VEGETATION AND LANDSCAPE ECOLOGY OF CENTRAL BIG PINE KEY

A Report Submitted to

THE NATURE CONSERVANCY

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February 1992

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I. INTRODUCTION.

Big Pine Key is the largest island in the Lower Florida Keys (Figure 1). Big Pine is best known as the center of distribution of the endangered Key Deer (*Odocoileus virginianus clavium*), whose range approximately coincides with the extent of the Pine Rockland-freshwater wetland vegetation mosaic in the Keys. Unfortunately, the future viability of the Key Deer population and the distinctive ecosystem complex which is its home is currently in conflict with the expansion of residential and commercial development on the island. In order to ensure the integrity of the water resources which sustain this system, the South Florida Water Management District has identified a critical zone of interest in central Big Pine Key, and has acquired a number of undeveloped properties within that area through the Save Our Rivers program (Figure 2). The following pages describe an ecological examination of the lands within the SFWMD project area.

IA. Objectives.

The examination had seven objectives. The first four involved an assessment of the current status of the ecological systems of the area, and are discussed in the RESULTS section. They were:

1. Provide a baseline inventory of the vegetation resources of the area as a whole.

2. Investigate the co-occurrence of vegetation elements and site factors within a subset of the entire area.

3. Establish a historical context for assessment of the resource through interpretation of current and old aerial photographs.

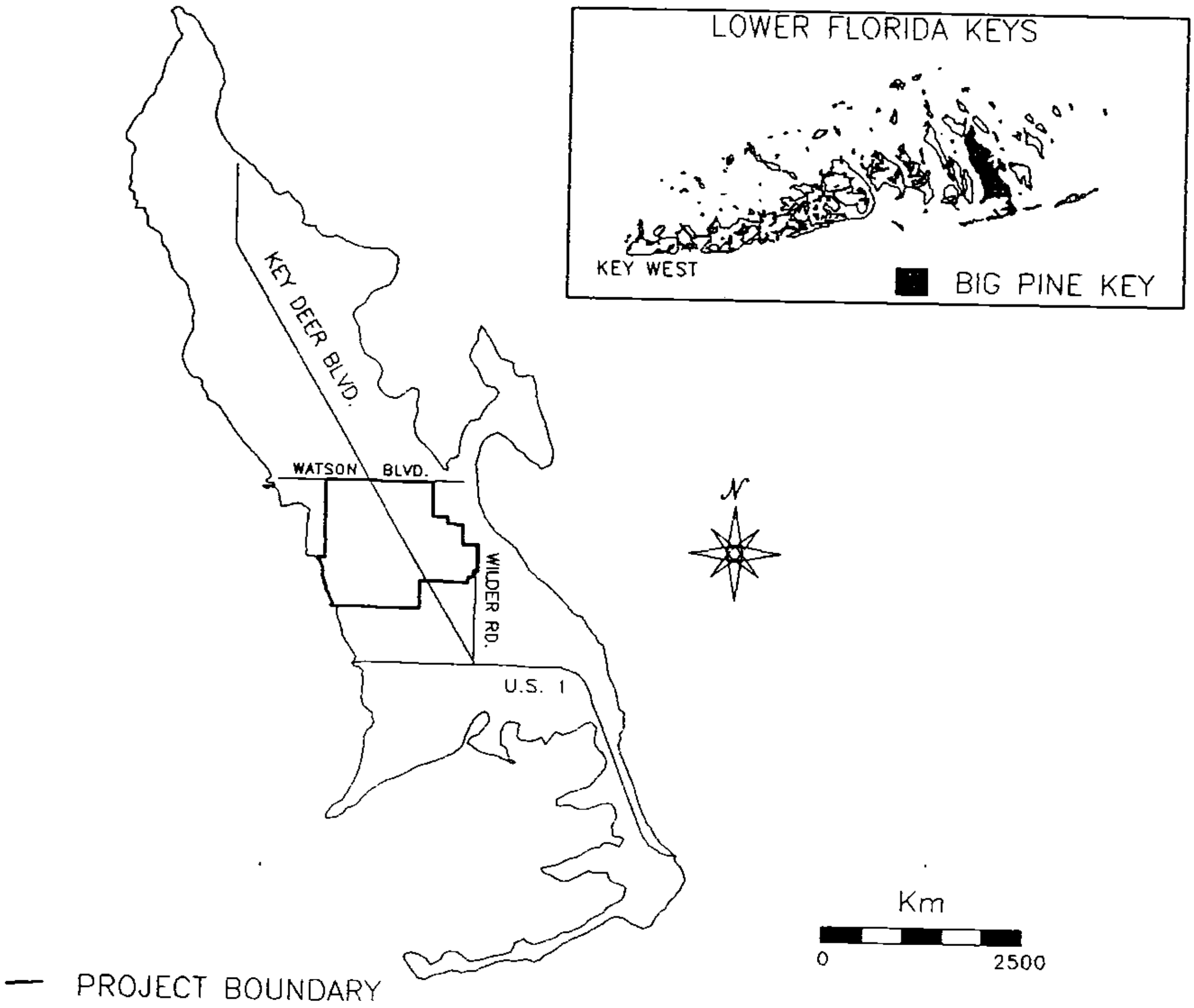

Figure 1. The Lower Florida Keys, Big Pine Key, and the SFWMD project area.

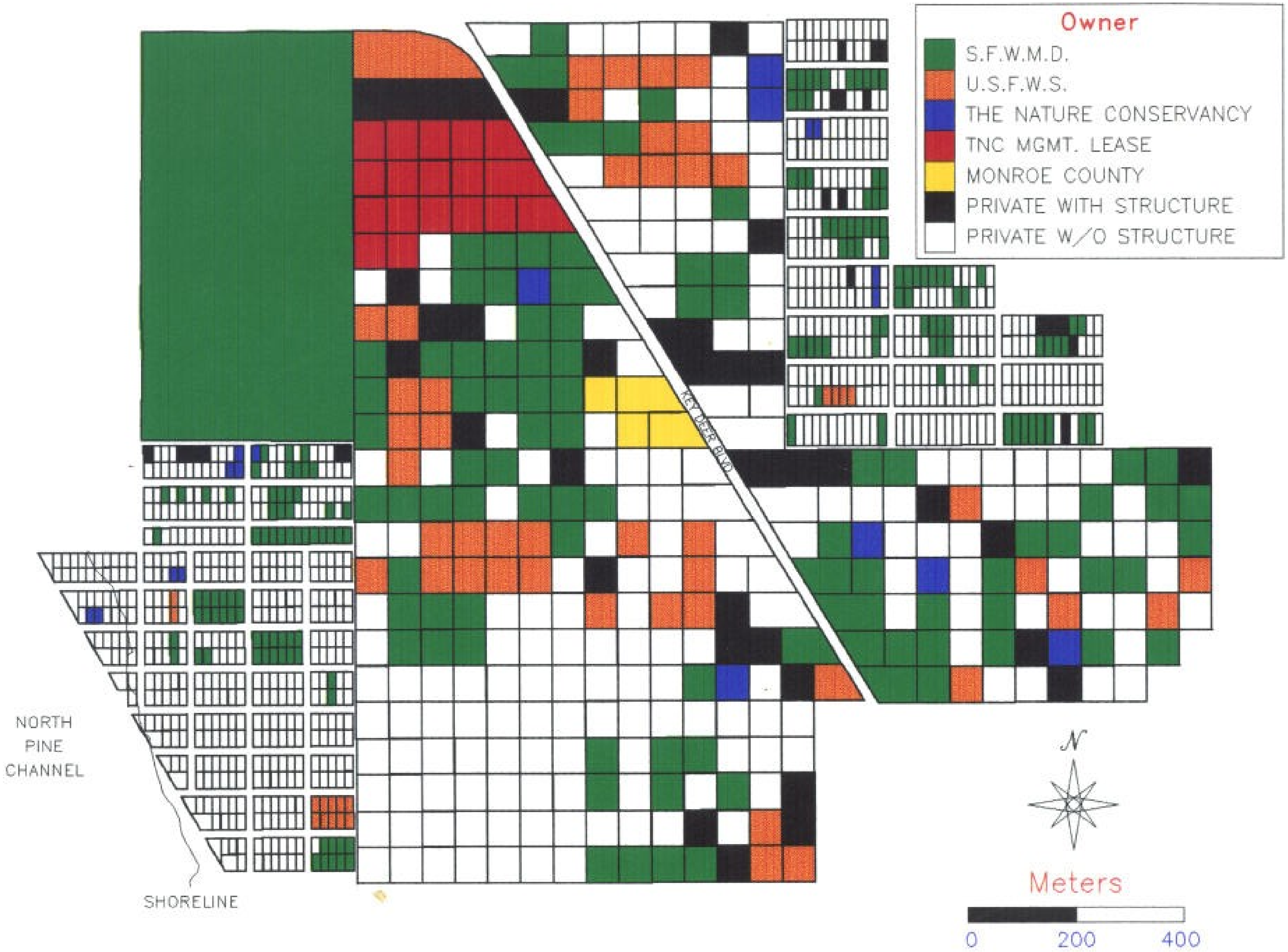

Figure 2. Ownership pattern within SFWMD project area.

4. Analyze how the vegetation resources are concentrated within the existing landscape and ownership pattern.

The last three objectives involved applications of the assessment discussed above, and are described in the RECOMMENDATIONS section. Those objectives were:

1. Suggest management activities which would help to restore or maintain the resources of the area.

2. Suggest acquisition priorities for privately owned lands within or adjacent to the SFWMD zone of interest.

3. Suggest research activities which would improve long-term management of the resource.

IB. Study area.

IB1. Geology.

The surface geology over most of Big Pine Key consists of the oolitic Miami Limestone underlain at 3.5-6.5 meters by the coralline Key Largo Limestone. In the vicinity of the SFWMD zone of interest, the contact between the two facies is about 4.5 meters from the surface (Wightman, 1990). Both rocks are Pleistocene in age. The Miami Limestone originated about 120-140,000 years ago, and the Key Largo about 40-60,000 years earlier, during a previous interglacial period. The practical importance of the discontinuity between these two limestone types lies in their very different permeabilities, and the resultant effects on groundwater hydrology.

Although both have the same effective porosity (about 15 percent), the Key Largo Limestone is much more permeable, because of its greater age and susceptibility to solution cavity development (Coniglio and Harrison, 1983).

IB2. Hydrology.

The subsurface hydrology of Big Pine Key has been studied by examining downhole salinity in different-depth wells distributed throughout the island (Hanson, 1980), and alternatively, by surface geophysical techniques (Wightman, 1990; Beaudoin, in prep.). National Audubon Society has been monitoring water level, salinity, and nutrient concentration in wells on four islands since 1989, including a series of locations north of the study area on Big Pine. Together, these studies indicate the large extent and overall temporal stability of the fresh groundwater resources of the island, a stability that contrasts with their sensitivity to alterations in the outline of the island via dredge and fill activities.

The extensiveness of fresh water on Big Pine Key is related to the geologic material which comprises the island. Because of the low permeability of the outcropping Miami Limestone, recharge from precipitation has a long residence time. The result is a lens of more or less fresh water whose depth at any point is controlled primarily by a) the proximity to marine waters, and b) the depth to the Key Largo-Miami Limestone contact, which tends to truncate the base of the lens.

Both Hanson (1980) and Wightman (1990) mapped the freshwater resources of Big Pine Key as two individual lenses, separated by an area which includes much of the SFWMD zone of interest. For at least some of the inter-lens area, however, both of these studies indicated that shallow groundwater layers accessible to plants were fresh during significant portions of the year. The same has been found for surface waters ponded in sinkholes and other depressions, though some of these have reached 15-20 ppt salinity during the dry season (C. Kruer, pers. comm.). Our own research suggests that the coarse-scale Hanson and Wightman surveys do not reflect the influence of fresh groundwater near the island edges, especially in the northern sections. It also shows very conclusively that hydrologic factors (e.g., depth to groundwater, hydroperiod, groundwater salinity) exert a controlling influence on vegetation structure and composition (Ross et al., in press).

Groundwater nutrient concentration is another factor which may affect --- or be affected by --- aspects of the biological communities above. Levels of soluble groundwater phosphorus in remote locations on Big Pine and Sugarloaf Keys are low in comparison to similar sites on Upper Keys islands. Groundwater-P is especially depressed in pineland habitats, becoming higher in mangrove habitats near the edges of islands. Soluble forms of groundwater nitrogen are maximum in the most productive communities; on Big Pine Key, the highest levels have been recorded in hammocks along Pine Channel. Surprisingly little is known about anthropogenic nutrient inputs into Florida Keys groundwater. Comparing nutrient concentrations in wells in residential yards on seven islands with a control well in the Key Deer Refuge on Big Pine Key, Lapointe et al. (1991) found elevated levels of both nitrogen and phosphorus in a number of suburban locations. Nevertheless, little is known about the encroachment of these effects into surrounding communities of native vegetation.

IB3. Soils.

Most Florida Keys soils, especially in upland locations, are rocky, shallow, dominated by organic materials, and lacking in profile development. Variation among such skeletal soils may be critical in shaping plant community structure, but has been difficult to encapsulate in an effective classification scheme. The classification and maps developed by the Soil Conservation

Service for the Florida Keys (USDA, 1988) divide Keys soils into 16 units, four of which occur within the SFWMD zone of interest. The great majority of the upland soils in the SFWMD tract were mapped in the "Keyvaca" series, while the most common wetland soil was the "Cudjoe" series. The Soil Conservation Service maps are useful as a guide to the types of soil found in the area as a whole, but their scale of resolution is insufficient for many management purposes. Field and lab analyses of soils mapped in the "Keyvaca" series 1-2 km north of the study area (L. Coultas, unpublished data) indicated a rocky, high-organic mineral soil, 0-4" in depth, high in pH (8.0), low in both nitrogen and phosphorus, relatively low in soil salinity, and strongly effervescent with acid. The outstanding characteristic of such soils is the fine scale in which their variability is expressed, with expansive outcrops frequently broken up by mounds of gravelly fragments, or holes filled with deep organic soil. Wetland soils in the "Cudjoe" series were shallow (0-4"), calcitic marly peats or peaty marls, with an algal mat and occasional rock outcrops.

IB4. Climate.

Although the Keys lie a few degrees north of the Tropic of Cancer, the climate can be considered tropical. The Keys had a mean annual temperature for the period 1951-1980 of 25.2^{0}C. Brief periods of freezing temperatures have occurred in the northernmost islands closest to the Florida mainland, while temperatures below 5^{0}C have never been recorded in the Lower Keys (pers. comm., U.S. Weather Service). Rainfall is seasonal throughout the Keys, 2/3 occurring during the months June-October, with conditions becoming drier and slightly warmer from Upper to Lower Keys (Figure 3). The Keys are included in Holdridge's (1967) Tropical Dry Forest Life Zone and Walter's (1985) Zonobiome II (tropical with summer rain). Homoclines of the Keys occur in Cuba, the Bahamas, the Yucatan peninsula, and the north coast of Jamaica (Walter et al., 1975; Kapos, 1986).

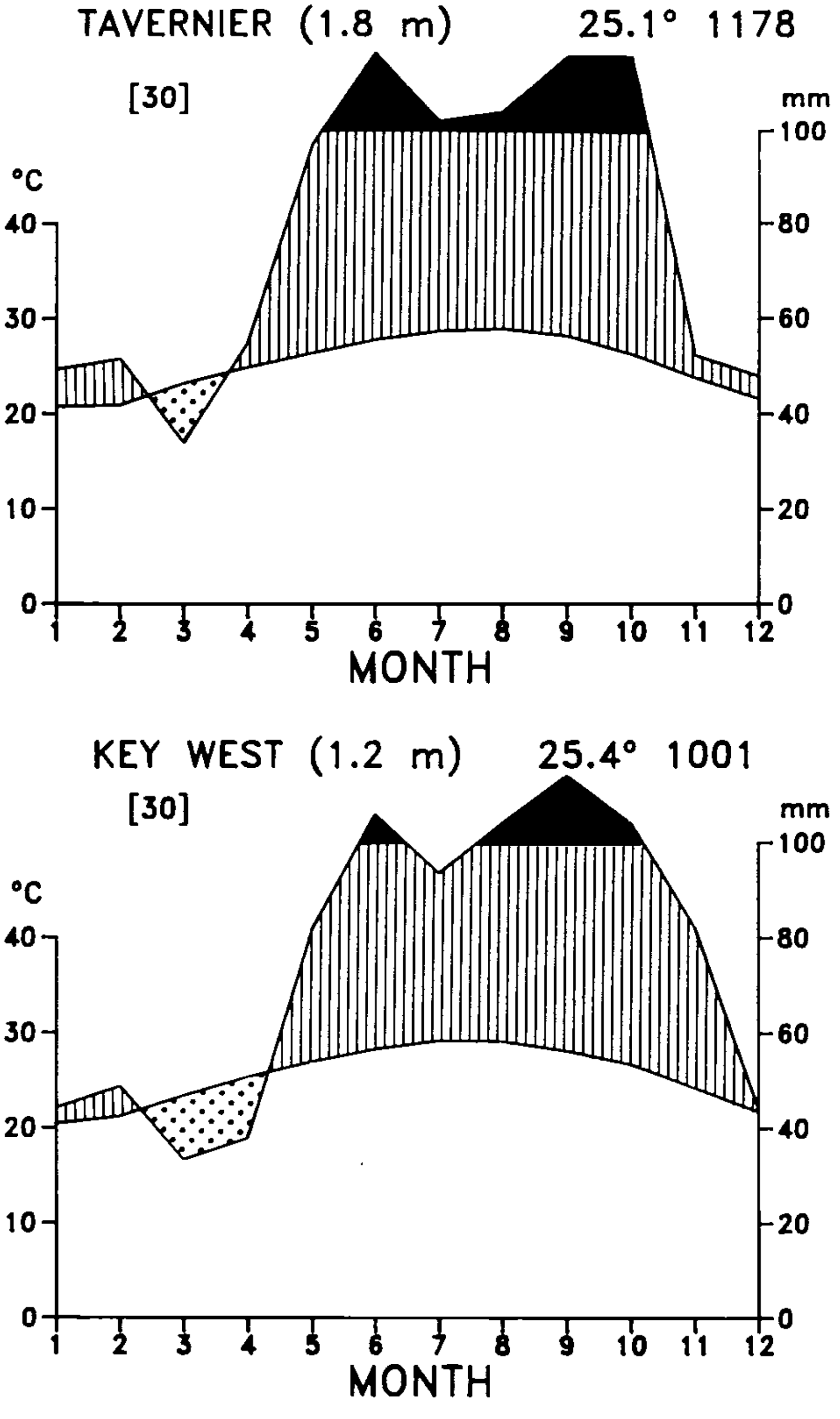

Figure 3. Climate diagram (after Walter, 1985) for Tavernier (Upper Keys) and Key West (Lower Keys), based on monthly means for period 1951-1980. Stippled areas represent dry conditions, vertical bars represent humic conditions, and black areas represent perhumid conditions.

IB5. Vegetation.

The flora of the Florida Keys is primarily of West Indian origin, with substantial representation from more northern genera. Florida Keys terrestrial plant communities are arranged along two major gradients. The first is the local gradient encountered moving inland and upslope from an island periphery. The second is the complex geographic gradient encountered moving south and west away from the Florida mainland. Ross et al. (in press) identified 13 major Ecological Site Units in the Keys (Table 1), twelve of which can be found on Big Pine Key. Two units which reach their maximum Florida Keys expression on Big Pine are Pine Rockland and Freshwater Marsh. A relative intolerance to salt water, and tolerance to fire, low nutrient conditions, and perhaps browsing pressure may explain their success in the broken upland flats, shallow soils, and abundant fresh water resources characteristic of Big Pine.

Slash pine (*Pinus elliottii* var *densa*), the dominant plant in Pine Rockland canopies in the Florida Keys, rarely becomes established in deep shade or on deep organic seedbeds. For that reason, its abundance on Big Pine Key indicates that disturbances which open the forest canopy and remove the litter layer have been a feature in the island's history. While hurricanes may in some situations create suitable conditions for pine establishment, most researchers agree that the extensive pine forests of Big Pine Key are at least in part a result of the long history of fire on the island (Dickson, 1955; Alexander and Dickson, 1973; Carlson, 1989). Alexander and Dickson (1973) estimated that Florida Keys Pine Rocklands developed a closed canopy in about 50 years in the absence of fire, about twice as slowly as their mainland counterparts. Soon after the publication of this and other papers focusing on the role of fire in natural ecosystem function, the Key Deer Refuge shifted from a policy of fire suppression to one of fire management, instituting a prescribed burning program on Refuge lands north of the SFWMD tract.

Table 1. Ecological site classification of Florida Keys terrestrial habitats.

I. Intertidal sites.

  A. ESU-1: Peaty Mangrove Forest.
  B. ESU-2: Peaty Mangrove Woodland.
  C. ESU-3: Dwarf Mangrove Mudflat.

II. Supratidal sites.

  A. ESU-4: Graminoid Supratidal Scrub.
  B. ESU-5: Succulent Supratidal Scrub.
  C. ESU-6: Cordgrass Salt Marsh.

III. Wet and periodically inundated interior sites.

  A. ESU-7: Freshwater Marsh/Swamp.
  B. ESU-8: Transitional Thorn Woodland.

IV. Sites inundated only during major storms.

  A. ESU-9: High Productivity Rockland Hammock.
  B. ESU-10: Pine Rockland Forest.
  C. ESU-11: Low Productivity Rockland Hammock.
  D. ESU-12: Medium Productivity Rockland Hammock.
  E. ESU-13: Coastal Strand Forest.

Pine Rocklands are of particular concern because of their restricted U.S. and global distributions. Besides the Florida Keys, Pine Rocklands are found on the southeastern Florida mainland, the Bahamas (especially Andros Island), and Cuba. The original acreage of upland vegetation on the Miami Rock Ridge in Dade and Broward Counties was approximately 180,000 acres, the majority Pine Rockland. Today less than 22,000 acres remain, 18,000 in Everglades National Park (C. Lippincott, pers. comm.). There are no comparable figures for Pine Rocklands in the Florida Keys, but pineland loss due to land clearing and sea level rise has been substantial. The loss of Pine Rocklands is especially serious because of the number of endemic species they harbor. Of the 88 vascular plants endemic to southeast Florida, 54 are found in Pine Rockland habitat, many exclusively so (Herndon, pers. comm.).

II. METHODS.

IIA. Field methods.

IIA1. Vegetation.

The SFWMD zone of interest was mapped into eight habitat categories on the basis of a black-and-white Florida Department of Transportation aerial photo (flown Feb. 1991) and followup groundtruthing. The original print (scale: 1"=2080') was rephotographed and printed at a scale of 1"=1200'. The mapping units included a single "disturbed" category and seven "ecological site units" (Ross et al., in press) for relatively undisturbed areas. Ecological site units are defined on the basis of both vegetation and site factors, but are recognizable by vegetation alone in the absence of recent major disturbance. The scale of the photograph used to map habitats was large enough to recognize and map most mosquito ditches, as well.

Current vegetation was sampled in 114 plots within the boundaries of the SFWMD zone of interest (Figure 4). Sixty-seven of these were concentrated within the Boss and Terrestris tracts, while the other 47 plots were distributed as evenly as possible on SFWMD- and TNC-owned lands throughout the rest of the area.

Plots were 65 meters on a side (approximately 1 acre). The center of each plot was marked with a metal stake driven into the underlying bedrock. Sampling methods were as follows:

1. From the center stake, a point-quarter method (Mueller-Dombois and Ellenberg, 1974) was used to estimate the density of pine seedlings (<1 m height), pine saplings (<5 cm diameter at 1.4 m), pine trees (>5 cm diameter), and competing tree species. The method allowed the determination of mean diameter and height for pines and competing trees, as well as total basal area in each of these groups.

2. Species abundance was assessed for vascular plants covering an area larger than 1 m^2 within a 10 m radius of the plot center. Visual estimates were used to place species in one of five cover classes: 0.3-1%, 1-5%, 5-16%, 16-33%, >33%.

3. The entire 1 ac. block was carefully surveyed in order to record the presence of all plant species with cover less than 1 m^2 within 10 m of the center stake, as well as species recognized by the U.S. Fish and Wildlife Service, Florida Department of Agriculture, or the Florida Natural Areas Inventory to be of special concern.

4. In the aftermath of fire, pinelands gradually develop a dense layer of understory and subcanopy vegetation. The current density of understory vegetation might therefore serve as a good index of the length of time since the last fire. A three-step approach was

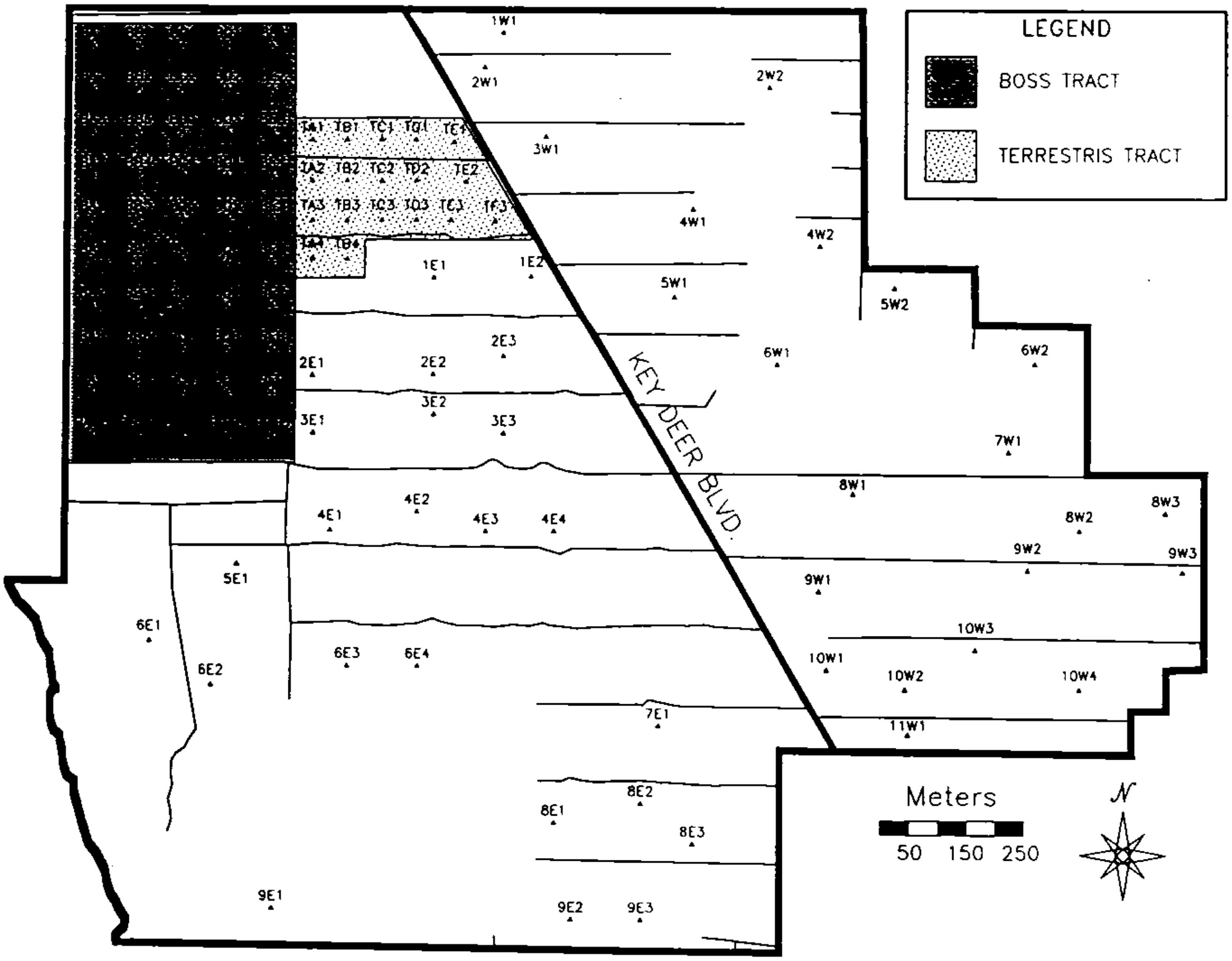

Figure 4. Vegetation plot locations and identification numbers.

therefore taken to making a preliminary assessment of the history and effect of fire in the study area:

a. The relationship between date of last fire and foliage density profile was established in stands of known fire history outside the SFWMD zone of interest.

b. The fire history of a portion of the study area was estimated based on estimates of foliage density, in conjunction with the relationship developed in Step 1.

c. Foliage density in the area examined in Step 2 was used as an independent predictor of pine regeneration density and the presence of understory plant species of special concern.

To accomplish the steps listed above, foliage density was estimated at 1, 2, and 3 meters above the ground in all pineland plots in the Boss and Terrestris tracts, as well as in three sites approximately 4 km north in the Key Deer Refuge. According to U.S.F.W.S. reports and information from neighboring landowners, these "standards" had last burned in 1961, 1973, and 1987, respectively. Foliage density was determined by moving a board horizontally away from an observer positioned at the pertinent height, and recording the distance at which 50 percent of its surface was obscured by leaves (MacArthur and MacArthur, 1961). Distances greater than 10 meters were assumed to be 20 meters. Foliage density (k, in square meters of foliage per cubic meter of space) was then estimated from the formula:

$$k=\log_e 2/D,$$ where D=distance from board to observer.

In Boss and Terrestris plots, estimates of foliage density for each height were made from three locations (5 meters from the plot center at azimuth 0°, 120°, and 240°), looking in three directions (0°, 120°, and 240°). In the Refuge sites, six locations were randomly chosen, with three sampling positions at each location.

For the most part, the SFWMD zone of interest was undisturbed by humans prior to 1960. It was therefore possible to create a pre-development habitat map on the basis of a 1959 D.O.T. aerial photograph (scale: 1"=1530'). Because several ecological site units were impossible to confidently distinguish without groundtruthing, it was necessary to simplify the map to include only five units of natural vegetation.

IIA2. Soils. Soils were examined in each of the 67 Boss and Terrestris plots. Three parameters were recorded for the area within 10 m of the center stake: 1) maximum soil depth, 2) percentage of area without soil cover, i.e., with exposed bedrock, and 3) degree of relief in the plot, assessed on a 3-point scale.

IIA3. Topography. Topographic transects were surveyed adjacent to three woods roads extending the length of the Boss tract, with elevations determined every 20 meters. A fourth transect was run off the Terrestris tract's U-shaped road system. All four transects were tied into a nearby U.S.G.S. vertical control benchmark. A contour plot of elevations was developed from these data using the minimum curvature method of grid interpolation in the SURFER program (Golden Software, Inc.).

IIB. Data treatment and analysis. The data analysis was intended to answer three sets of questions:

1. What are the overall characteristics of the vegetation mosaic within the SFWMD zone of interest, how does it vary spatially, and how might this pattern affect acquisition priorities?

2. Are all pinelands ecologically equivalent, i.e., do they differ in terms of stand structure, species composition or the abundance of pine regeneration? Can anything be said about the underlying causes of this variability?

3. How are the plant species of special concern distributed within the study area, what factors affect their distribution, and how might management activities such as prescribed fire affect them?

In order to address the landscape issues implied in the first question, as well as to facilitate future management activities within the area, all of the vegetation and site information discussed above was entered into ATLAS*GIS (Strategic Mapping, Inc.), a desktop geographic information system. The Monroe County Tax Assessor's map of property boundaries and ownerships within the SFWMD zone of interest was also entered into the GIS system (Figure 2). By overlaying different sources of site, vegetation, or ownership information on one another, it was possible to detect landscape patterns that would not otherwise have been evident.

Because many of the plant species of concern are associated with pinelands, questions #2 and #3 are closely linked. Several multivariate statistical procedures were used to define and examine the differences among pineland types. In particular, two-way indicator species analysis (TWINSPAN) was used to distinguish categories of pinelands (Gauch, 1986). TWINSPAN is a hierarchical divisive classification procedure which uses a reciprocal averaging ordination to sequentially subdivide larger units on the basis of their species composition. The level at which the divisions are no longer useful is left to the researcher. This decision was based on 1) the capacity to easily recognize the subunit in the field, and 2) the amount of intra-group variation explained by further division. By utilizing the types of pineland thereby defined, it was possible to determine how various plant species were distributed among and within types, as well as how their distribution varied with site factors, via analysis of variance, regression and goodness of fit techniques. Where necessary, data were transformed in order to homogenize variances.

III. RESULTS.

IIIA. Landscape pattern and the changing habitat mosaic.

The SFWMD zone of interest is a keystone area on Big Pine Key, in that it includes the most extensive freshwater wetlands on the island, as well as portions of uplands that virtually enclose them on four sides. Although residential development around the edges of the area have substantially modified it since 1959, the pre-development vegetation and landscape patterns remain a useful reference point for management and restoration of the system. In 1959, the vegetation of central Big Pine Key exhibited a clear gradation from the tidally-influenced western areas to the freshwater systems to the east (Figure 5). This sector of the island has been segregated into four biophysiographic zones on the basis of location, physiography and vegetation: 1) the Northwestern Pinelands, 2) the Central Wetland Complex, 3) the Southeastern Pinelands, and 4) the Western Coastal Fringe (Figure 6). These zones are still applicable today (Figure 7), and to some extent are represented in areas to the north and south.

The Northwestern Pinelands Biophysiographic Zone includes most of the interior of northern Big Pine Key. It extends into the project area primarily to the west of Key Deer Blvd., where it forms an upland border to the extensive wetlands to the south and west (Figures 5, 6,

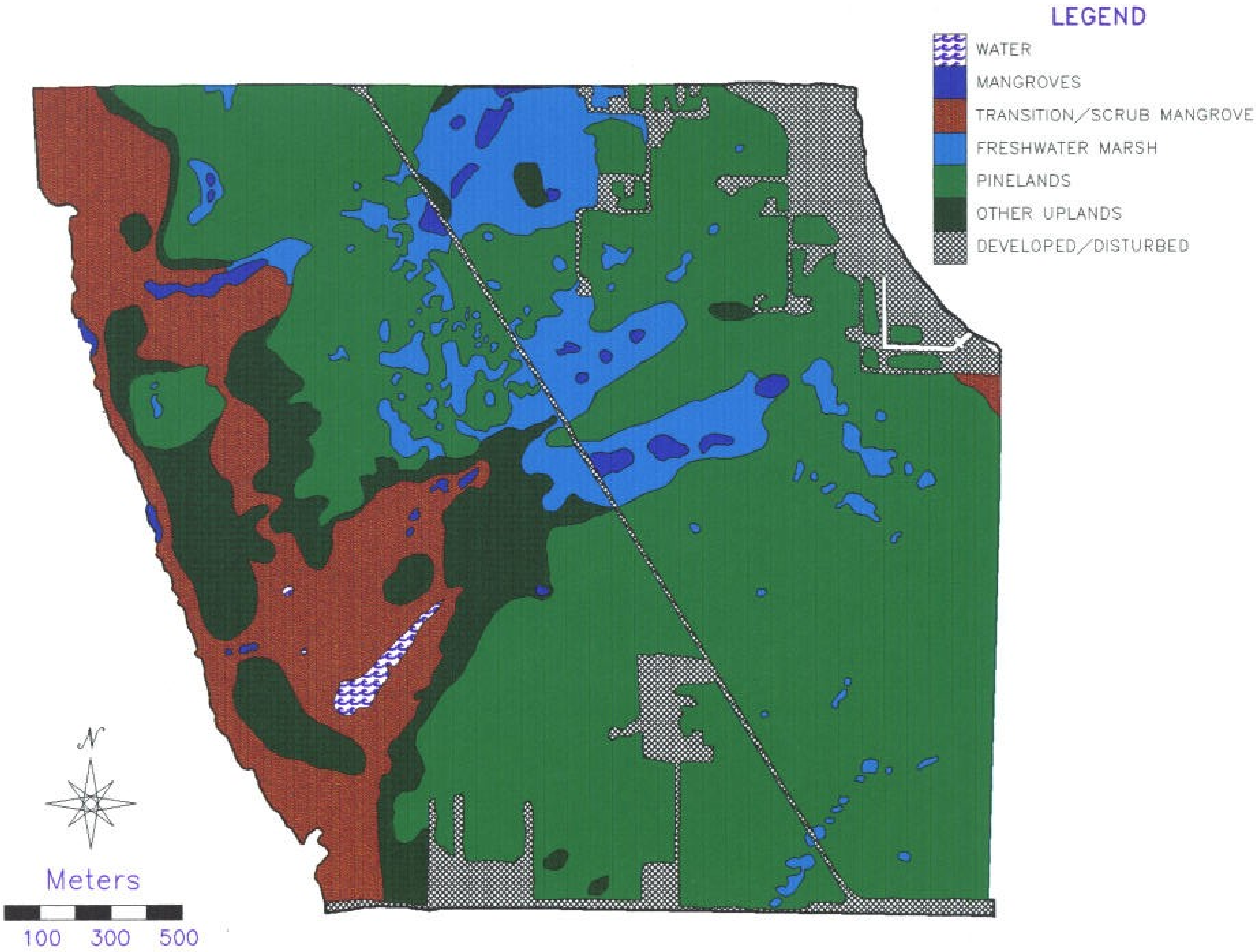

Figure 5. Habitat units of central Big Pine Key, 1959.

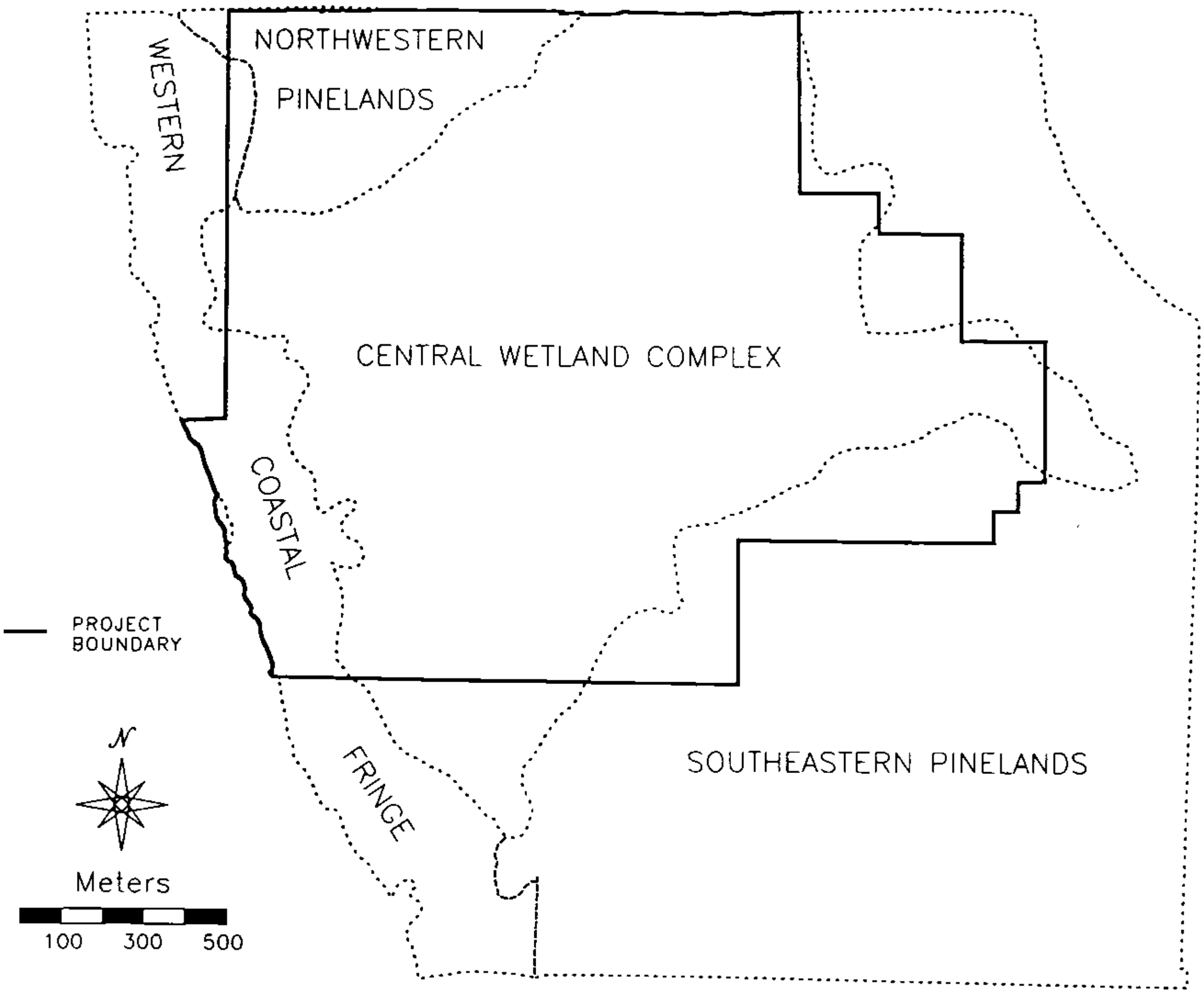

Figure 6. Biophysiographic zones of central Big Pine Key.

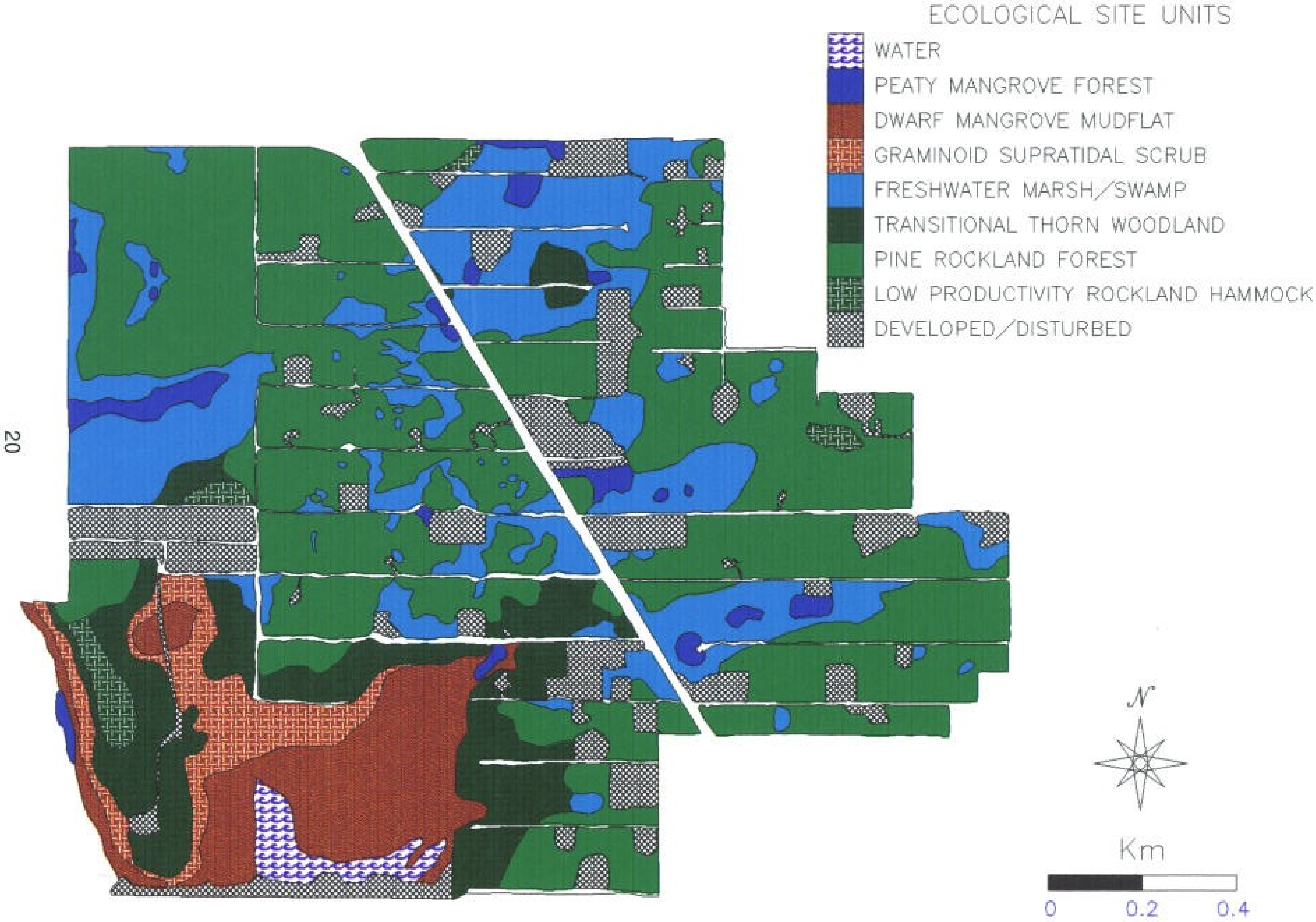

Figure 7. Ecological site units in SFWMD project area, 1991.

and 7). The southern edge of the Northwestern Pinelands also marks the furthest extent of the northern freshwater lens described by Hanson (1980). As its name suggests, the Northwestern Pinelands is characterized by occasional freshwater marshes and sinkholes in a pine forest matrix. Within the project area, the habitat composition of the Northwestern Pinelands has been relatively unchanged since 1959 (Table 2).

The Southeastern Pinelands Zone (Figure 6) includes most of southern Big Pine Key, extending a few hundred meters south of Highway 1. It forms an upland border to the project area south of Watson Blvd and east of Key Deer. The Southeastern Pinelands are closely associated with Hanson's (1980) southern freshwater lens, although Stewart et al. (1989) present evidence that, during the last decade, the lens may have retreated toward the center of the island from its former position. In the 1959 photo, the Southeastern Pinelands has the same appearance as its northwestern neighbor---an open pine plain broken by intermittent isolated freshwater wetlands (Figure 5). Today it remains largely unchanged within the project area (Figure 7, Table 2), but has been heavily developed to the south (Figure 8), where it comprises the downtown area of Big Pine.

Prior to development, the Western Coastal Fringe was a series of narrow uplands, interrupted by tidal passages, which lined Pine Channel on the western side of the island (Figures 5, 6). The passages allowed tidal exchange with well-defined interior wetlands, and the uplands featured the best-developed hammocks on the island, perhaps because these locations burned less frequently or intensely than the island interior. Today some of these hammocks remain in part or intact, but coastline alteration has destroyed most of the tidal function. The SFWMD project area is a case in point. There were originally two tidal passages into the area (Figure 5). One has long been blocked by the Eden Pines subdivision, and the second has been replaced by the northernmost canal in Pine Channel Estates (Figure 8). The upland forest remnant in this zone (Figure 7) is probably the best-developed hammock within the project boundaries.

Table 2. Area (hectares) of seven site types in four biophysiographic zones within SFWMD project area, 1959 and 1991.

	Central Wetland Complex		Northwestern Pinelands		Southeastern Pinelands		Western Coastal Fringe	
Site type	1959	1991	1959	1991	1959	1991	1959	1991
Pineland	64.6	61.7	25.2	24.2	27.4	20.6	3.5	1.6
Other Upland	27.3	17.0	0.2	0.2	0.5	0.7	11.8	9.2
Supratidal scrub/ scrub mangrove	31.5	22.9	--	--	--	--	4.3	4.7
Freshwater marsh	48.3	40.8	1.1	1.2	0.3	0.4	0.1	1.3
Mangrove forest	6.0	4.6	0.1	0.9	--	--	0.5	0.5
Water	0.7	3.1	--	--	--	--	--	--
Developed/ disturbed	4.3	35.7	0.4	1.1	0.5	7.0	0	2.5

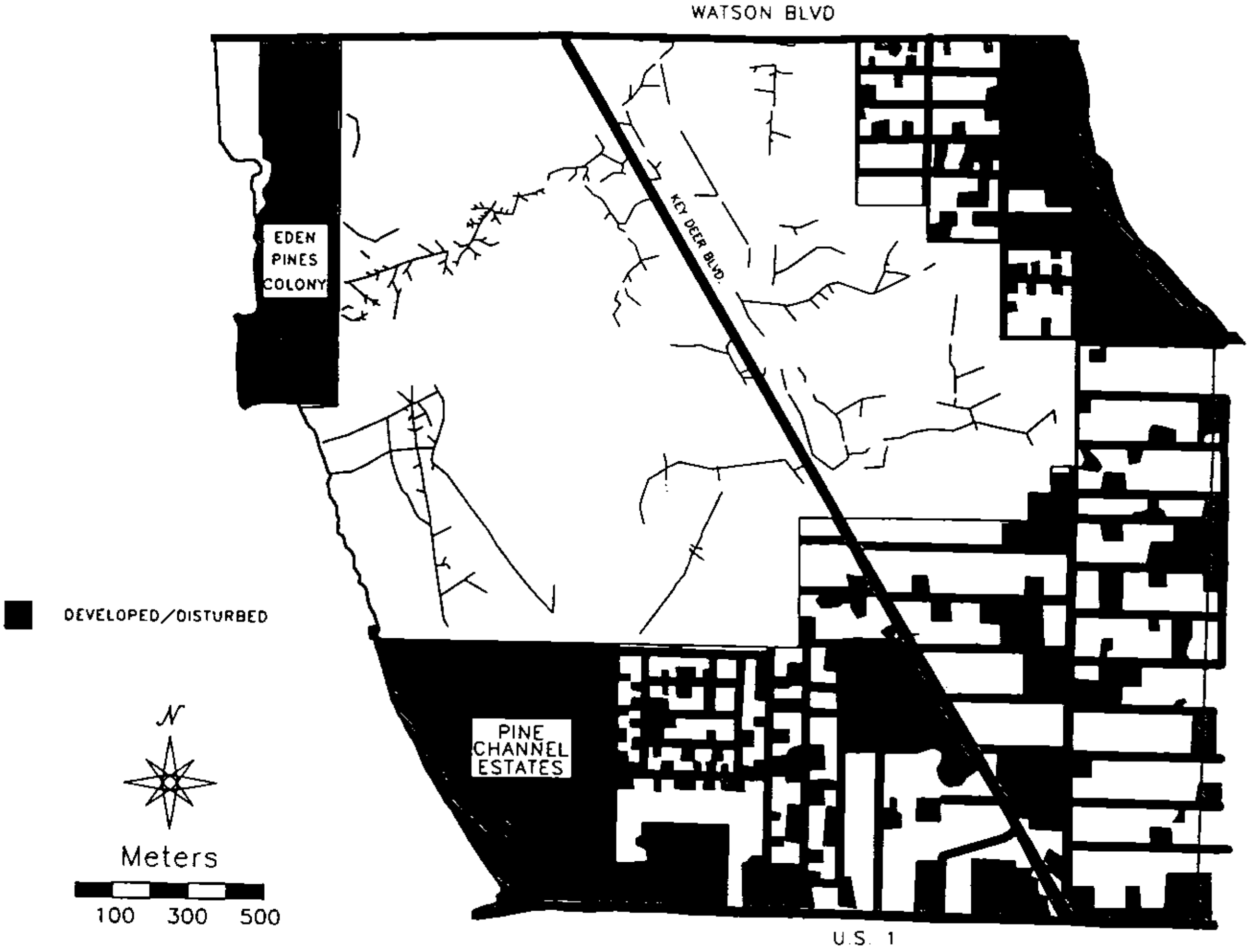

Figure 8. Development pattern outside the SFWMD project area, 1991. Also included is mosquito ditch network inside project area.

The Central Wetland Complex, a broad zone separating the Northwestern and Southeastern Pinelands, is a heterogeneous mixture of pinelands, freshwater marshes, and the remains of the tidal wetlands which once occupied parts of this area (Figures 5, 6). Occurring as it does between the two lenses, it serves as a catchment basin for subsurface flow from those sources. Because water ponds in this area during wet periods, the Central Wetland Complex attracted a lot of attention from the mosquito ditchers in 1964-65, when most of Big Pine Key was treated (Figure 8). Today this Zone is still very lightly developed, but has nevertheless undergone significant vegetation change since 1959 (Table 2). These changes are explored more closely in Figure 9. The most extensive transformation has been the "freshening" of the transitional wetlands at the base of the Northwestern Pinelands, a result of the aforementioned Eden Pines impoundment (Figure 8). Changes from a) pineland to broadleaved upland vegetation, b) upland to transition vegetation, and c) transition vegetation to a permanently flooded situation occur together in the southwestern corner of the project area. These changes appear to be associated with landclearing activities as well as a high levee on the northernmost canal in Pine Channel Estates (Figure 8), which would serve to increase the hydroperiod and salinity variation of the area to the north. Both Watson and Key Deer Boulevards have also been the source of impoundment effects, resulting in vegetation changes at several points where they intersect existing sloughs, but these changes affected areas too small to be included in Figure 9.

IIIB. Pine rocklands of central Big Pine Key.

The pine forests of the project area were widespread and variable in composition. A classification program (TWINSPAN) was applied to determine how, or if, the pinelands should be subdivided. The two groups defined by TWINSPAN's Level 1 division were clearly recognizable on the basis of species composition (Table 3). Among the high-abundance species on which the analysis was based, Group 1 was typified by the presence of fern species (e.g., *Anemia adiantifolia, Pteridium aquilinum,* and *Pteris longifolia*), a higher abundance of a few characteristic

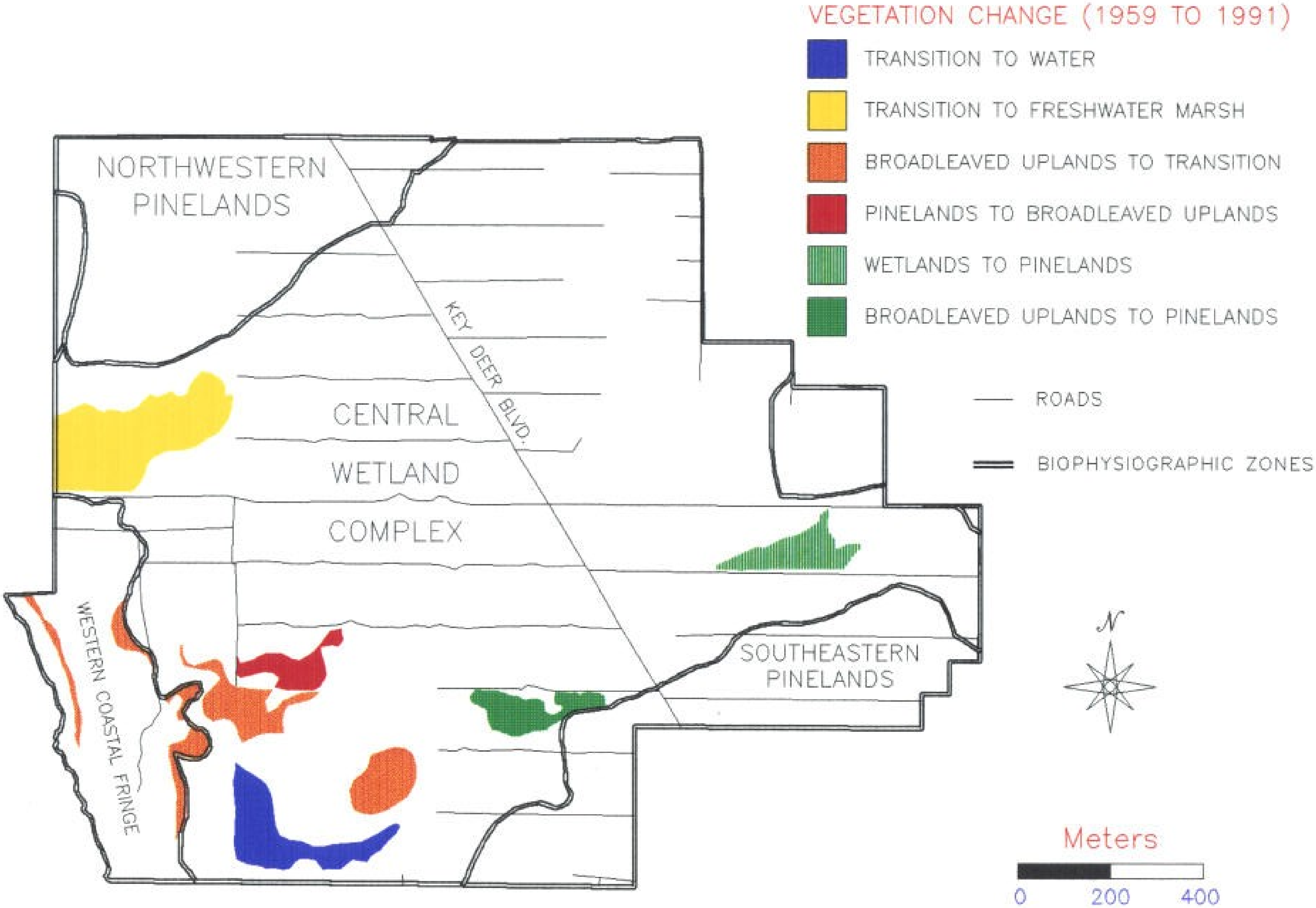

Figure 9. Large (> 1 hectare) areas of vegetation change in SFWMD project area, 1959-1991.

Table 3. Mean species cover of two TWINSPAN-defined pineland compositional groups. Based on Table 4 and Figure 11, Groups 1 and 2 are subsequently referred to as High and Low Pine Rocklands, respectively. Only species with mean cover > 0.8% are included.

	Group 1 (n = 32)	Group 2 (n = 42)
VINES, HERBS, AND LOW SHRUBS		
Anemia adiantifolia	1.6	--
Cassytha filiformis	1.0	1.1
Cassia keyensis	1.0	--
Ernodea littoralis	3.3	6.2
Morinda royoc	1.1	--
Pteridium aquilinum	2.4	--
Pteris longifolia	1.0	--
Smilax havanensis	0.9	--
Chiococca pinetorum	--	2.3
TREES AND TALL SHRUBS		
Byrsonima lucida	3.9	10.5
Coccothrinax argentata	5.6	1.1
Coccoloba uvifera	1.1	2.2
Metopium toxiferum	5.1	8.9
Myrica cerifera	2.1	1.5
Myrsine floridana	1.5	2.5
Pinus elliottii	19.7	11.4
Pisonia rotundata	2.9	--
Pithecellobium guadalupense	5.2	2.2
Psidium longifolia	12.5	12.5
Serenoa repens	1.7	1.4
Sophora tomentosa	1.6	1.7

Table 3. (continued)

Thrinax morrisii	8.7	11.9
Conocarpus erecta	1.1	16.6
Casuarina equisetifolia	--	1.5
Guapira discolor	--	0.9
Manilkara bahamensis	--	2.8
Jacquinia keyensis	--	1.3
Randia aculeata	--	1.1
GRAMINOIDS		
Dichromena floridensis	1.1	2.4
Schizachyrium gracile	2.7	0.9
Schizachyrium rhizomatum	2.5	0.9
Schizachyrium semiberbe	0.9	--
Sorghastrum secundum	2.1	--
Aristida purpurea	0.9	0.8
Muhlenbergia capillaris	0.8	--
Cladium jamaicensis	--	23.6
Panicum neuranthum	--	0.8
Schoenus nigricans	--	2.4

woody plants (e.g., *Coccothrinax argentata, Pisonia rotundata*), and a greater representation of graminoids of the family Poaceae (e.g., *Schizachyrium gracile, S. rhizomatum, Sorghastrum secundum*). Group 2 pinelands were characterized by the relative abundance of a suite of woody trees and shrubs (e.g., *Byrsonima lucida, Manilkara bahamense, Conocarpus erecta*), as well as graminoids of the family Cyperaceae (e.g., *Cladium jamaicense, Schoenus nigricans,* and *Dichromena floridensis*). Subsequent TWINSPAN division of these two groups yielded subunits that were not nearly so easily distinguished. Furthermore, those divisions only accounted for about 15% of the variation in Groups 1 or 2 (as compared to 25% for the initial division). It was therefore decided to limit the subdivision of Pine Rocklands to the two categories described above.

The site factors underlying the compositional groupings described above are of considerable management interest. Soils information was available from the 39 pineland plots on the Boss and Terrestris tracts, and the elevation of each of these plots was estimated by interpolation from the topographic map of the same area (Figure 10). On average, Group 1 plots were higher, with more continuous soil coverage than pinelands classified in Group 2 (Table 4). There is very little overlap in elevation among groups, with only 16% of Group 1 plots occurring below the 80 cm contour, and only 12% of Group 2 plots occurring above it (Figure 11). In the Florida Keys, distance to the water table, as well as groundwater and soil salinity, are in large part a function of elevation (Ross et al., in press; L. Coultas, pers. comm.; Caballero and Vacher, 1991); any of these factors might exert a controlling influence on species establishment, growth, or survival. Although the exposure differences indicated in Table 4 may also influence species distribution, it was decided to label Groups 1 and 2 according to their relative elevations, i.e., High and Low Pine Rocklands, respectively.

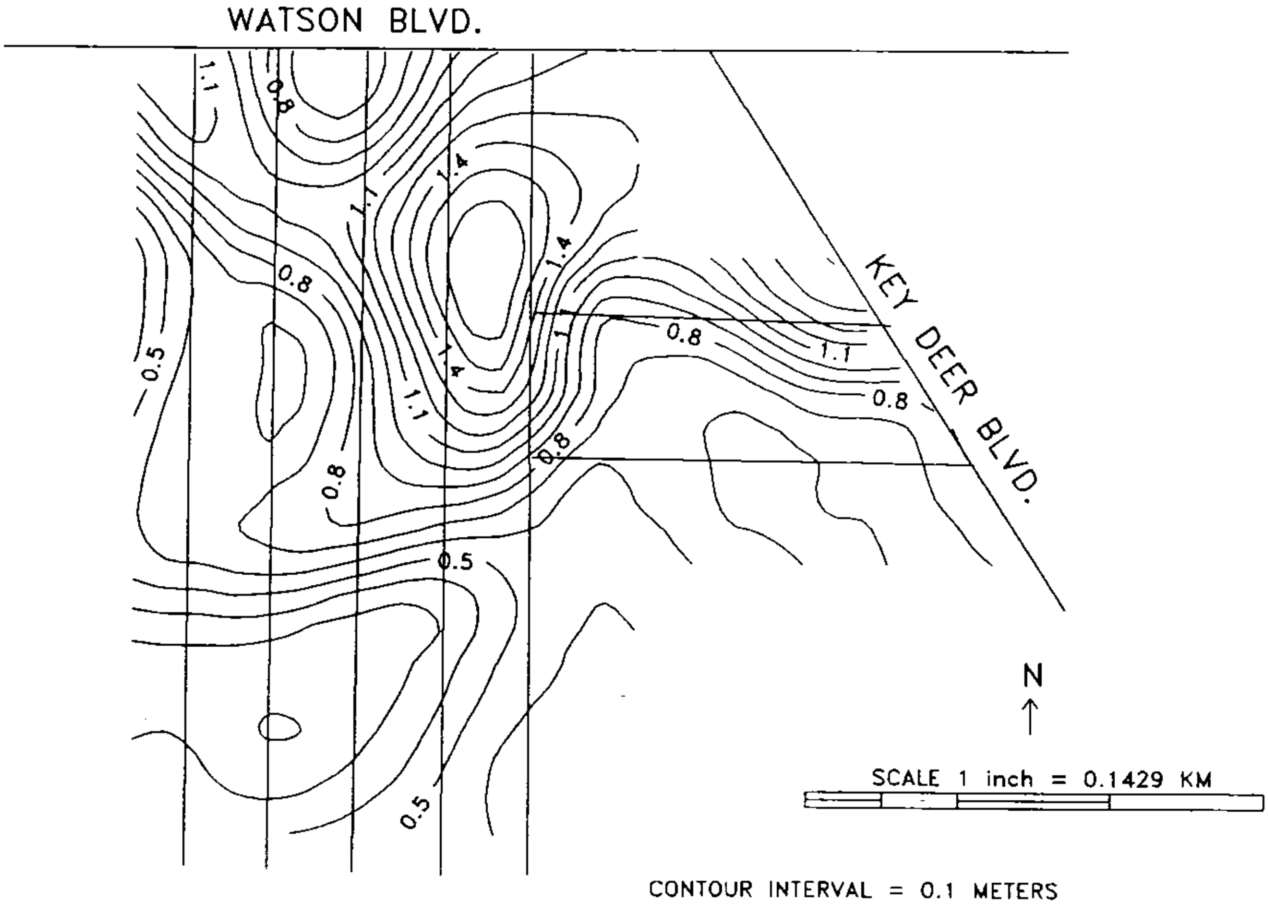

Figure 10. Topographic map of the Boss and Terrestris tracts in the northwestern section of the SFWMD project area.

Table 4. Mean site characteristics of two TWINSPAN-defined pineland groups. On the basis of this table and Figure 11, Groups 1 and 2 are subsequently referred to as High and Low Pine Rocklands, respectively. *, **, and *** signify a difference in population means at $\alpha = 0.10, 0.05$, and 0.01, respectively.

Site Characteristics	Group 1 (n = 25)	Group 2 (n = 17)
Elevation (cm)	102.8***	62.9
Maximum soil depth (cm)	3.7	2.3
Percent exposed rock	27.7	40.6*
Topographic index[a]	1.6	1.6

[a] 1 = flat topography; 2 = slightly rolling; 3 = substantial mounds and swales.

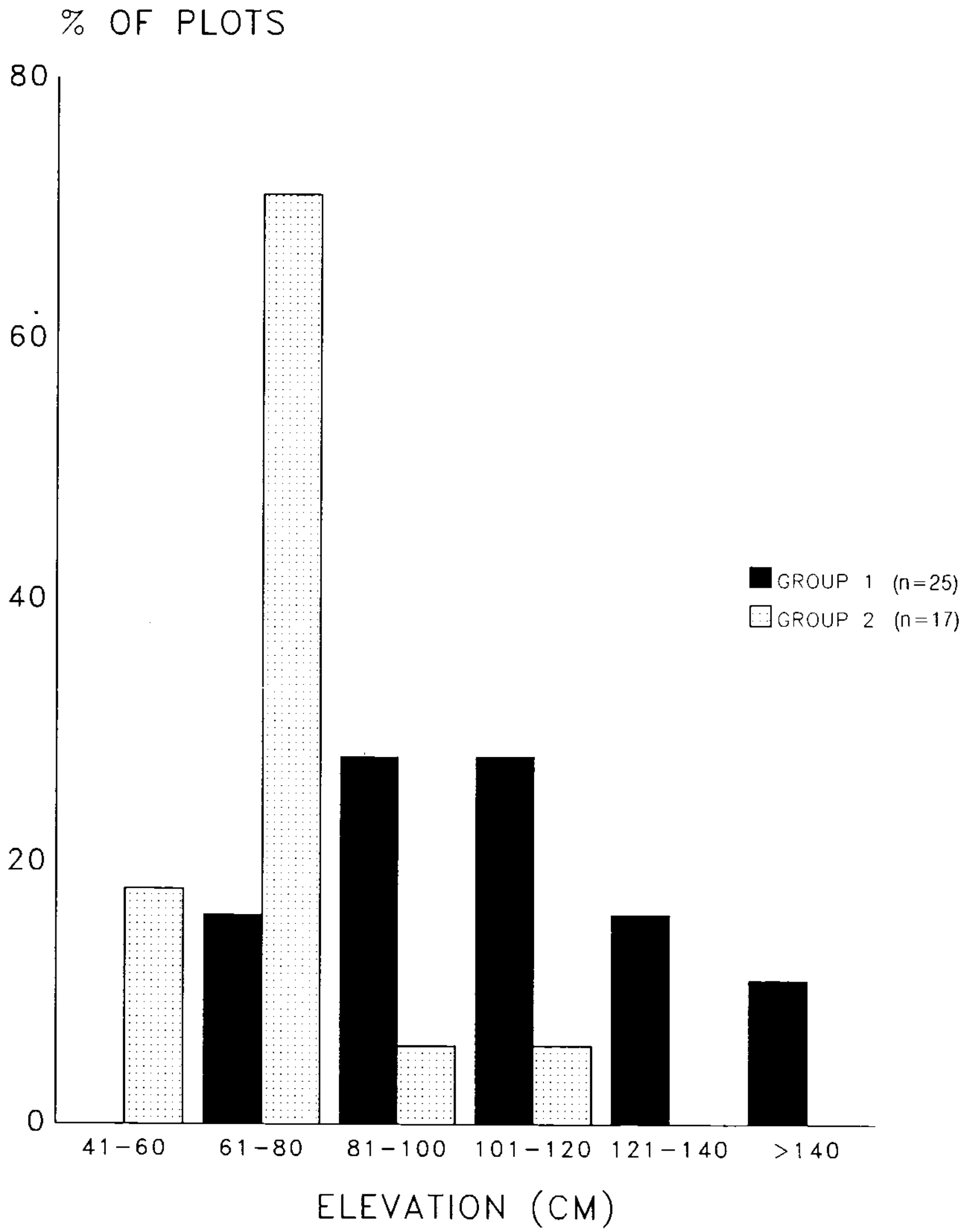

Figure 11. Elevations of two TWINSPAN-derived pineland groups. On the basis of this graph and Table 4, Group 1 and 2 are subsequently referred to as High and Low Pine Rocklands, respectively.

The vegetation structure of High and Low Pine Rocklands in central Big Pine Key shared a number of characteristics (Table 5). Although High Pine Rockland forests were slightly larger in mean pine tree height and total basal area, both types featured a low, open pine canopy subtended by an even lower subcanopy of broadleaved trees or palms. Both were densely vegetated within a meter or so of the ground, but decreased in foliage density dramatically in the next few meters upward. Compared to other Florida Keys vegetation types, Pine Rocklands of either type in this area were rich in plant species, though the higher pinelands supported a more diverse flora. The single structural characteristic in which the two differed substantially was regeneration density, which was approximately four times higher in High Pine Rocklands. Because of the open condition of the canopy throughout most of these stands, many of the pine saplings and some of the seedlings were likely to survive to maturity in the absence of disturbance. Nevertheless, even in the higher pinelands, the distribution of regeneration was very patchy, abundant in places and entirely absent in others.

Although the two groups often occur in admixture, High and Low Pine Rocklands are not randomly distributed in the landscape. Within the SFWMD zone of interest, high pinelands are the dominant type in the Northwestern and Southeastern Pineland region, while low pinelands predominate in the Central Wetland Complex (Figure 12). The islands of pine in this region (and presumably Low Pine Rocklands in general) appear to maintain themselves through significant periods of inundation. On October 28, 1991, Big Pine Key received nearly six inches of rain, culminating a two-week period in which about 11 inches fell. Seven rainless days later, the low pinelands sampled in the central portion of the study area were still covered with as much as six inches of fresh water. Because downpours like that of October 28 are not uncommon in the Keys during the rainy season, it seems likely that, during most years, the Low Pine Rocklands experience "wetland hydrology" by any responsible definition.

Table 5. Mean structural characteristics of High and Low Pine Rocklands. *, **, and *** signify a difference in population means at $\alpha = 0.10, 0.05$, and 0.01, respectively.

Structural characteristics	High	Low
Total basal area (m^2/ha)	11.4**	8.3
Mean pine tree height (m)	7.1***	6.3
Mean height competing trees (m)	3.7	3.6
Mean pine tree diameter (cm)	12.4	12.0
Pine seedling density (#/ha)	612.0***	163.0
Pine seedling & sapling density (#/ha)	1433.0***	321.0
Foliage density at 1 m (m^2/m^3)	199.7	201.2
Foliage density at 2 m (m^2/m^3)	111.4	104.5
Foliage density at 3 m (m^2/m^3)	80.4	76.8
Species richness (#/plot)	44.6***	37.2

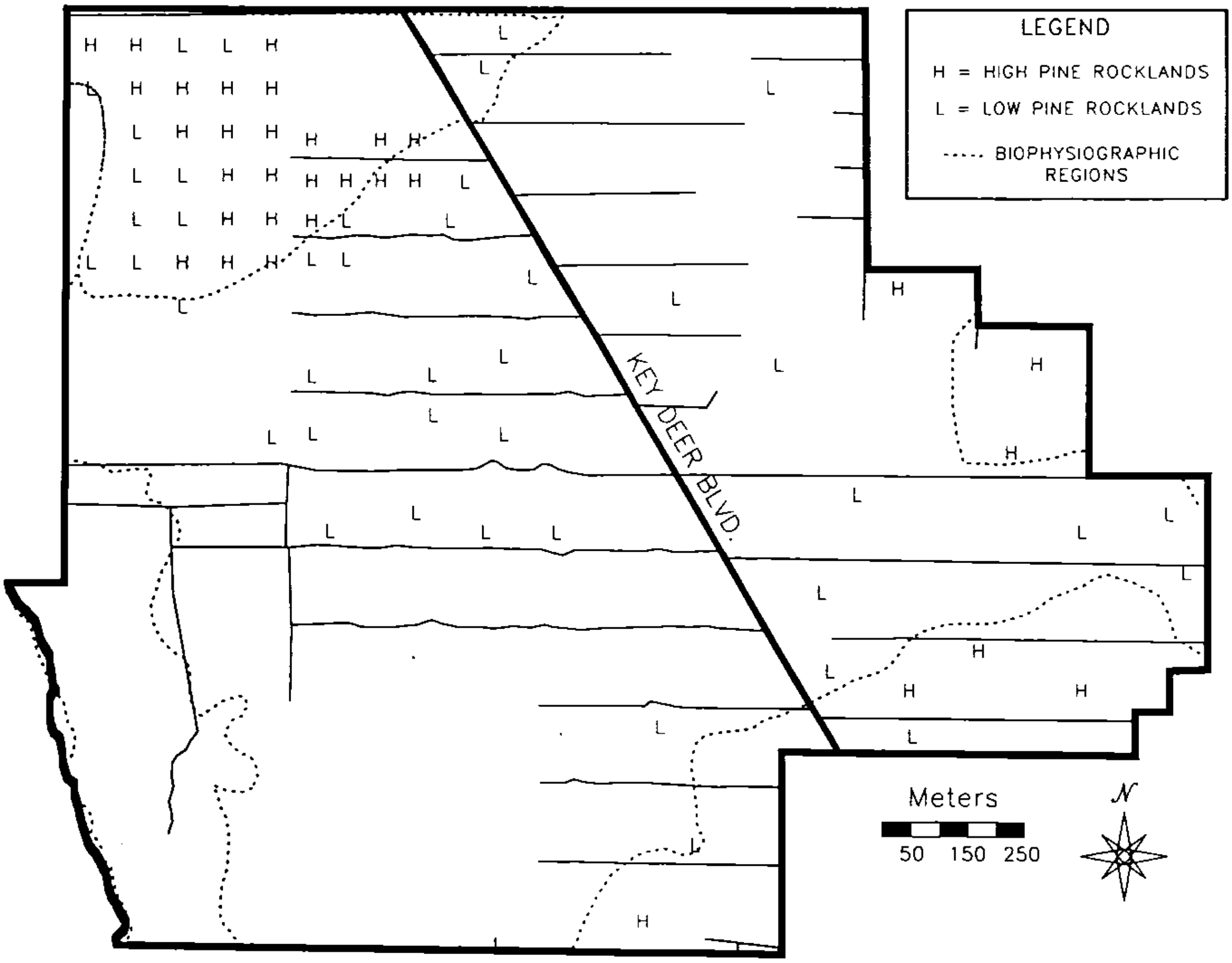

Figure 12. Distribution of High and Low Pine Rockland vegetation plots in the SFWMD project area.

Whereas Pine Rocklands are quite capable of enduring short periods of inundation with fresh water, they may be quite vulnerable to longer periods of flooding and/or higher salinity. O'Brien et al. (1991) documented a situation on nearby Sugarloaf Key in which sea level rise over a period of more than 60 years caused a gradual diminution in the extent of pinelands. On that island, areas where pines survived were higher and had fresher groundwater at the time of the study than areas where pines had succumbed. The plants found in the relict pinelands were considered more tolerant of brackish conditions in their rooting zone than the pineland species they replaced. Similar zones of dead pine snags among more salt- and flooding-tolerant vegetation were found within the SFWMD management area, most prominently in two regions west of Key Deer Blvd. (Figure 13). Because of the impoundments and mosquito ditches that have transformed the hydrology of the area, especially on the west side of the island, it is difficult to distinguish the effects of sea level rise from anthropogenic effects. Nevertheless, sea level rise, which is currently occurring at a rate of about 40 cm/century in South Florida, is a potent force to consider in the longterm management of conservation lands on Big Pine Key.

Fire, another critical element in future management of the area, was examined indirectly, through its effect on vegetation density. The foliage density profiles of the three pine stands examined in the Key Deer Refuge resembled those described above for Boss/Terrestris in their sharp drop in vegetation density above 1 meter (Figure 14). As expected, foliage density increased with time since fire, but the pattern of diminished foliage density with height was maintained throughout the age range sampled. It is notable, however, that the percentage increase in foliage density between age 19 and age 31 was greater at the 2 and 3 meter levels than at 1 meter. By using the three stands described in Figure 14 as standards, it was possible to estimate the most likely time since fire for each of the Boss/Terrestris pineland plots (Figure 15). Clearly, the subcanopy structure indicated that fire has been absent for more than two decades in a great majority of the tract. Furthermore, the spatial distribution of fire ages in Figure

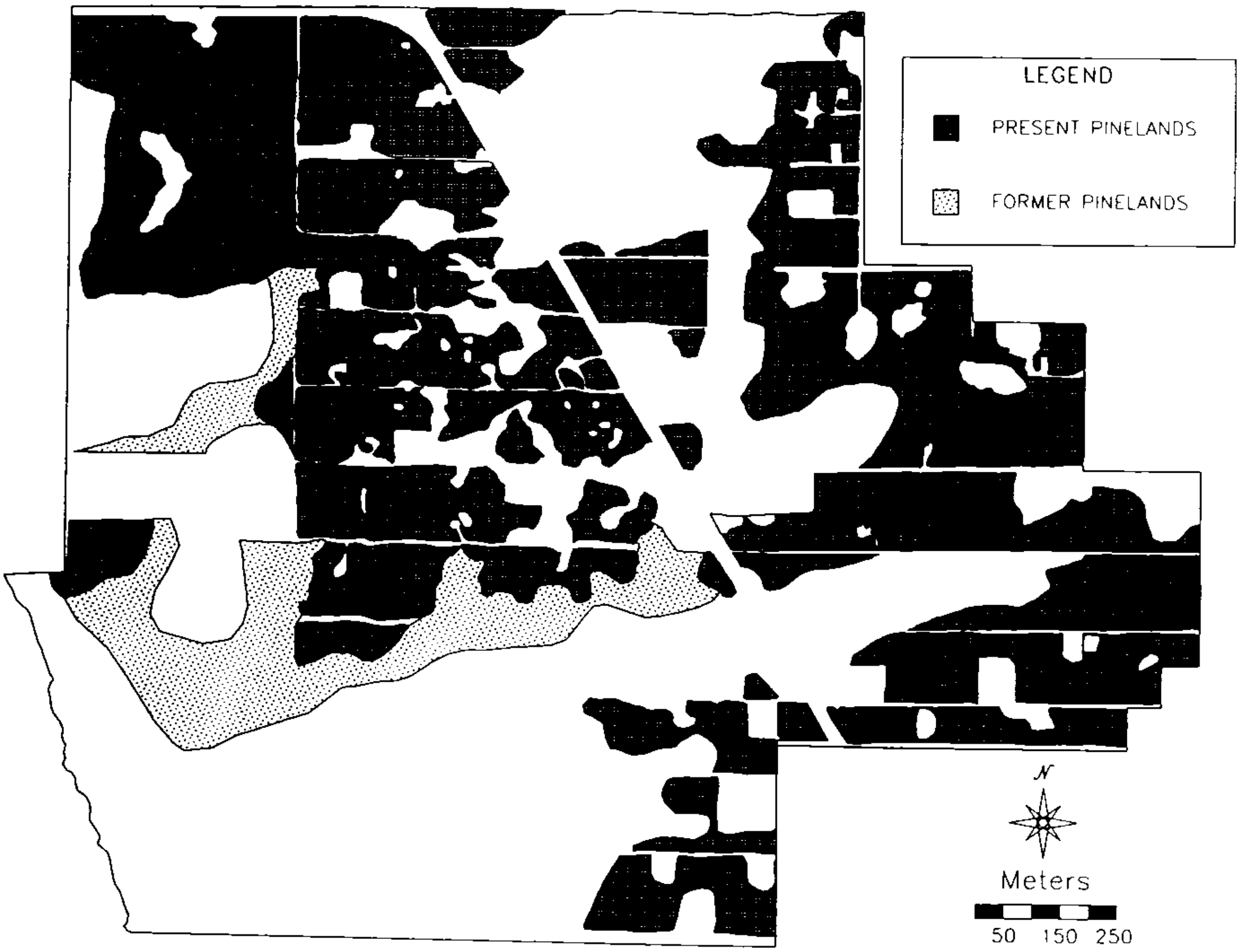

Figure 13. Distribution of current and relict pinelands in project area.

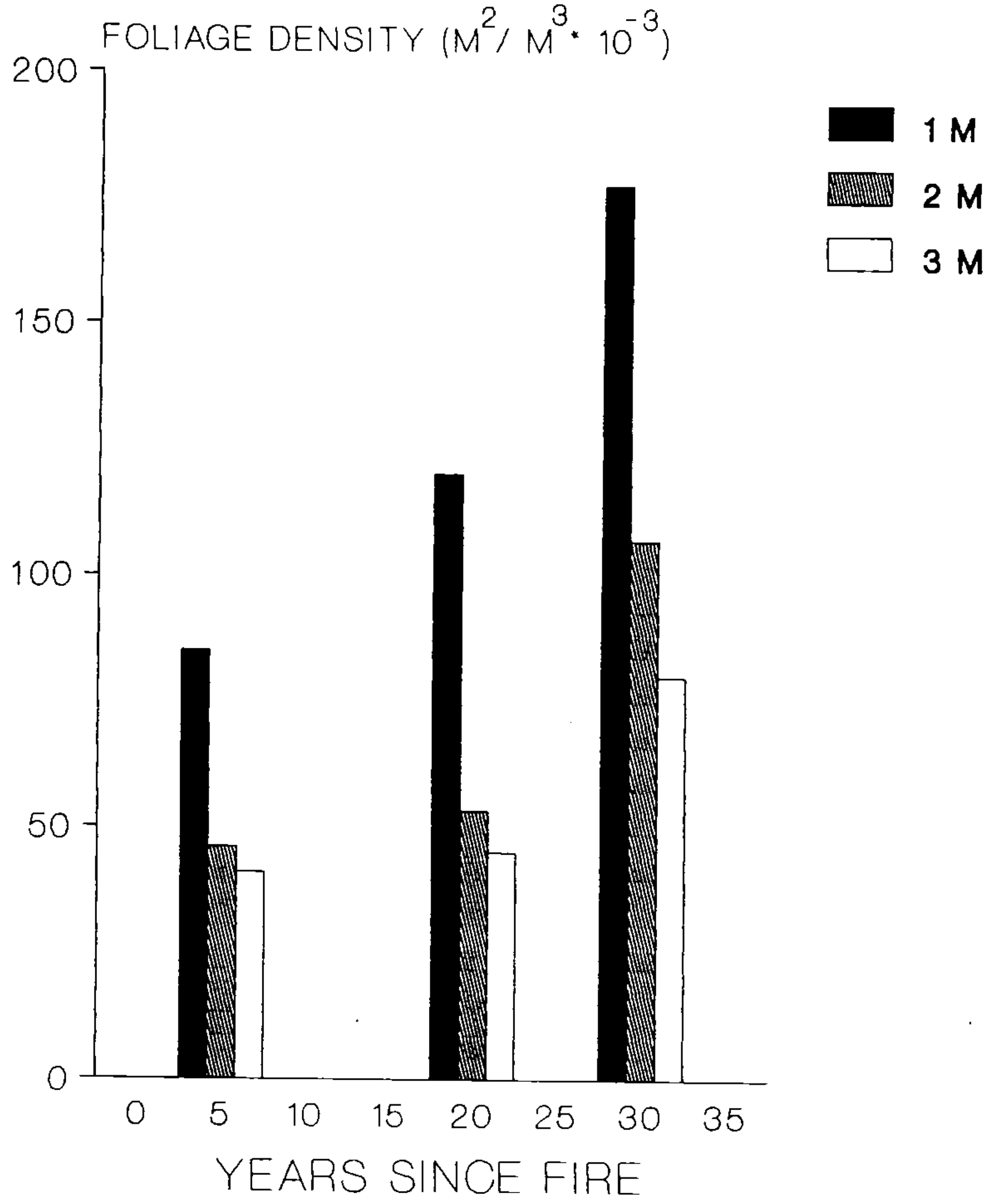

Figure 14. Foliage density profile of three High Pine Rockland stands in the USFWS Key Deer National Wildlife Refuge. According to USFWS fire reports and information from neighboring landowners, these stands burned in 1987, 1973, and 1961, respectively.

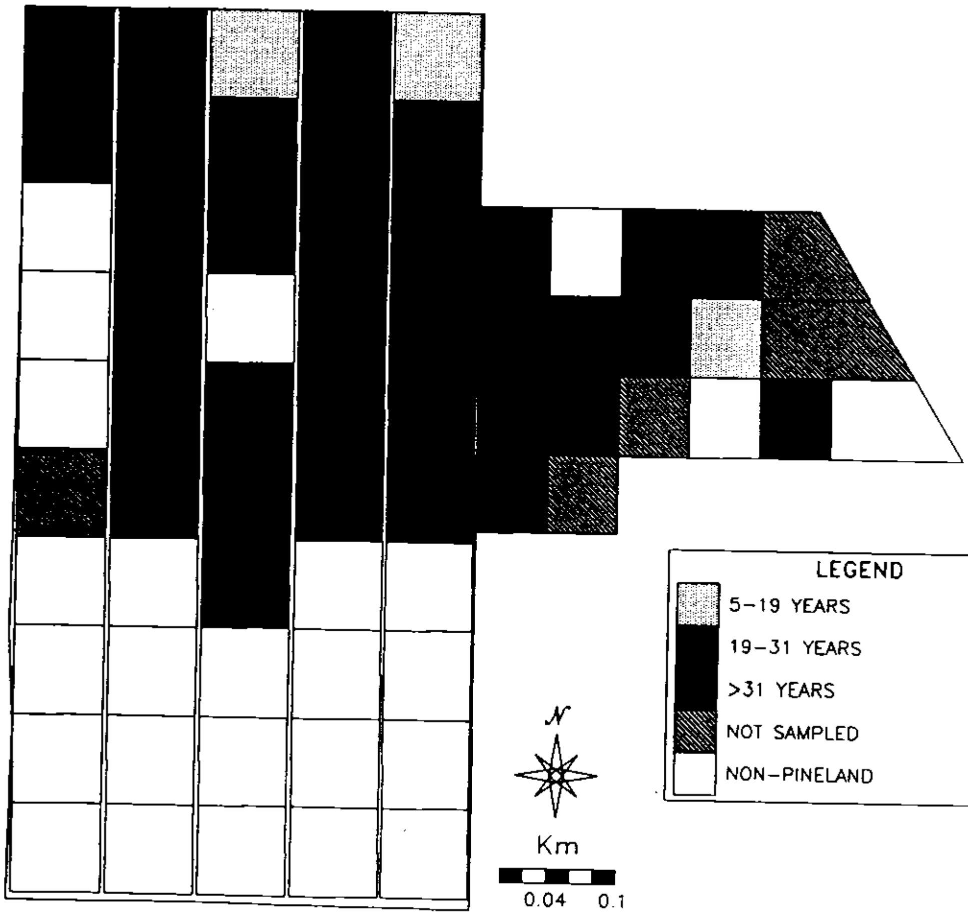

Figure 15. Estimated time since fire in Boss and Terrestris tracts. Estimates are based on comparison of plot foliage density at 1, 2 and 3 meters with foliage density of three "standards" profiled in Figure 14.

15 suggests that the area should be treated uniformly with respect to fire history, i.e., no large portion of the tract burned more recently than another.

Intuitively, one might expect a densely vegetated forest understory to compete with pine seedling regeneration, resulting in a negative correlation between those variables. The Boss/Terrestris data set generally confirmed the negative influence of vegetative cover on pine seedling regeneration. At the 5% confidence level, seedling density was negatively correlated with foliage density at the 2- and 3-meter levels, but uncorrelated with foliage density at 1 meter. The effect of vegetation density on the distribution of rare and endemic plants will be discussed in the next section.

IIIC. Plant species of special concern.

IIIC1. Habitat preferences among site units.

Table 6, which lists the habitat preferences of 31 species of special concern in the SFWMD zone of interest, includes 12 confirmed South Florida endemics, 6 potential endemics, 10 non-endemic species listed by the Florida Natural Areas Inventory, 2 problem exotics, and one species, *Basiphyllaea corallicola*, that is neither listed by FNAI nor endemic, but is extremely rare in South Florida (R. Hammer, pers. comm.).

The habitat preferences of eight species were undetermined because they occurred in too few (<6) plots (Table 6). Of these, *Strumpfia maritima* was found in low pinelands and wetland edges, *Vernonia blodgettii* occurred only in an abandoned nursery in the Terrestris tract, while the other six species were not observed outside of pineland plots.

Table 6. Habitat preference of species of special concern in the SFWMD zone of interest.

Species	Status[a]	Pineland/ Wetland[b]	High/Low Pineland[c]
Basiphyllaea corallicola	Rare	Undetermined	--
Borreria terminalis	Conf. end.	Pineland	None
Bumelia celastrina	Pot. end.	Wetland	--
Casurina equisetifolia	Exotic	Wetland	--
Cassia keyensis	Conf. end.	Pineland	High
Catesbaea parviflora var. *septentrionalis*	Pot. end.	Undetermined	--
Chamaesyce deltoidea serpyllum	Conf. end.	Pineland	High
Chamaesyce porteriana var. *scoparia*	Conf. end.	Pineland	Low
Coccothrinax argentata	Listed	Pineland	High
Crossopetalum ilicifolium	Listed	Pineland	High
Dichromena floridensis	Conf. end.	Pineland	None
Ernodea littoralis	Listed	Pineland	None
Forestiera segregata var. *pinetorum*	Conf. end.	Undetermined	--
Heterotheca graminifolia var. *tracyi*	Pot. end.	Pineland	High
Hymenocallis latifolia	Listed	Undetermined	--
Linum arenicola	Conf. end.	Pineland	High
Phyllanthus pentaphyllus var. *floridanus*	Conf. end.	Pineland	High
Polygala boykinii var. *sparsifolia*	Pot. end.	Pineland	None
Pteris longifolia	Listed	Pineland	High
Rhyncosia cinerea	Pot. end.	Pineland	High
Ruellia caroliniensis	Pot. end.	Pineland	None
Schizachyrium rhizomatum	Conf. end.	Pineland	None
Schinus terebinthifolius	Exotic	None	--
Sophora tomentosa	Listed	None	--
Strumpfia maritima	Listed	Undetermined	--
Stylosanthes calcicola	Conf. end.	Pineland	High
Tillandsia flexuosa	Listed	None	--
Tragia saxicola	Conf. end.	Undetermined	--
Vanilla barbellata	Listed	Pineland	None
Vernonia blodgettii	Conf. end.	Undetermined	--

[a] Conf. end. = confirmed endemic; Pot. end. = potential endemic; Listed = other listed species (FNAI $\geq$ G4); Rare = unlisted species with very restricted distribution in south Florida; Exotic = problem exotic species.

[b] Based on goodness of fit test (G-test; confidence level = 95%) applied to frequency of occurrence in wetland/transition and pineland plots. Expected frequency in each category was species frequency over all plots.

[c] Based on G-test applied to frequency in High and Low Pine Rockland plots. Expected frequency in each category was species frequency over all Pine Rockland plots.

Among the 23 remaining species, 18 were associated with pinelands, two with wetland and transitional areas, and three were distributed evenly among these groups (Table 6). The two problem exotics were either wetland-associated (*Casuarina equisetifolia*) or cosmopolitan in distribution (*Schinus terebinthifolius*). *C. equisetifolia* of all sizes were most commonly sampled on the levees of mosquito ditches in wetland areas. *S. terebinthifolius* of seedling size were common in pineland plots, but were rarely observed as mature individuals in such sites. In fresh or saltwater wetlands, the species was frequently found mixed with buttonwoods or mangroves in slightly elevated microsites.

Most of the pineland associates were more frequently found in High than Low Pine Rocklands. Three of these species (*Cassia keyensis*, *Chamaesyce deltoidea serpyllum*, and *Linum arenicola*) are considered to be globally imperiled. *Chamaesyce porteriana* var. *scoparia*, the lone species studied here with a strong preference for Low Pine Rocklands, frequents but is not restricted to the banks of mosquito ditches. *C. porteriana* is another globally imperiled species.

A brief mention should be made regarding species listed in Table 6 as having no preference for pineland v. wetland sites, or for high v. low pinelands. These species undoubtedly thrive best in some optimal conditions within one of those categories, but which our sampling design was insufficient to detect. The preferences listed in Table 6 are based on the presence or absence of each species in a 1-acre plot, a relatively insensitive measure, and are considered to be quite conservative. Thus a great deal of confidence may be placed in the relationships listed as statistically significant in Table 6.

IIIC2. Habitat preferences within High Pine Rocklands.

The results of the previous section highlight the importance of high pinelands as a habitat for rare and endemic plant species. Table 7 indicates that the community structure found in all

Table 7. Comparisons of site and structural characteristics of plots in which the following species were present (P) vs. absent (A). All plots were High Pine Rocklands in the Boss/Terrestris tracts. Species included were all endemics present in 3-18 of 21 High Pine Rockland plots. *, **, *** signify a difference in A and P population means at α = 0.10, 0.05, and 0.01, respectively. ns = not significant at α= 0.10.

	Species				
	Chamaesyce deltoidea serpyllum	*Heterotheca graminifolia* var. *tracyi*	*Linum arenicola*	*Rhyncosia cinerea*	*Stylosanthes calcicola*
<u>Structural characteristics</u>					
Foliage density at 1 m	ns	A > P*	A > P***	A > P*	A > P*
Foliage density at 2 m	ns	ns	A > P**	ns	ns
Foliage density a 3 m	ns	ns	ns	ns	ns
Mean pine diameter	ns	ns	ns	ns	ns
<u>Site characteristics</u>					
Elevation	ns	P > A***	P > A***	P > A**	P > A*
Soil depth	ns	ns	ns	ns	ns
Exposed rock	ns	ns	P > A**	ns	ns
Topography	ns	ns	ns	ns	ns

High Pine Rocklands is not equally amenable for at least four plants associated with such sites. Each species of that group (i.e., *Heterotheca graminifolia* var. *tracyi*, *Linum arenicola*, *Rhyncosia cinerea*, and *Stylosanthes calcicola*) was less likely to be present when foliage density was high at the 1 meter level. At 2 meters, only *Linum arenicola* exhibited a similar negative association with foliage density, and at 3 meters the relationship was non-significant for all taxa. Species occurrence was unrelated to mean pine diameter, a likely index of stand age. These results are not unexpected, and suggest that the population viability of a number of pineland herbs may be dependent on maintenance of open conditions near the forest floor. Maintenance of a community structure favorable for such plants will probably require a precisely tuned fire management system.

Table 7 also reflects the sensitivity of this group of High Pine Rockland species to small differences in elevation which do not result in a significant change in overall species composition. High Pine Rockland plots from which *H. graminifolia*, *L. arenicola*, *R. cinerea*, and *S. calcicola* were absent were lower in elevation than plots in which those species were present. With respect to the anticipated rise in sea level discussed earlier, this result suggests that losses in a number of sensitive understory herbs may precede more noticeable changes in overall community structure.

IV. RECOMMENDATIONS.

The management, acquisition, and research recommendations to follow are based on biological considerations, derived from the results reported above, the existing literature, and our experience in Florida Keys ecosystems over the last four years. Not included are administrative and politically-based recommendations: for instance, the necessity for cooperation and communication among agencies and organizations concerned with the biological integrity of the area. The management objective is assumed to be the restoration or maintenance of the ecological systems within the project area in their natural state. A second assumption is that all things are possible within the laws of nature, even in our current economic state, even in the fragmented ownership pattern of the project area, even on Big Pine Key.

IVA. Management "shoulds".

IVA1. Pineland management should treat High and Low Pine Rocklands as separate subcategories, with prescriptions designed specifically for each.

High and low pinelands differ in overall species composition, pine regeneration density, and the occurrence of rare and endemic species. They differ in the immediacy of the threat posed by rising sea level. They may differ in their influence on fire behavior, in their susceptibility to direct fire mortality, and in their post-fire succession rates and directions. Further research is likely to show that Low Pine Rocklands are wetlands by legal definition, while High Pine Rocklands are not. Now that it is possible to define these pineland types very precisely in the field, an accurate, objective map of their distributions within the project area would be --- with the aid of high quality photography --- a relatively simple task.

IVA2. Fire management should be directed at reproducing a forest structure which addresses specific needs.

In this study, potential effects of forest structure on seedling regeneration and the occurrence of a number of rare plants were examined. The data suggested that a developing broadleaved subcanopy had a negative impact on both groups of plants, but different canopy levels were involved. Other kinds of organisms (e.g., deer, tree snails, white-crowned pigeons) may have a range of responses to canopy closure. Efforts to manipulate structure through prescribed burning ought to consider this multiplicity of response for the forest as a whole. With these responses and a clear set of wildlife management objectives in mind, the burning program could go about creating and maintaining the distribution of "pineland recovery states" which best meets those objectives. The method of assessing forest structure used in this study are objective and relatively rapid, but other alternatives might be equally good.

IVA3. Management, especially fire management, should build in a research tie-in, with research feeding back on management, and vice-versa.

In the situation discussed above, the direction of the fire management program depends on understanding the structural preferences of important species groups. It is also an excellent example of potential synergism between management and research.

IVA4. Management should be directed, as much as possible, to restoring or maintaining the original hydrology of the system.

Several significant steps could be taken to restore the pre-development hydrology in the project area. Some are costly or politically difficult, others are relatively inexpensive.

1. Break mosquito-ditch connections which allow tidal flow between the ocean and areas of the interior which were originally non-tidal. Complete filling is unnecessary.

2. Re-assert tidal exchange in southwestern portion of project area, where it existed during pre-development times. Currently, levee on northernmost canal in Pine Channel Estates ponds water to the north. The probable effect is to increase the variability in salinity in the

area, potentially affecting upland areas to the north as well. Culverts should be placed through the levee at several locations, particularly toward the western end of the canal. Our understanding is that this levee has previously been the subject of a Corps of Engineers enforcement action, which they should be encouraged to follow through on.

3. Do not allow any filling within the project boundaries which would significantly impede surface water flow. This would include the paving of any of the existing dirt roads in the area.

4. Place and maintain culverts under Key Deer and Watson Boulevards in locations where the roadbed interferes with surface flow of water during wet periods. At present there are three locations on Key Deer and one on Watson where culverts would help to reestablish the original hydrology and vegetation of the area.

5. Eliminate or regulate commercial pumping of groundwater within and around the project boundaries, if not on the island as a whole. At a minimum, require commercial users of groundwater to pay a fee which would finance monitoring of the effects of their water use.

IVA5. In the absence of better information, management should assume that sea level will continue to rise at current rates, with consequent effects on plant communities.

Sea level has been rising at a rate of approximately 4 cm per decade for the last 55 years (Wanless, 1989). With a continuation of that trend over the next few decades, we can expect an ongoing loss of pinelands, as well as a gradual transformation of High to Low Pinelands. This is grim news, but must be taken into account in management and acquisition decisions. It obviously puts a premium on the highest land, and gives warning that procedures for transplanting rare plants upslope may become necessary. Sea level rise can also exacerbate the negative effects of existing or proposed impediments to surface water flow.

IVA6. Vegetation restoration should focus on filled areas and on closed-off sections of existing roads.

Restoration of areas degraded by vehicle traffic or filling will not always require active measures. A number of "roads to nowhere" can and should be closed off. Some of these would revegetate to a natural state within a decade or so without assistance, while others may require seedbed preparation, fill removal, replanting, or exotic control. Abandoned roads and roadsides, especially on upland sites, tend to have more than their share of rare and endemic plants.

IVA7. The goal of exotic plant management should be to keep them from becoming a more serious problem than they currently are.

Brazilian pepper and Australian pine were not well-established in native upland communities. Brazilian pepper occasionally grew to maturity and large size in mangrove or buttonwood-dominated wetlands, and may require control in such settings. Australian pine was most common where fill had been placed on wetlands, especially on mosquito ditch levees. Large trees should be removed to eliminate the major seed sources. *Ficus microcarpa*, a species that has become a problem in some areas, was observed occasionally in the project area.

IVA8. Future management should include a continuing monitoring program.

The vegetation observations on which this report is based ought to be repeated at five-year intervals in the same permanent plots, at the same time of year. The same areas should also be revisited in May or June of 1992, in order to record the presence of any species that were not detected in our early fall survey. Once a prescribed fire program has begun in the project area, a denser plot network and more frequent samples may be required.

IVB. Acquisition priorities.

IVB1. Two strong bases for prioritizing acquisition are watershed protection and uniqueness of the habitat within the project area.

There are 259 hectares within the project area, with 36% (94 hectares) currently protected under SFWMD, USFWS, or TNC ownership. Properties in the Western Coastal Fringe (12% protected) and the Southeastern Pinelands (23% protected) are currently underrepresented among protected lands (Table 8). Both of these zones have very significant ecosystem values. In particular, the Southeastern Pinelands may provide watershed protection for the Central Wetland Complex, by serving as a buffer against groundwater pollution from upslope septic sources in the heavily developed areas of Big Pine. The uplands of the Western Coastal Fringe historically formed a barrier between the marine systems and the interior wetlands during high astronomical and storm tides, though they were breached by tidal inlets that are no longer functional. Today, the hammock and transitional woodlands of this zone are still the most extensive and well-developed broad-leaved forests in the project area, and are nearly all in private ownership (Table 8).

IVB2. Another good rationale for prioritization is consolidation of fire management units.

Of the lots comprising the 165 hectares of privately-owned land in the project area, only a small proportion currently support a structure, but such lots are well-distributed. As such, they

Table 8. Protected[a] acreage in eight site types within the SFWMD project area. Areas (in hectares) are stratified by Biophysiographic Zone.

Biophysiographic Zone	Central Wetland Complex			Northwestern Pinelands			Southeastern Pinelands			Western Coastal Fringe			Entire Project Area		
Protection status	Total	Protected	%	Total	Protected	%	Total	Protected	%	Total	Protected	%	Total	Protected	%
Site Type															
Peaty Mangrove Forest	4.6	2.8	61	0.9	0.1	11	--	--	--	0.5	0.2	40	6.0	3.1	52
Dwarf Mangrove Mudflat	16.5	1.5	9	--	--	--	--	--	--	1.6	0.0	0	18.1	1.5	8
Supratidal Scrub	6.4	0.8	12	--	--	--	--	--	--	3.1	0.1	3	9.5	0.9	9
Freshwater Marsh	40.8	21.6	53	1.2	1.2	100	0.4	0.2	50	1.3	1.2	92	43.7	24.2	55
Transitional Thorn Woodland	16.4	6.7	41	--	--	--	0.2	0.0	0	7.4	0.3	4	24.0	7.0	29
Pine Rockland	61.7	28.6	46	24.2	18.2	75	20.6	6.2	30	1.6	0.2	12	108.1	53.2	49
Low Rockland Hammock	0.6	0.6	100	0.2	0.0	0	0.5	0.0	0	1.8	0.3	17	3.1	0.9	29
Developed/Disturbed	35.7	2.6	7	1.1	0.2	18	7.0	0.3	4	2.5	0.0	0	46.3	3.1	7
Total	182.7	65.2	36	27.6	19.7	71	28.7	6.7	23	19.8	2.3	12	258.8	93.9	36

[a] In USFWS, SFWMD, or TNC ownership

place an important limitation on the fire management program that is necessary for the long-term viability of the area's pinelands, because the program will require relatively large blocks of contiguous, undeveloped land. An attempt was made to identify privately-owned properties without structures whose purchase would allow blocks large enough to be burned efficiently to be consolidated under a single management philosophy. This was a two-step process. The first step was to identify suitable blocks in the interstices between the existing structures, and the second was to identify unbuilt privately-owned lots within each block. Three constraints were placed on the suitability of the blocks: 1) Size: a minimum size of 130 meters on a side was chosen; 2) Vegetation: pinelands comprised 75% or more of the block; and 3)Isolation: the edges of the block were more than 65 meters from the nearest structure. The lots whose purchase is necessary to complete such blocks are highlighted in Figure 16.

IVC. Research priorities.

The results described in earlier sections of this report are based on the covariation of site factors with vegetation variables, all expressed at a plot size of one acre. It was hoped that the relationships thus observed would allow the enumeration and testing of stronger hypotheses on the subjects of fire, hydrology, and the population biology of rare, endemic, and exotic plants.

Fire research with a fairly short return on investment might center on how within-unit variation in fire intensity and elevation affects a) the survival and seed production of mature pines? b) the survival of pine regeneration? c) the establishment of new pine seedlings? d) the survival and flowering of rare, endemic, and exotic plants? and e) the establishment of new individuals of these taxa?

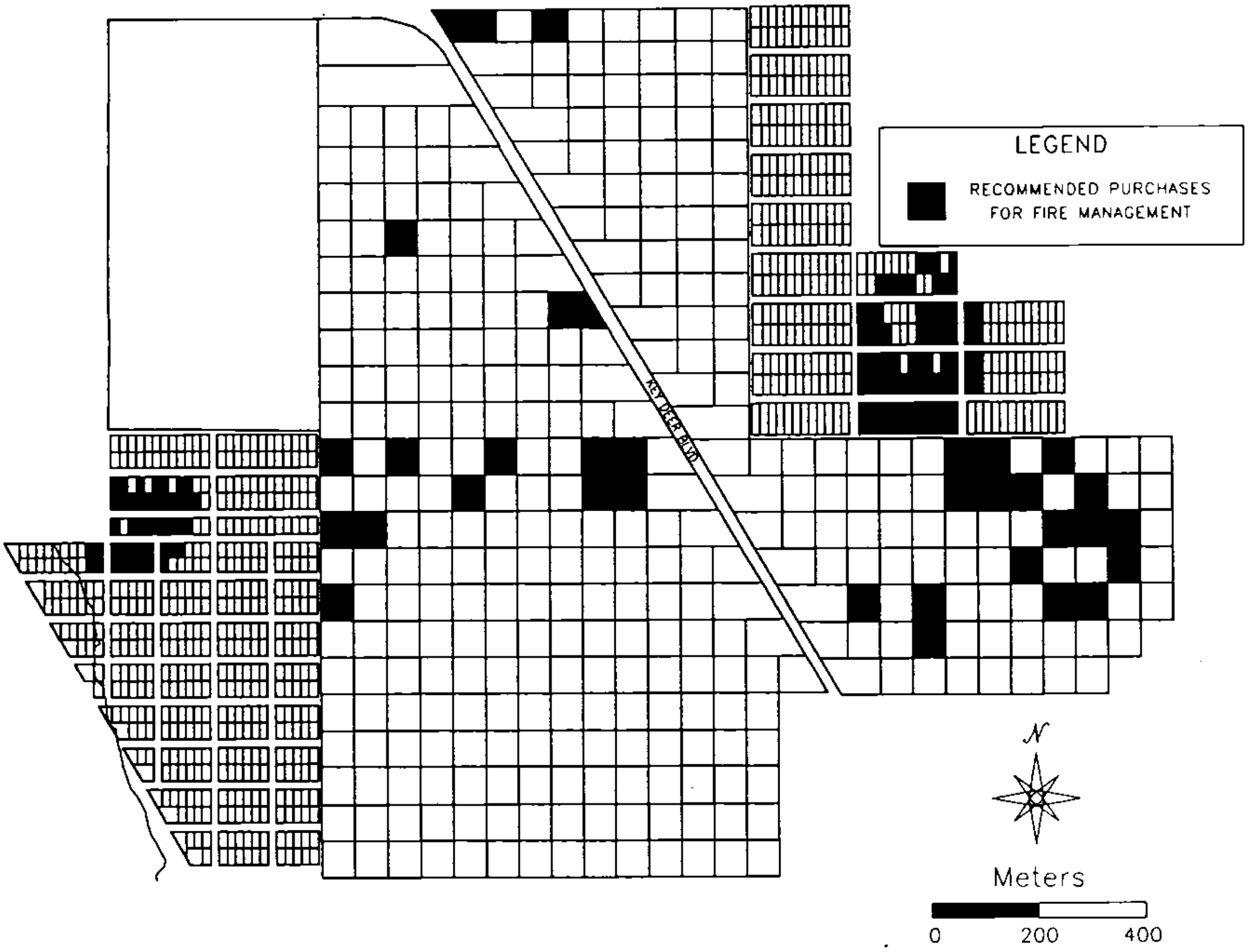

Figure 16. Privately-owned properties without structures that are necessary to consolidate large areas of pineland-dominated habitat for fire management.

Three hydrologic questions of great management importance come immediately to mind:

1. Do Low Pine Rocklands meet the federal definition for wetland hydrology?

2. Do mosquito ditches affect groundwater characteristics nearby?

3. Does nutrient pollution of suburban groundwater through septic systems adversely affect the groundwater characteristics of adjacent lands?

Finally, knowledge of the microhabitat requirements of the rare, endemic, and exotic species of the project area is necessary. What are their seedbed requirements? What sorts of hydroperiod do they tolerate/require? What sort of light environment is required for establishment? for reproduction? How are their seeds dispersed?

With luck and commitment, the SFWMD project area can provide a model for the integration of conservation management and conservation biology research, while preserving a unique piece of Big Pine Key's natural heritage.

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Appendix 1. List of plant taxa sampled in the SFWMD project area, with six-letter acronym, and status.

ACRONYM	TAXON	FWS[a]	FLA D of A[b]	FNAI[c]	ENDEMIC[d]
ABIOVA	*Abilgaardia ovata*				
ACAPIN	*Acacia pinetorum*				
ACRAUR	*Acrostichum aureum*		X	X	
AGASPP	*Agalinis* spp.				
ALOVER	*Aloe vera*				
ANDGLO	*Andropogon glomeratus*				
ANDVIR	*Andropogon virginicus*				
ANEADI	*Anemia adiantifolia*		X		
ANGBER	*Angadenia berterii*				
ARDESC	*Ardisia escallonioides*				
ARIPUR	*Aristida purpurascens*				
ASTTEN	*Aster tenuifolius*				
AVIGER	*Avicennia germinans*				
BACANG	*Baccharis angustifolia*				
BACMON	*Bacopa monnieri*				
BASCOR	*Basiphyllaea corallicola*		X		
BIDPIL	*Bidens pilosa*				
BLEPUR	*Bletia purpurea*		X		
BORARB	*Borrichia arborescens*				
BORFRU	*Borrichia frutescens*				
BOROCI	*Borreria ocimoides*				
BORTER	*Borreria terminalis*				X
BRAACT	*Brassia actinophylla*				
BUCFLO	*Buchnera floridana*				
BUMCEL	*Bumelia celastrina* var. *angustifolia*				X
BUMSAL	*Bumelia salicifolia*				
BYRLUC	*Byrsonima lucida*				
CACSPP	Unknown cactus				
CAEPAU	*Caesalpinia pauciflora*				
CARPAP	*Carica papaya*				
CASASP	*Cassia aspera*				
CASCHA	*Cassia chapmanii*	X			
CASEQU	*Casuarina equisetifolia*				
CASFIL	*Cassytha filiformis*				
CASKEY	*Cassia keyensis*	X	X	X	X
CATPAR	*Catesbaea parviflora*		X	X	X
CENECH	*Cenchrus echinatus*				
CENVIR	*Centrosema virginianum*				
CHAADE	*Chamaesyce adenoptera*				
CHADEL	*Chamaesyce deltoidea serpyllum*	X		X	X
CHAHIR	*Chamaesyce hirta*				
CHAHYS	*Chamaesyce hyssopifolia*				
CHAMES	*Chamaesyce mesambryanthemifolia*				
CHAPIN	*Chamaesyce pinetorum*				
CHAPOR	*Chamaesyce porteriana* var. *scoparia*	X		X	X
CHIPIN	*Chiococca pinetorum*				
CHRICA	*Chrysobalanus icaco*				
CIRHOR	*Cirsium horridulum*				
CLAJAM	*Cladium jamaicensis*				
CLUROS	*Clusia rosea*		X		
COCARG	*Coccothrinax argentata*			X	
COCNUC	*Cocos nucifera*		X		
COCUVI	*Coccoloba uvifera*				

Appendix 1. continued

ACRONYM	TAXON	FWS[a]	FLA D of A[b]	FNAI[c]	ENDEMIC[d]
CONCAN	*Conyza canadensis*				
CONERE	*Conocarpus erecta*				
CORLEA	*Coreopsis leavenworthii*				
CROILI	*Crossopetalum ilicifolium*				
CROLIN	*Croton linearis*				
CROMAR	*Crotalaria maritima*				
CRORHA	*Crossopetalum rhacoma*				
CYNBAH	*Cynanchum bahamense*				
CYNBLO	*Cynanchum blodgettii*				
CYNPAL	*Cynanchum palustre*				
CYNSES	*Cynoctonum sessilifolium*				
CYPPOL	*Cyperus polystachyos*				
DACAEG	*Dactyloctenium aegyptium*				
DESCAN	*Desmodium canum*				
DICFLO	*Dichromena floridensis*				X
DISSPI	*Distichlis spicata*				
DODVIS	*Dodonaea viscosa*				
ECHUMB	*Echites umbellata*				
ELECAR	*Eleocharis caribaea*				
ELECEL	*Eleocharis cellulosa*				
ENCTAM	*Encyclia tampensis*		X		
ERACIL	*Eragrostis ciliaris*				
ERAELL	*Eragrostis elliottii*				
ERIFRU	*Erithalis fruticosa*				
ERNLIT	*Ernodea littoralis*		X		X
EUGAXI	*Eugenia axillaris*				
EUGFOE	*Eugenia foetida*				
EUPTIR	*Euphorbia tirucalli*				
EUSEXA	*Eustoma exaltatum*				
EUSPET	*Eustachys petraea*				
FICCIT	*Ficus citrifolia*				
FICMIC	*Ficus microcarpa*				
FIMCAS	*Fimbristylis castanea*				
FIMSPA	*Fimbristylis spathacea*				
FLALIN	*Flaveria linearis*				
FORSEG	*Forestiera segregata* var. *pinetorum*	X		X	X
GALPAR	*Galactia parvifolia*				
GUADIS	*Guapira discolor*				
HABQUI	*Habenaria quinqueseta*		X		
HEDCOR	*Hedyotis corymbosa*				
HEDNIG	*Hedyotis nigricans*				
HELPOL	*Hedyotis polyphyllum*				
HETGRA	*Heterotheca graminifolia* var. *tracyi*				X
HYMLAT	*Hymenocallis latifolia*			X	
HYPWRI	*Hypoxis wrightii*				
IPOSPP	*Ipomoea* spp.				
JACKEY	*Jacquinia keyensis*		X		
JACPEN	*Jacquemontia pentantha*				
KALTUB	*Kalanchoe tubiflora*				
LAGRAC	*Laguncularia racemosa*				
LANINV	*Lantana involucrata*				
LIATEN	*Liatris tenuifolia*				
LINARE	*Linum arenicola*	X	X	X	X
LYCCAR	*Lycium carolinianum*				

Appendix 1. continued

ACRONYM	TAXON	FWS[a]	FLA D of A[b]	FNAI[c]	ENDEMIC[d]
MACLAT	*Macroptilium lathyroides*				
MANBAH	*Manilkara bahamensis*				
MANZAP	*Manilkara zapota*				
MELQUI	*Melaleuca quinquenervia*				
METTOX	*Metopium toxiferum*				
MIKSCA	*Mikania scandens*				
MONLIT	*Monanthochloe littoralis*				
MORROY	*Morinda royoc*				
MUHCAP	*Muhlenbergia capillaris*				
MUSSPP	*Musa* spp.				
MYRCER	*Myrica cerifera*				
MYRFLO	*Myrsine floridana*				
NEPPUB	*Neptunia pubescens*				
OPUSTR	*Opuntia stricta*		X		
PANNEU	*Panicum neuranthum*				
PANVIR	*Panicum virgatum*				
PASBLO	*Paspalum blodgettii*				
PASMON	*Paspalum monostachyum*				
PASSUB	*Passiflora suberosa*				
PECLEP	*Pectis leptocephala*				
PHYANG	*Physalis angustifolia*				
PHYNOD	*Phyla nodiflora*				
PHYPEN	*Phyllanthus pentaphyllus* var. *floridanus*	X			X
PILMIC	*Pilea microphylla*				
PINELL	*Pinus elliottii* var. *densa*				
PINPUM	*Pinguicula pumila*				
PIRCAR	*Piriqueta caroliniana*				
PISPIS	*Piscidia piscipula*				
PISROT	*Pisonia rotundata*				
PITGUA	*Pithecellobium guadalupense*				
PLUODO	*Pluchea odorata*				
PLUROS	*Pluchea rosea*				
POIPIN	*Poinsettia pinetorum*				X
POLBOY	*Polygala boykinii* var. *sparsifolia*	X			X
POLGRA	*Polygala grandiflora*				
PORRUB	*Portulaca rubricaulis*				
PSILON	*Psidium longipes*				
PSINUD	*Psilotum nudum*		X		
PTEAQU	*Pteridium aquilinum*				
PTELON	*Pteris longifolia* var. *bahamensis*		X		
PTEPYC	*Pterocaulon pycnostachyum*				
PTEVIT	*Pteris vittata*		X		
RANACU	*Randia aculeata*				
REYSEP	*Reynosia septentrionalis*				
RHABIF	*Rhabdadenia biflora*				
RHIMAN	*Rhizophora mangle*				
RHOSPA	*Rhoeo spathacea*				
RHYCIN	*Rhyncosia cinerea*	X		X	
RHYPAR	*Rhyncosia parvifolia*				
RHYREP	*Rhynchelytrum repens*				
RICCOM	*Ricinus communis*				
RUECAR	*Ruellia caroliniensis*				X
RUPMAR	*Ruppia maritima*				
SABGRA	*Sabatia grandiflora*				

Appendix 1. continued

ACRONYM	TAXON	FWS[a]	FLA D of A[b]	FNAI[c]	ENDEMIC[d]
SABPAL	*Sabal palmetto*				
SACOFF	*Saccharum officinarum*				
SALBIG	*Salicornia bigelovii*				
SALVIR	*Salicornia virginica*				
SAMEBR	*Samolus ebracteatus*				
SARCLA	*Sarcostemma clausa*				
SAVBAH	*Savia bahamensis*				
SCHGRA	*Schizachyrium gracile*				
SCHNIG	*Schoenus nigricans*				
SCHRHI	*Schizachyrium rhizomatum*				X
SCHSEM	*Schizachyrium semiberbe*				
SCHTER	*Schinus terebinthifolius*				
SCLVER	*Scleria verticillata*				
SERREP	*Serenoa repens*				
SESMAC	*Sesbania macrocarpa*				
SETGEN	*Setaria geniculata*				
SIDACU	*Sida acuta*				
SISARE	*Sisyrinchium arenicola*				
SMIHAV	*Smilax havanensis*				
SOLDON	*Solanum donianum*				
SOLSTR	*Solidago stricta*				
SOPTOM	*Sophora tomentosa*				
SORSEC	*Sorghastrum secundum*				
SPASPA	*Spartina spartinae*				
SPOVIR	*Sporobolus virginicus*				
STESEC	*Stenotaphrum secundatum*				
STRMAR	*Strumpfia maritima*		X		
STYCAL	*Stylosanthes calcicola*				X
STYHAM	*Stylosanthes hamata*				
SURMAR	*Suriana maritima*		X		
TERCAT	*Terminalia catappa*				
THRMOR	*Thrinax morrisii*				
TILBAL	*Tillandsia balbisiana*		X		
TILCIR	*Tillandsia circinata*		X		
TILFAS	*Tillandsia fasciculata*				
TILFLE	*Tillandsia flexuosa*		X		
TILUTR	*Tillandsia utriculata*				
TRASAX	*Tragia saxicola*	X		X	X
URELUT	*Urechites lutea*				
VANBAR	*Vanilla barbellata*		X		
VERBLO	*Vernonia blodgettii*				X

[a] "X" signifies designated status "UR2" or above by the U.S. Fish and Wildlife Service.
[b] "X" signifies designated status "T" or above by the Florida Department of Agriculture.
[c] "X" signifies designated status G3 or above by Florida Natural Areas Inventory.
[d] "X" signifies species is endemic or potentially endemic to south Florida.

Appendix 2. Cover class of selected rare and endemic plant species in 114 plots. Cover classes: 0, present but uncommon; 1, 0.3-1%; 2, 1-5%; 3, 5-16%; 4, 16-33%; 5, > 33%. Plot locations are illustrated in Figure 4. Full species names are listed in Appendix 1.

	Plot #													
Species	1E1	1E2	1W1	2E1	2E2	2E3	2W1	2W2	3E1	3E2	3E3	4E1	4E2	4E3
BASCOR														
BORTER		0	0		0	0	0			0	0	0	0	0
CASKEY			0											
CATPAR														
CHADEL			0				0							
CHAPOR	0	0	0		0	0	0	0			0		0	0
CROILI			0											
FORSEG														
HETGRA														
HYMLAT			0											
LINARE														
PHYPEN			0		0		0			0	0			0
POIPIN							0							
POLBOY	0	0	0	0	0	0	0			0	0	0	0	0
RHYCIN														
RUECAR				0						0				
SCHRHI			2		0		0			0				
STRMAR							0		0					0
STYCAL			0											
TRASAX														
VANBAR			0		0	0	0			0			0	
VERBLO														

	4E4	4W2	5W1	5W2	6E3	6W1	6W2	7E1	7W1	8E3	8W1	8W2	8W3	9E3
BASCOR														
BORTER		0	0	0			0			0	1	0		0
CASKEY				0			0		0					1
CATPAR														
CHADEL			0											0
CHAPOR	0	0	0	0		0	0		0	0	0	0	0	0
CROILI														
FORSEG							1							
HETGRA														
HYMLAT														
LINARE									0					0
PHYPEN		0		0			0		0	0	0	0	0	0
POIPIN														
POLBOY	0		0	0		0			0	0				0
RHYCIN		0		0			1							
RUECAR				0			0					0		0
SCHRHI	2	2		3		1	2	1	2	0	3	1		2
STRMAR			0											
STYCAL							0		0					
TRASAX														
VANBAR	0	0	0	1	0	0								
VERBLO														

Appendix 2. continued

	Plot #													
Species	9W1	9W3	10W2	10W3	10W4	11W1	BA1	BA2	BA6	BB1	BB2	BB3	BB4	BB5
BASCOR														
BORTER	0		0			0								
CASKEY			0	0	2		1			2	2	0		0
CATPAR														
CHADEL			2	3	0	0	0	0		0	0	0	0	
CHAPOR	0	0	0	0	0	0			0			0		
CROILI			0				0				0			
FORSEG														
HETGRA			0	0	1		0							
HYMLAT														
LINARE				0	0									
PHYPEN	0	0	0		1	0	0	0		0	0	0		0
POIPIN														
POLBOY	0	0	1	0	0		0	0			0	0	0	0
RHYCIN														
RUECAR	0		0		1	0	0			0		0		
SCHRHI	0	0	2	2	0	2	3	1	0	2	1	1	0	1
STRMAR														
STYCAL					0		0							
TRASAX														
VANBAR	0													
VERBLO														

	BB6	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC10	BD1	BD2	BD3	BD4	BD5
BASCOR														
BORTER										0				
CASKEY	0			0	0		1				2	2	0	1
CATPAR														
CHADEL					0		0						0	
CHAPOR	0	0		0	0	0				0				
CROILI														0
FORSEG														
HETGRA											0	0	0	
HYMLAT														
LINARE														
PHYPEN			0		0		0			0	0	0	0	0
POIPIN														
POLBOY	0		0	0	0	0	0	0		0	0			
RHYCIN				0					0		0		0	0
RUECAR	0									0				
SCHRHI	2		1		0	1	2			1	0	1	1	
STRMAR														
STYCAL				0							0		0	
TRASAX														
VANBAR														
VERBLO														

Appendix 2. continued

Species	Plot #													
	BD6	BD7	BE1	BE2	BE3	BE4	BE5	BE6	BE7	BE9	BE10	TA1	TA2	TA3
BASCOR					0									
BORTER														0
CASKEY	0		1	1	1	1	0	0				1	2	1
CATPAR														
CHADEL	0			0		0		1				0	1	
CHAPOR								0						0
CROILI												0		
FORSEG														
HETGRA			0	0	0	0	0					0		
HYMLAT														
LINARE			0	0	0						0			
PHYPEN	0		0	0	0	0	0	0				0	0	0
POIPIN					0							0		
POLBOY	0		0	0	0	0	0	0	0			0	0	0
RHYCIN			0	0	0	1	0					0	0	
RUECAR												0		0
SCHRHI	2		3	3			1	1			1	0		0
STRMAR										0				
STYCAL			1	1	0	0	0	0				0	0	0
TRASAX												0		
VANBAR		0						0						
VERBLO														

	TA4	TB1	TB2	TB3	TB4	TC1	TC2	TC3	TD1	TD2	TD3	TE1	TE2	TE3
BASCOR														
BORTER			0				0		0					
CASKEY		0	0			1	1		0					
CATPAR							0							
CHADEL		0	0			1	1		1	1	0	0		
CHAPOR		0		0	0		0	0			0	0	0	0
CROILI														
FORSEG														
HETGRA		0				0								
HYMLAT														
LINARE							0							
PHYPEN		0				0	0		0	0	0			
POIPIN						0								
POLBOY		0	0	0		0			0	0	0	0	0	0
RHYCIN		0				1								
RUECAR		0				0			0	0				
SCHRHI		0	0			1	1		2	2				
STRMAR														
STYCAL		0				0	0							
TRASAX		0												
VANBAR	0			0	0	0	0		0					
VERBLO		0												

Appendix 3. Mosquito ditches in SFWMD project area, with protected properties.