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Barrier Island Vegetation Mapping Using Digitized Aerial Photography

Employing color infrared photography, a high degree of classification success was achieved for the photograph on which signature development had occurred.

Abstract: *A vegetation map of the Assateague Island National Seashore has been constructed from computer analysis of three-band digitized color IR photographs using the ORSER digital data processing system. Because the raw data were not calibrated and corrected for density variation across the photographs, a large number of spectral signatures had to be developed for each vegetation class. Classification accuracy was measured against existing vegetation maps of small sections of the island and against a sample of points ocularly interpreted on the photographs. Area estimates were adjusted for the difference between photointerpreted and computer-generated vegetation types. A high degree of classification success was achieved for the photograph on which signature development had occurred, and moderate success on other frames.*

Introduction

The Atlantic coast barrier islands have long interested a broad spectrum of Americans. Their proximity to population centers and their scenic beauty, together with the great controversy surrounding shoreline development, ensure the continuation of this interest (e.g., DeMott, 1980; MacLeish, 1980). At the same time, the dynamic nature of the islands maintains a fascination for conservationists, ecologists, and geologists, who see them as easily accessible laboratories for observing the naturally accelerated processes of change (Dolan *et al.*, 1980).

One of the larger, relatively undeveloped islands is Assateague, 60 kilometres long, and famous for its herds of wild ponies. The island is bisected by the Maryland-Virginia border. With the exception of a small state park and a few small private inholdings, the portion in Maryland is designated as the Assateague Island National Seashore, and is administered by the National Park Service.

Vegetation on the island is a complex mosaic of plant communities, controlled largely by water table depth and the degree of protection from salt spray and blowing or shifting sands. When the National Park Service recently began a new round of management planning for the island, the need for an accurate up-to-date vegetation map was recognized—in part to locate possible sites of rare or endangered species and in part to assist in forage studies associated with management of the ponies. Mapping of such an area could be economically achieved only with the aid of large-scale aerial photography. Fortunately, high-quality color infrared photography, at a scale of approximately 1:21,000, acquired in June of 1974, was available from the NASA base at Wallops Island. A reduced-scale sample frame (Bunting's Woods area) is shown in Plate 1. These photos had been used by Daniels (1976) for visual interpretation and mapping of three test sites on the island. While this conventional approach could have been continued to include the whole National Seashore, the process would have been lengthy and expensive.

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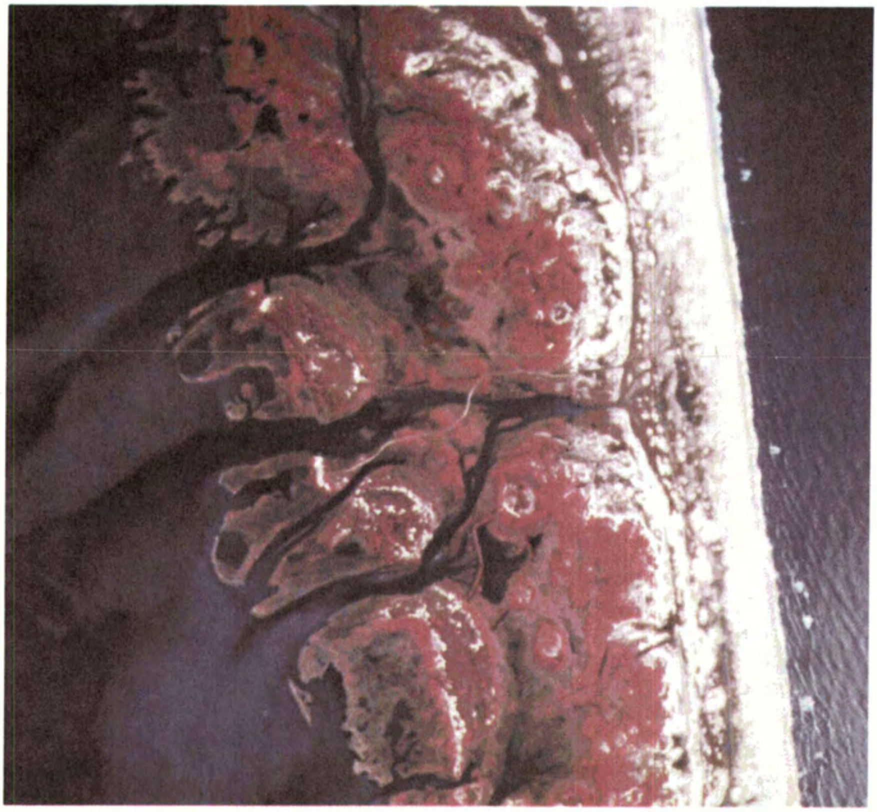
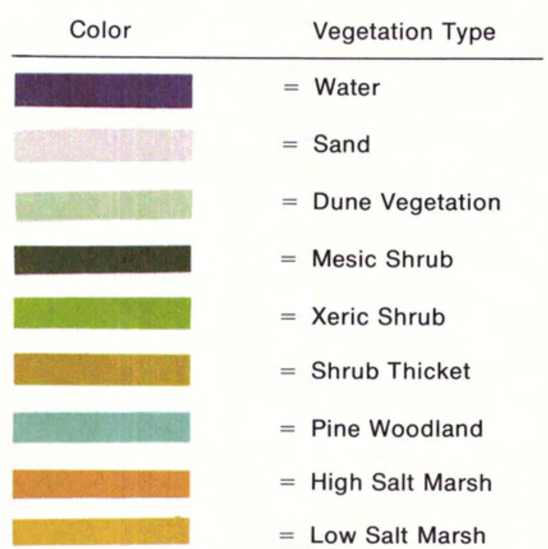


Plate 1. Portion of one of the original color-infrared photographs showing the Bunting's Woods area.

Plate 2. Classification map of the Bunting's Woods area.



The National Park Service therefore contracted with the Office for Remote Sensing of Earth Resources (ORSER) at The Pennsylvania State University, to explore the feasibility of using its comprehensive software and computing facilities to interpret the photographs and produce a vegetation map by automated means. It was accepted at the outset that this experiment might end up being more expensive than conventional mapping, but if the new technology proved successful, the cost of subsequent applications would be substantially less. Furthermore, automated mapping had the following potential advantages over the conventional method:

- Once the rules for defining a vegetation type are established, they can be consistently applied over the whole area;
- scale changes are easily effected and the maps can be readily produced in a variety of formats;
- areas of types are automatically estimated; and
- once the data are in digital form, they can be incorporated into computerized geographic data bases.

The software available to conduct the study had been developed to analyze multispectral scanner (MSS) data from a variety of aircraft and satellite sources. Hence, it seemed reasonable that the "ORSER System" (Turner *et al.*, 1978) would be able to analyze a multi-channel digitized data set produced by scanning aerial photographs under several different narrow-band filters.

Our objectives, therefore, were to test the feasibility of producing a detailed vegetation map of an extensive area by applying conventional MSS data analysis procedures to a set of digitized aerial photographs, and to test the accuracy of the resultant map.

Procedure

The Bunting's Woods area, centrally located in the Maryland section of the island, was chosen for most of the preliminary analyses and signature development. This area had been mapped by Daniels (1976), using a biophysical classification scheme based on both vegetative and topographic factors. Since these maps constituted the best available independent source of correlative data, the decision was made to adhere as closely as possible to Daniels' classification system. She described the following community types:

I. Beach
   1. Pioneer community
II. Fore dune
   2. Dunegrass
   3. Dunegrass-low thicket mixture
III. Back dune
   4. Herbaceous dune
   5. Xeric shrub
   6. Mesic thicket
IV. Mudflat
   7. Herbaceous mudflat
V. Upland
   8. Pine woodland
   9. Mixed woodland
VI. Bayshore
   10. Low salt marsh
   11. High salt marsh
   12. Shrub thicket
   13. Brackish reed community

Preprocessing

Eleven photographs, available as 23 by 23 cm color-infrared transparencies and chosen from the 1974 photography to provide complete coverage without excessive overlap, were digitized on the Optronics scanning microdensitometer at NASA Wallops Island. They were scanned at 50 micrometres, the coarsest resolution available, with each of four different filters: red (Kodak Wratten #29), green (#74), blue (#47B), and clear. The data for each photograph were output to four magnetic tapes, one from each filter. Because the ground resolution of approximately 1 m^2 was judged to be too fine for vegetation typing and the computer cost of processing all the data would have been very high, the resolution was further coarsened so that a single pixel represented 15 original data points. The ratio of three points on the X-axis to five points on the Y-axis was chosen so that the resulting maps, output from the high-speed printer with a character-spacing/line-width ratio of 3:5, would have the least geographic distortion. Initially, interpolation by cubic convolution was used to obtain a single spectral response vector to represent each block of 15 data points. It was later found, however, that simply averaging the spectral responses for the 15 pixels, and using this mean vector to represent them, produced nearly identical results at less than half the computer cost.

To test for redundancy, the four-channel data for the area were subjected to multiple correlation analysis. The multiple correlation coefficient between the clear filter channel and the other three channels was 0.995, based on 122,880 data points. Because the clear filter channel had high simple correlations with each of the other three channels, it was eliminated, and the highest multiple correlation coefficient (between the green channel and the other two) then became 0.979. At this stage, using standard programs available in the ORSER System, a single tape containing the three-channel data was prepared for each frame of digitized photographic data.

Signature Development

Satisfactory determination of spectral signatures by the supervised classification procedure requires the location and identification of relatively uniform training areas whose identities (i.e., community types) are known. This process was unusually difficult and complex in this case for the following reasons:

- Supporting ground truth materials were either limited in coverage (Daniels, 1976) or poor in quality. (The original transparencies could not be removed from Wallops Island and, therefore, only enlarged prints from 35-mm slides of the transparencies were available.)
- The spatial patterns of the plant communities are complex.
- In some communities, notably pine woodland, the scale of local variations (texture) was larger than the resolution of the averaged data.
- The photographic process produces an image with higher average density (for a given target) near the edge of the photograph than near the center. The distribution of points (in spectral density space) representing a community is, therefore, ellipsoidal rather than approximately spherical. That is, the variation in overall density within a type may be greater than the variation in signature shape between types.
- The decision to work as closely as possible to Daniels' definitions of communities in determining categories of signatures was somewhat constraining, because several of the types represented arbitrary decision points on a continuum (e.g., mesic shrub and xeric shrub).

In general, the processing sequence followed the standard ORSER methods for analyzing digital remotely sensed data (Turner *et al.*, 1978). A brightness map (NMAP program) was output to assist in locating geographic features in the scene. A uniformity map (UMAP program) was then used to define areas of local uniformity. For those uniform areas that seemed to be geographically coincident with major community types defined by Daniels (1976), mean and standard deviation vectors of film density values were obtained (USTATS program). After several iterations, a library of spectral signatures was developed and a classification map was produced (CLASS program). This map was compared with Daniels' map and the original photograph. Cluster analysis (CLUS program) was used extensively to define signatures for non-uniform or anomalous areas.

The resultant set of signatures was then applied to data for the frames adjacent to the Bunting's Woods frame to the north and south. These classification maps were examined for unclassified or incorrectly classified areas and additional signatures were obtained using the previous procedure. When it became apparent that no further improvement could be made without considerable extra effort and expense, a final set of signatures was defined.

At this stage there were several signatures for each vegetation type. In order to find a consistent pattern, both among the several signatures representing a single category and among the groups of signatures representing different categories, a graph was constructed with Channel 1 (red filter) as ordinate and Channel 2 (green filter) as abscissa. (These two channels were chosen because they had the lowest correlation of the three possible pairs.) Approximately 250 randomly chosen sample density vectors were plotted with a colored symbol indicating the community type represented. A consistent pattern was found for targets that were intrinsically uniform and easily recognized, such as WATER and SAND. All of the points within these target types tended to be aligned closely along one or more diagonal straight lines. For many of the less uniform communities, such as LOW and HIGH SALT MARSH or MESIC and XERIC SHRUB, the signatures formed one or more elongated elliptical patterns. The communities which had consistently been the most difficult to identify, however, had signatures which formed broad, overlapping, less elliptical patterns, commonly with outliers. When it could be determined that these outliers resulted from erroneous target identification, their identity was corrected; otherwise, they were ignored.

This target pattern suggested that the response space might be partitioned to approximately reflect the actual relationships if each type were represented by several signatures chosen to lie along the principal axis of the ellipse formed by the set of sample signatures representing the type. The principal axes for the various groups of signatures were determined by principal components analysis (ROTATE program) using all three channels of data. Location and spacing of the signatures along the axis were based on (1) the classification limits, (2) the proximity and location of signatures for contrasting types, and (3) trial and error. A graph of the final set of signatures (Channels 1 and 2 only) is shown in Figure 1. Although overall results were significantly improved by this scheme, PINE WOODLAND was still not clearly separated from other types.

CLASSIFICATION

Each frame was classified using a minimum Euclidean distance classifier with the signatures which had been developed. The classification results were resampled to produce square pixels for display on the ORSER Ramtek color display system. Because whole frames would not fit on the Ramtek screen, half-frames were displayed for examination. In no case were large areas found unclassified, nor were significant departures from major known patterns found.

Each half-frame (plus some overlap) was centered on the screen (to minimize distortion) and photographed using Ektachrome and Kodacolor 400 films. Standard 35-mm slides were produced from the Ektachrome film, and 28 by 30.5 cm prints were made from the Kodacolor negatives (an example of the Bunting's Woods area is shown

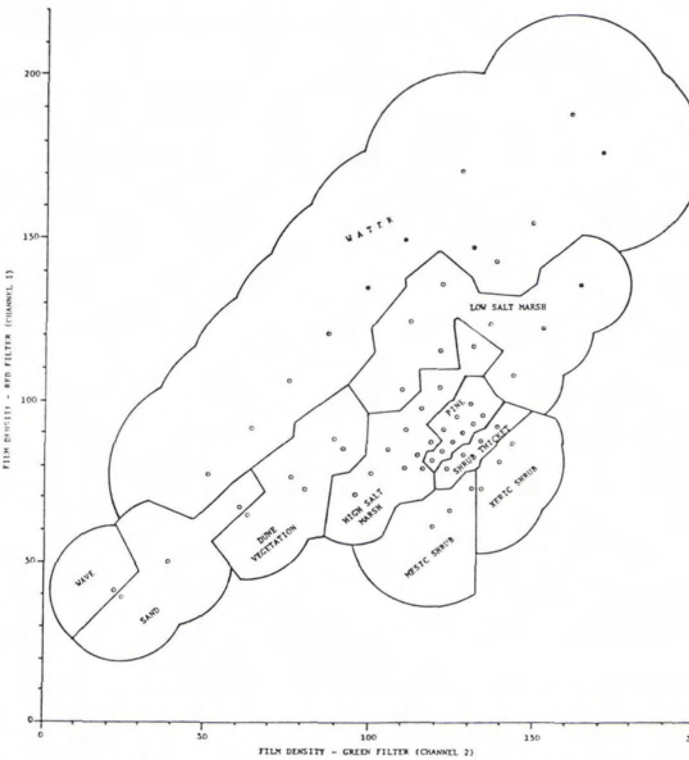


Figure 1. Red-filter/green-filter decision boundaries for the final set of mean signatures.

in Plate 2). Adjacent prints were visually edge-joined, and type categories and boundaries were found to match reasonably well across frame edges. Thus, a complete mosaic of the Maryland section could have been produced, although its size (about 6-m long) would limit its usefulness.

RESULTS

The vegetation types mapped were primarily those defined by Daniels (1976) and listed earlier. These were cross-checked against those of Higgins *et al.* (1971). Consolidation of some communities was necessary. After analysis and validity checking (described later), the following cover types were defined:

- WATER, including ocean, bays, channels, freshwater ponds, lakes, and streams. It also includes other non-vegetative, low-reflectance targets such as blacktop roads, parking lots, and buildings with black roofs. In the final color maps, the few unclassified pixels were also included here.
- SAND, including bare beach and dune sand as well as most of the beach pioneer community (scattered *Cakile edulenta* and *Salsola Kali*) and the more sparsely vegetated, dry portions of the dunegrass, and herbaceous dune communities. It also includes some bare or sparsely vegetated dry mudflats.
- DUNE VEGETATION, including all dry areas with grasses and forbs, from scattered to dense, together with clumps of low shrubs (primarily *Myrica cerifera*). This category is a consolidation of the major parts of the dunegrass, dunegrass and low thicket mixture, and herbaceous mudflat dune communities. It includes much of the herbaceous mudflat community as well. In addition to *M. cerifera*, the major species are *Ammophila breviligulata, Solidago sempervirens, Cakile edentula, Spartina patens,* and *Andropogon virginicus*. Some bayshore areas with sparse vegetation and light-colored soil are also included. Wet or marshy swales and depressions in the back-dune area are not included.
- MESIC SHRUB, dominated by *M. cerifera, M. pennsylvanica, Baccharis halimifolia,* and *Rhus radicans*.
- XERIC SHRUB, dominated by *M. cerifera, Smilax glauca, Prunus serotina, Pinus taeda, Lonicera japonica, R. radicans, B. halimifolia,* and *Iva frutescens*.
- SHRUB THICKET, including most marshy areas where the cover is a mixture of shrubs or of trees and herbaceous vegetation.
- PINE WOODLAND, including both pine woodland and mixed woodland. In the former, *Pinus taeda* is dominant; other important species are the shrubs *M. cerifera, M. pennsylvanica,* and *Rhus copallina* and the lianas *Smilax rotundifolia* and *S. glauca*. Most important species in the mixed

woodland are *P. taeda, Quercus nigra, Q. falcata,* and *Salix nigra* in the overstory; the shrub *M. cerifera;* and the lianas *S. glauca, S. rotundifolia,* and *Vitis rotundifolia.*

- HIGH SALT MARSH, including the bayshore communities dominated by *Spartina patens* associated with *Distichlis spicata, Juncus gerardi, Eleocharis* sp., *Solidago* sp., and *I. frutescens.* This category also includes freshwater marsh areas (without standing water) within the other types, particularly the swales and depressions in the back-dune area. Dominant species in the latter areas include *Eleocharis parvula, Scirpus americanus, S. patens,* and *Juncus* sp.
- LOW SALT MARSH, including areas that are frequently flooded by tides and are dominated by *Spartina alterniflora;* it also includes the wetter of the freshwater marshes, especially those with standing water. Species found in these areas include *Eleocharis* sp., *Scirpus americanus,* and *Juncus* sp. This category may also include some shallow ponds or parts of ponds invaded by emergent aquatic plants.

Analysis of Results

After generation of the classification map, it was necessary to determine how validly the map represented the true conditions in the study area. It was also important to determine map scale and estimate the area represented. Two approaches were taken in checking the validity of the classification maps. The first was to visually compare portions of three frames with the vegetation maps compiled by Daniels (1976). The second was to quantitatively estimate classification precision using the transparencies at Wallops Island from which the data were obtained.

Visual Comparison

Copies of Daniels' (1976) three vegetation maps were tinted using the color code selected for the Ramtek-produced prints. Visual comparison of the two Bunting's Woods maps showed no major observable differences between the computer-classified map and that of Daniels, although Daniels' map was more generalized. The greater detail in the computer map appeared to demonstrate more accurately the complex mosaic character of the plant communities. Since all the signature development work was done on the Bunting's Woods data, one would expect good correspondence between the two maps.

Substantially less agreement was found when the other two areas were examined. In general, the confusion resulted from somewhat different definitions of types. Daniels' types were constructed primarily on the basis of species composition, whereas the computer-interpreted types were purely a function of spectral characteristics. For example, although one would not expect to find dune vegetation in the back-bay area, some parts of this area consisted of light-colored sand supporting sparse vegetation and thus were computer-classified as DUNE VEGETATION. Thus, Daniels' "dune vegetation" might be more appropriately called "sparse herbaceous vegetation" in the computer classification. Some differences are undoubtedly due to the greater level of generality in Daniels' boundary locations or, to put it differently, in the larger minimum area considered by Daniels. Furthermore, the possibility of errors in Daniels' interpretation cannot be wholly discounted. For example, in the photograph of the Whittington Point area, there is a great variation in texture in a large area lumped together by Daniels as "xeric shrub," which seems to indicate that the computer map may more accurately reflect this variation.

Quantitative Comparison

Between 50 and 100 random points were located on each frame of the original transparencies at Wallops Island. (The actual number was proportional to the land area included in each frame.) The Bunting's Woods frame was excluded because it was used for nearly all the developmental work. Each point, identified by the line and element numbers on the classification map, was marked on a transparent overlay on which the same line and element grid, scaled to fit the original transparencies, had been engraved. The grid was laid over the transparency on a light table, and the vegetation type at each point was determined by visual interpretation without knowledge of the computer-determined classification. Some difficulties in interpretation were experienced, particularly with closely related types such as HIGH SALT MARSH and LOW SALT MARSH.

The photointerpreted classifications were compared with the computer classifications and a confusion matrix was constructed (Table 1). As shown in Table 2, the matrix indicates an overall agreement of 62 percent, ranging from 13 percent for SHRUB THICKET (3 percent of the land area) to 87 percent for SAND (27 percent of the land area) and 89 percent for WATER. If the analysis is confined only to the vegetation types (SAND and WATER excluded), the agreement was only 48 percent.

When the misclassifications were examined, it was found that most of the confusion was between closely related types. For example, vegetation cover on dunes ranges from 0 to almost 100 percent, so the point at which SAND becomes DUNE VEGETATION is arbitrary. Thus, most of the misclassifications in these two types were in the closely related type. When two such classifications were added together, however, their areas did not always agree on the two maps. For instance, more DUNE VEGETATION was observable to the photointerpreter than to the computerized classifier. This result was in part due to the coarse resolution of

TABLE 1. CONFUSION MATRIX FOR PHOTOINTERPRETED AND COMPUTER-CLASSIFIED POINTS

Photointerpreted Class	Computer Map Class									
	Sand	Dune vegetation	Mesic shrub	Xeric shrub	Pine woodland	Shrub thicket	High salt marsh	Low salt marsh	Water	Total
Sand	90	9	0	0	0	1	4	0	0	104
Dune vegetation	39	44	0	0	0	0	14	2	0	99
Mesic shrub	0	1	19	3	2	2	7	0	0	34
Xeric shrub	0	0	2	1	0	0	0	0	0	3
Pine woodland	0	0	0	0	3	6	2	1	0	12
Shrub thicket	1	0	5	0	3	4	14	2	2	31
High salt marsh	3	13	1	1	5	1	72	15	4	115
Low salt marsh	0	11	0	0	0	0	30	49	13	103
Water	1	3	0	0	0	0	2	5	93	104
Total	134	81	27	5	13	14	145	74	112	605

the digital data when compared to the dimensions of the sparse dunegrass areas. Also, because of the poor quality of the print used to identify training areas during signature development, some vegetated areas were identified as bare sand. Continuums existed between MESIC and XERIC SHRUB, between HIGH SALT MARSH and LOW SALT MARSH, between LOW SALT MARSH and WATER, and between HIGH SALT MARSH and SHRUB THICKET. As was true for the visual comparison, the quantitative results suggested that much of the misclassification error might be due to different rules for defining the classes on the two representations of the area. If the "near misses" were accepted, the overall rate of agreement increased to 82 percent, and for the vegetation types alone it increased to 75 percent (Table 2). The poorest results were still obtained with SHRUB THICKET (29 percent) and PINE WOODLAND (25 percent); however, these two types together comprised only 6 percent of the total land area.

CALCULATION OF AREAS AND SCALE

Because the analyzed areas overlapped, non-overlapping polygons were defined on each character map so that the total areas by vegetation types could be estimated. The mean pixel size was determined to be 0.0015172 hectares, and pixel counts were made to give the total areas by vegetation types for the entire Maryland section of the island. The total land area (excluding all points identified as water) was calculated to be 3397 hectares.

Because the chi-square test supported the hypothesis that the random points could be considered a random sample, the confusion matrix (Table 1) was used to correct the computer-calculated area estimates for the difference between the photointerpreted and computer-generated types. For example, the computer-estimated acreages for MESIC and XERIC SHRUB were 182 and 62 hectares, respectively. Since two of the 27 points labeled by the computer as MESIC SHRUB were interpreted as XERIC SHRUB and one of the five points labeled by the computer as XERIC SHRUB was interpreted as MESIC SHRUB (Table 1), the corrected area estimate for XERIC SHRUB was estimated as

$$\frac{2}{27}(182) + \frac{1}{5}(62) = 26 \text{ hectares.}$$

The corrected area estimates are given in Table 3. They represent the best area estimates available from these data and are representative of what one would obtain from visual photointerpretation. The total of 3455 hectares of land area is appreciably less than the official land area of the Maryland portion, which is given as 4070 hectares. However, this latter figure probably includes land-locked and partially land-locked water, which are

TABLE 2. EXTENT OF AGREEMENT OF PHOTOINTERPRETED TYPES WITH COMPUTER-CLASSIFIED TYPES

		Computer-Classified Types					
		Correct Class		Near Misses[a]		Correct Plus Near Misses	
Photointerpreted Types	Total Points	No.	%	No.	%	No.	%
Sand	104	90	87	9	9	99	95
Dune vegetation	99	44	44	39	39	83	84
Mesic shrub	34	19	56	3	9	22	65
Xeric shrub	3	1	33	2	67	3	100
Pine woodland	12	3	25	0	0	3	25
Shrub thicket	31	4	13	5	16	9	29
High salt marsh	115	72	63	15	13	87	76
Low salt marsh	103	49	48	43	41	92	89
Water	104	93	89	5	5	98	94
Totals	605	375	62	121	20	496	82
Totals, vegetation only	397	192	48	107	27	299	75

[a] Classified in a closely related type.

excluded from the computer estimates. Lins (1980) gave a similar figure of 4087 hectares for the area of "Assateague Island North," which apparently included a small portion of the Virginia half of the island as well as some small bayside islands not included in our estimate. This estimate was derived from Level I photointerpretation and did exclude "Waterbodies."

The scale of the 28 by 30.5 cm photographic prints of the final map, calculated from the pixel size and knowledge of the number of lines and elements displayed on the Ramtek screen, was approximately 1:8000. A reduced-scale sample print was shown in Plate 2.

DISCUSSION

This project has pointed out some of the problems inherent in processing digitized aerial photographs by conventional digital remote sensing techniques. The lack of calibration of the data prior to signature development and classification was a major difficulty. Scarpace (1978), Scarpace and Friederichs (1978), and Scarpace and Quirk (1980) have described the complexities of the non-linear relationships between incident light and film density for multi-emulsion imagery, and the desirability of radiometric calibration of data from a microdensitometer before they are analyzed by classification algorithms. Although radiometric calibration more than doubles the cost of the data, it would presumably result in substantial savings by reducing the necessity for multiple signatures for the same category to account for overall film density variations.

The use of a minimum Euclidean distance classifier presented another problem. If a classifier which did not require the assumption of hyperspherical decision boundaries (such as a likelihood ratio classifier) had been used, less multiple signature development would have been necessary. Such classifiers have recently been added to the ORSER System.

The problem of optimum resolution was well illustrated by this project. On the one hand, finer resolution than that actually used (approximately 15 m^2) would have been useful in detecting sparse dune vegetation. On the other hand, the difficulty in defining the PINE WOODLAND type may well have been due to the resolution elements often being smaller than individual pine crowns. Aldrich (1979) and others have already suggested that the optimum resolution is not necessarily the finest. Research is needed to find the appropriate compromise.

The lack of adequate ground truth information was a major stumbling block. It would have been useful if the original photographs could have been studied in the field in the early stages of the in-

TABLE 3. LAND AREA ESTIMATE CORRECTIONS

	Before Correction		After Correction	
Class	No. of Ha	%	No. of Ha	%
Sand	915	27	715	21
Dune vegetation	609	18	701	20
Mesic shrub	182	2	250	7
Xeric shrub	62	5	26	1
Pine woodland	104	3	86	2
Shrub thicket	99	3	211	6
High salt marsh	942	28	778	23
Low salt marsh	484	14	688	20
Totals	3397	100	3455	100

vestigation. The dynamic nature of the island's features limited the use of photography taken on other dates. For the same reason, field data collected at the time of analysis would also have been of limited use.

Even if timed correctly, field investigation of the study area would have been particularly difficult since the only features which can be used for orientation and location are vegetation differences and bayline indentations. Because of this problem, only one of the three transects run in the Bunting's Woods area to check the typing for the feasibility study could be positively stated to be correctly located and thus could provide useful data.

The procedure developed to evaluate the success of the classification process was the most appropriate in view of the difficulties in field checking and the paucity of ground truth information. Because of the possible bias of the photointerpreter, who had also selected the training areas for computer analysis, the results are stated in terms of agreement between the manual and computerized interpretations, and are not to be interpreted as absolute.

Conclusions

It has been shown that a detailed vegetation map of a complex ecosystem, such as exists on a barrier island, can be produced by computer analysis of digitized, large-scale, color infrared photographs. The degree of success in classification of the vegetation communities is a function of a large number of variables, including the calibration of the digitized data, the experience of the analyst, the opportunity to make ground observations, and the amount of ancillary ground-truth data available.

In this study, several constraints hampered classification success. Since the digital data were not calibrated prior to processing, many more signatures were needed to describe each category than are normally required with remotely sensed data. Opportunities for on-site visitation and access to the best available aerial photography of the area were both limited, and adequate ancillary data were unavailable.

Despite these drawbacks, a high degree of success was achieved on the frame on which all the signature development had occurred, and moderate success was achieved on the other frames. This success was measured in terms of agreement with existing photointerpreted vegetation-type maps of parts of the island and with visual interpretation of the color-infrared transparencies from which the data were digitized.

The true value of the vegetation maps can only be assessed by the users. The area measurements are probably the most accurate yet available, despite their known imprecision. The locations of type boundaries appear relatively accurate, but positive identification of the cover types requires careful field evaluation.

For further use of this technology, the following recommendations are made:

- Before data processing, the analyst should become familiar with the vegetation in the field and its corresponding appearance on the digitized images;
- Experimentation to determine the most appropriate pixel size should precede digitization;
- Clear-filter data need not be acquired if three color filters are used;
- Before analysis begins, the microdensitometer data should be calibrated using the methods developed at the University of Wisconsin (Scarpace, 1978; Scarpace and Friederichs, 1978);
- If pixel consolidation is required, pixel averaging should be used rather than the more expensive cubic convolution interpretation;
- The ORSER System, or a similar system suitable for spectral analysis of digitized photographs, should be used in preference to the development of new computer programs; and
- Random point validation should be used to determine the accuracy of the results and to correct the area statistics.

References

Aldrich, R. C., 1979. *Remote Sensing of Wildland Resources: A State-of-the-Art Review*, USDA Forest Service General Technical Report RM-71.

Daniels, S. M., 1976. *Applications of Remote Sensing to Resource Classification and Inventory of a National Shoreline Park*. Unpublished M.S. thesis, American University, Washington, D.C.

DeMott, J. S., 1980. America's Abused Coastline, *Time* (Sept. 15): 28-29.

Dolan, R., B. Hayden, and H. Lins, 1980. Barrier Islands, *American Scientist* 68(1):16-25.

Higgins, E. A., R. D. Rappleye, and R. G. Brown, 1971. *The Flora and Ecology of Assateague Island*, Bull. A-172, Agricultural Experiment Station, University of Maryland, College Park.

Lins, H. F., 1980. *Patterns and Trends of Land Use and Land Cover on Atlantic and Gulf Coast Barrier Islands*, U.S. Geological Survey Professional Paper 1156, 164 p.

MacLeish, W. M., 1980. Our Barrier Islands Are the Key Issue in 1980, the "Year of the Coast," *Smithsonian* 11(6):46-59.

Scarpace, F. L., 1978. Sensitometry on Multi-Emulsion Imagery, *Photogrammetric Engineering and Remote Sensing* 44(1):1279-1292.

Scarpace, F. L., and G. A. Friederichs, 1978. A Method of Determining Spectral Analytical Dye Densities, *Photogrammetric Engineering and Remote Sensing* 44(1):1293-1301.

Scarpace, F. L., and B. K. Quirk, 1980. Land-Cover Classification Using Digital Processing of Aerial Imagery, *Photogrammetric Engineering and Remote Sensing* 46(8):1059-1065.

Turner, B. J., D. N. Applegate, and B. F. Merembeck, 1978. *Satellite and Aircraft Multispectral Scanner Digital Data User Manual*, ORSER Technical Report 9-78, The Pennsylvania State University, University Park.

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