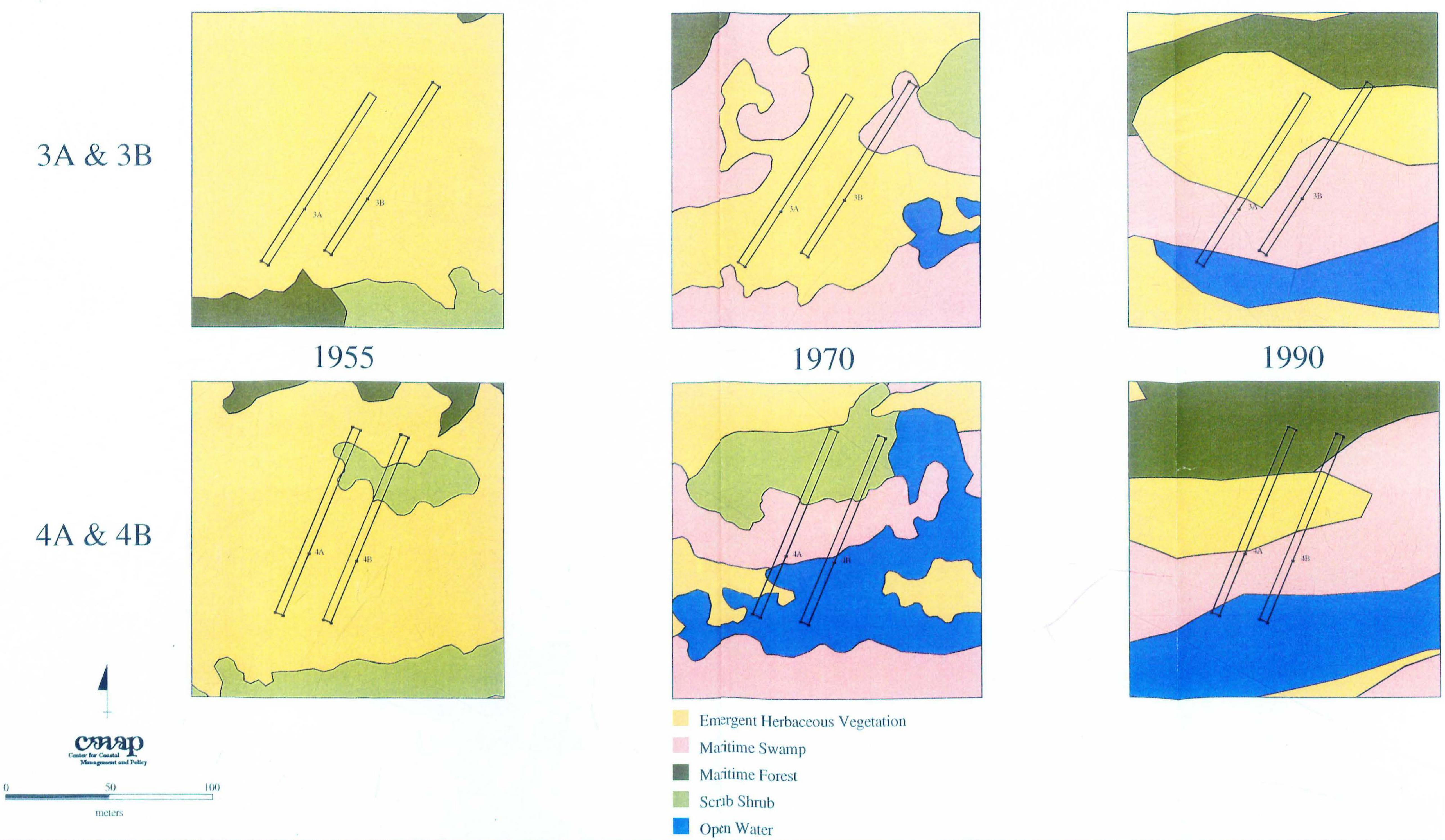
Source: North Carolina Department of Transportation

APPENDIX 2

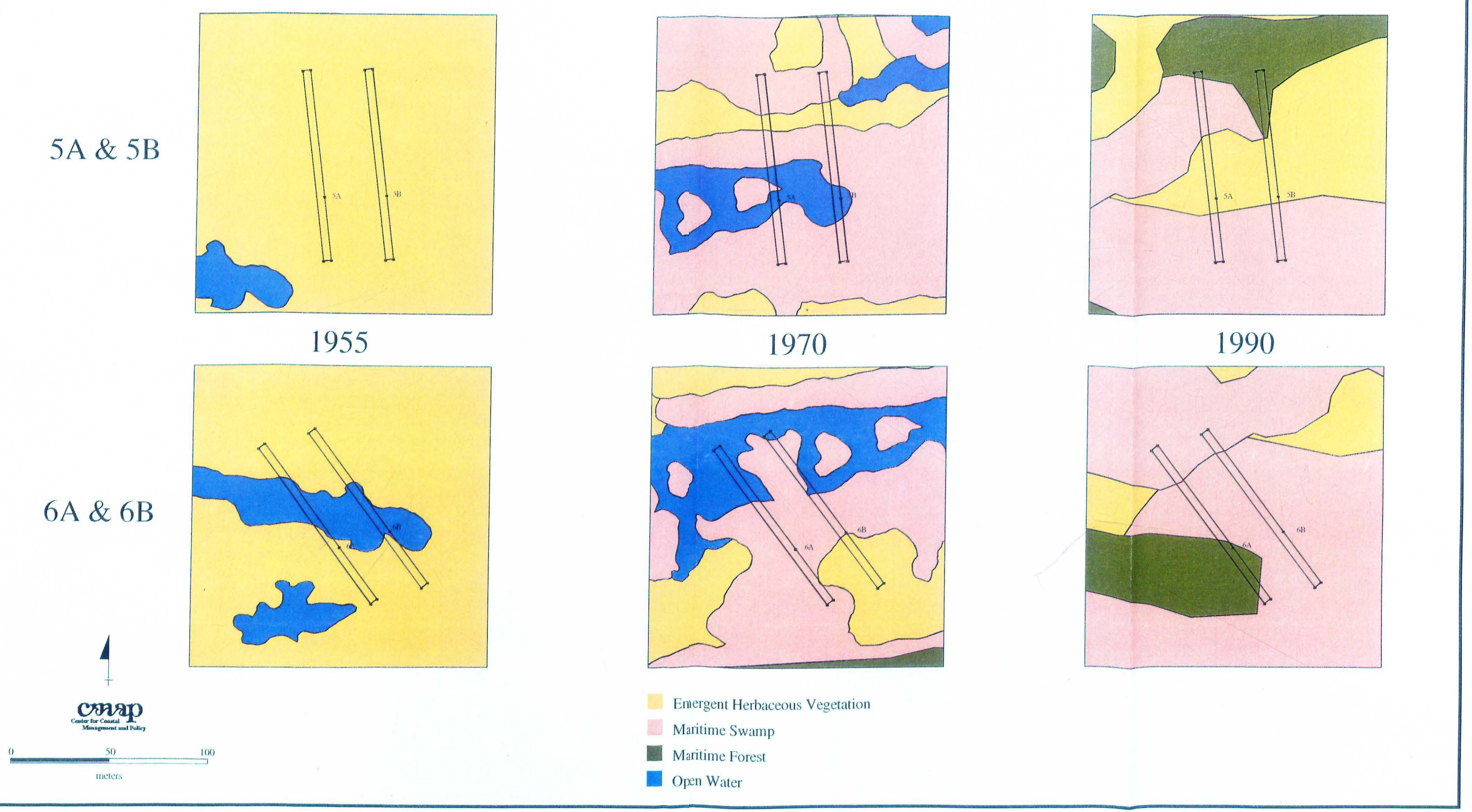
Buxton Woods Transects



Buxton Woods Transects



Buxton Woods Transects



APPENDIX 3

1955 Vegetation Comparison (in hectares)

Transect	scrub shrub	em. herbaceous	maritime swamp	maritime forest	mar. for./harvest	scrub shrub/em	water
1A	outside study	outside study	outside study	outside study	outside study	outside study	out.
1B	" "	" "	" "	" "	" "	" "	" "
2A	-0-	-0-	.033	.007	-0-	-0-	-0-
2B	-0-	-0-	.022	.019	-0-	-0-	-0-
3A	-0-	.038	-0-	-0-	-0-	-0-	-0-
3B	-0-	.038	-0-	-0-	-0-	-0-	-0-
4A	.004	.035	-0-	-0-	-0-	-0-	-0-
4B	.007	.031	-0-	-0-	-0-	-0-	-0-
5A	-0-	.038	-0-	-0-	-0-	-0-	-0-
5B	-0-	.038	-0-	-0-	-0-	-0-	-0-
6A	-0-	.026	-0-	-0-	-0-	-0-	.013
6B	-0-	.026	-0-	-0-	-0-	-0-	.013

1970 Vegetation Comparison (in hectares)

Transect	scrub shrub	em. herbaceous	maritime swamp	maritime forest	mar. for./harvest	scrub shrub/em	water
1A	outside study	outside study	outside study	outside study	outside study	outside study	out.
1B	" "	" "	" "	" "	" "	" "	" "
2A	-0-	-0-	.002	.025	-0-	-0-	-0-
2B	outside study	outside study	outside study	outside study	outside study	outside study	out
3A	-0-	.038	-0-	-0-	-0-	-0-	-0-
3B	-0-	.023	.015	-0-	-0-	-0-	-0-
4A	.015	.002	.013	-0-	-0-	-0-	.008
4B	.013	-0-	.012	-0-	-0-	-0-	.013
5A	-0-	.003	.028	-0-	-0-	-0-	.008
5B	-0-	.005	.027	-0-	-0-	-0-	.007
6A	-0-	-0-	.026	-0-	-0-	-0-	.013
6B	-0-	.013	.021	-0-	-0-	-0-	.004

1990 Vegetation Comparison (in hectares)

Transect	scrub shrub	em. herbaceous	maritime swamp	maritime forest	mar. for./harvest	scrub shrub/em	water
1A	outside study	outside study	outside study	outside study	outside study	outside study	out.
1B	" "	" "	" "	" "	" "	" "	" "
2A	-0-	.001	.028	-0-	-0-	-0-	-0-
2B	outside study	outside study	outside study	outside study	outside study	outside study	out
3A	-0-	.023	.012	-0-	-0-	-0-	.003
3B	-0-	.013	.025	.001	-0-	-0-	-0-
4A	-0-	.016	.011	.010	-0-	-0-	.001
4B	-0-	.012	.016	.005	-0-	-0-	.005
5A	-0-	.016	.022	.001	-0-	-0-	-0-
5B	-0-	.014	.012	.012	-0-	-0-	-0-
6A	-0-	-0-	.026	.012	-0-	-0-	-0-
6B	-0-	-0-	.039	-0-	-0-	-0-	-0-