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Development of a Vegetation Map for Water Conservation Area 3

By

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Executive Summary

The environmental jewel of the Comprehensive Everglades Restoration Plan (CERP - www.evergladesplan.org), is the Water Conservation Area 3 (WCA-3) Decompartmentalization and Sheet Flow Enhancement (aka: DECOMP) project. Impoundments such as WCA-3, originally designed for flood control and water supply, must now be restored for their ecological value. A current vegetation map of this area was needed to establish baseline conditions. This mapping Project, initiated in 1994, is the first comprehensive detailed vegetation map produced for WCA-3.

Water Conservation Area 3 is a 234, 913 ha impoundment located in the central portion of the remnant Everglades. In the late 19th century, human efforts began to control the timing, quantity, quality, flow, and distribution of water within this once vast pristine marshland. Impounding and partitioning activities were completed in phases starting in 1952 and ending in 1973, resulting in five sub-compartments that, over time, developed their own unique hydrologic and floral characteristics. More important than the effects of altered hydrology on plant community structure within these sub-compartments may be the changes in concentration and loadings of phosphorus (P) in waters flowing into this oligotrophic environment. These two attributes, altered hydrology and changes in concentration and loadings of P, have had significant effects on the original plant community structure and composition of WCA-3.

The objective of this mapping project was to create a seamless and complete GIS vegetation database of WCA-3 utilizing 1:24000 scale color infrared aerial photographs to identify and code all vegetation communities using a single, hierarchal, classification system. Up to three codes of vegetation representing the dominant, co-dominant, and third dominant were included to label each polygon. Overall map classification accuracy was 89.7 percent.

The total area mapped was 234,913 ha. comprised of 155,434 digitized and labeled polygons. The largest group of polygons (52,683 or 33.89%) was 0.01 to 0.05 ha in size. Sawgrass and Wet Prairie communities accounted for the greatest area (205,564 ha) and percentage (87.5%) of polygons categorized for the entire project. This was also true for each of the five sub-compartments within WCA-3, where these two communities accounted for 76.16 – 94.68% of the labeled polygons. Cattail habitat encompassed five percent of the project area, or 11,751 ha. The relative contribution of cattail found in each of the sub-compartments ranged from 605 to 6861 ha.

This final product provides the most detailed, spatially explicit vegetation information ever compiled for any part of the Everglades. It also provides the only current detailed vegetation map of WCA-3 and should provide a valuable baseline of information from which future mapping efforts for this area can be gauged. It is hoped that this mapping project provides a source of baseline information needed for the WCA-3 CERP Decompartmentalization project to succeed in restoring this environmental jewel of the Everglades.

Introduction

Water Conservation Area 3 is a 234,913 ha impoundment (Figure 1) located in the central portion of the remnant Everglades. In the late 19^{th} century, human intervention began to control the timing, quantity, flow, and distribution of water within the once vast pristine marshland. Impounding and partitioning activities were completed in phases resulting in sub-compartments developing their own unique hydrologic characteristics.

By 1917, three muck scalped canals were constructed that dissected the Everglades from Lake Okeechobee to the Atlantic Ocean. Two of these canals affected the land area of the yet to be created WCA-3 impoundment, the Miami canal and the North New River Canal. The North New River canal eventually became the northeast boundary of WCA-3 (Figure 1) and the Miami Canal bisected WCA-3 from the northwest to the southeast. In 1915, Tamiami Trail road construction began in order to link Miami with Naples and eventually became the southern boundary of WCA-3 (Light and Dineen, 1999).

Major hurricanes occurring in 1947-48 caused extensive flooding throughout much of south Florida. As a result a massive federal project called the Central and Southern Florida Project for Flood Control was formed in 1948. Its mission was to develop a system of canals, pumping stations, water storage areas (including WCA-3), and levees to reduce flooding and encourage agricultural and urban development in southern Florida. That effort, which was undertaken by the Army Corps of Engineers, occurred over a period of four decades and finalized the completion of the present day WCA-3 impoundment.

From 1952 to 1954, a north-south levee/borrow canal system was constructed on the eastern boundary of WCA-3 to provide a flood control barrier to the ever increasing populated regions of the east coast. A northern levee/borrow canal system was put into place from 1954 to 1959 to provide flood protection to the developing agricultural lands to the north. Hydrologists had determined that the southeast section of WCA-3 was draining rapidly through the porous limestone and into the aquifer. As a result, the area was separated into WCA-3A and WCA-3B by a levee/borrow canal system built from 1960 to 1963. The remaining western border was then completed by constructing a levee/borrow canal system that extended from the northern and southern boundaries, which separated WCA-3 from the Big Cypress watershed. However, a 7.5 mi. gap was left in place to allow water to flow in from the west off privately held lands.

During this same time construction of structures (both pumping and gravity fed), produced a complicated water movement system for the WCA-3 impoundment. Events that started in the 19^{th} century and continued through 1995 had significant impacts on WCA-3, resulting in compartmentalization that subjected each sub-compartment to different water timing, quantity, flow, and distribution.

Altered hydrology (e.g. water depth, hydroperiod, flow) has been shown to

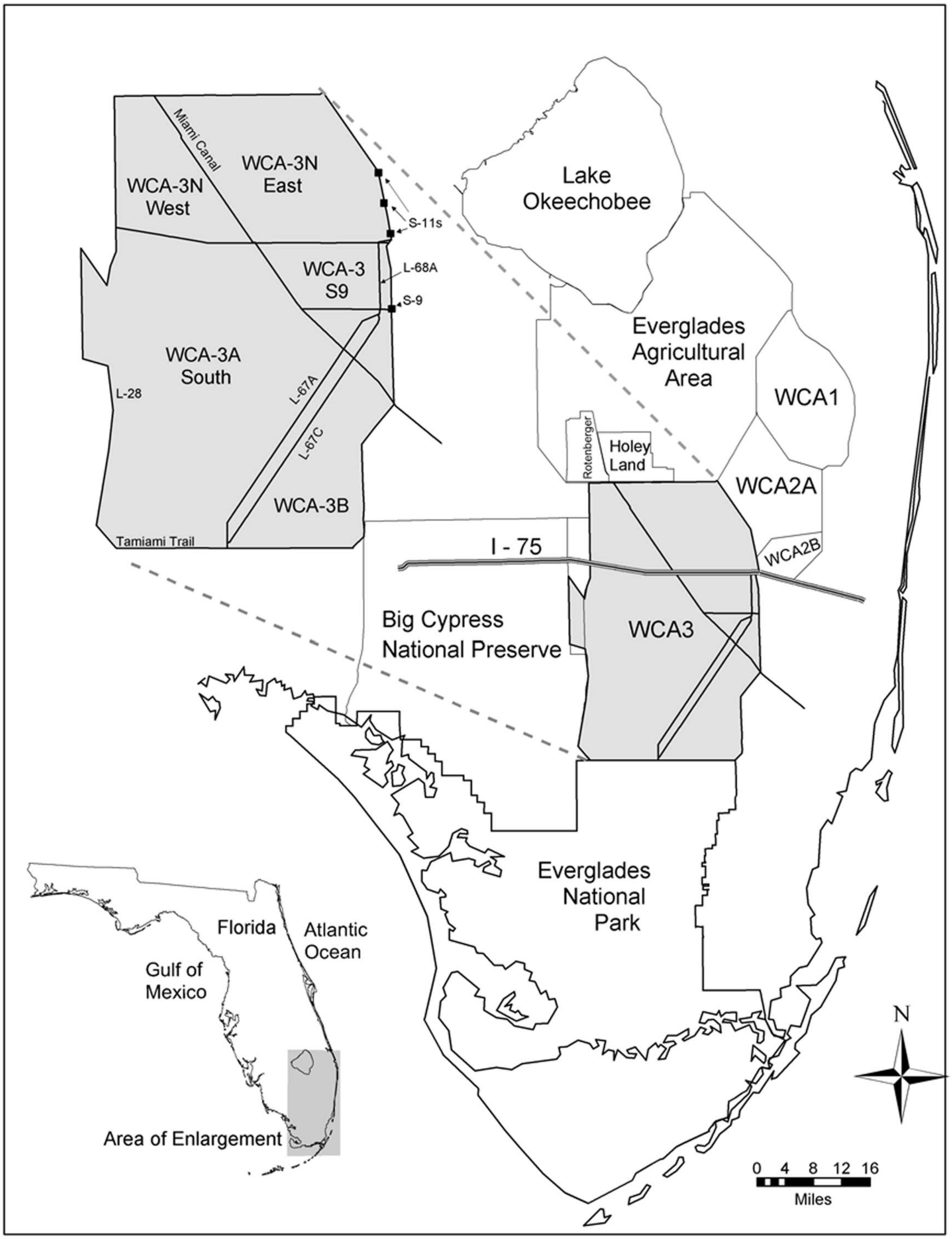

Figure 1. Location map of WCA-3.

cause dramatic changes in the composition and structure of plant communities within the Everglades (Alexander and Crook, 1975; Davis *et al*., 1994). In general, the aforementioned construction works have altered the hydroperiod differently for each of the sub-compartments within WCA-3. WCA-3N West, WCA-3N East, and WCA-3B sub-compartments (Figure 1) have been altered most by hydrologic reductions in flow and duration. An exception is the southeast corner of WCA-3N East where it is wetter because of discharges from the S-11 structures. The WCA-3N West sub-compartment tends to be wetter than WCA-3N East. However, there are no major inflows of water in the northern section of this compartment, resulting in a gradient of dryer to wetter conditions from north to south. The central section of WCA-3A South may be the least impacted area. Nonetheless, the sloping topography from north to south and the downstream barrier presented by the Tamiami Trail have produced substantial ponding in the southern end of this sub-compartment. The WCA-3 S-9 sub-compartment typically exhibits the longest annual inundation of all sub-compartments. This is due to the back-pumping of water into the impoundment from the east through the S-9 pump station in addition to the flow of water entering the area from the S-11 structures in the north.

Water quality has also changed. Concentrations and loadings of phosphorus (P) into the soil and water column have increased from point source inflows from agricultural runoff in the north (Davis, 1994) and from water backpumped westward through the S-9 structure for flood attenuation in the C-11 Basin. Nutrient enrichment has been shown to alter the vegetation complex of the Everglades (Davis, 1991; Doren *et al*., 1997; Newman *et al*., 1996; Miao and DeBusk, 1999; Rutchey and Vilchek, 1999). Elevated soil P at interior sites, away from inflow structures, has also been found in WCA-3N East and may result from soil oxidation and compaction.

The Comprehensive Everglades Restoration Plan (CERP - www.evergladesplan.org), authorized as part of the Water Resources and Development Act (WRDA) of 2000 (U.S. Congress 2000), is an $8 billion hydrologic restoration project for all of south Florida. CERP includes 68 separate projects to be managed over the next 30 yrs by the South Florida Water Management District (SFWMD), Corp of Engineers and other State and Federal agencies. One project, considered by many to be the environmental jewel of CERP, is the Water Conservation Area 3 Decompartmentalization and Sheet Flow Enhancement (aka: DECOMP) project. Impoundments such as WCA-3, originally designed for flood control and water supply, must now be restored for their ecological value. The objective of the DECOMP project is to re-establish the ecological and hydrological connection between Water Conservation Areas 3A and 3B, Everglades National Park, and Big Cypress National Preserve. The project includes elevating and opening Tamiami Trail and filling in portions of the Miami, L-68A, L-28, L-67A and L-67C canals within WCA-3 (See Figure 1).

Restoration Coordination and Verification (RECOVER) is a system-wide program of the CERP designed to organize and provide the highest quality scientific and technical support during implementation of the restoration program (RECOVER, in prep.). It is the role of RECOVER to develop a system-wide Monitoring and Assessment Plan

(MAP) (RECOVER, 2004) and to document how well the CERP is meeting its objectives for ecosystem restoration. One critical component of the MAP is vegetation mapping to document changes in the spatial extent, pattern, and proportion of plant communities within the landscape.

To document baseline conditions as part of the South Florida Vegetation Mapping Project (Doren *et al.* 1999), the SFWMD has developed a detailed land-cover vegetation map of WCA-3 (Figure 1). The South Florida Vegetation Mapping Project was a collaborative effort between the National Park Service South Florida Natural Resources Center at Everglades National Park, the Center of Remote Sensing and Mapping Sciences at The University of Georgia, and the SFWMD (Doren *et al.* 1999, Welch *et al.* 1999). This collaboration has resulted in a seamless and complete GIS vegetation database of the entire remnant central and southern Everglades utilizing color infrared aerial photographs and a single classification system. However, the methods and materials used to create the WCA-3 section were substantially different from the rest of the southern Everglades mapping effort and are documented here for historical purposes. This map is the first comprehensive detailed vegetation map produced for WCA-3.

Materials and Methods

The WCA-3 vegetation mapping project relied on manual stereoscopic analysis of high resolution, hard copy air photos. It was conducted in two phases utilizing 1:24,000 scale color-infrared positive transparencies (23 by 23 cm format) flown in September 1994 and June 1995 for phases I and II, respectively (Figure 2). Both air photo missions resulted in a 60% overlap between photos along the same flight line and a 20% overlap between adjacent flight lines. A phased approach was taken for two reasons. First, a new air photo mission was flown during June, 1995 to take advantage of a nearly complete "brown-out" of cattail within WCA-3. The reasons for this apparent senescence may have been due to a caterpillar infestation. This data set offered improved definition between cattail (*Typha spp.*) and other macrophytes with similar physiognomy, such as sawgrass (*Cladium jamaicense*). Second, acquisition by the District of an analytical stereo plotter offered a new and improved method for vegetation mapping in Phase 2 with better optical resolution as well as superior spatial accuracy of the output. Phase 1 used a stereoscope and was more reliant on manual techniques.

Vegetation was delineated and classified using *A Vegetation Classification System for Southern Florida's National Parks and Preserves* (Jones et al. 1999). Up to three codes of vegetation representing the dominant, co-dominant, and third dominant could be included to label any polygon. Based on work done by Obeysekera and Rutchey (1997), a minimum mapping unit of one hectare was chosen for both study phases. However, every effort was made to map smaller features to portray the heterogeneous nature of the vegetation, producing a minimum mapping unit much smaller than one hectare.

Consistency of photo-interpretation was of primary importance in compilation of the maps. The lag of nine months between the two photography data sets

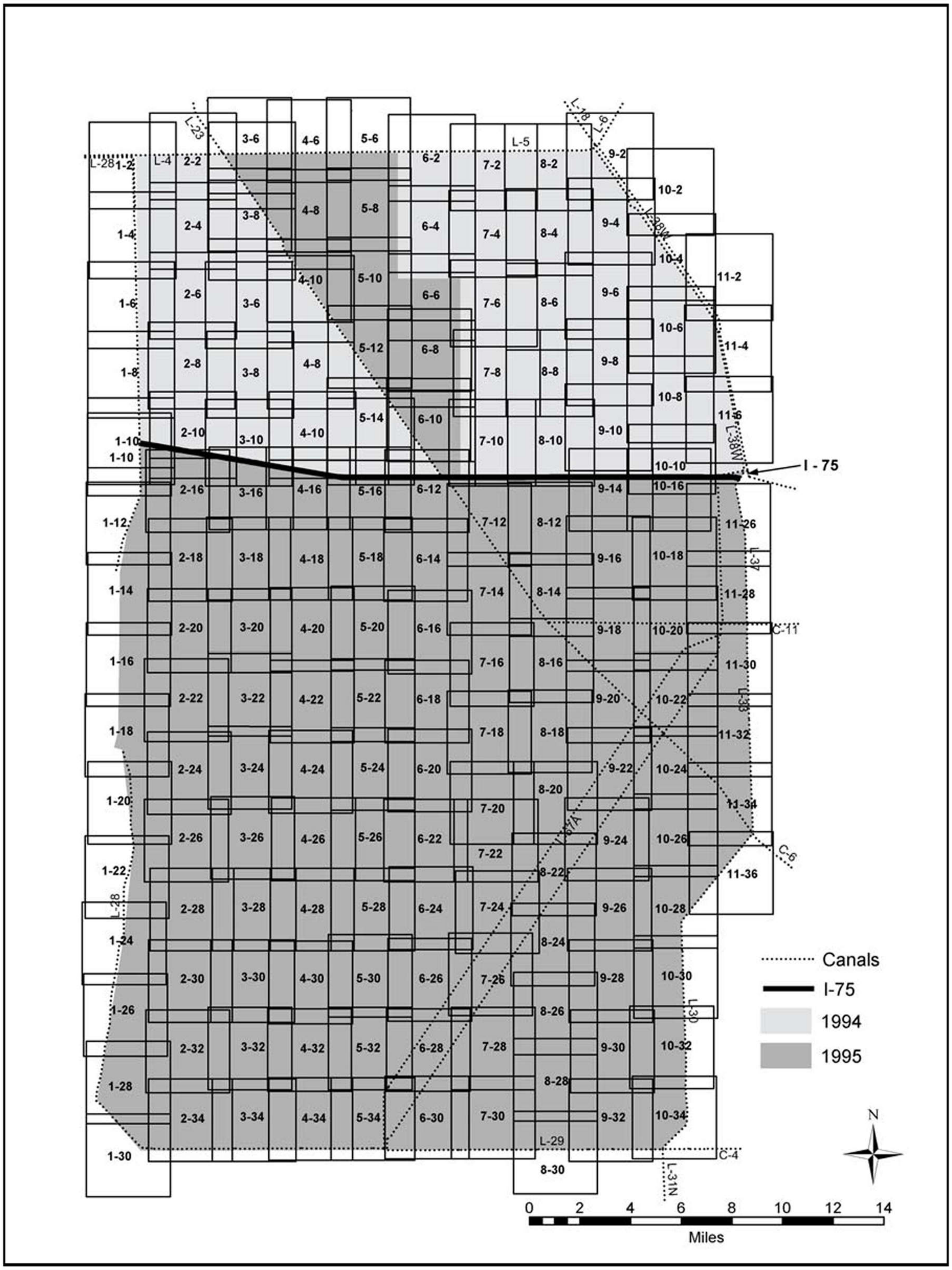

Figure 2. The WCA-3 vegetation mapping project depicting the two phases utilizing 1:24000 scale color-infrared positive transparencies (23 by 23 cm format) flown in September 1994 and June 1995 for phase I and II, respectively.

could have been problematic, but differences in seasonality and other environmental conditions between the two sets of photography did not pose technical problems for mapping vegetation. In fact, both air photo sets were commonly used in tandem to help support delineations in areas of special concern. The delineation of vegetation polygons and collection of all field ground-truthing was conducted by two experienced remote sensing analysts familiar with Everglades plant community structure. All map production was done in the Universal Transverse Mercator (UTM) grid coordinate system referenced to the North American Datum of 1983 (NAD 83).

To assure photointerpretation quality, a second photo-interpreter reviewed all delineated line work under stereo. Most minor errors found (e.g. missing labels) were typically corrected by the reviewer. Systematic inconsistencies were addressed in a more formal fashion through discussions between mapping staff with the original photointerpreter making subsequent corrections when necessary. Through constant open communication, the photointerpreters built and maintained a project knowledge base which served as the foundation for the entire mapping effort.

<u>Phase 1</u>

The geographic extent of Phase 1 included all areas north of I-75 (WCA-3N West, and WCA-3N East; Figure 1) and was covered by 87 photos from the 1994 photo mission and 21 photos from the 1995 mission (Figure 2). One photo of each stereo pair was covered with clear stabilene mylar. Registration marks were transferred to the mylar from the photograph. Neat lines were added to define the working area on each photograph and to match the boundaries of work areas from adjacent photos. Vegetation patches were interpreted with the use of a Bausch & Lomb SIS-95 stereoscope. Neat lines, vegetation boundaries, ground control points (GCPs), and associated annotations were delineated under stereo directly on the mylar overlays using a 0.25-mm Rapidograph (Koh-I-Noor) drafting pen.

A minimum of four GCPs were identified and numbered on each photo with at least one GCP located in each corner of the photo. In addition, each GCP selected had to meet the criteria of commonality with at least 3 adjacent photos (i.e. each GCP was common to the overlap of 4 adjoining photos). This resulted in a total of seventy-eight unique points. Contiguous SPOT satellite scenes encompassing the WCA-3 project area were rectified to an accuracy of approximately $\pm$ 5 to $\pm$ 9 meters and used to find approximate UTM locations for the GCPs. These points were then visited in the field by helicopter or airboat where global positioning system (GPS) data were collected at the precise locations seen on the photos. These point locations were then differentially corrected resulting in a final GCP data set with horizontal accuracies of less than one meter. These GCPs were then assigned to their respective feature on the photo by marking them individually on the mylar overlays.

In order to correlate the spectral signature of vegetation types on the photos to field conditions, a total of 252 ground-truth sites were interactively selected from the photography during initial and subsequent photointerpretation. In this way the entire Phase 1 project area was examined for representative and problematic signatures. These ground-truthing points were then located on the rectified SPOT satellite scenes to obtain UTM coordinates. After these points were loaded into a GPS unit they were field checked via helicopter. Two observers verified vegetation from the helicopter by estimating the percent areal cover of vegetation within an approximated 20 by 20 meter square at each site. Experience and information gained from the ground-truthing investigations was crucial in creating the detailed delineation of vegetation polygons. Vegetation communities and zones were delineated and labeled directly on the mylar overlays under stereo using a multi-tiered hierarchal coding system described by Jones et al. (1999), where up to three vegetation types representing the dominant, co-dominant, and third-dominant could be included to label any polygon.

All mylar overlays with delineated linkwork and GCPs were scanned digitally using a Howtec Scanmaster III at 600 dpi with "line arc" scanning, intensity -26, contrast 0.5, and gamma 0.45. Resulting scan lines were then "skeletonized" and digitally inverted so that background and linkwork pixels were set to "0" and "1" respectively. Final output for scanned files was in the "tif" file format. The ArcInfo® (Registered trademark of Environmental Systems Research Institute Inc., Redlands, CA) "imagegrid" and "gridline" commands were used to convert the "tif" files into vector coverages. ArcInfo tolerances were set and the vector files rectified and transformed to a UTM projection using the GCPs marked on the photo mylars. Ground control points for each photo containing any ground-truth sites were digitized and a set of rectification coefficients were generated which allowed x,y ground coordinates to be determined for each site (Welch *et al.* 1995).

Vector files were then edited in the ArcEdit® (Registered trademark of Environmental Systems Research Institute Inc., Redlands, CA) module of ArcInfo to remove label annotation and clean up any artifacts or gaps in the linkwork resulting from the scanning process. All ArcInfo vector files from each photography data set were edge-matched and appended to form one master vector coverage for the WCA-3 north (Phase 1) project area. Having each GCP meet the criteria of commonality within the overlap of adjacent photos resulted in a limited amount of edge-matching to append the individual photo vector files together. Label points were added to the coverages and the attribute fields were defined according to delineated linkwork annotation. ArcInfo Arc Macro Language (AML) scripts were developed and used to automate the process of converting scanned image data to a vector format with minimal manual processing.

Error analysis of each digital coverage was accomplished in two ways. First, the coverage was checked for proper labeling by using the ArcInfo "dissolve" and "labelerrors" commands. The dissolved coverage was then checked to see if adjacent polygons were joined because of either a photo-interpretation or labeling error. The "labelerrors" command was used to check for missing or duplicate labels within polygons. Second, vector coverages were manually verified against mylar labeling annotations to check for any discrepancies.

Phase II

In mid-1997 the South Florida Water Management District purchased an SD2000 analytical stereoplotter from LH-Systems. This high precision optical instrument, which allows viewing of aerial photography stereoscopically at multiple scales, offered a number of features that significantly improved and streamlined the vegetation map compilation process. Improvements included vector superimposition through the optics, so that delineations could be transformed directly and immediately into a digital format. It allowed block adjustments or aerotriangulation on the aerial photos, requiring much less ground control, significantly improving horizontal spatial accuracy and precision.

Phase II included all areas south of I-75 (WCA-3A South, WCA-3 S9 and WCA-3B; Figure 1), which encompassed 202 photos (Figure 2). A fully analytical aerotriangulation was performed on the photography using ORIMA® (Registered trademark of Dr. L. Hinsken) software. Initially, pass and tie points were identified and marked on the aerial photography diapositives in a nine-point pattern at the corner and nadir positions of each stereo pair. In addition, nineteen points were identified on the photos, mostly on the outside periphery of the project area, to serve as ground control points for the entire block. Coordinates for the photo-identifiable GCPs were acquired by visiting these points in the field and collecting GPS data at the precise locations seen on the photos. These points were then differentially corrected, which resulted in a final GCP data set having horizontal accuracies of less than one meter. These reference points (Tie, Pass, and GCPs) were then measured using the steroplotter's ORIMA software. Independent strip adjustments using CAP-A® (Registered trademark of Dr. L. Hinsken) software produced an interim simultaneous block adjustment using a least squares solution for all ground and photogrammetric observations. After all strips were successfully tested and adjusted, they were combined and a simultaneous block adjustment for the entire project area was performed and finalized.

Photointerpretation was performed utilizing modern digital stereo compilation techniques under sufficient magnification to accurately identify, delineate, and classify vegetation types as described by Jones *et al* (1999). Polygons were delineated with PRO600® (Registered trademark of Leica Geosystems) and Microstation® (Registered trademark of Bentley Systems, Inc) software as part of the SD2000 system. Each of the 202 aerial photos was assigned a unique Microstation file of delineated polygons and labels. A programmed keyport pad automated selection of commands to delineate and label polygons.

Twenty-one hundred and fifty ground-truthing sites for Phase 2 were selected from the aerials at locations where photo signatures were questioned or simply unrecognized. Horizontal coordinates for the sites were derived from the PRO600® on-screen display of the analytical stereoplotter. Ground-truthing sites were located by helicopter or airboat utilizing real-time GPS receivers with horizontal accuracy of less than one meter. Each site visited was compared to the signature on the photograph and vegetation types, site location, site number, photo ID number, and other pertinent information were recorded on a field data sheet. Field verification data were then utilized to finish delineating and labeling the photos.

ArcInfo AML scripts were composed to: 1) import the Microstation files for each of the 202 photos into individual ArcInfo coverages, 2) perform iterative QA/QC analyses for proper topology and label attribution resulting in a color-coded "error" plot, and, 3) append the individual photos together resulting in a seamless mosaic of the entire project area. The ArcInfo command "igdsarc" was used to convert the Microstation files to ArcInfo coverage format. QA/QC analyses included checking for missing or duplicate labels within polygons using the ArcInfo "labelerrors" command and correcting these discrepancies. The ArcInfo "dissolve" command revealed adjacent polygons containing the same label. Where common borders were dissolved, the images were rechecked to determine if the border dissolution was appropriate. When polygon labels were correct, the border in question was removed. If either label were in error, the label was corrected and the border in question was retained. Once all the photos for each of the north-south strips were checked and corrected, they were appended. The same QA/QC process was then performed on each strip until all labeling problems were repaired. Finally all strips were combined and again the same QA/QC process was repeated until all labeling problems were resolved.

The five separate ArcInfo compartment coverages from Phase I and II were then combined to create a complete coverage for the entire WCA-3 project area. A final annotated map was produced with output files generated in a number of formats suitable for hardcopy plotting (See inserted map).

Map Analysis

For each WCA-3 compartment, polygon size distributions and spatial characteristics were analyzed. A query was conducted to select all polygons within defined size categories based on the area field HECTARE within the polygon attribute table. The query was performed using the "Selection by Attributes" tool in ArcGIS. The sum of polygons selected within each size class were then recorded.

Similar analysis was conducted for class category distributions in order to differentiate vegetation community characteristics between compartments. The DOMINANTVEG field was summarized for each area and the sum of each class was calculated. This was accomplished using the "Summarize" tool applied to the field of interest in the coverage polygon attribute table in ArcGIS 8.3. The output dBase files from this process were combined into one spreadsheet and graphed. Only the eleven most common dominant vegetation classes were used, comprising 99% of the polygons present in each compartment.

Accuracy Assessment

The entire WCA-3 final ArcInfo vector coverage was rasterized to a grid with two by two meter cells using the Spatial Analyst extension of ArcGis 8.3. This grid was then converted to ERDAS® (Registered trademark of ERDAS, Inc) "img" format using the ERDAS Import module. ERDAS software was also used to generate the 204 random sampling points needed for this assessment. (These number of sampling points were used because suitable accuracy assessment routines based on binomial probability formulas require the use of a minimum of 204 points to check for an 85 percent accuracy level with an error of ±5 percent (Snedecor and Cochran, 1978)).

All assessment points north of I-75 were located on the 1995 SPOT panchromatic satellite scene and then visually correlated and located on the appropriate photograph. These points were then viewed using the Bausch & Lomb SIS-95 stereoscope. All assessment points south of I-75 were located and inspected by utilizing the SD-2000 analytical stereoplotter. Two photointerpreters stereoscopically viewed the photography and classified the 204 random points independently. All points that were classified the same by the two photo-interpreters were denoted as correct and all points that were classified differently were considered wrong. Results for overall accuracy for entire label correct, dominant and co-dominant label correct and third-dominant label wrong, and first label correct and co-dominant and third-dominant labels wrong were computed using ERDAS Imagine software.

Results

Rectification of photos north of I-75 resulted in planimetric errors ranging from ±2.2 to ±29.9 m with an overall average of ±10.5 m on the ground. The fully analytical aerotriangulation that was performed on the block of photos south of I-75 resulted in root mean square errors of 0.48 and 0.40 m for the x and y directions, respectively. Because of south Florida's flat terrain, vertical relief was not measured or assessed.

Results for overall map classification accuracy are presented for polygon labels with up to three codes in Table 1.

Table 1. Map Accuracy Assessment Results

LABEL CODES			
DOMINANT	CO-DOMINANT	THIRD-DOMINANT	ACCURACY
correct	correct	correct	89.7%
correct	correct	incorrect	90.7%
correct	incorrect	incorrect	93.1%

Overall map classification accuracy was 89.7 percent. Ground-truthing for the entire project resulted in a 2,402 records data base. Data fields for each record included site location, vegetation type(s), site number, photo ID number and other pertinent information about the site.

Polygon number and size distribution figures, along with calculations for each of the five sub-compartments, are reported in Table 2. The WCA-3 project area contains 155,434 digitized and labeled polygons. The greatest number

Table 2. Polygon number (a) and percentage (b) distribution figures for WCA-3. Note: The total number of polygons do not add up to the total number from the WCA-3 coverages because of the splitting process into compartments.

a	PHASE I & II	PHASE II Sub-Compartments			PHASE I Sub-Compartments		PHASE I	PHASE II
# of Polygons	**WCA3**	**WCA3S**	**WCA3B**	**S9**	**WCA3NE**	**WCA3NW**	**N of I-75**	**S of I-75**
# > =10ha	1180	698	88	135	140	124	264	921
# <10 >= 1ha	10642	5908	1370	1479	910	975	1885	8757
# < 1ha >=.5ha	10437	5864	1579	1515	720	759	1479	8958
# < 0.5ha >=0.25ha	16025	9042	2742	2134	1043	1064	2107	13918
# < 0.25ha >=0.1ha	29787	17889	5525	3368	1662	1343	3005	26782
# < 0.1ha >=0.05ha	27157	17223	5186	2623	1470	655	2125	25032
# < 0.05ha >=.01ha	52683	39019	8294	3678	1583	110	1693	50990
# < 0.01ha >=.005ha	6732	6199	384	133	16	0	16	6716
# < 0.005ha >=0.001ha	791	775	14	1	1	0	1	790
Total	155434	102617	25182	15066	7545	5030	12575	142864

b

	PHASE I & II	PHASE II Sub-Compartments			PHASE I Sub-Compartments		PHASE I	PHASE II
Percent	**WCA3**	**WCA3S**	**WCA3B**	**S9**	**WCA3NE**	**WCA3NW**	**N of I-75**	**S of I-75**
% > =10ha	0.76	0.68	0.35	0.90	1.86	2.47	2.10	0.64
% <10 >= 1ha	6.85	5.76	5.44	9.82	12.06	19.38	14.99	6.13
% < 1ha >=.5ha	6.71	5.71	6.27	10.06	9.54	15.09	11.76	6.27
% < 0.5ha >=0.25ha	10.31	8.81	10.89	14.16	13.82	21.15	16.76	9.74
% < 0.25ha >=0.1ha	19.16	17.43	21.94	22.35	22.03	26.70	23.90	18.75
% < 0.1ha >=0.05ha	17.47	16.78	20.59	17.41	19.48	13.02	16.90	17.52
% < 0.05ha >=.01ha	33.89	38.02	32.94	24.41	20.98	2.19	13.46	35.69
% < 0.01ha >=.005ha	4.33	6.04	1.52	0.88	0.21	0.00	0.13	4.70
% < 0.005ha >=0.001ha	0.51	0.76	0.06	0.01	0.01	0.00	0.01	0.55

of polygons (52,683 or 33.89%) were between 0.01 to 0.05 ha. in size. Separate calculations for areas north (Phase I) and south (Phase II) of I-75 were also performed. Many more polygons were labeled during Phase II (142,864 polygons) than Phase I (12,575 polygons) of the project. Phase II is approximately 2.3 times larger in areal extent than Phase I. Phase I had the greatest percent of polygons digitized in the 0.1 to 0.25 ha. category as was the case for each of its sub-compartments. Phase II also had the greatest percentage of polygons digitized in the 0.01 to 0.05 ha. category as was the case for each of its three sub-compartments.

Polygon species categorization for the entire project area, along with hectare calculations for each of the five sub-compartments of the WCA-3 project, is found in Table 3. The total area mapped was 234,913 ha. Results show that Sawgrass and Wet Prairie communities accounted for the greatest area (205,565 ha.) and percentage (87.5%) of polygons categorized for the entire project. This was also true in each of the sub-compartments where these two communities combined accounted for

Table 3. Polygon species categorization by percentage (a) and hectares (b) for WCA-3

a	PHASE II			PHASE I		
PERCENTAGES	**WCA3S**	**WCA3B**	**S9**	**WCA3NE**	**WCA3NW**	**WCA3**
Trees/shrub	3.44	1.45	0.75	2.72	9.75	3.39
Cypress	1.39	0.00	0.00	0.00	0.00	0.63
Sawgrass	47.73	82.36	49.54	73.13	59.88	60.06
Wet Prairie	43.62	12.32	32.97	3.03	24.56	27.44
Broadleaf	1.72	0.96	4.17	4.41	0.03	2.14
Cattail	1.43	1.52	9.12	14.53	4.87	5.00
Exotics	0.00	0.03	0.01	0.17	0.04	0.04
Other	0.66	1.37	3.43	2.00	0.87	1.28

b

	PHASE II			PHASE I		TOTALS
HECTARES	**WCA3S**	**WCA3B**	**S9**	**WCA3NE**	**WCA3NW**	**WCA3**
Trees/shrubs	3671.22	575.85	132.46	1284.06	2309.60	7973.20
Cypress	1486.23	0.11	0.00	0.00	0.00	1486.35
Sawgrass	50898.38	32767.96	8707.51	34532.12	14188.79	141094.76
Wet Prairie	46519.24	4903.08	5795.75	1431.63	5820.10	64469.80
Broadleaf	1831.44	380.38	733.70	2084.27	7.52	5037.31
Cattail	1527.19	605.18	1603.51	6860.82	1153.86	11750.56
Exotics	0.91	10.33	2.14	80.52	9.22	103.11
Other	700.87	543.19	602.55	945.77	206.01	2998.40
TOTALS	**106635.48**	**39786.09**	**17577.63**	**47219.19**	**23695.09**	**234,913.49**

between 76.16 - 94.68% of the labeled polygons. Sub-compartments WCA-3B and WCA-3NE each had much more sawgrass than wet prairie, whereas WCA-3NW and WCA-3 S9 had ratios typical of the project area as a whole. WCA-3S had an even mixture of Sawgrass and Wet Prairie communities. The amount of cattail habitat encompassed five percent of the project area or 11,751 hectares. Most of the cattail (6,861 ha.) was found in the WCA-3NE sub-compartment with each of the other sub-compartments having 605 to 1604 ha. of cattail habitat, respectively.

A number of data files were generated as a result of this project, which include ArcInfo photo location coverages for the 1994 and 1995 aerial photography data sets, database and point coverage of ground-truthing sites, completed final ArcInfo coverage, and a jpeg hardcopy printout of the final ArcInfo coverage. A listing and description of these files can be found in Table 4, which describes the files on the enclosed CD.

Table 4. List of digital files on enclosed compact disc with descriptions

FILE NAME	DESCRIPTION
wca3veg.e00	ArcInfo Exported coverage of the vegetation of WCA-3, 1994-5
wca3veg.jpg	Final output map in .jpg format
wca3gt.e00	ArcInfo Exported coverage of ground-truthing points
wca3gt.xls	2,402 ground-truthing points in Excel format
wca3gt_README.doc	README text file for ground-truthing data
wca3_checksite_abbreviations.xls	Checksite abbreviations
wca3_ap_94.e00	ArcInfo exported coverage of 1994 air photo index
wca3_ap_95.e00	ArcInfo exported coverage of 1995 air photo index
wca3veg.mxd	ArcMap Composition
Veg_classification.doc	Classification used for mapping WCA-3 vegetation

Discussion

The overall objective of this project was to create a seamless detailed map for WCA-3 as part of the South Florida Vegetation Mapping Project (Welch et al. 1999), which also included Everglades National Park, Big Cypress National Preserve, Biscayne National Park and the Florida Panther National Wildlife Refuge. These objectives were met even though the methods used for creating the WCA-3 vegetation portion of the project differed from those used for the Federal lands portion. The binding mechanisms that allowed for the seamless end products were that both mapping efforts utilized a common classification system (Jones et al. 1999) and ArcInfo data architecture. Although the intention was to work on this effort as part of the South Florida Vegetation Mapping Project, it was later envisioned that this product would also be used as a base map for the CERP DECOMP project. New photography collected in the last quarter of 2003 for CERP will be utilized to update this first initial map. This will provide an additional data set which could potentially show some trends in vegetation distribution and community structure that were occurring before the CERP DECOMP project construction started.

Rectification

The geo-rectification results for Phases 1 and 2 were significantly different. This was expected considering that the two phases used very different methods for rectification. Rectification results for Phase 1 were disappointing considering the efforts that were made to acquire good ground control. One potential cause for lesser accuracy may have been due to the use of a low end scanner with poor geometric consistency to digitize the linkwork from the mylar overlays. However, this issue was somewhat mitigated by using ground control points common to the overlap of four adjacent photos, resulting in a limited amount of edge-matching effort when appending the individual photo vector files together.

During Phase 2 mapping, use of the analytical stereoplotter and ORIMA software program allowed for the camera/lens information, film registration data, and known ground position coordinates to be used to construct a three dimensional "model" of the terrain by utilizing air photo stereo pairs. This process of "orientation" removed the radial distortion associated with the camera lens and relief displacement in the imagery, allowing the photointerpreter to trace a floating mark around vegetation types and delineate the various plant communities while viewing the actual film transparencies in a real world map projection.

Although rectification for the horizontal control was very good (RMS was 0.48 m in the x direction and 0.40 m in the y direction) the RMS of the Z value (elevation) (0.25 m) were disappointing considering the very flat surface of the project area. Since the entire project had very little change in elevation from north to south, the initial Z values were estimated during aerotriangulation and adjusted as needed in order to get an acceptable final result for elevation. For future analytical aerotriangulations, proper elevation control should also be obtained for rectification purposes. Even though absolute elevation values were considered unreliable, relative elevation information was used to estimate general height differences between vegetation types. Notwithstanding the above mentioned concerns, the final aerotriangulation produced a workable mapping environment in which the photointerpreter was able to accomplish the delineations in a stable, real world map projection with limited parallax distortion.

Ground Truthing

This project was undertaken in an advantageous working environment which provided nearly on-demand access to airboats and helicopters for ground-truthing. These transport tools, along with state of the art GPS navigation technology, were heavily utilized during the mapping project. This combination resulted in the collection of a very robust data set of 2,402 ground-truthing sites (Table 4). Advantages exist for each mode of transportation for ground-truthing. Helicopters provided an efficient way to get to ground-truthing sites that weren't accessible by airboat and/or were scattered over a large spatial area in a reasonable amount of time. They also provided a unique perspective of the landscape by enabling one to see the patterning effects of different vegetation types from various altitudes. However, one negative aspect of using helicopter transport is that the associated movement, writing, and navigating can cause disorientation, motion sickness, and fatigue. Airboats were utilized when water levels were adequate and the terrain favorable. Although the spatial area covered was usually much smaller than by helicopter, an area could be intensively investigated and characterized while on site. This method of travel also afforded the time to stop for the inspection, collection, and analysis of vegetation types and community associations that were unknown or not well understood. Both of these travel modes were utilized successfully and should be considered critical to any extensive mapping project within the Everglades environment. The ground-truthing data set that resulted from this effort is a significant data source for measuring future potential changes in the landscape. Towards the end of this project a digital camera was utilized to document field conditions and to supplement the relatively simplified data collection procedures necessitated by time and logistical constraints. The use of digital photography at the ground-truthing sites is recommended for any future mapping efforts of this magnitude.

Labeling Rules and Delineation

The original classification system developed for the South Florida Vegetation Mapping Project by Jones et al. (1999) is hierarchical in structure and was meant to be dynamic. As a result, several species were added to the classification during the WCA-3 vegetation mapping project. Other labeling rules were also developed for special circumstances in which it was becoming apparent that delineations for certain classes were problematic and impractical to accomplish (see below).

The "Sawgrass" (*Cladium jamaicense*) category encompassed the largest (141,094.8 hectares; 60.1 percent) area for this mapping effort. The nearly total dominance of this species over such a large area is one of the distinguishing features of the Everglades (Kushlan, 1990) and was documented by Loveless (1959) to encompass approximately seventy percent of the remaining Everglades. The transition between Sawgrass and adjacent marsh communities is often sharply defined and therefore easily delineated. However, the delineation of the "Wet Prairies/Sloughs" category, when it was sparsely mixed in with sawgrass, became time intensive. This was especially true during Phase II when it could easily be separated due to the superior optics and the ability to zoom in on features with the SD2000 analytical stereoplotter. Some regional areas of "Sawgrass" had so many of these small "Wet Prairies/Sloughs" pockets that it was impractical to delineate them all. In order to resolve this issue and save time in the project, a new delineation rule was created for Phase II. All "Sawgrass" category delineations now had to be followed by a "Wet Prairies/Sloughs" category. This avoided separating the tens of thousands of small areas of the "Wet Prairies/Sloughs" out of the "Sawgrass" category. It also avoided the tedious time-consuming task of drawing lines around pure stands of "Sawgrass" and separating them from polygons that had "Sawgrass" as dominant and "Wet Prairies/Sloughs" as the second dominant category. This rule was somewhat subjective on a regional basis because in many instances small "Wet Prairies/Sloughs" delineations were still made within the "Sawgrass" category.

The category "Wet Prairies/Sloughs" encompassed the second largest area (64,469.8 hectares; 27.4 percent) in this mapping effort. The definition of "Wet Prairie/Slough" included both wet prairies and sloughs. Although sloughs and wet prairies are considered by many to be distinguishable, it wasn't possible to consistently and objectively draw a line to separate these two communities. Wet prairies are loosely defined as shallow water areas with a mix of short stature emergent vegetation, which for WCA-3 is almost always either Spike Rush (*Eleocharis* sp.), low-growing, very scattered Sawgrass, and/or *Panicum* species. Sloughs are deeper water areas that are often devoid of emergents and may have sparse floating mats of White Water Lily (*Nymphaea odorata*). Delineation of the "Wet Prairie/Slough" category offered no major problems during this mapping exercise. Spike Rush and Panicum flats were sometimes delineated, but almost always coincided with a ground-truthing effort. Without the benefit of field visits, these communities were consistently lumped into the "Wet Prairie/Slough" category.

The "Broadleaf Emergents" and "Floating Emergents" classes were often located within the "Wet Prairie/Slough" category. However, since they exhibit unique spectral signatures, an attempt was made to delineate them separately.

The "Broadleaf Emergents" category included Lance-leaf Arrowhead (*Sagittaria lancifolia*), Duck Potato (*Sagittaria latifolia*), Pickerelweed (*Pontederia cordata*) and Giant Leather Fern (*Acrostichum danaeifolium*). With a unique spectral signature, Giant Leather Fern was delineated to species level whenever feasible. The "Floating Emergents" category included Waterlily (*Nymphaea odorata*), Spatterdock (*Nuphar luteua*), Water Lettuce (*Pistia stratiotes*), Water Hyacinth (*Eichhornia crassipes*), and Water Pennywort (*Hydrocotyle spp.*). A luxuriant growth of Waterlily, responding to high nutrient conditions, has been documented in other studies (Newman et al. 2004; McCormick et al. 2001) and was observed many times during this study near canals or areas of suspected high nutrient water infiltration. This made Waterlily very challenging to delineate using the Jones et al. (1999) classification rules. A new delineation rule was implemented to deal with this species. When Waterlily was associated with the "Wet Prairies/Sloughs" community it had to be the dominant species in order to be separately delineated. This rule avoided the unnecessary delineation and labeling of thousands of additional polygons. The combined "Broadleaf Emergents" and "Floating Emergents" categories encompassed 5037.3 hectares or 2.1 percent of the WCA-3 landscape.

Other common components of the "Wet Prairie/Slough" category were Periphyton mats and submerged and/or floating Bladderwort (*Utricularia spp.*) communities. Periphyton, a community of algae, bacteria, and other microorganisms (McCormick et al. 2001), is typically attached to the submerged portions of aquatic vegetation in the Everglades. Commonly associated with Bladderwort and Spike Rush communities, these algal colonies tend to rise to the surface in the late summer and frequently form large floating masses on the water's surface. It is at these times that periphyton colonies are most evident in the field and exhibit strong characteristic spectral returns on aerial photography and other imagery. Because the formation and location of these mats can be so variable from year to year and season to season, it was deemed impractical to attempt to include these areas in the mapping effort. In fact, the typically bright dominant signature exhibited by periphyton can mask the spectral returns of sparse to even moderately dense emergent species in the same location, rendering the mapping process more difficult. However, on a smaller scale (e.g. < 5 hectares) as part of a temporal field experiment, periphyton mapping could be accomplished easily with the use of aerial photography and photointerpretation.

Surprisingly, the "Cattail" (*Typha spp*) category comprised the third largest area mapped for this project, encompassing 11,750.6 hectares or five percent of WCA-3. Cattail is not generally dominant over large areas of the landscape unless there is a nutrient source available which the plants utilize efficiently, typically out-competing other species (Davis, 1991; Doren *et al.*, 1997; Newman *et al.*, 1996; Miao and DeBusk, 1999; Rutchey and Vilchek, 1999). Cattail expansion in the region just west of the S-9 structure and along the Miami Canal was observed as early as 1990 (Davis 1991). Both areas receive nutrient-laden water from outside the remnant Everglades. In the case of the S-9 area, water is back-pumped westward from the C-11 canal through the S-9 structure into the marsh. The Miami Canal drains the Everglades Agricultural Area to the north and its phosphorus-rich waters filter into the marsh along its entire 60 kilometer reach through WCA-3. Alternatively, large expanses of cattail were also mapped in the WCA-3N East sub-compartment away from obvious potential nutrient effects. One hypothesis for this apparent anomaly is that soil oxidation and compaction over a period of decades concentrated nutrients in the muck soils. When historic rainfall events occurred in 1994/1995, the nutrients stimulated rapid growth of cattail within these areas. Another hypothesis is that the nutrient-enriched water from the Miami Canal reached these interior areas during those same historic rainfall events. It may be that both of these mechanisms played a role in this cattail expansion. Severe fire events in the region may have also had an impact by opening up otherwise sawgrass-dominated areas and allowing cattail to out-compete other flora. The area of cattail dominance documented by this mapping effort is alarming and will need to be monitored and analyzed more closely as part of the Long Term Plan (Burns and McDonnell, 2003) for reducing nutrients and the extent of cattail within the Everglades ecosystem.

The "Shrubland" category contained the dominant species Willow (*Salix caroliniana*), Wax Myrtle (*Myrica cerifera*), and, to a lesser extent, Buttonbush (*Cephalanthus occidentalis*), Primrose Willow (*Ludwigia spp.*), Cocoplum (*Chrysobalanus icaco*), and Pond Apple (*Annona glabra*). Some of these species could be delineated separately if a ground-truthing site occurred in the vicinity. However, they were typically lumped into the "Shrubland" category because the similarity of spectral signatures precluded shrub species differentiation. Willow and Wax Myrtle were the most commonly delineated species and encompassed 1,716.6 and 1,636.1 hectares, respectively. Willow in particular is of critical concern because of its utilization for wading bird nesting and roosting (Frederick and Spalding, 1994). Large concentrations of Wax Myrtle were observed along the far northern areas of the WCA-3N East and West sub-compartments. In general, these sub-compartments have historically been the most affected by hydrologic reductions in flow and duration. Except for propensity for fire events, the reduced hydroperiods exhibited by these regions were advantageous for the growth of Wax Myrtle. The "Shrubland" category was the fourth largest vegetation community mapped and encompassed a total of 7,460.6 hectares or 3.1 percent of the landscape.

Everglades tree islands have relatively recently become the focus of much scientific scrutiny due to their apparent sensitivity to hydrologic changes in the landscape and also because of their ability to serve as refugia for wildlife during high water conditions in the surrounding marshland. They are being studied as possible indicators of altered hydrology due to their delicate position in the hydrologic continuum. Because the classification system used for this mapping effort is based on vegetative life form and structure instead of community type, it did not allow for feature extraction associated with a predefined definition of a tree island. In fact there is no way to query the final GIS coverage data in order to generate a tree island map without including other forested or shrub-dominated communities such as those discussed in the Shrubland category.

The most common forested feature that was mapped was "Swamp Forest". A height threshold of five meters was used to differentiate between Scrub/Shrubland versus Forest. Consequently, areas dominated by woody vegetation taller than five meters would be designated as "Swamp Forest". Typically found on the northern portions of tree islands, these areas were dominated by Dahoon Holly (*Ilex cassiene*) taller than five meters. Other species of importance or association included Red Maple (*Acer rubrum*), Gumbo Limbo (*Bursera simaruba*), Red Bay (*Persea borbonia*), Sweetbay (*Magnolia virginiana*) and Strangler Fig (*Ficus aurea* Nutt.). A total of 512.7 hectares or 0.22 percent of WCA-3 was mapped as "Swamp Forest". Delineation to species level would have been unfeasible without extensive field work on each tree island and, even then, it would have been impossible to consistently distinguish species differences utilizing this scale of photography due to similarity of spectral signatures. Tree island "heads" with woody plants taller than five meters often occur on the north end of islands and were categorized as "Swamp Forest". Moving south, from the tree island "head", tree island vegetative structure typically grades into a shrub-dominated community and finally into a sawgrass community with scattered shrubs to form the island's "tail". Other efforts have attempted to categorize and/or map the tree islands of this WCA-3 impoundment (Heisler et al., 2002; Mason and van der Valk, 2002; Sklar and van der Valk, 2002). Armentano et al. (2002) made an attempt to classify island types within the southern Everglades based on species composition and environmental factors controlling tree island distribution and structure. Based on their definitions, the tree islands within WCA-3 most resemble that of a Bayhead Swamp Forest or simply Bayhead.

Because Cypress exhibits a characteristic signature on the aerial imagery, an effort was made to distinguish this species from other "Swamp Forest" trees. An attempt was made to use the original "Cypress Strands", "Cypress Domes/Heads", "Cypress" (not contained in strands or domes), "Cypress Savanna", and "Dwarf Cypress" categories within the original Jones et al. (1999) classification system. However, it became apparent that the category descriptions failed to provide a consistent approach to subset Cypress into these more specific classes. Drawing lines between "Cypress Strands", "Cypress Domes/Heads" and "Cypress" was inconsistent and arbitrary. In addition, the "Cypress Savanna" and "Dwarf Cypress" categories were not descriptive enough to allow for confident delineation. A more workable solution was to utilize three categories to map the Cypress communities. "Cypress Domes/Heads" was still utilized to delineate these obvious features on the photography. The "Cypress" category was retained and utilized to delineate areas other than the "Cypress Domes/Heads". Delineation between "Cypress Domes/Heads" and the "Cypress" category was still somewhat subjective, but considered justifiable. Finally, a new category was added to the Shrublands called "Cypress Shrub", which is described as Cypress that is shorter than five meters. A total of 1,486.4 hectares or 0.63 percent of WCA-3 was mapped as one of the Cypress categories.

Another very important category, but one that was fortunately a still minor component, was "Exotics". A total of 103.1 hectares or 0.04 percent of the landscape was mapped as exotics. A small stand of Australian Pine (*Casuarinas spp.*) was found on a tree island in the south end of the WCA-3A South sub-compartment. A total of 25.5 hectares of Brazilian Pepper (*Schinus terebinthifolius*) was found scattered mostly within the WCA-3N West and WCA-3B sub-compartments. Cajeput trees (*Melaleuca quinquenervia*) were found almost exclusively in the WCA-3N East sub-compartment, which contained 77.2 hectares. Since this mapping effort took place, almost all of these Cajeput have been treated with herbicide to eliminate these trees (K. Rutchey, *pers. obs.*).

Old World Climbing Fern (*Lygodium microphyllum*) was never observed during this mapping effort. However, recent observations by SFWMD staff have been noted within the WCA-3 South sub-compartment along areas adjacent to the Big Cypress National Preserve and also in the WCA-3N West sub-compartment. Lygodium has invaded approximately 11.6 percent (Wu et al., submitted) of the tree/brush coverage within the WCA-1 impoundment. Brandt and Black (2001) and Darby and McKercher (2002) also conducted studies on this species invasion of tree islands within the WCA-1 impoundment and noted that this species may alter the overall ecological integrity of the Everglades system by first changing vegetation communities and, subsequently, the wildlife that use these communities. Based on these findings, aggressive surveillance and defensive controls should be established for the WCA-3 impoundment so that the spread of this exotic does not reach the epidemic stages seen in the WCA-1 impoundment.

"Spoil Areas", which are composed of the dredged material from the digging of canals, were also delineated. This material is often used to create discontinuous mounds along canals, which allows water to pass from the canal into the marsh areas under high water conditions. Other uses for dredge material are construction of boundaries or levees along canals, which retain water in the canal by forming a continuous barrier along the marsh areas. The category "Canals" encompassed 898.9 hectares or 0.38 percent of the landscape and the "Spoil Areas" that resulted from the digging of the canals encompassed 1,105.9 hectares or 0.47 percent of the area.

Other interesting landscape features resulting from the use of dredged material in WCA-3 were "deer islands". These elements were mapped under the category "Artificial Deer Islands", a sub-class of the "Spoil Areas" classification. Dineen (1972) reported that these constructed refuges for Florida white-tailed deer (*Odocoileus virginianus seminolus)* were a definite alteration of Everglades habitat. Dineen reported in 1972 that there were a couple of hundred of these in WCA-3. This current mapping effort noted 163 of these features. Very little documentation or literature is available with details on how and when they were created or if they were successful. They were originally constructed as refuges for deer escaping high water conditions in the surrounding marsh. "Walking" dredging machines were used to reach the site, remove the substrate, and deposit it immediately adjacent to the newly created small rectangular water body. Alligators (*Alligator mississippiensis*) are attracted to the ponds especially during periods when the marshes are devoid of standing water. The islands are typically no longer than 100 meters and average approximately 50 meters in width. They are found mainly within the WCA-3N East, WCA-3B and northwest WCA-3A South sub-compartments. Many of the original islands have been degraded or destroyed by fire over the years. The open water bodies created as a result of these man-made deer islands along with other such open water bodies in WCA-3 were labeled as "Water".

Other categories of interest were "Human Influence" features, which could include structures, buildings, fish or hunting camps, parking lots, roads, cultivated lawns, and the Florida Power and Light (FPL) right of way that is maintained on the northeast side of the WCA-3N East sub-compartment. The FPL right of way, which encompasses 624.6 hectares, is mowed on a regular basis to reduce the potential hazards of fire damage to the overhead power lines. Interstate Highway 75 crosses WCA3 in an east-west direction partitioning WCA3 into the north and south compartments and was the only major road that was mapped for this effort. It encompassed 267.5 hectares. Sixty-seven "Human Influence" features were mapped of which fishing and hunting camps constitute the majority. These camps, scattered throughout WCA-3, have a long heritage in providing a place of overnight shelter for hunters, fishermen, and other outdoor enthusiasts. Unfortunately, as more people have discovered these treasures, additional camps have been built on previously undisturbed islands. Camp clearings are periodically mowed, providing habitat for early successional and weedy herbaceous species (Heisler *et al.*, 2002). Many times, owners plant non-native tropical and ornamental foliage and fruit trees. This results in camp islands having larger number of plant species than normal including various troublesome exotics. Recent rules have been established that allow existing camps to remain in use, but restrict construction of additional camps or camp additions. These measures need to be enforced to preserve the fragile botanical integrity of the remaining tree islands within WCA-3.

Conclusion

This map project provides the most detailed, spatially explicit vegetation information ever compiled for any part of the Everglades. This mapping effort extended over a period of seven years with sub-compartment vegetation maps being released as they were completed. Considering the available staff (2 full time mapping specialists), resources, the project extent, and the target resolution (minimum mapping unit), a project of this magnitude can be completed within three years if staff is allocated solely to mapping. It took 7 years due to shifts in priorities, resources and staff.

Regardless, the final results provide a robust data set that can be utilized for a multitude of tasks and analyses. It provides the only current detailed vegetation map of WCA-3 and is the baseline of information from which future mapping efforts for this area can be gauged.

Obeysekera and Rutchey (1996) analyzed a classified SPOT image of WCA-2A in an attempt to determine what scale or minimum mapping unit is necessary for Everglades landscape models in order to retain information on trends or predictions. This question is also critical for mapping projects such as those that will be required for CERP to track anticipated changes to the ecosystem through time. It is critical to streamline the mapping process for the CERP RECOVER effort. This new data set is currently being analyzed extensively (Rutchey et al., *in prep*) with new, novel metrics that have recently been developed to determine the minimum mapping unit requirement for capturing vegetation trends through time.

The ridge and slough landscape of the Everglades is an important ecological component necessary for restoration success (McVoy *et al., in prep).* However, until recently (Wu *et al.*, *submitted*; Nungesser and Rutchey, *in prep;* Nungesser *et al., in review*) there has been little research done on quantifying these patterns and correlating them to changes in hydrology. Modeling work is currently being undertaken to understand how Everglades landscape patterns originated and evolved, as well as processes that lead to long-term maintenance or degradation of the ridge and slough structure (Wu , *in prep*). Natural water flow and hydropatterns of WCA-3 have been greatly modified by the canals and levees that subdivide this once continuous landscape. Polygon species categorization for the entire project area, along with hectare calculations for each of the five sub-compartments, reveals that Ridge and Slough fragmentation differences occur between the sub-compartments. These findings should prove useful in understanding how Ridge and Slough pattern formation occurs within the Everglades.

Recommendations

The CERP RECOVER Monitoring and Assessment Plan (MAP) (RECOVER, 2004) will be the primary guidance document used to outline how all future vegetation mapping efforts will be conducted for this massive ecological restoration project. The MAP states that:

"the vegetation mapping program is the cornerstone of all other elements of the MAP for the greater Everglades wetlands. An all embracing, multi-decade vegetation mapping program will require appropriate resources and dedicated staff of biologists with mapping/photo-interpretation experience and familiarity with the Everglades. The group conducting such an extended program will need a high level of commitment and stability in order to provide a continuity of sound information, to update and maintain the vegetation database, and to exploit potentially new applications for mapping Everglades vegetation."

It is the authors' view that the resources needed for this "all embracing and supported program" are currently not in position to complete this component of the MAP successfully. It is the authors' experience, based on forty plus years of combined experience, that out-sourcing (i.e.. contracting) of these types of vegetation mapping activities usually produce inferior results for the District and other south Florida agencies involved in mapping Everglade's vegetation. These poor results are most likely caused by the lack of ground-truthing in compiling maps, a most costly venture given the need for helicopter and airboat transportation. In addition, few mapping contractors have all the resources available in-house or in the actual project locality. Typically, portions of the mapping process such as air photo acquisition, georectification, field work, photointerpretation, GIS tasks, and quality control are broken up and distributed between parent contractors and sub-contractors leading to communication problems, inaccurate photointerpretation, and multiple points of responsibility. Few mapping contractors take a personal interest in the integrity and completeness of the final products compared to agency personnel doing their own work. It is also critical to use ecologists who are familiar with the Everglades and that have experience in mapping and photointerpretation. This expertise takes time to acquire and is often lost where technicians are shifted continuously to projects that are currently paying the bills. In conclusion, management needs to establish a mechanism to support stability of mapping staff and vegetation mapping efforts because they provide a baseline for establishing trends, modeling, and monitoring changes related to the restoration and preservation of the Everglades.

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