

Restoration Plan For Dade County's Pine Rockland Forests Following Hurricane Andrew



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for
Dade County's Pine Rocklands
Following Hurricane Andrew**

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Acknowledgements

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Section 1. Introduction and Scope

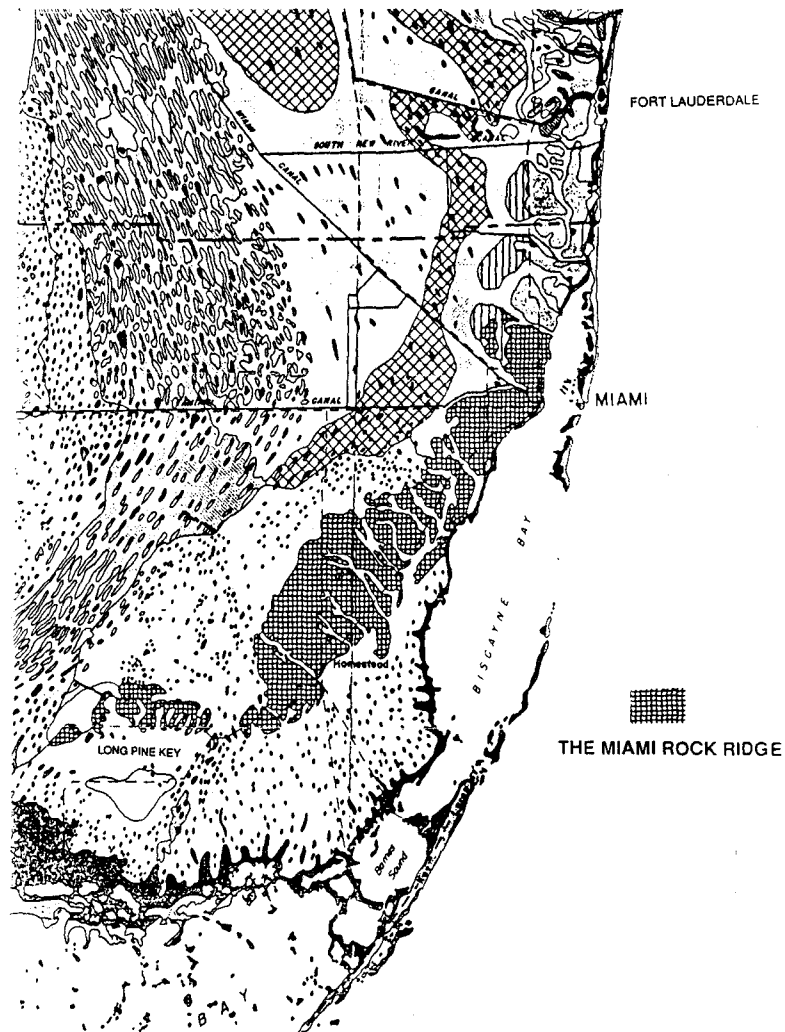
Hurricane Andrew crossed southern Florida on August 24, 1992 with sustained winds in excess of 145 miles per hour. Andrew's severest impacts were associated with the path of an intense eyewall, approximately 25 miles in diameter, which crossed Dade County between S.W. 120 Street and S.W. 408 Street. This region contains 4,400 acres of pine rockland forest, 99% of the acreage remaining in Dade County outside of Everglades National Park. Hurricane Andrew's destructive force exposed the fragile nature of Dade County's urbanized, highly fragmented upland forests. Initial damage assessments indicated that between 40% and 60% of the mature slash pine trees were snapped or uprooted by the storm. Seedling and sapling trees suffered less from direct impacts presumably because of their size and flexibility. The Florida Division of Forestry reported severe outbreaks of pine bark beetles (*Ips spp.*) and pine reproduction weevils in the year following the storm. Eighteen months after Hurricane Andrew, almost 90% of the mature slash pines had died as a result of initial and indirect (delayed) impacts. The loss of so much mature pine canopy in central and southern Dade has made reforestation of pine rocklands a high priority.

Several local agencies, including the Florida Division of Forestry, Dade County Park & Recreation Department, Dade County's Environmentally Endangered Lands Program, Dade County Department of Environmental Resources Management, and Fairchild Tropical Garden were involved in various aspects of pine rockland restoration before Hurricane Andrew. The restoration of Dade County's pine rocklands will require a sustained, cooperative effort by these agencies. The purpose of this plan is to establish the framework for future restoration activities. This document contains a summary of literature pertinent to the restoration of Dade County's pine rocklands and uses this information to build a comprehensive, long-term restoration and management plan. Section 3 contains a summary of pine rockland goals, objectives and recommended actions. This plan can be effectively implemented by using input and data from appropriate research and monitoring studies to build a baseline for decision-making. Research and monitoring reports on pine rockland restoration will be included as appendices to this document, so that future resource managers have a chronological record of restoration decisions and actions. Accomplishment of the restoration objectives for Dade County's pine rocklands will require continued interagency cooperation and support.

Section 2. Natural History of South Florida Pine Rocklands

2.1 Physiography, Soils, and Rainfall

Dade County's uplands were formed of Pleistocene marine sediments overlaid by coastal sand deposits. The Atlantic Coastal Ridge is the primary upland geologic feature in Dade County and its composition differs from north to south. In northern Dade County, deep Pamlico sands form the exposed portion of the Atlantic Coastal Ridge (Missimer 1984). In the southern portion of the Atlantic Coastal Ridge, between northeastern Dade County and the Mahogany Hammock region of Everglades National Park (ENP), the oolitic limestone bedrock is exposed. This topographic feature, called the Miami Rock Ridge, averages 9 feet and is no more than 25 feet in elevation and varies between 4 and 10 miles in width (Davis 1943; USDA, 1947). The surface of the rock ridge is very irregular with frequent pinnacle rock and solution hole formations. Numerous transverse channels were formed where Pleistocene tidal waters eroded portions of the oolite shoal. These transverse channels contained freshwater graminoid wetland vegetation before in presettlement times and divided the rock ridge into a series of islands that were historically covered by pine rockland forest. Dade County's pine rocklands occupied approximately 180,000 acres in presettlement times (USDA 1947).



Map of the Miami Rock Ridge (from Davis 1943).

The soil patterns of the restoration area are important. The USDA Soil Conservation Service (SCS) classifies two types of soils associated with slash pine forests in southern Dade County: Opalocka Sand-Rock Outcrop Complex and the Cardsound Rock Outcrop Complex (USDA 1990) (see Appendix 1). Opalocka Sand-Rock Outcrop soils are described as quartz sands overlaying oolitic limestone that is frequently exposed. Robertson (1955) called the rocky pineland forests associated with sand deposits, "Northern Biscayne Pinelands". According to SCS maps, the southern limits of the Opalocka Outcrop series is a line drawn roughly between the following points: approximately S.W. 194th Avenue and S.W. 216th Street; and, S.W. 112 Avenue and S.W. 240th Street. Sand deposits are not uniform in thickness and deposits appear to become thinner in the southern portion of the range. South of this line the soil group associated with pine rocklands is the Cardsound Rock Outcrop Complex. These soils are the typical "Redland" soils, i.e. shallow silty clay loams overlaying oolitic limestone with frequent rock outcroppings. Robertson (1955) termed these pinelands on shallow soils "Southern Biscayne Pinelands". Cardsound Rock Outcrop soils contain few soil deposits that would be suitable for pine planting.

The geographic location and the soil characteristics of any given restoration site will certainly influence reforestation strategies. Planting slash pine trees or tubelings may be very difficult in Cardsound Rock Outcrop soils. In Opalocka Sand-Rock Outcrop soils, the ability to plant slash pine may be improved due to the existence of sand pockets. Nevertheless, the effectiveness of planting and seeding will need to be explored on both soil types.

Rainfall patterns are important considerations in reforestation of pine rocklands. Rainfall in Dade County is spatially variable, over 64 inches fall annually in north-central to northwest Dade while between 48 and 56 inches fall annually in the remainder of Dade (Squillace 1966; MacVicar and Lin, 1984). More important is the temporal distribution of rainfall. Approximately 75% of the annual rainfall occurs between June and September. A distinct dry season generally occurs from October through May. Although the rainy season may start any time between May and July, years in which the onset of the rainy season is delayed beyond the end of June are generally considered to be drought years (Snyder et al. 1990). The seasonality of rainfall will be a key consideration in planning for restoration and management actions, including replanting, re-seeding, exotic control and fire management.

2.2 Flora of the Pine Rocklands

2.2.1 Floral Diversity

The Miami Rock Ridge was historically dominated by southern slash pine (*Pinus elliottii* var. *densa*) forests. Dade County's pine rockland forests are further characterized by a diverse understory of herbs, graminoids, and woody plant species. Its floral composition can be attributed to its proximity to the tropics, peninsular connection to the temperate zone, and the unique, isolated nature of the underlying limestone substrate (Robertson, 1953; Snyder, 1986). Loope et al. (1979) studied the understory vegetation of pine rocklands in Everglades National Park, Dade County, and Big Pine Key, Florida. Of the 76 taxa determined to be major floral components, 44% were of West Indian origin and 33% had a significant portion of their distribution north of southern Florida. A total of 135 herb and graminoid species and 50 woody species were recorded. Endemic species were found to be important in the pine rockland flora. Of the 76 ubiquitous understory species, 17% were endemic to South Florida. In total, over 55 endemic taxa occur in southern Florida pinelands (Herndon 1991).

Robertson (1955, p.118) stated that changes occurred in the herbaceous pineland understory as one travels north on the Miami Rock Ridge. He attributed this to increasing frequency of acid-sand pockets. The study by Loop, et al. (1979) confirm these observations. Of the 186 herb, graminoid, and woody species recorded, 31 occurred only in pine rocklands in Dade

County outside of Everglades National Park. Nine of these species were endemic to Dade County's pine rocklands. Many pine rockland plant species are now considered rare due to the reduction of this habitat type. The Florida Natural Areas Inventory considers approximately 40 pine rockland plant species to be globally rare. The Florida Game and Fresh Water Fish Commission (1994) includes 34 pine rockland plants on its list of Endangered and Potentially Endangered Fauna and Flora in Florida. The U.S. Fish and Wildlife Service lists five pine rockland plant species (*Amorpha crenulata*, *Euphorbia deltoidea* ssp. *deltoidea*, *Euphorbia garberi*, *Galactia smallii*, and *Polygala smallii*) as endangered and lists 12 species as candidates for listing (U.S. Fish and Wildlife Service 1988). Appendix 2 contains a comprehensive list of pine rockland plant species and includes their conservation status.

2.2.2 Exotic and Invasive Plant Species

Tropical and subtropical ecosystems are particularly prone to invasion by exotic plant species (Doren, 1991). Pine rocklands in subtropical southern Florida are no exception. Dozens of introduced plant species can be found in virtually every pine rockland forest stand outside Everglades National Park. Proximity to exotic seed sources and high degree of fragmentation contribute to this problem. Disturbance at the edges of pine rockland stands creates ideal sites for the establishment of exotic plants, which then have a greater potential to spread (by seeding or vegetatively) into adjacent undisturbed habitat. In addition to exotic pest plants, some native pioneer species have invasive characteristics. Examples include woody species such as Florida Trema (*Trema micrantha*), Southern sumac (*Rhus copallina*), Mahogany (*Swietenia mahagoni*), Wild tamarind (*Lysiloma latisiliqua*), and Willow bastic (*Dipholis salicifolia*); and, vines such as Poison ivy (*Toxicodendron radicans*), Grape (*Vitis spp.*), and Virginia creeper (*Parthenocissus quinquefolia*). Species such as these may be considered invasive in pine rocklands, and should be factored into vegetation control programs in pine rockland restoration.

Categorization schemes have been developed as a basis to prioritize exotic plant infestations and treatments. Florida's Exotic Pest Plant Council (EPPC 1995) published a list of the most invasive plants in Florida. EPPC's list divides exotic plants into two categories based upon the plant's ability to invade intact habitats and its range in Florida. Category I species invade and disrupt undisturbed ecosystems. Of the 60 Category I species in Florida, six can be found in pine rocklands. Category II species, based on their aggressive nature, have the potential to invade natural areas. Nine Category II species are known to occur in pine rocklands. Appendix 3 is a list of those exotic plant species on EPPC's list that occur in pine rocklands. Appendix 1 also lists many exotic plants, which are indicated by an 'E'.

Whiteaker and Doren (1989) categorized over 220 exotic plant species in Everglades National Park in order to prioritize management treatments. Exotic plants were categorized into five groups according to distribution, potential to invade native areas, and management approach. One of the key principles utilized in their prioritization scheme was published by Moody and Mack (1988). Frequently, the invasion of exotic plants occurs through the dispersal and establishment of a few seeds or propagules at a distance from a heavy infestation. The expansion of these isolated (outlier) infestations can quickly increase the total area infested. Treatment of outlier infestations greatly increases the effectiveness of exotic plant treatments. Treatment of the main infestation without treatment of outliers leads to rapid expansion of the exotic plant from isolated infestations. Whiteaker and Doren's categorization of exotic plants in Everglades National Park is listed below by priority.

- 1) Plants that are widespread, established and able to spread into undisturbed habitat. Population levels are so high that treatments must be focused on high resource value areas. Outliers are high priority for treatment.

- 2) Plants that are localized, but spreading rapidly, or have potential to do so. Because they are localized, they have high priority for treatment to prevent further spread.
- 3) Plants that are localized, but spread slowly due to short distance dispersal. Treatment priorities are determined based upon the value of the resource they are threatening. Monitoring of spread is encouraged.
- 4) Plants that form dense, monotypic stands on disturbed sites, but have not been documented as invaders of natural vegetation.
- 5) Plant species which have not naturalized, but are left over landscape species or annual weeds that occur in low numbers.

The categorization utilized by EPPC (1995) and Whiteaker and Doren (1989) are useful in developing control priorities and strategies. In pine rockland restoration exotic plant species that alter ecosystem or habitat structure (e.g. *Schinus terebinthifolius*, Brazilian pepper) or alter natural ecosystem processes such as fire (e.g. *Neyraudia reynaudiana*, Burma reed) should be considered a high priority for treatment. On a site specific basis, resource or habitat quality and severity of infestation should be evaluated in developing exotic control priorities.

Several dozen exotic plant species are known to invade pine rocklands. Their distribution, abundance, rate of spread, and habitat altering characteristics should be evaluated in order to prioritize treatments. Exotic plant treatments vary according to the characteristics of each species. Site specific exotic plant control plans should be developed in the context of future plans to restore pine trees and manage pine rockland habitat.

2.2.3 Biology of the South Florida Slash Pine

An understanding of the life history and reproductive biology of the South Florida slash pine is critical to reforestation planning and implementation in Dade County. South Florida slash pine (*Pinus elliottii* var. *densa*) is the keystone species of the pine rockland community because they strongly influence the species diversity and composition as well as physical processes maintaining the pine rocklands. Slash pines provide nesting and foraging habitat for wildlife. Fallen pine needles create a flammable fuel that influences the frequency and intensity of fire, thereby maintaining an open understory for pine seedlings and numerous endemic plant species. Pine needle fall comprises 70-80% of the total litter in pine rocklands. Pine litter accumulation begins to increase about one month before the wet season begins and is continuous throughout the wet season (Hemdon and Taylor 1985; Snyder 1986). The loss of this input of flammable fuel due to extensive post-storm pine mortality is a serious concern in southern Dade County. Maintaining the necessary frequent fire regime during restoration will be challenging without pine needles as a fine fuel source.

The reproductive cycle of slash pine takes essentially two years to complete. Pine flowering (sporulation) usually occurs between January and March before the spring flush of needles. Male strobili are sessile, short and in the lower crown on ends of branches. Female strobili form in the upper crown, often in whorls of 1-3. Wind-pollination takes place during this period of sporulation (Little and Dorman 1952). Male cones shrivel and fall soon after pollen is released. Fertilization takes place approximately one year after pollination. Maturing female cones remain green and with tightly overlapping scales (Tomlinson 1980). One year old cones (conelets) are stalked and usually 15-22mm long and 10-15mm wide (Little and Dorman 1952). Cones mature in August-September of the second year

(Lohrey and Kossuth 1990); the ripened cones are woody and enlarged (Tomlinson 1980). Generally trees seldom bear cones before being 10 years old and 4 inches in diameter. Most trees begin to bear large numbers of cones after 20 years. Heavy seed crops (masts) usually occur once every three years, however, in South Florida slash pine some amount of seed is usually produced annually. Two heavy seed crops were reported in the six year period between 1966 and 1971 on Long Pine Key (Wade et al. 1980). Mast crops have an even rather than a patchy distribution in pine stands (Platt pers. comm.).

The bulk of seed dispersal occurs in October, although some cones with seed may remain on the tree until March. Ninety percent of seeds fall within 150 feet of parent tree (Lohrey and Kossuth 1990). No extended seed dormancy is exhibited by slash pine. Under suitable conditions, viable seed generally germinates within six months (Platt pers. comm.). In other parts of the southern United States, slash pine (*Pinus elliottii* var. *elliottii*) seeds germinate in warm periods of the fall if adequate soil moisture exists. Some portion of the dispersed seed may over-winter and germinate in the spring. In warmer regions, germination occurs throughout winter (Derr and Mann 1971). Seed predation may be high. Major predators of pine seed in the southern United States include rodents, birds (including doves, quail, meadowlarks, and sparrows), hogs, rabbits, shrews, crawfish, armadillos, insects (ants), and cutworms (USDA undated).

Seedling establishment criteria are unknown in the wild. Seedlings go through a one to three year "grass stage" in which roots and stems thicken (Hardin 1993). Pine seedlings store carbohydrates in their roots during fall. These reserves are important for spring flush as low starch levels in roots have been correlated with seedling mortality in slash pine (McNabb, 1985). Seedlings are fire proofed by dense needle growth. Fast-moving fires do little damage to seedlings after their first year. After fire, saplings and seedlings may appear dead, but have been known to come back after 6-8 months. Fire also controls spot fungus, a pest of slash pine (Hardin 1993). Mature trees are protected from fire by thick, insulating bark comprised of expanded vascular cells (Landers 1989).

The slash pine life history and reproductive cycle outlined above provide important baseline information necessary in the development of reforestation and fire management strategies. Forest monitoring will be required to predict seed production, examine seedling survival, and evaluate management treatments. Fire management and reforestation efforts should be timed to closely follow the natural life cycle of slash pine.

2.2.4 Genetic Diversity of South Florida Slash Pine

Determining appropriate seed sources is required to effectively restore canopy to damaged pine rockland habitats. In natural areas restoration, much attention has recently been paid to the genetic make-up of restoration plant material. There is very little published information on slash pine genetics. Squillace (1966) investigated phenotypic variations in slash pine over its geographic range. The study concluded that variation in traits within and among stands tended to be greater in southern Florida. Squillace suggested that the discontinuous nature of stands in southern portion of the species' range may have caused the variation through genetic drift. Squillace stated that extreme southern Florida was undersampled, in fact, of the 54 stands sampled, only two were on rockland soils.

After the severe dry season of spring 1993, less than one year after Hurricane Andrew, local land managers and foresters knew that significant reforestation would be required in southern Dade County. All agreed that genetically appropriate slash pine seed stock has should be used. The major issue was determining the appropriateness of utilizing seed stock from sandy sites for reforestation on rockland soils. Differing edaphic (soil) conditions have been linked to phenotypic and genotypic variation in other pine species

(see Millar 1989, Furnier and Adams 1986). More information on the genetic diversity of South Florida slash pine was required for the planning of future reforestation efforts in Dade County.

To address this issue, Dade County funded a study of the genetic diversity of South Florida slash pine. The objective of the study was to gather genetic background data on this taxon in order to help determine which slash pine forest sites were appropriate seed donor sites for long term reforestation. The study was conducted by Dr. James L. Hamrick of the University of Georgia. Dade County and Florida Division of Forestry collected the samples from rockland and sandy soils throughout southern Florida. Excerpts from Hamrick's conclusions are printed below. The entire report is included in this document as Appendix 4.

"South Florida slash pine has a high level of genetic diversity as measured by these allozyme traits and the vast majority of its genetic variation occurs within rather than among its populations. Furthermore, although there are statistically significant differences in allele frequencies among its populations, the actual differences in allele frequencies are small and probably are not biologically important. There are even smaller differences in allele frequencies between the rockland populations from sandy soils. Only 0.4% of the total genetic diversity occurs among populations representing the two soil types. This result is undoubtedly due to the relatively small geographic scales involved, the close proximity of the rockland and sandy populations to one another, and the ability of conifer trees to distribute pollen over long distances.

Readers of this report should interpret the data presented here with some caution. The general consensus is that variation at allozyme loci are not subject to intense natural selection pressures. Thus, on a limited geographic scale such as South Florida, gene flow would be expected to be of predominant importance in shaping the genetic structure of the species. Other genetically controlled traits that are subject to more intense selection pressures (e.g. growth rate, tree form, insect and disease resistance, drought tolerance, etc.) would be expected to demonstrate more differentiation among populations and perhaps between the two soil types."

Hamrick's conclusions provide a portion of the answer to issue of seed source location. There is a very large amount of gene exchange between slash pine on rocky and sandy soils, which means that a portion of the genome of rockland slash pines probably comes from sandy site parents. Hamrick (pers comm.) does not predict that a high degree of natural selection occurs between the soil types due to the great amount of gene flow in the region; however, he recommends that Dade County implement a conservative approach to reforestation. That is, where possible, utilize rockland seeds for reforestation on rockland sites. Further, since rockland seeds may not be readily available, monitoring the germination and growth of slash pine on reciprocal soil types is strongly suggested.

2.3 Forest Dynamics and Structure

2.3.1 Fire and Canopy Structure

Several authors provided accounts of pine rocklands prior to the extensive logging that occurred in southern Florida before 1950. John Harshberger (1914) described pine rocklands as consisting "of tall slash pine trees...with an open canopy admitting light to the forest floor beneath. The trunk diameter may reach 1.5 meters, but in the forest there are all ages of growth, so that diameters vary widely". Lacking in Harshberger's documentation was any mention of the role of fire in the development of the forest structure he observed. Natural wildfire strongly influences the structure and composition of pine rockland forests (Robertson 1955, Wade et al. 1980, Platt et al. 1990, Snyder et al. 1990, Doren et al. 1992). The frequency, intensity, and season of fire influence the structure and composition of pine rocklands. The source of historic wildfire was primarily lightning. Most lightning activity in southern Florida is associated with summer convective storms. Ninety-three percent of the lightning-caused fires occur between May and September. Lightning strikes at the transition from dry to wet season are most likely to ignite and burn vegetation. In Everglades National Park, between 1948 and 1988, more acreage burned annually in the months of May and June (Snyder 1989). Throughout Florida, more wildland acreage burns in early summer (May-July) since fuel moisture is usually at an annual low during this period (Brenner 1991). These "transition season" fires burn larger acreages and burn with greater intensity than late wet season fires.

Doren, Platt and Whiteaker (1993) studied the structure of three pine rockland stands in relation to logging and fire history. They studied two unlogged sites and one logged (second growth) site. The logged site (Long Pine Key) and one of the unlogged sites (Pines West) were subjected to prescribed winter backing fires for approximately 30 years. The remaining stand, a remote, unlogged stand (Lostman's Pines), experienced primarily wet season head fires. Lostman's Pines had an uneven age structure, consisting of different patches of even-aged trees. The density of adult (i.e. > 4 inches dbh) pines was approximately 59 trees per acre with juvenile trees comprising 75% of the stand. The density of adult trees at Long Pine Key (logged, winter burned) was five times higher, 302 trees per acre. Juvenile trees comprised 34% of the stand. At Pines West (unlogged, winter burned) the density of adult trees was 196 trees per acre, while juvenile trees comprised only 15% of the stand.

The results of this study provide strong evidence of a direct relationship between pine rockland forest structure and both season of burn and firing method. Additionally, the structure of Lostman's Pines (unlogged, natural fire) may provide an excellent model for the development of reforestation goals and strategies. The winter prescribed burning regime implemented at Pines West altered the structure of this unlogged, old growth stand by killing the largest trees and discouraging the establishment of seedlings. Winter burning was conducted using "cool", backing fires. Backing fires reduce flame heights thereby reducing crown scorch to adult trees. Unfortunately, backing fires also move slowly into the wind and the flame front has a longer "residence time" in the forest understory resulting in the overheating of the mature trees' root systems. Backing fires are very effective in consuming all fuels in the stand under prescription. Seedlings, which typically germinate in fall, do not get the opportunity to become established in areas burned by winter backing fires because backing fires usually completely consume the understory. For this reason, few juvenile trees existed at either Long Pine Key or Pines West.

The structure of Lostman's Pine (unlogged, natural fire) was characterized by highly variable tree age classes and density. Natural fires, which presumably influenced the structure of this stand, occur as wind-driven head fires which have greater flame heights, but short residence times in the understory. Adult slash pine trees are rarely killed by such fires since they can refoliate if scorched by fires during the growing season. In addition, the short residence time of the flame front spares most grass stage seedlings. Fire can kill saplings emerging from the grass stage since their buds are not protected from heat, however head fires burn vegetation in a patchy manner thereby sparing a variable portion of the vulnerable saplings.

Robbins and Myers (1989) summarized the effects of season of fire and intensity on pines. Southern pines (including South Florida slash pine) are multinodal, which means that new buds and needles are formed 3-4 times per year in the growing season. In this way pines can refoliate if defoliated by fire in the growing season. Young and mature pines are less likely to die as a result of crown scorch early in the growing season. If defoliated after the last flush of needles late in the growing season, southern pines cannot flush again until spring. Pines injured by fire in the fall are more likely to die because carbohydrate reserves are at their annual low. Increased fuel accumulation can influence pine mortality. Roots growing in needle duff are susceptible to fire, especially in the dormant (winter) season. Young pines are more vulnerable to fire when fuel loading increases, thereby increasing fire intensity.

Fire has played a critical role in the evolution of pine rocklands, influencing various adaptations of ecosystem components. The role of fire in the maintenance and continued evolution of this ecosystem cannot be overemphasized. The restoration of appropriate fire regimes into forest fragments must occur in conjunction with their reforestation. By restoring and maintaining an uneven aged structure, the understory floral diversity will be maintained and the pine rockland fragments will be more resistant to disturbance.

2.3.2 Pine Rockland Understory Dynamics

Man's manipulation of natural ecosystems and subsequent recognition of natural fire's ecological and management role has prompted much intentional burning of wildlands in all seasons for a variety of purposes. Season of burn and its effects on understory vegetation have been discussed in the literature often in the context of prescribed burning for hardwood control (e.g. Robertson 1955; Wade et al. 1980; Snyder 1986, Waldrop et al. 1992). It is widely thought that winter burning is not as effective as growing-season burning in the control of invasive woody species. Woody species are generally dormant in winter with energy reserves stored primarily in their roots. Snyder (1986) studied the effects of winter and summer burning on pine rocklands. Winter burns were conducted in January and March, while summer burns were conducted in August and September. Hardwood top-kill occurred in both winter and summer burns. Hardwood recovery trends did not clearly parallel seasonality of burn; recovery of the 1-year post fire hardwood biomass after a summer burn was greater than the winter burn in one study area. In this burn, the fuel moisture of the summer burn site was very high, making the fire actually "cooler" than the winter burn. Snyder believes that fire temperature has a greater effect than season on hardwood recovery. In addition, since most hardwoods in pine rocklands are evergreen, it is thought that they may show less seasonal differences than deciduous species in response to fire.

Pine rockland is sometimes termed a fire 'subclimax' plant community, because the frequency of natural fire is sufficient to retard hardwood succession. Robertson (1955) argued that the pine rockland understory flora, with its high level of herbaceous plant endemism, is evidence that these forests burned regularly and often, but the effects of fire on the

herbaceous understory have not been extensively studied. Season of burn has little effect on the recovery of herbaceous (grass and forb) plant biomass; recovery to preburn biomass usually occurs within seven months. Most herbaceous plants flower and set seed after fire (Snyder 1986).

Most ecologists agree that pine rocklands on the mainland historically burned at least twice per decade. Platt et al. (1990) believe that the Miami Rock Ridge, due to its porous bedrock and dominance by pine forest, is potentially more flammable than the surrounding grassland (tropical savannah) communities. Increased fire frequency is thought to promote the development of grass or forb-dominated understory plant associations (Kozłowski and Ahlgren 1974; Daubenmire 1986; Waldrop et al. 1992). Grasses flower and reproduce more after early growing season fires (Platt, pers. comm.).

The mortality of mature pine canopy has drastically reduced the input of pine needles, a fine fuel that is important to sustaining the flammability of pine rocklands. Re-establishing native grassy fuels will be critical to maintenance of an appropriate fire regime on sites being restored. Managing urban pine rockland fragments in Dade County toward a grass-pine needle fuel composition would be ideal because:

- (1) less smoke is produced in the combustion of fine fuels than in the burning of woody fuels,
- (2) "mop-up" (extinguishing of smoldering material) and suppression are less problematic in fine fuels,
- (3) an open, grassy understory is ideal for pine reproduction,
- (4) an open, grassy understory enhances habitat for the pine rockland's diverse, herbaceous flora.

2.3.3 Pre- and Post-Andrew Structure of Pine Rockland Fragments

Fire is a frequent event influencing the structure of pine rocklands in southern Florida. Hurricanes also affect forest structure, but occur much less frequently. Hurricane Andrew was the most powerful storm to impact southern Dade County since the 1947 storm that ravaged the Richmond Naval Air Station, the location of the present-day Miami Metrozoo. Since the 1947 storm, Dade's pine rocklands have been further isolated from their historic source of ignition: lightning-caused everglade prairie fires. Lack of fire (fire exclusion) or too frequent winter-spring arson fires have contributed to the alteration of stand structure, often creating even-aged stands with little seedling recruitment and establishment. Data collected by DERM during the Natural Forest Community Inventory in 1990-1991 included the frequency of young and mature pines (DERM 1993a). The results (excluding the 853 acre Richmond Pinelands) show that just under one-half of the acreage sampled (1,606 of 3,255 acres) contained less than a 25% frequency of young trees. Seventy-nine percent of this acreage occurred on privately-owned land. Moderate-to-high (between 25% and 100%) frequencies of young trees were detected on 1,649 of the 3,255 acres sampled. Stand size appeared to correlate positively with the frequency of young pines as the mean size of low regeneration sites was 6.9 acres and on high regeneration sites 13.7 acres. These data may help define the scope of reforestation and locate sites in which forest monitoring may be desired.

Andrew's immediate impacts to pine rocklands were mostly limited to the canopy. Understory woody shrubs were defoliated and top-killed by the storm. Canopy damage was severe in most sites. In a study conducted by DERM and the National Audubon Society, the four pine rockland

stands sampled that were struck by continuous northern eyewall winds (considered to be the strongest winds of a hurricane) lost 62% of their trees; whereas, the four sites encountering Andrew's eye lost 42%. The Trinity Pineland, located north of the eyewall sustained only 10% mortality. Andrew removed approximately one-third of the trees from Long Pine Key in Everglades National Park. Higher mortality was observed along roads and adjacent to transverse glades (Doren et al. 1993). Lostman's Pines had less mortality than either Dade County fragments or Long Pine Key, losing only 15% of its trees. Most of the trees killed at Lostman's Pines were mature trees (Platt, pers comm.).

DERM resurveyed 18 pineland stands in the fall of 1993 to examine delayed mortality. The frequency of pines was measured in 5-6x6 meter plots located systematically along a 50 meter transect. Transects were laid in the same location as in the 1991 inventory. Prior to Andrew, the average frequency of mature pines in the sampled stands was 65.5%, while the average frequency of young pines was 28.8%. In 1993, the frequency of living mature pines had dropped to 6.7%; only two of the 18 sites surveyed had any live mature trees. There was no detectable decline in the frequency of young pines, however the sampling methodology could not have detected changes in density. Doren (1993) believes that chronic stresses, such as logging, fragmentation, and an unnatural fire regime, combined with Hurricane Andrew contributed to the extensive post-hurricane canopy pine mortality seen outside Everglades National Park.

2.3.4 Insect Pests

The delayed mortality described above has been attributed to a combination of physical tree damage, drought, and insect infestations. On June 16, 1993 Ed Barnard, Forest Pathologist and Jim Meeker, Forest Entomologist with the Florida Division of Forestry, visited South Florida to evaluate the mortality attributed to bark beetles. Meeker reported that inspection of standing, recently-killed trees at the Navy Wells Pineland Preserve revealed occasional occurrence of *Ips calligraphus*, and lethal levels of both *Ips avulsus* and *Ips grandicollis* in various life stages (larvae, pupae, and adults). The number of successful larval mines and pupal chambers located along parent galleries indicated that the bark beetles were reproducing rapidly and at a very high rate of success, reflecting a vigorous population.

The overall lack of pitch tubes in the presence of mass beetle attacks suggests that the pine trees were under severe moisture stress. The high winds of Hurricane Andrew undoubtedly damaged the root systems and conductive tissues, hindering moisture acquisition and translocation. Pitch tubes represent the pine tree's defense against bark beetles. The amount of pitch, and pressure under which pitch flows from wounds is directly related to internal moisture conditions. Coupled with a lack of moisture created by an abnormally dry spring in 1993, the most weakened trees in Hurricane Andrew's path were unable to defend themselves against insect attack.

Meeker said that a bark beetle epidemic was inevitable and little, if anything, could have been done to prevent it. Attempts to control the bark beetle epidemic were not justified, and seldom are successful. The cost and risks of insecticide treatments outweigh the value of the few potentially remaining treated trees. The remaining trees are still susceptible to future attacks because the damage to roots and conductive tissue will not be alleviated.

Two species of weevils, the pales weevil (*Hylobius pales*) and the pitch eating weevil (*Pachylobius picivorus*) can be serious pests of pine reproduction. They are collectively known as reproduction or regeneration weevils. Adults feed on pine seedling stems and roots, removing small patches of bark down to the wood. Heavy feeding activity essentially girdles young trees, causing their death.

The widespread abundance of dead, recently killed and dying pine trees in the path of Hurricane Andrew, created a large supply of breeding material for reproduction weevils. The bark beetle epidemic of 1993 would established an new supply of fresh material for weevils in 1994. All indications pointed toward a regeneration weevil population that could have been devastating to existing or planted pine seedlings in 1994, Meeker said in his report. Below are descriptions of three major pest insects of southern pines, including *Pinus elliottii* var. *densa*.

Ips Bark Beetles (*Ips* spp.)

Three species of *Ips* engraver beetles are present in the southern United States: 6-spined engraver (*Ips calligraphus calligraphus*), eastern 5-spined engraver (*Ips grandicollis*), and small southern pine engraver (*Ips avulsus*). They usually attack trees weakened by stress from storms, lightning, drought, fire, or wounds. All three species of *Ips* beetles may attack the same tree. Signs of infestation include, yellowing needles, red-brown boring dust in bark, and sometimes pitch tubes. Healthy trees can produce enough pitch to drown attacking beetles. Adults attack the upper crown and basal portions of large branches. Egg galleries are Y or H shaped. Feeding larva make individual tunnels. Exit holes of emerging adults look like scattered shot-holes (unlike black turpentine beetles in which many adults exit from same hole). The life cycle takes 21-40 days to complete. *Ips* are inactive below 59°F. The chemical control of *Ips* is seldom warranted (Connor and Wilkinson, 1983).

Adults carry Blue Stain fungus spores, which germinate in egg galleries. Fungus colonies grow and clog the water transport system of the host tree. This can cause the death of the host tree. "Brood" adults consume Blue Stain fungus spores before emerging from tree.

Pine Reproduction Weevils (*Hylobius pales* and *Pachylobius picivorus*)

Both species are frequent pests of young trees and seedlings, causing high mortality in some cases. Damage is highest within 100-200 feet of damaged trees, stumps, or logging slash. Weevils respond to odors associated with injured pines. Adults feed at night, eating the inner bark of twigs, and removing bark in irregular patches. Adults move to the litter layer in daytime.

Eggs are laid in crevasses on pine root collars. Larvae feed on the vascular tissue of the pine roots. Two to three generations may be produced in a year. Control includes delay of reforestation until at least one year after harvest (in Dade County's case, one year after hurricane related mortality of adult pines)(Dixon and Foltz 1990).

Black Turpentine Beetle (*Dendroctonus terebrans*)

The black turpentine beetle lives in the inner bark of pines and can be detected by the existence of long (18") vertical galleries (tunnels) or D-shaped galleries 12" across. This beetle usually attacks damaged or stressed trees greater than 6" in diameter. Black turpentine beetles are usually found in the lower 3-8' of the host tree, where they cause the formation of pitch lumps on the lower trunk which also aid in their detection.

Black turpentine beetles generally produce 2-1/2 to 3 generations per year. Individual larva can devour up to a 2 square foot area of inner bark before emerging. Emerging adult insects may attack the same host tree. Activity of adults is lowest in cool months. Black turpentine beetles do not carry Blue Stain fungus but may stress pine trees, making them more susceptible to attack by other species (wood borers, or *Ips* beetles) (Dixon 1986).

Section 3. Goals, Objectives, and Recommended Actions for Pine Rockland Restoration

Goal: Restore and maintain environmentally endangered pine rocklands to maximize biotic diversity and preserve their natural resource values.

Objective: Ensure that long-term inter-agency coordination and public support are maintained throughout the pine rockland restoration effort.

Recommended Actions:

- * Establish a Pine Rockland Restoration Committee made up of representatives from the Florida Division of Forestry, Metro-Dade County Park & Recreation Department, Dade County Department of Environmental Resources Management, Everglades National Park, Fairchild Tropical Garden, and The Nature Conservancy. The purpose of the Committee would be to establish priorities, periodically evaluate the progress of restoration, and plan future restoration activities.
- * Establish a Pine Rockland Research Subcommittee consisting of scientists and resource managers to address restoration issues requiring factual support, documentation, research and/or monitoring.
- * Execute appropriate interagency agreements to solidify essential pine rockland restoration components such as fire management, reforestation, exotic plant and animal control, and research.
- * Continue and expand efforts to educate the public through means such as the Natural Areas Newsletter, Adopt-a-Natural Area Program, the Post-hurricane Restoration Program, and the Environmentally Endangered Lands Program.

Objective: Restore and maintain naturally occurring plant and animal associations and the abiotic processes of the pine rockland habitat by employing appropriate management techniques.

Recommended Actions:

- * Conduct a comprehensive inventory of the pine rocklands of Dade County that includes status of pine canopy, extent of exotic plant invasion, soil type, flammable fuel loading, and property ownership. This inventory should be used to establish restoration priorities throughout the County. The inventory methods and existing databases being used by DERM, Fairchild Tropical Garden, and the Park & Recreation Department should be coordinated and shared.
- * Develop site-specific restoration plans according to the priorities determined from analysis of the pine rockland inventory. Utilize existing baseline inventory data to establish specific restoration objectives integrating fire management, reforestation, exotic control, monitoring and public relations. Establish and implement annual workplans as outlined by the Pine Rockland Restoration Committee.
- * Develop a county-wide fire management strategy by utilizing inventory data and examining funding, staff and locational needs and constraints. Execute interagency agreements that clearly identify the roles and responsibilities of the participating agencies. Implement the prescribed burning program to coordinate with reforestation, exotic control, and rare plant recovery efforts.

Objective: Re-establish South Florida slash pine in pine rockland habitats affected by Hurricane Andrew.

Recommended actions:

- * Determine the scope of reforestation required by reviewing existing forest inventory data, conducting additional inventories, monitoring status of pine rockland stands, and asking private landowners if they desire reforestation plant material.
- * Locate genetically appropriate seed sources to maximize the probability that reforestation materials will be adapted to site conditions. Monitor phenology of acceptable seed source areas to locate most productive collection sites and facilitate planning and coordination of seed collection.
- * Collect seed using methods that minimize damage to trees and pine rockland habitat. Continue to collect seed after sufficient seed collections are obtained for current needs to maintain a collection of South Florida slash pine seeds for future needs.
- * Initiate planning for the establishment of South Florida slash pine nurseries to provide supplemental seeds and seedlings for future pine rockland restoration needs in Dade County.
- * Monitor insect population levels to determine best time to replant or re-seed, and to detect potential threat to seed sources outside the hurricane impacted area.
- * Develop reforestation strategies that will (1) achieve uneven-aged forest structure, (2) mimic the density and distribution of pine trees occurring in appropriately-managed natural systems, (3) be coordinated with other restoration objectives and activities, and, (4) be conservative of reforestation tree stock.
- * Replant or re-seed in the season best suited to the survival of the respective material. Experiment to determine appropriate planting or seeding procedures for the density of trees desired. Utilize repellent treated seed in direct seeding efforts to minimize losses to seed predators.

Objective: Restore and maintain a forest canopy structure of uneven-aged pine trees and an understory with a mosaic of shrub gaps.

Recommended actions:

- * Conduct early wet season prescribed burns where possible to maintain open canopy structure, create pine recruitment sites and maintain understory plant species diversity and enhance the spread of native grasses. Utilize site preparation and firing techniques that minimize mortality to existing or re-established trees. Pre- and post-burn monitoring should be conducted to assess fire effects on vegetation. Fire behavior should be monitored to assess prescribed burning objectives and correlate fire behavior with management objectives.
- * Develop methodologies for the restoration of understory structure and composition including the control of palms and invasive woody species, and, the reintroduction of native herbaceous plants, particularly grasses. Experiment with the replanting or re-seeding of native grasses into sites where graminoid flora is reduced or lacking to re-establish fine fuels and enhance diversity.

- * Control invasive plants to minimize competition with pine trees and other native plant species. Control native woody species in reforestation areas to minimize competition with pine trees and create gaps in the shrub layer for pine reproduction and herbaceous flora.

- * Explore opportunities for restoration of hydric components of pine rocklands, including pineland/prairie ecotones.

Objective: Ensure the viability of rare, threatened, endangered, endemic species and species of special concern consistent with the preservation and enhancement of pine rockland habitat.

Recommended actions:

- * Monitor existing rare plant and animal species to ensure that such activities do not have an adverse impact on them.

- * Locate slash pine planting sites away from areas containing concentrations of rare or endangered plant species.

- * Re-introduce, where appropriate, rare plant and animal species to pine rockland sites.

Section 4. Management Recommendations

The restoration of Dade County's hurricane-damaged pine rocklands will require a long-term, multi-agency effort. This ecosystem, so highly fragmented by urban and agricultural development, now needs man's intervention to recover. Fire management, exotic species control, reforestation, endangered species management and recovery, public education, and safety are major elements that need to be addressed. The primary recommendation is to establish a Pine Rockland Restoration Steering Committee made up of professional and technical staff with expertise in various aspects of pine rockland management. It is proposed that the Pine Rockland Restoration Steering Committee consist of representatives from the Florida Division of Forestry, Metro-Dade County Park & Recreation Department, Dade County Department of Environmental Resources Management, Everglades National Park, Fairchild Tropical Garden, and The Nature Conservancy. The first task of the committee should be to endorse this plan as a template for future restoration activities. This plan can be effectively implemented by using data from appropriate research and monitoring studies to build a baseline for decision-making. Research and monitoring reports on pine rockland restoration should be added to this document as appendices so that future resource managers have a chronological record of restoration decisions and actions.

It is further recommended that a Pine Rockland Research Subcommittee be created to plan and implement essential research required in Dade County's pine rockland restoration efforts. Scientists and graduate students should also be encouraged to participate, as information gained through this effort may be broadly applicable. It may be advisable to create a pool of funds to reimburse researchers.

Interagency communication and coordination will be vital to successful pine rockland restoration and management. Interagency Memorandums of Understanding (MOU's) need to be developed that define agency responsibilities in pine rockland restoration, including fire management, reforestation, exotic plant control, monitoring, and education.

In this section, the key issues of pine rockland restoration will be addressed, beginning with the status of baseline information. Fire management recommendations are in subsection 4.2. Reforestation and understory restoration are discussed in Section 4.3. including the topics of exotic plant control and endangered species recovery. Each section addresses various administrative issues relating to the topic and provides recommendations for implementation.

4.1 Forest Inventory and Monitoring

The total number of pine rockland stands and total acreage that require reforestation are very important. Monitoring the health of living stands is also critical to prioritizing restoration activities. Inventory protocols should provide information necessary to integrate fire management, exotic plant control, endangered species recovery, and reforestation. Pre-storm inventories can provide useful information on the condition of forest stands. Several forest inventory and monitoring projects have been initiated in Dade County since Hurricane Andrew. The data generated by these projects will aid in determining appropriate seed collection locations, the scope of reforestation, and restoration priorities. This section outlines these ongoing inventory projects.

4.1.1 Natural Forest Community Inventory

Dade County had initiated a Natural Forest Community inventory 1990, but Hurricane Andrew interrupted the project in its final stages. Nevertheless, these data are useful in determining pre-storm stand conditions. This database, which is maintained by DERM, includes pre-storm frequency data for approximately 35 indicator plant species (including selected exotic plants, young and mature pines).

Approximately 375 pine rockland stands totaling nearly 4,400 acres remained outside of Everglades National Park in 1990. Pine rockland fragments average only 12.1 acres in size; ranging from 1 acre to 853 acres in area. Approximately one-half of the total pine rockland acreage in Dade County is in public ownership. Public properties tend to be the largest forest fragments remaining, averaging 48 acres in size. The Richmond Pine Rocklands, an 853 acre complex of forest owned by the county and various federal agencies located in south-central Dade, accounts for more than one-third of all publicly-owned pine rocklands. Dade County Park & Recreation Department manages approximately 1,070 acres. Federal agencies control nearly 440 acres mostly in the Richmond Pine Rocklands. The State of Florida CARL and Dade County's Environmentally Endangered Lands Program's acquisitions total approximately 290 acres (with an additional 400 acres on acquisition lists). The State also owns approximately 130 acres of the 300 acre Navy Wells Pineland Preserve.

Pine rockland reforestation actions will require prioritization within and between public and private sites. Private pine rockland sites average only 6.8 acres in size. The largest privately-owned sites, that are not on acquisition lists, are about 30 acres in size; and, several 20 acre sites exist. Many private pine rocklands remain designated as Natural Forest Communities (NFC); the designation carries with it local regulations regarding the proportion of each site which may be cleared.

The frequency data collected during this inventory provides a general view of prestorm forest structure. Section 2.3.3 summarizes these data. Appendix 5 contains a list of all existing pine rockland stands including ownership, size, and stand identification number, and pre-storm frequency of young and mature pines.

4.1.2 Computerized Pine Rockland Inventory

In 1994, Dade County was awarded funds from the Hurricane Andrew Urban Reforestation Grant Program to establish a GIS-based natural area inventory system for county-wide use. The source of the grant funds was a U.S. Congressional Dire Emergency Supplemental Appropriation Bill (PL-103-50). The computerized inventory, which will include approximately 150 pine rockland stands totaling approximately 790 acres, will be on line by September 1995. The inventory techniques were used by DERM during the development of a management plan for the 853 acre Richmond Pine Rocklands (DERM 1994).

The goal of the project is to classify important pine rockland stand conditions in order to identify restoration needs and priorities. The data collected during this project will allow for the creation of three map layers: Vegetation Classification, Forest Structure, and Fuel Loading. Descriptions of each classification scheme are included in Appendix 6. These data layers allow for rapid assessment of forest conditions. This database would assist in the planning and coordination of reforestation and management efforts by providing an inventory that could be periodically updated. The inventory will be compatible with existing county GIS coverages and could be used in future emergency situations to identify sensitive forest areas.

4.1.3 Remote Sensing

The Park & Recreation Department, in conjunction with the University of Wisconsin, is utilizing remote sensing techniques to map the natural areas of the Deering Estate, Matheson Hammock, Metrozoo/Larry & Penny Thompson Park, and the Tamiami Pineland Preserve. The purpose of this project is to assess the utility of using false-color infrared photography in monitoring natural areas in Dade County. Aerial color infrared photography is at a 1:24,000 scale and 1/2 meter pixel resolution in three color bands. The near red infrared band is displayed as red and reflects proportionate to the amount of chlorophyll biomass (green vegetation). It is also useful in discriminating wet and dry areas since infrared light is completely absorbed by water. Using these images, vegetation assemblages, patterns, and even some individual plant species can be identified using two methods. First, visual interpretation can be done on-screen or from original photographs. The other method uses computer programs to classify landcover types using statistical groupings of pixels with similar values in the three color bands. With this technology, changes in the cover of understory palms, exotic plants, fine fuels, and slash pine regeneration should be detectable.

4.1.4 Pest Insect Monitoring and Management

Dr. Jim Meeker, DOF's Forest Entomologist, is compiling post-hurricane insect trapping data. His office had recommended that planting be delayed to allow for the natural reduction in populations of pests of pine regeneration: weevils, tip moths, and pine web worms. Populations of pest insects should be at endemic or background levels by summer 1995, greatly reducing the risk to pine seedlings in future planting or direct seeding projects. Dr. Meeker recommends that reforestation areas be surveyed frequently to detect early damage from regeneration pests. Mortality or damage (from insect pests) to more than 30% of the seedlings or saplings in a 5% sample of the reforestation area is cause for concern. Pest outbreaks should be immediately diagnosed by Dr. Meeker at the Forest Pathology Office at the University of Florida. Pest management programs are more effective when initiated immediately upon detection of an outbreak.

4.2 Fire Management

Of all the fire-maintained habitats in Florida, pine rocklands and longleaf pine/wiregrass would rate as among the easiest to manage with fire. The reason is that the major flammable plant components of these communities are fine fuels (pine needles and grasses). These fine fuels help sustain the frequent fire intervals of these pine communities. When pine rocklands are kept on a frequent burn regime, heavier fuels, the chief contributors to smoke events, do not accumulate as rapidly. As a result, smoke management is simplified because the duration of smoke events is much shorter and "mop-up" is reduced. In pine rocklands, strong consideration should be given to the thinning of saw palmettos (*Serenoa repens*), particularly in more urbanized areas. Palmettos burn hotter than other vegetation and produce large volumes of smoke. The combined effects of decreased palmetto cover and increased native grass cover should markedly reduce smoke outputs from prescribed burns. In Section 4.3.1, the restoration of understory structure (palmetto thinning and native grass restoration) is further discussed as an important component in pine rockland restoration.

Early wet season fires (sometimes called lightning season or transition season fires) are best suited for the restoration and maintenance of pine rocklands, therefore prescribed burning should be conducted, whenever possible, in the early wet season. During this part of the year mature pines can more readily withstand the scorching that occurs during a burn. Pine seedlings, that have germinated in the fall of the previous year, also have a better chance of surviving. Invasive hardwoods are

more effectively pruned by fire. Burning in the early summer will be more effective in preparing sites for planting or seeding, because the herbaceous groundcovers will be given time to recover prior to reforestation (particularly direct seeding) in the late summer and fall. This is important in reducing the desiccation of seeds or seedlings. Most native grasses respond well to transition season fires, flowering and seeding vigorously in the fall. These aspects of pine rockland restoration are discussed in more detail in the sections following.

From strictly a vegetation management standpoint, fire management of pine rocklands is relatively easy. The primary difficulties arise from the proximity of pine rocklands to residences, roads, businesses. Dade County can have an effective burning program. It will require a dedicated public education effort and diligent monitoring program. Public notice is a minimum requirement prior to ignition of prescribed burns, but a greater effort must be made to educate the public of the benefits of fire. In doing so, the needs of the public can be expressed to local fire managers and the science of prescribed burning can be demonstrated to the public. Fire behavior, smoke emissions and fire effects should be monitored to assess prescribed burning objectives and correlate fire behavior with management objectives. Experimentation with innovative techniques is recommended to reduce smoke emissions and improve vegetation management. Each fire should be a study in how to improve some aspect of pine rockland management.

Fire management of pine rockland in Dade County's urban interface will be a significant challenge. Approximately 2,200 acres of pine rockland will eventually be in public ownership, once State and County acquisitions of pine rockland are completed. Consider the prescribed burning of these public sites during the ecologically-optimal early growing season. If the average burn unit size is 10 acres, and a 3-year burn interval is considered, then approximately 73 prescribed burns must be completed every year! Further, if the optimal burning window for ecological management is the 8-week period from mid-May to mid-July, then 9 burns would be necessary every week for this period - every year! This is an ambitious goal, but one that needs to be explored. The window of burning may need to be expanded to accommodate the magnitude of the burning program and site with particular management goals. A county-wide fire management strategy needs to be developed and funding needs to be secured to assure that the prescribed burning program persists. Interagency agreements are required that identify the roles and responsibilities of the participating agencies.

4.3 Understory Restoration

4.3.1 The Restoration of Understory Structure

The understory structure and composition of pine rocklands was historically probably highly variable, depending upon elevation, location, and edaphic factors. Alteration of the natural fire regime due to fragmentation has changed the understory of many stands. In stands on Opalocka Sand-Rock Outcrop soils, fire exclusion has led to the growth of dense stands of saw palmetto, often with little herbaceous diversity. There are many fire excluded pine rockland stands on Cardsound Rock Outcrop soils with an understory composition of dense, invasive hardwoods (both native and exotic). The ideal understory structure for pine rocklands should be similar to that which occurs in the frequently burned portions of the Richmond Pine Rocklands. Here the understory consists of a mosaic of palms, grasses and forbs. Hardwoods are present, but reduced in stature and cover. Palms occupy approximately 25% of the understory cover, while the shrub gaps are occupied by a diverse mixture of grasses and forbs (DERM, 1993b). It is recommended that the objective of pine rockland understory restoration be directed towards this structure and composition for the following reasons:

- (1) Gaps in the palm/shrub layer are required for the establishment of pines and the existence of the diverse understory flora. Without the maintenance of shrub gaps, pine rocklands cannot be self sustaining to any degree.

(2) Palms burn at temperatures several hundred degrees higher than grasses, therefore maintaining a dense saw palmetto cover will lead to consistently hotter fires. Restoring pines into such areas will be difficult, since hotter fires are more likely to kill young trees. Restoration of such areas should not be undertaken until palmettos have been thinned to recreate gaps in the shrub strata.

(3) Pine rocklands require fire to be self sustaining. The biggest hurdle to overcome in urban fire management is smoke management. Hardwood and/or palm dominated understories burn with higher intensity and produce much smoke. Grasses, on the other hand, produce less initial and residual smoke. "Mop-up" after prescribed burns is easier in grass-dominated sites. It is further recommended that Dade County examine the replanting or re-seeding of native grasses into sites where graminoid flora is reduced or lacking to re-establish fine fuels and enhance diversity.

4.3.2 Exotic and Invasive Plant Control

The control of invasive species is critical to pine rockland restoration. General priorities for control should be based upon the quality of habitat and the sensitivity of resources present. High quality habitat should be a high priority for treatment. Exotic-dominated disturbed areas, (e.g. stand edges) should be secondary in priority. This strategy will save money in the long run because it is cheaper to maintain high quality areas now then to restore them later. As an operational goal, exotic plant coverage should be kept below 1% of the vegetative cover. In order to maintain this low coverage, treatment of exotics is necessary at least once per year. If exotic plant treatments are conducted intermittently, the costs will rise dramatically because the cover of some exotics can expand extremely rapidly. Pine rockland substrate should not be damaged during exotic plant control or reforestation because exotic plants can quickly invade and dominate disturbed soil.

The existence of live pine trees will also influence exotic treatment priorities. Exotic invasion (particularly Burma reed) can increase the fuel loading of pine rocklands to extreme levels, which can dramatically increase the fire intensity in the event of a wildfire. In these situations wildfire can kill the pine canopy. Considering the great loss of mature slash pines in southern Dade County, any site that contains immature pine trees should be a high priority for exotic control and fuel reduction treatments.

Exotic infestations can threaten endangered plants by shading or crowding which can reduce their vigor and reproductive success. Exotic control activities (herbicide application and foot traffic) can also damage native vegetation, including endangered plants. Rare or endangered plants should be located prior to treatments. Herbicide applications must be done to avoid chemical contact with rare plants.

Several dozen exotic plant species occur in Dade County pine rocklands. Each species has different distribution, density and tendency to invade. Most exotic plants can easily invade disturbed areas where soil is newly scraped or damaged. Some species also invade intact habitats. Some of the species with the tendency to invade intact pine rocklands are: Rosary pea, Ear-leaf acacia, Lantana, Burma reed, Brazilian pepper, Sisal hemp, Woman's tongue, Dalbergia, Lead tree, Natal grass, Molasses grass, Silver trumpet, and Rattle box. Of these, the following can alter habitat structure and natural processes: Burma reed, Brazilian pepper, Lead tree, Woman's tongue, and Ear-leaf acacia, Dalbergia, and Silver trumpet. As work proceeds on the high priority exotics, an evaluation of the other exotics needs to be made. Pine trees are sensitive to competition from woody species including woody exotics. In addition, some exotics pose a significant fire hazard as their density increases, altering

the fuel characteristics of a stand. It is important to identify areas in which these plants pose concern to living pine trees or rare plants. Often, exotics in moderate to high cover classes contribute significantly to the fuel load. Particular attention needs to be paid to areas infested with Burma reed (*Neyraudia reynaudiana*). This exotic grass is more common on the sandy, Opalocka Sand-Rock Outcrop soils. Burma reed burns readily and with high intensity. Reduction of Burma reed cover in areas containing live pine trees should be a high priority. Exotic plant status should be assessed in order to determine reforestation, fire management and rare plant recovery priorities.

4.3.3 Endangered Plant Species Recovery

Pine rocklands contain a great number of rare and endangered plant species. The restoration and management activities advocated in this plan are intended to benefit these rare pine rockland plants. The U.S. Fish & Wildlife Service (1988) published a recovery plan for the endangered pine rockland plant species. The plan states that, due to the extensive destruction of pine rockland habitat, the delisting of these species may not be attainable. The Service recommends the acquisition and appropriate management of pine rockland sites; and, particularly stresses the need for prescribed burning.

The U.S. Fish & Wildlife Service's Recovery Plan also acknowledged the lack of information existing on these plants and recommended that monitoring of these plants be initiated. Dade County DERM, through grants from the Service, conducted status surveys and some life history monitoring on these species from 1991 to 1993 (DERM 1993c). With the assistance of the Endangered Plant Recovery program at Fairchild Tropical Garden, DERM conducted further monitoring of these species in 1994, focusing on habitat characteristics (unpublished). These data, and future monitoring of endangered plants and pine rockland habitat should help serve as a benchmark for the effectiveness of restoration and management activities.

The Center for Plant Conservation (CPC) and the Southeast Environmental Research Program (SERP) (1995) prepared a conservation plan for the native plants of Florida. This plan advocates the furtherance of public education and dialogue between resource managers and ecologists. The plan also recommends that *in situ* and *ex situ* plant conservation actions be integrated. That is, that disciplines such as plant genetics, horticulture and resource management should work towards common plant conservation goals. In Dade County, considerable progress toward meeting these objective has already occurred. Fairchild Tropical Garden's Endangered Plant Conservation Program, Dade County Park & Recreation Department, and Dade County DERM have worked cooperatively on a number of plant conservation projects.

4.4 Reforestation

Reforestation is an important aspect of Dade County pine rockland restoration, and one that will require a great deal of planning to be effective. Reforestation efforts should be planned to follow the natural life cycle of the South Florida slash pine. Results may not be visible for many years, as pine seedlings can remain in an extended grass stage in the understory. The following sections outline the key elements of pine rockland reforestation and how they relate to other restoration activities such as prescribed burning and exotic plant control.

4.4.1 Seed Sources and Collection

Monitoring of sporulation intensity and cone development will be useful to locate harvestable cones from appropriate locations. South Florida slash pines begin their reproductive cycle between January and March, but female cones remain much reduced in size for over one year after pollination. Male strobili fall from the trees soon after pollination. In the spring, finding the light-brown, male strobili on the ground indicates that pollen release has occurred. Female cones may be seen on smaller trees in spring, but usually they are obscured by needles. In summer, often two crops of female cones may be visible on a tree. Larger, ripening cones are located on upper branches away from branch tips, while young cones are located near the branch tips and may be obscured by a tuft of needles.

Estimating crop size and seed yield is easily accomplished. In "mast" years (maybe every 3 years in South Florida), the number of ripening cones per tree may double that of moderate years. Monitoring forest stands twice annually, in late February and between June and July, may be sufficient to predict relative crop size.

Cone crop size alone may not be proportional to seed yield since ovaries may abort, leaving portions of the cone without seed. Derr and Mann (1971) provide a procedure for estimating seed yield by cone dissection. After the cone is bisected with a knife, the number of exposed seeds are proportional to total seeds (per W.C. Asher, A formula for estimating slash pine seed yields. *Journal of Forestry* 62:37-39. 1964).

No. Seed Exposed	Total No. of Seeds
2	31
4	50
6	69
8	87
10	106
12	124
14	143

Phenological monitoring of sites on the Miami Rock Ridge should be initiated. Additionally, since the genetic profile conducted by Dr. Hamrick (see Appendix 4) indicated that other locations may be suitable, monitoring should be expanded to include likely seed donor sites. The following locations are known to have live trees and should be monitored: Long Pine Key in Everglades National Park, Trinity Pineland, Tropical Park, and A.D. Barnes Park. In addition, stands of individual slash pine trees (not in forests) in Dade County should be identified and monitored. These trees may be more accessible than those trees in natural areas and the seed collection should have little ecological impact. Several sites within the hurricane impact area have significant numbers of live trees. Monitoring of these sites is strongly recommended. Further, phenological monitoring should be combined with pine survivorship monitoring, since the scope of reforestation will depend upon these data.

It is recommended that each reviewing agency examine its resources, and consider taking responsibility for monitoring forest stands. Further, it is recommended that the public be made aware of Dade's reforestation efforts. Additional suitable seed source stands may be located in this way.

Monitoring of sites with mature or regenerative pine trees will be vital because it will define the magnitude of reforestation needed and help locate potential seed donor sites. This monitoring should be combined with insect monitoring to see if surviving saplings are threatened by regeneration weevils. If insect traps are not established, the existence of weevils may be determined by examining branches for tell-tale bark removal patterns. Wildfire will probably be a chief cause of mortality in stands with live trees. Efforts should be made to prevent wildfires in stands with live mature or immature trees. Sites that do burn should be monitored to determine the extent of pine mortality.

4.4.2 Restoration and Maintenance of Forest Structure

Lostman's Pines, the remote, old growth forest, is the best example of slash pine forest structure remaining in southern Florida. According to Platt (pers. comm.), the slash pine forest structure, like most conifers, consists of patches of even-aged trees, but the sizes of trees vary between patches. These patches represent cohorts of trees that have invaded openings in the canopy at differing times. The seedlings and/or trees within these patches can be quite dense, but thin as the cohort gets older. Most patches at Lostman's Pines are on the order of 1/4 to 1/2 acre in size and vary in shape. Mature trees, that cast seeds into forest canopy gaps, make up less than 25% of the overall pine tree population. The oldest trees may exceed 200 years of age. The forest goes through a continuous cycle of growth, reproduction, patch formation and thinning. This is the structure and process that must be encouraged in the reforestation of Dade County's pine rocklands. The large-scale, landscape level dynamics will not be achievable due to the small size of the forest fragments, but most sites (depending on size) will accommodate many patches of trees. Since it will take perhaps two decades for the first reforestation trees to reproduce, it is recommended that seeding or planting of sites be staggered at appropriate intervals to create an uneven-aged forest structure. The uneven-aged stands will be better suited to withstand 50 year Category-4 hurricane events, such as Andrew.

Trials will need to be conducted to examine all possible combinations of variables: soil type, planting vs. seeding, time of planting or seeding, repellent treatment, and the density of planting/seeding. Planting should be done in the wet season (June through October) to ensure greater seedling survival rates. Direct seeding trials should be conducted at various application rates and at various times of the year (e.g. normal seedfall time vs. early wet season). The survivorship and growth of trees needs to be monitored. Inspections for pest insect damage should also be conducted in reforestation areas.

On sites without living pine trees, small (1/4-1/2 acre) patches of pines should be established by seeding or planting. Care should be taken not to disturb areas with endangered plants while planting or seeding, as disturbance leads to exotic plant invasion. Additional patches of seedlings should be established several years after the first planting or seeding to create an uneven age structure. On sites with sparse mature pines, a similar strategy could be employed.

On sites with dense mature trees (Trinity Pineland is an example) artificially opening canopy gaps is recommended. Smaller trees can be felled to create gaps of appropriate size, the largest trees should be left to seed these areas. Burning the canopy gap areas is advisable several months prior to seed release. On large sites with a variety of age classes in different areas, it would be advisable to reforest more remote areas first, leaving areas adjacent to forested areas to be naturally seeded. Tree density in areas with sparse seedlings or saplings may be augmented by seeding or planting.

In terms of existing stand structure and status, priority should be given to sites without trees and with an understory structure containing adequate shrub gaps, followed by sites with only sparse mature trees. Sites without pines that require extensive structural restoration of the understory should be third in priority. Large sites should be given priority over small sites. Initial experimentation should be carried out on public land. Effort must be made to contact private landowners to determine their reforestation desires. Reforestation of private pine rocklands will be dependent upon the landowners commitment to the long-term management of the site. Both DERM and DOF have created staff positions to address this issue.

In dense understories, opening shrub gaps and maintaining existing shrub gaps is recommended. Pines are sensitive to competition from hardwoods (Oppenheimer et al 1988), and their growth would be enhanced by hardwood control. In addition, maintaining gaps in the shrub layer will create open understory habitat for pine regeneration and a diversity of grasses and forbs.

Most sites with dense understories have been fire excluded. Fire exclusion of more than 15 years usually results in the loss of herbaceous flora (Herndon, pers comm.). These areas presently have sufficient fuel to carry fire, but without pine needles and grasses, they have little chance of carrying subsequent fires. Strong consideration should be given to re-seeding or replanting such sites with native grasses. Appropriate native grasses should be grown for understory restoration. On sites that have reduced grass components, burning areas that have native grasses in the early growing season should stimulate seed production and promote the expansion of existing grasses.

Exotic plant species should be continuously monitored and controlled in reforestation areas. Exotic or ruderal (weedy) species are likely to invade sites in which the dense understory must be opened during structural restoration. If planting is opted for, these areas should be monitored to detect the invasion of exotic plants in the disturbed soil around plantings.

4.4.3 Planting vs. Direct Seeding

Much silvicultural reforestation in the southeastern United States today is done by planting (McNabb 1985). Most silvicultural land in the southeastern United States occurs on soils that can be readily manipulated (plowed, furrowed, or disked) prior to planting seedlings or containerized stock. In Dade County, these site preparation methods are not acceptable. The major goal of reforestation is to enhance and protect the biological diversity of pine rocklands. Endemic plants and oolitic rock formations are unique to this community type and their protection is a high priority. Reforestation of this magnitude has never been attempted in Dade County, therefore it is recommended that an experimental approach be taken. No reasonable reforestation method should be discounted unless it is shown not to work in the field.

Derr and Mann (1971) summarized direct seeding procedures used in the southern United States. Direct seeding is most appropriate for reforesting large acreages and is useful for restoring sites damaged by wildfire or windstorms. They reported that direct seeding was also effective in reforesting rocky areas such as slopes which could not be planted. At normal application rates seeds became lodged behind rocks and germinated. Among the advantages were lower cost (due to high labor costs for planting) and the establishment of trees randomly rather than in rows.

The advantages of planting include efficient use of limited seed and extended planting season. Disadvantages are increased cost and site preparation, and inconvenience of handling. Containerized pine seedlings can grow well under adverse planting conditions because their root systems are undisturbed and can acclimate to site conditions (Barnett and Brissette 1986, Vanderveer 1993). It is unknown whether effective slash pine reforestation can be accomplished in the rocky soils of Dade County. In areas with some sand pockets, planting could be attempted; however, observations of seedlings and trees growing on both soil types in Dade County seem to indicate that most trees become established in crevasses in the oolitic rock rather than in the sand pockets. With southern pines, seedlings are grown in tubes that are 4-5 inches long and about 1-1.25 inches wide. Hand planting is often done using a hand dibble, which displaces the soil to make room for the seedling. Hand dibbles could be used in sandy areas of appropriate depth in Opalocka Sand-Rock Outcrop soils, but probably would not work in rocky, Cardsound Rock Outcrop soils. Monitoring of both planted and seeded areas will be required to determine the most effective reforestation method on each soil type.

Consideration should be given to establishing a slash pine seedling nursery in Dade County. Currently, the Division of Forestry operates a nursery in Chiefland, located in northern Florida. The variation in climate between northern and southern Florida has some disadvantages to reforestation in Dade County. Since slash pine seedlings can be damaged by frost, the DOF must delay sowing of seeds until after the last frost. Under normal growing regimes, the earliest that tubelings can be ready is mid-July, whereas the optimal time to start planting is in early June. Having a nursery in Dade County would provide some seedlings for early planting, allowing reforestation efforts to be expanded over the entire summer. This is preferable, since mustering resources for planting within a narrow window of time can be problematic.

A major issue with reforestation in Dade County is the amount of seed necessary to reforest. Currently, no substantial seed collection exists for South Florida slash pine. A small amount of seed were collected in 1993, but it is far below the amount necessary for large scale reforestation. Derr and Mann (1971) recommended that for slash pine, broadcast rates be approximately 1 pound of seed per acre. Slash pines average 13,000 seeds per pound. In order to obtain one pound of seeds, if the average cone contains 100 seeds, 130 cones would need to be collected. The application rate and coverage recommended by Derr and Mann was intended to establish a dense, even-aged stand over an entire site. In pine rockland reforestation, it is recommended that 1/4 to 1/2 acre patches of even-aged trees be established. In order to recreate uneven age structure, seeding or planting should be staggered, with several years between seeding or planting. This will create a desirable forest structure and reduce the immediate demand on seeds.

Slash pine seeds have a high germination rate, greater than 85% (Derr and Mann 1971). Growing tubelings or container stock will not be problematic; however, seed predation will be a great concern in direct seeding. Prior to direct seeding, seeds can be treated by applying a repellent coating to deter rodent and bird predators. Derr and Mann (1971) used a combination of repellents, Thiram and Endrin, and found that they were effective against seed predators. Thiram is a bird repellent and fungicide while Endrin repels mammal and insects. (Endrin is no longer on the market, however several other repellents are available¹). Derr and Mann (1971) reported that only 2% of untreated slash seed produced seedlings whereas 26% of the treated seeds did produce seedlings. It should be noted that the application rate

1 . In April, 1995, DOF and Dade County collaborated on a study of the effectiveness of three repellents that are on the market: Gustafson 42, RoPel, and Hot Sauce. The results of this study are in the process of being summarized.

used in this study was over 22,000 seeds per acre. Seed predators, like any predator, are attracted to dense food supplies. If direct seeding were conducted by seeding small patches using low broadcast rates (500-1,000 seeds per patch depending on size), seed predation may be reduced. Storage of repellent-coated seeds is not recommended, but cold storage of treated seed for 40-120 days is not detrimental.

The season of planting or seeding is critical to the survival of seedlings or tubelings. Adequate soil moisture is the key determinant. Slash pine can be sown in fall or spring in northern Florida, but spring generally has given good results in silvicultural practices. Fall sowing after 2-4" rainfall is effective (Derr and Mann 1971). McMinn (undated) studied direct seeding in southwestern Florida. He found that the best germination occurred at the shallowest soil depth with adequate soil moisture. Fall seeding provided satisfactory results because soil moisture remained high from summer rainfall. In pine plantations in sandy soil, over 70% survival of planted seedlings is frequently accomplished (McNabb 1985). Soil moisture is most critical at time of planting. Planting during drought conditions, spring in Dade County, is not advisable (Barnett and Brissette 1986).

To conclude, both planting and seeding have advantages and disadvantages. Both techniques will need to be experimentally attempted in both soils types in the reforestation area. Both planting and seeding should be conducted to create a patchy forest structure. It is recommended that planting trials in rocky soils be conducted in recently-disturbed, high quality areas rather than intact areas with high resource value, such as areas containing endangered plants. Direct seeding should be conducted using various, low rates in patches. Low application rates may attract less predators and conserve seed.

4.4.4 Site Preparation

Site preparation techniques have been tested in the southeastern United States primarily in conjunction with silvicultural practices. Lennartz and McMinn (1971) examined several site preparation treatments prior to planting slash pine. Treatments reduced initial competitive vegetation to help establish planted pines. In all cases, trees grew more rapidly on prepared sites. The clearing treatment (burning followed by removal of competitive vegetation by bulldozer) was the most effective because it removed vegetation more completely. Burning without other vegetation removal was the next most effective treatment. In pine rocklands, site preparation must be limited to burning and/or manual treatment of competing vegetation because oolitic limestone formations are fragile and unique. Soil disturbance frequently leads to invasion by exotic pest plants which degrades the site and increases long-term management costs.

Whether sites are replanted or re-seeded, site preparation considerations include protection of living pine trees (if any exist), exotic plant control treatments, understory structural restoration, and prescribed burning. The timing of site preparation is important. As much as possible, burning should be accomplished in the early growing season, mid-May to mid-July after the first rains. Burning in this season should enhance the native grasses, which provide important cover for pine seedlings and improve the fine fuel characteristics of the site. In smoke sensitive locations, reduction of heavy fuels (3" or greater in diameter) may be required to reduce residual smoke problems.

Site preparation should include provisions to minimize the mortality of living pine trees (in any size class). Fuel should be reduced around living pines, particularly palm fuels that burn at high temperatures. In addition, the exotic grass Burma reed (*Neyraudia reynaudiana*) should be controlled in any management area containing live trees due to its flammability. Burning priority should be given to areas without living pines to reduce the threat of wildfire carrying into adjacent areas with living pines.

Grass stage seedlings should be able to withstand brief headfires, but backing fires may be detrimental. To be safe, it is recommended that individual seedlings or patches of seedlings be wetted or foamed to reduce the heat encountered by the bud. Patches of seedlings should be left unburned by foaming and blacklining. Fuel reduction may be desirable in stands that have existing pines to minimize threats from wildfires. Fuel reduction will also serve to improve the understory structure of stands. Removal and treatment of Burma reed that exists in these stands is strongly recommended. Mature trees have root systems that are susceptible to heat, therefore foaming the area beneath the dripline may prevent overheating of the roots. On sites that contain patches of seedlings or saplings, it may be advisable to burn those portions of a site not containing seedlings or saplings in order to protect valuable regeneration.

If a site contains only mature trees, decisions to burn should be based upon tree density and long term reforestation goals. If mature trees are sparse, it may be desirable to burn portions of the site that don't contain trees several months prior to seed fall. If trees are too dense, protection of the largest vigorous trees should be the first priority.

The recommendations offered above, in addition to preparing sites for reforestation, will provide additional benefits. These sites will have significantly improved understory structure and composition (fewer exotics and more shrub gaps) necessary for pine regeneration and long term sustainability of a diverse herbaceous layer.

4.5 Other Management Issues

4.5.1 Private Site Management

Management of private sites is an issue that needs to be addressed. There are approximately 325 privately owned pine rockland stands in Dade County. They range from one acre to 90 acres in size. The average size of these stands is 6.8 acres and many of the larger vacant parcels have been proposed for acquisition by both the Dade County Environmentally Endangered Lands and State of Florida CARL Programs. The restoration and management of the remaining private sites will be dependent on the desires of individual landowners. DERM and the Division of Forestry have initiated programs aimed at providing incentives, management advice and training to landowners. The Tax Reduction Program administered by DERM allows owners to voluntarily restrict their property's development rights; and, in return receive a reduced property tax assessment. DERM's Post-hurricane Forest Restoration Program provides management advice and training to landowners interested in restoring their forestland. The program is funded through December 1995 by a federal emergency allocation. The Division of Forestry initiated a the Hurricane Andrew Wildfire Reduction Program (HAWRP) to assist landowners in creating firebreaks and reducing post-storm hazardous fuel accumulations. This program will end in September 1995. The DOF will retain a forester through 1996 to help coordinate reforestation efforts. Funding should be sought to continue these State and County programs.

4.5.2 Pine Rockland "Clean-up" Efforts

In the three years since Hurricane Andrew, much cleanup of pine rocklands has already occurred. The Federal Emergency Management Agency (FEMA) funded the removal of dead pines that posed a safety hazard in public parks. The Division of Forestry, with FEMA funding, created the Hurricane Andrew Wildfire Reduction Program HAWRP, which will end in September of 1995.

There still exists a substantial number of dead standing pine trees in southern Dade County. These "snag" trees provide a remarkable ecological benefit for wildlife. Snags are habitat for a host of cavity nesting birds including woodpeckers and owls. Snags provide roosting habitat for a number of large birds of prey including osprey, eagles and hawks. It is strongly recommended that snags remain standing, wherever they do not pose a safety hazard. Prior to prescribed burns, snags can be secured by a foam application at the base. Despite efforts to preserve snags, they eventually will fall. Consideration should be given for the establishment of artificial snags to provide some of the habitat benefits of dead trees.

Other forms of clean-up, such as removal of vegetation (living or dead) or debris should be conducted in a manner that does not degrade the pine rockland substrate. Exotic plants can quickly invade if soils are damaged as often occurs when sites are bulldozed. The removal of pine rockland vegetation is regulated by County Code Chapter 24-60. A permit is required prior to removal of any vegetation or debris.

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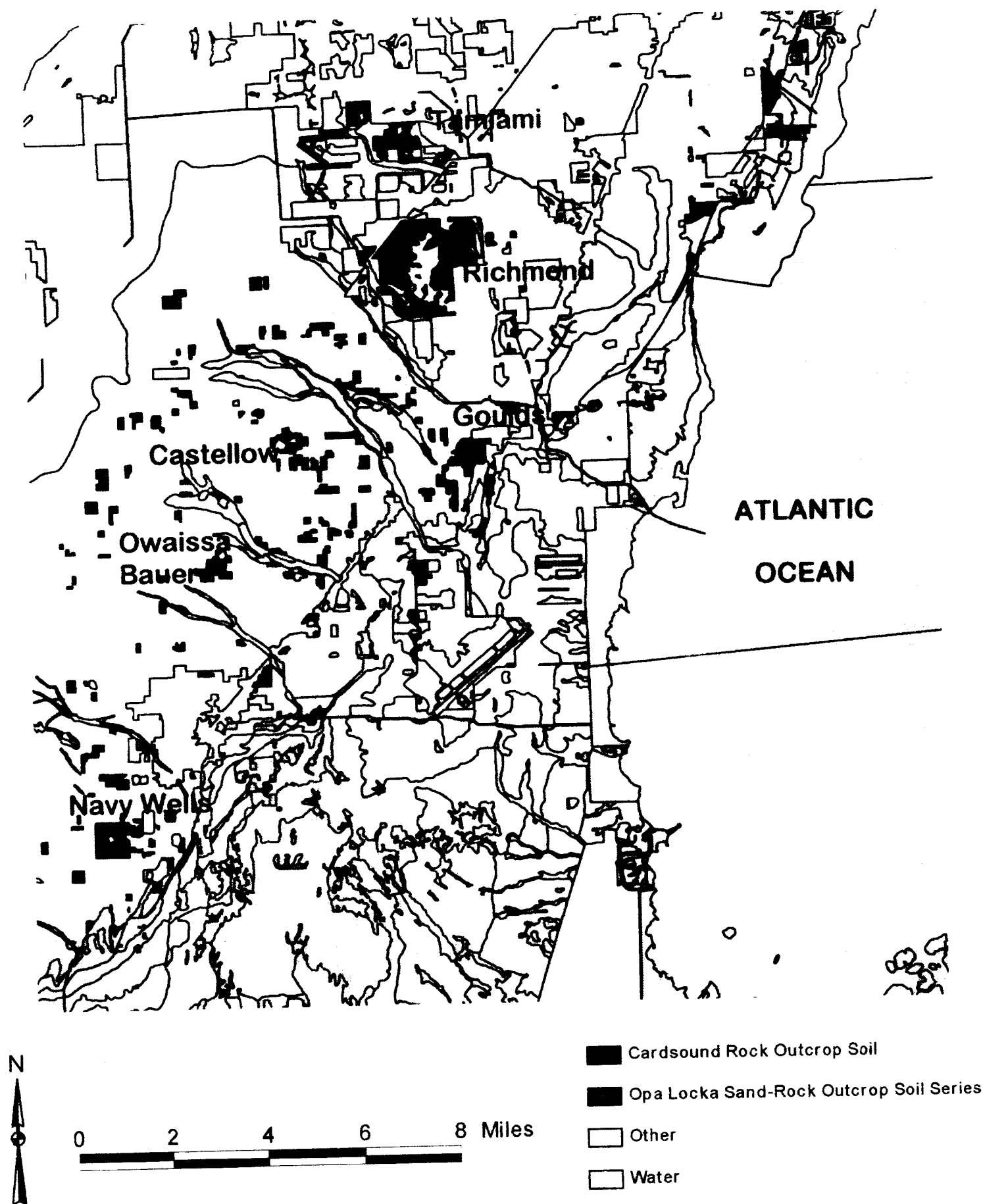
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Appendix 1
DADE COUNTY PINE ROCKLAND SOILS
(Soil Conservation Service 1994)



Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

Plant taxa are listed by habit and origin.

"N" indicates native to South Florida rocklands.

"R" indicates ruderal (including taxa of undetermined origin).

"E" indicates exotic to South Florida rocklands (includes native taxa naturalized outside of historic range).

➤ indicates that the species is considered *endangered* by the United States Fish and Wildlife Service.

◦ indicates that the species is considered *threatened* by the United States Fish and Wildlife Service.

▪ indicates that the species is a *candidate* for listing by the United States Fish and Wildlife Service.

GRAMINOIDS (Grasses and Sedges)

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Abildgaardia ovata</u> (<u>A. monostachya</u>)	Flat-spiked Sedge	N
<u>Andropogon glomeratus</u> var. <u>pumilus</u>	a Bushy Bluestem	R
<u>Andropogon gyrans</u> var. <u>gyrans</u>	a Bluestem	N
<u>Andropogon longiberbis</u>	a Bluestem	N
<u>Andropogon ternarius</u> var. <u>cabanisii</u>	Southern Splitbeard Bluestem	N
<u>Andropogon tracyi</u>	Tracy's Bluestem	N
<u>Andropogon virginicus</u> var. <u>virginicus</u>	Virginia Bluestem	N
<u>Aristida condensata</u>	Big Threeawn	N
<u>Aristida purpurascens</u>	Arrowfeather	N
<u>Aristida beyrichiana</u> (<u>A. strica</u> of authors)	Wiregrass	N
<u>Arundo donax</u>	Giant Reed	E
<u>Bothriochloa pertusa</u>	Two-hole Grass	E
<u>Bouteloua hirsuta</u>	Hairy Grama	N
<u>Brachiaria mutica</u> (<u>Panicum purpurascens</u>)	Paragrass	E
<u>Bulbostylis barbata</u>	a Sedge	E
<u>Bulbostylis ciliatifolia</u>	a Hair Sedge	N

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Cenchrus incertus</u>	Coastal Sandspur	R
<u>Cenchrus echinatus</u>	Southern Sandspur	
<u>Cenchrus gracillimus</u>	Slender Sandspur	N
<u>Chrysopogon pauciflorus</u>	Florida Rhaphis	N
<u>Cladium jamaicensis</u>	Sawgrass	N
<u>Cynodon dactylon</u>		
var. <u>dactylon</u>	Co. Bermudagrass	E
<u>Cyperus filiculmis</u>	a Sedge	N
<u>Cyperus ligularis</u>	Silver Sedge	R
<u>Dichanthelium aciculare</u>	a Panicgrass	N
<u>Dichanthelium acuminatum</u>		
var. <u>acuminatum</u>	a Panicgrass	N
<u>Dichanthelium commutatum</u>	a Panicgrass	N
<u>Dichanthelium ensifolium</u>		
var. <u>unciphyllum</u>	a Panicgrass	N
<u>Dichanthelium ovale</u>	a Panicgrass	N
<u>Dichanthelium strigosum</u>		
var. <u>glabrescens</u>	a Panicgrass	N
(<u>D. leucoblepharis</u>		
var. <u>glabrescens</u>)		
<u>Digitaria ciliaris</u>	Southern Crabgrass	R
<u>Digitaria dolichophylla</u>	Pineland Crabgrass	N
<u>Digitaria villosa</u>	a Crabgrass	N
(<u>D. filiformis</u> of authors)		
<u>Eleusine indica</u>	Goosegrass	E
<u>Elyonurus tripsacoides</u>	Pan-American Balsamscale	N
<u>Eragrostis campestris</u>	Elliott's Lovegrass	N
(<u>E. elliottii</u>)		
<u>Eragrostis spectabilis</u>	Purple Lovegrass	N
<u>Eremochloa ophiuroides</u>	Centipedegrass	E
<u>Eustachys petraea</u>	Pineland Fingergrass	N
(<u>Chloris petraea</u>)		

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Fimbristylis cymosa</u>		
var. <u>spathacea</u>	Hurricane Sedge	R
<u>Gymnopogon ambiguus</u>	Bearded Skeletongrass	N
<u>Hackelochloa granularis</u>	a Grass	E
<u>Heteropogon contortus</u>	Tanglehead	N
<u>Imperata brasiliensis</u>	Silver Plume	N
<u>Juncus megacephallus</u>	a Rush	N
<u>Melinis minutiflora</u>	Molasses grass	E
<u>Muhlenbergia capillaris</u>		
var. <u>filipes</u>	a Muhly-grass	N
<u>Neyraudia reynaudiana</u>	Burma-reed	E
<u>Panicum maximum</u>	Guinea-grass	E
<u>Panicum tenerum</u>	a Panicgrass	N
<u>Panicum virgatum</u>		
var. <u>cubense</u>	Cuban Switchgrass	N
<u>Panicum virgatum</u>		
var. <u>virgatum</u>	Co. Switchgrass	N
<u>Paspalum blodgettii</u>	Coral Paspalum	N
<u>Paspalum conjugatum</u>	a Paspalum	R
<u>Paspalum caespitosum</u>	Blue Paspalum	N
<u>Paspalum fimbriatum</u>	Winged Paspalum	E
<u>Paspalum monostachyum</u>	Gulfdune Paspalum	N
<u>Paspalum notatum</u>	Bahiagrass	E
<u>Paspalum sauetii</u>	a Paspalum	N
<u>Paspalum setaceum</u>		
var. <u>ciliatifolium</u>	Ciliate Thin Paspalum	N
<u>Pennisetum purpureum</u>	Napiergrass	E
<u>Rhynchelytrum repens</u>	Natalgrass	E
<u>Rhynchospora colorata</u>	a White-top Sedge	N
(<u>Dichromena colorata</u>)		
<u>Rhynchospora floridensis</u>	Fla. Whitetop Sedge	N
(<u>Dichromena floridensis</u>)		
<u>Rhynchospora globularis</u>	Pineland Beakrush	N

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Rhynchospora grayi</u>	Gray's Beakrush	N
<u>Rhynchospora intermedia</u>	a Beakrush	N
<u>Rhynchospora plumosa</u>	Feather Beakrush	N
<u>Rottboellia cochinchinensis</u> (<u>R. exaltata</u>)	Itchgrass	E
<u>Schizachyrium gracile</u>	Thinleaved Bluestem	N
<u>Schizachyrium rhizomatum</u>	South Fla. Bluestem	N
<u>Schizachyrium sanguineum</u> var. <u>sanguineum</u> (<u>S. semiberbe</u>)	a Bluestem	N
<u>Setaria lutescens</u>	Yellow Foxtail	E
<u>Setaria parviflora</u> (<u>Setaria geniculata</u>)	Knotroot Foxtail	N
<u>Sorghastrum secundum</u>	Lopsided Indiangrass	N
<u>Sporobolus indicus</u>	Smutgrass	R
<u>Sporobolus juncus</u>	Pineywoods Dropseed	N
<u>Sporobolus pyramidalis</u> var. <u>jacquemontii</u> (<u>S. indicus</u> of authors)	West Indian Rushgrass	R
<u>Tripsacum floridanum</u> *	Florida Gamagrass	N

FORBS AND WOODY GROUNDCOVERS

<u>Acalypha chamaedrifolia</u>	Threeseeded Mercury	N
<u>Aeschynomene viscidula</u>	Shy-leaf	N
<u>Agalinis fasciculata</u> (<u>Gerardia fasciculata</u>)	a False Foxglove	N
<u>Agalinis purpurea</u> (<u>Gerardia purpurea</u>)	Purple False Foxglove	N
<u>Argemone mexicana</u>	Mexican Poppy	R
<u>Aletris bracteata</u>	a Colicroot	N
<u>Alysicarpus vaginalis</u>	Alice-clover	E
<u>Amaranthus spinosus</u>	Spiny Amaranth	E

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Amorpha herbacea</u>		
var. <u>crenulata</u> ➤	Crenulate Lead-plant	N
(<u>A. crenulata</u>)		
<u>Ambrosia artemisiifolia</u>	Co. Ragweed	R
<u>Anemia adiantifolia</u>	Pine Fern	N
<u>Angadenia berterii</u>	Pineland-allamanda	N
<u>Argythamnia blodgettii</u> ▪	Blodgett's Wild Mercury	N
<u>Arnoglossum ovatum</u>		N
<u>Asclepias tuberosa</u>		
ssp. <u>rolfsii</u>	Butterfly Weed	N
<u>Asclepias verticillata</u>	a Milkweed	N
<u>Asclepias viridis</u>	Green Milkweed	N
<u>Asparagus densiflorus</u>		
cv. <u>Sprengeri</u>	Asparagus-fern	E
(<u>A. sprengeri</u>)		
<u>Aster adnatus</u>	Clasping Aster	N
<u>Aster concolor</u>		
var. <u>concolor</u>	an Aster	N
<u>Aster concolor</u>		
var. <u>simulatus</u>	an Aster	N
<u>Aster dumosus</u>	an Aster	N
<u>Ayenia euphrasiifolia</u>		N
<u>Bacopa monnieri</u>	Water Hyssop	N
<u>Balduina angustifolia</u>	Yellow-buttons	N
<u>Basiphyllaea corallicola</u>	Carter's Orchid	N
<u>Berlandiera subacaulis</u>	Green-eyes	N
<u>Bidens alba</u>		
var. <u>radiata</u>	Spanish-needles	R
(<u>B. pilosa</u>)		
<u>Blechnum brownei</u>	Green Shrimp Plant	E
<u>Blechnum serrulatum</u>	Swamp Fern	N
<u>Bletia purpurea</u>	Pinepink	N

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Brickellia eupatorioides</u>		
var. <u>floridana</u> *	False Boneset	N
(<u>B. mosieri</u> ;		
<u>Kuhnia eupatorioides</u>)		
<u>Buchnera floridana</u>	a Blueheart	N
<u>Capraria biflora</u>	Goatweed	R
<u>Catharanthus roseus</u>	Madagascar Periwinkle	E
<u>Chamaecrista deeringiana</u>	Deering Partridge-pea	N
(<u>Cassia deeringiana</u>)		
<u>Chamaecrista fasciculata</u>		
var. <u>brachiata</u>	Coastal Partridge-pea	N
(<u>Cassia brachiata</u>)		
<u>Chamaecrista nictitans</u>		
var. <u>aspera</u>	Hairy Partridge-pea	N
(<u>Cassia aspera</u>)		
<u>Chamaesyce adenoptera</u>		
ssp. <u>pergamena</u>	a Spurge	N
<u>Chamaesyce blogettii</u>	Blogett's Spurge	N
<u>Chamaesyce conferta</u>	a Spurge	N
<u>Chamaesyce deltoidea</u>		
ssp. <u>adhaerens</u>	Hairy Deltoid Spurge	N
(<u>C. adhaerens</u>)		
<u>Chamaesyce deltoidea</u>		
ssp. <u>deltoidea</u> ➤	Smooth Deltoid Spurge	N
(<u>C. deltoidea</u>)		
<u>Chamaesyce deltoidea</u>		
ssp. <u>pinetorum</u>	Erect Deltoid Spurge	N
(<u>C. pinetorum</u>)		
<u>Chamaesyce garberi</u> °	Garber's Spurge	N
<u>Chamaesyce hirta</u>	Hairy Spurge	R
<u>Chamaesyce hypericifolia</u>	a Spurge	R
<u>Chamaesyce hyssopifolia</u>	a Spurge	R

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Chamaesyce lasiocarpa</u>	a Spurge	R
<u>Chamaesyce ophthalmica</u>	a Spurge	E
<u>Chamaesyce porteriana</u>		
var. <u>porteriana</u> "	Co. Porter's Spurge	N
<u>Chaptalia dentata</u>	Sunbonnet	N
<u>Chiococca parvifolia</u>	Pineland Snowberry	N
<u>Cirsium horridulum</u>	Purple Thistle	N
<u>Clematis baldwinii</u>		
var. <u>baldwinii</u>	Co. Pine Hyacinth	N
<u>Cnidoscylus stimulosus</u>	Stinging-nettle	N
<u>Commelina erecta</u>		
var. <u>angustifolia</u>	Thin-leaved Dayflower	N
<u>Commelina diffusa</u>	Baby Dayflower	R
<u>Complaya trilobata</u>	Creeping Wedelia	E
(<u>Wedelia trilobata</u>)		
<u>Conoclinium coelestinum</u>	Mistflower	N
(<u>Eupatorium coelestinum</u>)		
<u>Conyza canadensis</u>		
var. <u>pusilla</u>	Dwarf Horseweed	R
<u>Cordia bahamensis</u>	Granny Bush	N
<u>Crossopetalum ilicifolium</u>	Quailberry	N
<u>Crotalaria incana</u>	a Rattlebox	E
<u>Crotalaria pallida</u>		
var. <u>obovata</u>	a Rattlebox	E
(<u>C. mucronata</u>)		
<u>Crotalaria pumila</u>	Pineland Rattlebox	N
<u>Crotalaria retusa</u>	a Rattlebox	E
<u>Crotalaria rotundifolia</u>		
var. <u>rotundifolia</u>	Rabbit-bells	N
(<u>C. maritima</u> , in part)		
<u>Crotalaria spectabilis</u>	Showy Rattlebox	E
<u>Crotalaria vurrucosa</u>	Purple Rattlebox	R

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Croton glandulosus</u>		
var. <u>arenicola</u>	a Glandular Croton	N
<u>Croton glandulosus</u>		
var. <u>glandulosus</u>	Co. Glandular Croton	N
<u>Croton glandulosus</u>		
var. <u>simpsonii</u>	Simpson's Glandular Croton	N
<u>Croton linearis</u>	Pineland Croton	N
<u>Cyrtipodium paramaense</u>	Yellow Cowhorn Orchid	E
<u>Dalea carnea</u>		
var. <u>carnea</u>	Prairie-clover	N
(<u>Petalostomum carneum</u>)		
<u>Dalea carthagenensis</u>		
var. <u>floridana</u>	False Lead-plant	N
<u>Desmodium incanum</u>	a Beggarticks	N
(<u>Desmodium canum</u>)		
<u>Desmodium lineatum</u>		N
<u>Desmodium obtusum</u>		N
<u>Desmodium marilandicum</u>		N
(<u>D. ciliare</u> of authors)		
<u>Desmodium paniculatum</u>		N
<u>Desmodium scopiurus</u>		E
<u>Desmodium strictum</u>		N
<u>Desmodium tortuosum</u>	Tick-trefoil	R
<u>Desmodium triflorum</u>		R
<u>Desmodium viridiflorum</u>		N
<u>Dyschoriste angusta</u>	Twinflower	N
(<u>D. oblongifolia</u>		
var. <u>angusta</u>)		
<u>Eclipta prostrata</u>		R
(<u>E. alba</u>)		
<u>Emilia fosbergii</u>	a Tasselflower	E
<u>Emilia sonchifolia</u>	a Tasselflower	E
<u>Erechtites hieracifolia</u>	Fireweed	R

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Eryngium baldwinii</u>	Button Snakeroot	N
<u>Elytraria caroliniensis</u>		
var. <u>angustifolia</u>		N
<u>Ernodea cokeri</u>		N
<u>Ernodea littoralis</u>		
var. <u>angusta</u>	Pineland Goldencreeper	N
<u>Eupatorium capillifolium</u>	a Dog-fennel	R
<u>Eupatorium compositifolium</u>		N
<u>Eupatorium leptophyllum</u>	a Dog-fennel	N
<u>Eupatorium mikanioides</u>	Semaphoreplant	N
<u>Eupatorium recurvans</u>		N
<u>Eupatorium serotinum</u>	Late Thoroughwort	R
<u>Euphorbia cyathophora</u>	Wild Poinsettia	R
(<u>Poinsettia cyathophora</u>)		
<u>Euphorbia heterophylla</u>	Fiddler's Poinsettia	R
(<u>Poinsettia heterophylla</u>)		
<u>Euphorbia pinetorum</u>	Pineland Poinsettia	N
(<u>Poinsettia pinetorum</u>)		
<u>Euphorbia polyphylla</u>	Pineland Euphorbia	N
<u>Evolvulus sericeus</u>		
var. <u>averyi</u>	Avery's Creeping Morning-glory	N
<u>Evolvulus sericeus</u>		
var. <u>glaberrimus</u>	Glabrous Creeping Morning-glory	N
<u>Evolvulus sericeus</u>		
var. <u>sericeus</u>	Co. Creeping Morningglory	N
<u>Flaveria linearis</u>	Yellowtop	N
<u>Galactia floridana</u>	Florida Milkpea	N
<u>Galactia pinetorum</u> *	Pineland Milkpea	N
<u>Galactia smallii</u> >	Small's Milkpea	N
(<u>G. prostrata</u>)		
<u>Galium hispidulum</u>	a Bedstraw	N
<u>Gaura angustifolia</u>		N

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Gaura simulans</u>		N
<u>Gnaphalium obtusifolium</u>	a Cudweed	R
<u>Glandularia maritima</u> *	Beach Verbena	N
(<u>Verbena maritima</u>)		
<u>Habenaria quinqueseta</u>		
var. <u>quinqueseta</u>	an Orchid	N
<u>Hedyotis procumbens</u>	Innocence	N
<u>Helianthus annuus</u>	Annual Sunflower	N
<u>Heliotropium polyphyllum</u>		
var. <u>leavenworthii</u>	Pineland Heliotrope	R
<u>Heterotheca subaxillaris</u>	Camphorweed	N
<u>Hieracium megacephalon</u>	a Hawkweed	N
(<u>H. gronovii</u> of authors)		
<u>Houstonia nigricans</u>		
var. <u>floridana</u>	Fla. Diamondflowers	N
(<u>Hedyotis nigricans</u> var. <u>filifolia</u> of authors)		
<u>Hymenocallis palmeri</u>	Alligator Lily	N
<u>Hypericum hypericoides</u>		
var. <u>hypericoides</u>	St. Andrew's Cross	N
<u>Hypoxis wrightii</u>		N
<u>Hyptis alata</u>		
var. <u>stenophylla</u>	Musky Mint	N
<u>Indigofera caroliniana</u>	Carolina Indigo	N
<u>Indigofera hirsuta</u>	Hairy Indigo	E
<u>Indigofera miniata</u>		
var. <u>floridana</u>	Fla. Scarlet Indigo	N
<u>Indigofera spicata</u>	Creeping Indigo	E
(<u>I. endecaphylla</u> ;		
<u>I. hendacaphylla</u> of authors)		
<u>Indigofera suffruticosa</u>	Shrub Indigo	R
<u>Iresine diffusa</u>	Bloodleaf	N
(<u>I. canescens</u>)		

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Jacquemontia curtissii</u> *	Pineland Clustervine	N
<u>Juncus megacephalus</u>	a Rush	N
<u>Justicia angusta</u> (<u>J. ovata</u> var. <u>angusta</u>)	Waterwillow	N
<u>Lantana depressa</u> var. <u>depressa</u> *	Pineland Lantana	N
<u>Lechea cernua</u> *	Nodding Pinweed	N
<u>Lechea deckertii</u>	a Pinweed	N
<u>Lechea divaricata</u>	a Pinweed	N
<u>Lechea sessiliflora</u>	a Pinweed	N
<u>Lechea torreyi</u>	a Pinweed	N
<u>Lepidium virginicum</u>	Poorman's-pepper	R
<u>Liatris chapmanii</u>	a Blazing-star	N
<u>Liatris gracilis</u>	a Blazing-star	N
<u>Liatris tenuiflora</u> var. <u>quadriflora</u> (<u>L. t.</u> var. <u>laevigata</u>)	a Blazing-star	N
<u>Licania michauxii</u>	Gopher-apple	N
<u>Linum arenicola</u> *	Sand Flax	N
<u>Linum carteri</u> var. <u>carteri</u> *	Carter's Small-flowered Flax	N
<u>Linum carteri</u> var. <u>smallii</u> *	Carter's Large-flowered Flax	N
<u>Lobelia paludosa</u>	White Lobelia	N
<u>Macroptilium lathyroides</u> (<u>Phaseolus lathyroides</u>)	Wild Bush Bean	E
<u>Malvastrum corchorifolium</u>		R
<u>Mecardonia acuminata</u>		N
<u>Melanthera angustifolia</u>		N
<u>Melanthera aspera</u> var. <u>aspera</u>		N
<u>Melanthera parvifolia</u> *	Small-leaved Cat Tounge	N

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Mimosa quadrivalvis</u>		
var. <u>angustata</u>	Sensitive-briar	N
(<u>Shrankia microphylla</u>)		
<u>Mitreola sessilifolia</u>	a Mitrewort	N
(<u>Cynoctonum sessilifolium</u> ; <u>C. angustifolium</u>)		
<u>Morinda royoc</u>	Yellowroot	N
<u>Myrica cerifera</u>		
var. <u>pumila</u>	Dwarf Wax-myrtle	N
<u>Nephrolepis exaltata</u>	Co. Boston Fern	R
<u>Nephrolepis cordifolia</u>	Tuberous Boston Fern	E
<u>Nephrolepis multiflora</u>	a Boston Fern	E
<u>Neptunia pubescens</u>		
var. <u>pubescens</u>		N
(<u>N. floridana</u>)		
<u>Oeceoclades maculata</u>	African Ground Orchid	R
(<u>Eulophidium maculatum</u>)		
<u>Ocimum micranthum</u>	Wild Basil	N
<u>Opuntia humifusa</u>		
var. <u>austrina</u>	a Prickly-pear Cactus	N
<u>Palafoxia integrifolia</u>		N
<u>Parthenium hysterophorus</u>	Santa Maria	E
<u>Pectis glaucescens</u>	a Teablinkum	N
(<u>P. leptcephala</u>)		
<u>Pectis prostrata</u>	a Teablinkum	N
<u>Penstemon multiflorus</u>	Beardtongue	N
<u>Phyla nodiflora</u>	Capeweed	R
<u>Phyllanthus amarus</u>		R
<u>Phyllanthus caroliniensis</u>		
var. <u>saxicola</u>		N
<u>Phyllanthus pentaphyllus</u>		
ssp. <u>pentaphyllus</u>		
var. <u>floridana</u> *	Fla. 5-petalled Leafflower	N

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Phyllanthus tenellus</u>		E
<u>Phyllanthus urinaria</u>		E
<u>Physalis viscosa</u>		
var. <u>walteri</u>	Elliott's Ground-cherry	N
(<u>P. viscosa</u> var. <u>elliottii</u>)		
<u>Phytolacca rigida</u>	a Pokeweed	R
<u>Pilea microphylla</u>	Artillery Plant	R
<u>Piloblephis rigida</u>	Pennyroyal	N
(<u>Satureja rigida</u>)		
<u>Piriqueta caroliniana</u>		
var. <u>tomentosa</u>	Hairy Piriqueta	N
<u>Pityopsis graminifolia</u>		
var. <u>tracyi</u>	Tracy's Silkgrass	N
(<u>Heterotheca graminifolia</u> var. <u>tracyi</u>)		
<u>Pluchea rosea</u>	Marsh Fleabane	N
<u>Polanisia tenuifolia</u>		N
(<u>Aldenella tenuifolia</u>)		
<u>Polygala boykinii</u>		
var. <u>sparsifolia</u> *	a Boykin's Milkwort	N
<u>Polygala grandiflora</u>		
var. <u>angustifolia</u>	Thin-leaved Candyweed	N
<u>Polygala incarnata</u>	Procession-flower	N
<u>Polygala smallii</u> >	Small's Milkwort	N
<u>Polygonella ciliata</u>		
var. <u>ciliata</u>	Co. Wireweed	N
<u>Polygonella polygama</u>		
var. <u>brachystachya</u>	Southern Jointweed	N
<u>Polypremum procumbens</u>	Rustweed	N
<u>Psilotum nudum</u>	Whisk Fern	N
<u>Pteridium aquilinum</u>		
var. <u>caudatum</u>	Southern Braken	N

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<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Pteris bahamensis</u>	Bahama Ladder Brake	N
<u>Pteris vittata</u>	China Brake	E
<u>Pteris X delchampsii</u>	Delchamp's Brake	E
<u>Pterocaulon virgatum</u>	Rabbit-tobacco	N
(<u>P. pycnostachyum</u>)		
<u>Pteroglossaspis ecristata</u>	an Orchid	N
(<u>Eulophia ecristata</u>)		
<u>Quercus minima</u>	Dwarf Live Oak	N
<u>Quercus pumila</u>	Running Oak	N
<u>Richardia grandiflora</u>	Large-flowered Peavyweed	N
<u>Rhynchosia cinerea</u>		N
<u>Rhynchosia michauxii</u>		N
<u>Rhynchosia reniformis</u>	Dollar-weed	N
<u>Ruellia caroliniensis</u>		
ssp. <u>caroliniensis</u>		
var. <u>succulenta</u>	a Wild-petunia	N
<u>Ruellia caroliniensis</u>		
ssp. <u>ciliosa</u>		
var. <u>heteromorpha</u>	a Wild-petunia	N
<u>Russelia equisetiformis</u>	Firecracker Plant	N
<u>Sabatia stellaris</u>	a Marsh-pink	N
<u>Sachsia polycephala</u>		N
(<u>S. bahamensis</u>)		
<u>Samolus ebracteatus</u>	Water Pimpernel	N
<u>Scutellaria havanensis</u>	Havana Skullcap	N
<u>Selaginella arenicola</u>		
ssp. <u>arenicola</u>	a Sand Spike-moss	N
<u>Senna mexicana</u>		
var. <u>chapmanii</u>	Bahama Senna	N
(<u>Cassia bahamensis</u> ; <u>C. chapmanii</u>)		
<u>Senna obtusifolia</u>	Sicklepod	R
<u>Seymeria pectinata</u>		N

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Sida acuta</u>	Broomweed	R
<u>Sida elliottii</u>		N
<u>Sida rhombifolia</u>	Teaweed	R
<u>Sisyrinchium miamiensis</u>	Miami Blue-eyed-grass	N
(<u>S. atlanticum</u> of authors)		
<u>Solanum donianum</u>	Blogett's Potato	N
(<u>Solanum blodgettii</u>)		
<u>Solidago leavenworthii</u>	a Goldenrod	N
<u>Solidago odora</u>		
var. <u>chapmanii</u>	Chapman's Goldenrod	N
(<u>S. chapmanii</u>)		
<u>Solidago stricta</u>	a Goldenrod	N
<u>Sonchus oleraceus</u>	Co. Sow Thistle	E
<u>Spermacoce assurgens</u>		R
(<u>Borreria laevis</u> of authors)		
<u>Spermacoce prostrata</u>		N
(<u>Borreria ocimoides</u> of authors)		
<u>Spermacoce terminalis</u>		N
(<u>S. verticillata</u> of authors)		
<u>Spermacoce verticillata</u>		E
<u>Spigelia anthelmia</u>	West Indian Pinkroot	N
<u>Spiranthes torta</u>	a Ladie's tresses	N
(<u>S. tortilis</u>)		
<u>Stachytarpheta jamaicensis</u>	Blue Porterweed	R
<u>Stenandrium dulce</u>		
var. <u>floridanum</u>	Pinklet	N
<u>Stillingia sylvatica</u>		
ssp. <u>tenuis</u>	Queen's delight	N
<u>Stylosanthes calicicola</u>	a Pencilflower	N
<u>Stylosanthes hamata</u>	a Pencilflower	R

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Tephrosia angustissima</u>		
var. <u>angustissima</u>		N
<u>Tephrosia angustissima</u>		
var. <u>corallicola</u>		N
<u>Tephrosia florida</u>	Hoary-pea	N
<u>Tephrosia spicata</u>		N
<u>Thelypteris kunthii</u>	Woods Fern	N
(<u>T. normalis</u>)		
<u>Tragia saxicola</u> *	Pineland-noseburn	N
<u>Traia urens</u>		
var. <u>linearifolia</u>		N
<u>Tragia urens</u>		
var. <u>urens</u>		N
<u>Tridax procumbens</u>	Brittleweed	E
<u>Trichostema suffruticosa</u>	Southern Blue-curls	N
(<u>T. dichotomum</u> , in part)		
<u>Urena lobata</u>	Ceasar's weed	R
<u>Vaccinium myrsinites</u>	Shiny Blueberry	N
<u>Verbesina virginica</u>		
var. <u>laciniata</u>	Lobed Crownbeard	N
<u>Vernonia blodgettii</u>	Blodgett's Ironweed	N
<u>Vernonia cinerea</u>	Asian Ironweed	N
<u>Waltheria indica</u>		R
<u>Warea carteri</u>		N
<u>Youngia japonica</u>	Rocketweed	E
<u>Zamia integrifolia</u>	Co. Coontie	N
(<u>Z. pumila</u> ssp. <u>pumila</u> , in part)		
<u>Zeuxine strateumatica</u>	Lawn Orchid	E

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

VINES AND SCANDENT SHRUBS

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Abrus precatorius</u>	Rosary-pea	E
<u>Ampelopsis arborea</u>	Pepper Vine	N
<u>Cassytha filiformis</u>	Love Vine	N
<u>Centrosema virginianum</u>	Butterfly-pea	N
<u>Chiococca alba</u>	Co. Snowberry	N
<u>Cissus verticillata</u> (<i>C. cicyoides</i>)	Possum-grape	R
<u>Clitoria ternatea</u>	Blue-peas	E
<u>Cynanchum blodgettii</u>	Vine-milkweed	N
<u>Dioscorea alata</u>	White yam	E
<u>Dioscorea bulbifera</u>	Air-potato	E
<u>Echites umbellata</u> var. <u>umbellata</u>	Devil's potato	N
<u>Eupatorium odoratum</u> (<i>Chromolaena odorata</i>)	Bitter Eupatorium	R
<u>Galactia parvifolia</u>	a Milk-pea	N
<u>Ipomoea indica</u> (<i>I. acuminata</i>)	Purple Morning-glory	R
<u>Ipomoea microdactyla</u>	Man-in-the-ground	N
<u>Ipomoea sagittata</u>	Everglades Morning-glory	N
<u>Ipomoea tenuissima</u>	Rockland Morning-glory	N
<u>Jacquemontia curtissii</u>	Rockland Clustervine	N
<u>Jasminum dichotomum</u>	Gold Coast Jasmine	E
<u>Jasminum fluminense</u>	Trifoliate Jasmine	E
<u>Macfadyena unguis-cati</u>	Claw Vine	E
<u>Melothria pendula</u>	Creeping-cucumber	R
<u>Merremia dissecta</u>	White Wood-rose	R
<u>Merremia tuberosa</u>	Yellow Wood-rose	E
<u>Mikania scandens</u>	Climbing Hempweed	N
<u>Momordica charantia</u>	Wild Balsam-apple	R
<u>Mucuna pruriens</u> var. <u>pruriens</u>	Cow-itch	E

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Mucuna pruriens</u>		E
var. <u>utilis</u>		
(<u>M. deeringiana</u>)		
<u>Paederia cruddasiana</u>		E
ssp. <u>cruddasiana</u>	Sewervine	
<u>Parthenocissus quinquefolia</u>	Virginia Creeper	R
<u>Passiflora edulis</u>	Passionfruit	E
<u>Passiflora suberosa</u>	Corky-stemmed Passion-flower	N
<u>Pueraria montana</u>		E
var. <u>lobata</u>	Kudzu	
<u>Rhynchosia parvifolia</u>		N
<u>Rhynchosia minima</u>		R
<u>Smilax auriculata</u>	a Greenbrier	R
<u>Smilax bona-nox</u>	a Greenbrier	N
<u>Smilax havanensis</u>	Havana Greenbrier	N
<u>Stylisma villosa</u>		N
<u>Toxicodendron radicans</u>		R
ssp. <u>radicans</u>	Poison-ivy	
<u>Urechites lutea</u>		N
var. <u>sericea</u>	Hairy-leaved Wild-allamanda	
<u>Vigna luteola</u>	Cowpea	R
<u>Vitis aestivalis</u>	Summer Grape	N
<u>Vitis rotundifolia</u>	Muscadine	R
<u>Zornia bractiata</u>	Shy Vine	N

TREES AND SHRUBS

<u>Acacia auriculiformis</u>	Earleaf Acacia	E
<u>Acacia farnesiana</u>	Sweet Acacia	R
<u>Acacia pinetorum</u>	Pineland Acacia	N
<u>Agave decipiens</u>	False Sisal	R
<u>Agave sisalana</u>	Sisal hemp	E
<u>Albizia lebbek</u>	Rattlepod	E

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Alvaradoa amorphioides</u>	Mexican Alvaradoa	N
<u>Ardisia elliptica</u> (<u>A. solanacea</u> of authors)	Shoebutton Ardisia	E
<u>Ardisia escallonoides</u>	Marlberry	N
<u>Baccharis halimifolia</u> var. <u>angustior</u>	a Groundsel	N
<u>Baccharis glomeruliflora</u>	a Groundsel	N
<u>Baccharis dioica</u>	a Groundsel	N
<u>Bischofia javonica</u>	Bishopwood	E
<u>Bourreria cassinifolia</u>	Little Strongback	N
<u>Brassaia actinophylla</u> (<u>Shefflera</u> <u>actinophylla</u>)	Umbrella Tree	E
<u>Bumelia reclinata</u> var. <u>reclinata</u>	Co. Reclined Buckthorn	N
<u>Bursera simaruba</u>	Gumbo limbo	N
<u>Byrsonima lucida</u>	Locustberry	N
<u>Callicarpa americana</u>	American Beautyberry	N
<u>Carica papaya</u>	Papaya	E
<u>Casuarina glauca</u>	Suckering Australian pine	E
<u>Casuarina litorea</u> (<u>C. equisetifolia</u>)	Co. Australian pine	E
<u>Cestrum diurnum</u>	Day Jessamine	E
<u>Chrysobalanus icaco</u>	Cocoplum	N
<u>Citharexylum fruticosum</u>	Fiddlewood	N
<u>Coccothrinax argentata</u>	Silver Palm	N
<u>Colobrina cubensis</u> var. <u>floridana</u>	Florida Colubrina	N
<u>Crossopetalum rhacoma</u>	Rhacoma	N
<u>Delonix regia</u>	Royal Ponciana	E
<u>Dipholis salicifolia</u>	Willow bustic	N
<u>Dodonaea viscosa</u> var. <u>linearis</u>	Thin-leaved Varnishleaf	N

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Erythrina herbacea</u>	Coralbean	N
<u>Eugenia axillaris</u>	White Stopper	N
<u>Eupatorium villosum</u>	Shrub Eupatorium	N
<u>Ficus altissima</u>	Lofty Fig	E
<u>Ficus aurea</u>	Strangler Fig	N
<u>Ficus benghalensis</u>	Banyan Fig	E
<u>Ficus citrifolia</u>	Short-leaf Fig	N
<u>Ficus microcarpa</u>		
var. <u>nitida</u>	Laurel Fig	E
(<u>F. nitida</u> ; <u>F. retusa</u> var. <u>nitida</u>)		
<u>Flacourtia indica</u>	Governor's plum	E
<u>Forestiera segregata</u>		
var. <u>pinetorum</u>	Pineland privet	N
<u>Guapira discolor</u>		
var. <u>longifolia</u>	Narrow-leaved Blolly	N
<u>Guettarda elliptica</u>	Everglades Velvetseed	N
<u>Guettarda scabra</u>	Rough Velvetseed	N
<u>Ilex cassine</u>	Dahoon Holly	N
<u>Ilex krugiana</u>	Krug's Holly	N
<u>Lantana camara</u>		
var. <u>aculeata</u>	Spiny Shrub Verbena	E
<u>Lantana camara</u>		
var. <u>camara</u>	a Shrub Verbena	R
<u>Lantana camara</u>		
var. <u>mista</u>	a Shrub Verbena	E
<u>Lantana camara</u>		
var. <u>mutabilis</u>	a Shrub Verbena	E
<u>Lantana canescens</u>	Hammock Lantana	N
(<u>L. microcephalla</u>)		
<u>Lantana involucrata</u>	Wild sage	N
<u>Leucaena leucocephala</u>	Leadwood	R
<u>Lyonia fruticosa</u>	Staggerbush	N

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Lysiloma latisiliquum</u> (<u>L. bahamensis</u>)	Wild tamarind	N
<u>Metopium toxiferum</u>	Poisonwood	N
<u>Myrica cerifera</u> var. <u>cerifera</u>	Co. Waxmyrtle	N
<u>Myrsine floridana</u> (<u>M. guianensis</u> ; <u>Rapanea guianensis</u>)	Myrsine	N
<u>Neurolaena lobata</u> (<u>Pluchea symphytifolia</u>)	Bushy Fleabane	N
<u>Persea borbonia</u>	Redbay	N
<u>Pinus elliottii</u> var. <u>densa</u>	South Florida Slash Pine	N
<u>Psidium guajava</u>	Guava	E
<u>Psidium longipes</u>	Longstalked Stopper	N
<u>Psychotria nervosa</u>	Shiny-leaved Wildcoffee	N
<u>Quercus virginiana</u> var. <u>virginiana</u>	Co. Live Oak	N
<u>Randia aculeata</u>	White Indigoberry	N
<u>Rhus copallina</u> var. <u>leucantha</u>	Southern Sumac	N
<u>Ricinus communis</u>	Castor-bean	E
<u>Sabal palmetto</u>	Cabbage Palm	N
<u>Serenoa repens</u>	Saw Palmetto	N
<u>Schinus terebinthifolius</u>	Brazilian-pepper	E
<u>Swietenia mahagony</u>	West Indian Mahogany	E
<u>Tabebuia caraiba</u> (<u>T. argentata</u> of authors)	Silver Trumpet Tree	E
<u>Tabebuia heterophylla</u> (<u>T. rosea</u> of authors)	Pink Trumpet Tree	E
<u>Tecoma stans</u>	Yellow-elder	R

Appendix 2. Plant Taxa of Dade County Pine Rocklands, August 1995.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Origin</u>
<u>Tetrazygia bicolor</u>	West Indian-lilac	N
<u>Trema lamarkiana</u>	West Indian Trema	N
<u>Trema micranthum</u> (<u>T. floridanum</u>)	Florida Trema	N

EPIPHYTES

<u>Catopsis berteroniana</u>	Powdery Catopsis	N
<u>Encyclia tampensis</u> (<u>Epidendrum tampensis</u>)	Butterfly Orchid	N
<u>Phlebodium aureum</u> (<u>Polypodium aureum</u>)	Golden Polypody	N
<u>Tillandsia balbisiana</u>	Reflexed Wild-pine	N
<u>Tillandsia fasciculata</u> var. <u>densispica</u>	a Stiff-leaved Wild-pine	N
<u>Tillandsia setacea</u>	Needle-leaved Wild-pine	N
<u>Tillandsia utriculata</u>	Giant Wild-pine	N

This inventory is the combined effort of Keith Bradley and George Gann (Institute for Regional Conservation), and Roger Hammer (Natural Areas Management) of Dade County Parks and Recreation Department. Further observations have been contributed by George Avery, Edwin Bridges (Fairchild Tropical Garden), Alan Herndon, and members of the Dade County Native Plant Workshop.

Appendix 3: Exotic plants, from the EPPC's List of Florida's Most Invasive Species (EPPC 1995), that are found in pine rocklands.

Scientific Name

Common Name

Category I:

Abrus precatorius
Acacia auriculiformis
Casuarina glauca
Casuarina equisetifolia
Neyraudia reynaudiana
Schinus terebinthifolius

Rosary pea
Earleaf acacia
Australian pine
Australian pine
Burma reed
Brazilian pepper

Category II

Agave sisalana
Albizzia lebbbeck
Leucaena leucocephala
Melinis minutiflora
Rhynchelytrum repens
Urena lobata

Sisal hemp
Woman's tongue
Lead tree
Molasses grass
Natal grass
Caesar's weed

Appendix 4

Genetic Diversity Within and Among Populations of South Florida Slash Pine, Pinus elliottii var. densa.

Final Report

J. L. Hamrick

Background

Hurricane Andrew crossed southern Dade County, Florida on August 24, 1992 with sustained winds in excess of 135 miles per hour. Andrew, with an intense eyewall only 25 miles in diameter, impacted 99% of the pine rockland fragments in Dade County. Although initial impacts to pine rockland forests seemed minimal (some denser stands seemed to benefit), one year after the storm very few stands have living trees remaining. The Florida Division of Forestry (DOF) has reported severe outbreaks of pine bark beetles (Ips spp.) and many juvenile trees have been killed by pine reproduction weevils. This reduction of much of the mature slash pine canopy in central and south Dade Co. has made reforestation a high priority. Determining appropriate sources of seed for reforestation should be based upon a combination of genetic and ecological background information. Therefore, examining the genetic composition of Pinus elliottii var. densa is one of the first steps in the development of a comprehensive reforestation strategy.

The general goal of this genetic study was to determine whether significant levels of genetic differentiation is detectable between sites that have the potential to serve as seed donor sites for the reforestation of the destroyed stands. In particular the main questions were: (1) How does the genetic composition of the surviving pine stands compare to the genetic composition of sites unaffected by Andrew; (2) Is there genetic differentiation between forests growing on oolitic limestone and forests growing in sand? and (3) Is there any evidence that the disjunct rockland forests (eg. Lower Florida Keys, Long Pine Key, Big Cypress and the Miami Rock Ridge) are reproductively isolated or genetically less diverse?

Materials and Methods

Sixteen populations of Pinus elliottii var densa (south Florida slash pine hereafter SFSP) were sampled during March and April, 1994, by cutting approximately six inches of branch material from 48 individuals per population. Eight of the collection sites were located on sandy soils and the remaining eight populations inhabited rockland soils (Table 1). Samples from each population were collected into a labeled plastic bag, placed on ice in a cooler and shipped by overnight mail to the University of Georgia. Within two days of arrival enzymes were extracted from each sample by crushing a mixture of needle and bud material with a mortar and pestle. Liquid nitrogen was added prior to crushing to retard interactions between the enzymes and various secondary plant products. Once the plant material had been ground to a fine powder a phosphate extraction buffer (Mitton et al., 1979) was added. The resulting slurry was absorbed onto filter paper wicks which were stored at -70C in microtest plates until needed for electrophoresis.

Four buffer systems were used to resolve bands for 13 enzyme systems which encoded 21 allozyme loci. The buffer systems generally followed Soltis et al. (1983). Enzyme

systems, buffer systems and loci were as follows: alcohol dehydrogenase (System 6, Adh); aspartate aminotransferase (System 7, Aat1, Aat2, Aat3), diaphorase (System 6, Dial); fluorescent esterase (System 8, Fe1, Fe2), glutamate dehydrogenase (System 8, Gdh); fructose 1-6 diphosphatase (System 11, F16-2); isocitrate dehydrogenase (System 11, Idh); malate dehydrogenase (System 11, Mdh1, Mdh2); phosphoglucisomerase (System 6, Pgi1, Pgi2); phosphoglucumutase (System 6, Pgm1, Pgm2); 6- phosphogluconic dehydrogenase (System 11, 6Pgd1, 6Pgd2); shikimate dehydrogenase (System 11, Skdh); triosephosphate isomerase (System 6, Tpi1, Tpi2).

Standard population genetic parameters including the percent polymorphic loci (P), the mean number of alleles per polymorphic locus (A_p), observed heterozygosity (H_o) and gene diversity (ie expected heterozygosity, H_e) were calculated for each population (Hedrick, 1985) and for the species (Hamrick and Godt, 1989). Allele frequencies were compared across all populations by χ^2 analyses to determine whether there was significant genetic differentiation among populations. Nei's (1973, 1977) gene diversity statistics were used to estimate the total gene diversity at a polymorphic locus across all populations (H_T), the mean gene diversity within each population (H_S) and the proportion of the total genetic variation that was found among populations (G_{ST}). These values were calculated for each polymorphic locus, and these were averaged to obtain measures over all loci. Because of the hierarchal nature of the sampling (two soil types and populations within soil types), it was possible to partition the genetic diversity among populations into an among soil type component and an among populations within soil type component. Indirect estimates of gene flow were calculated from the G_{ST} values (Wright, 1951). The gene flow equation measures N_m , the number of migrants per generation becoming established in a population. Finally, genetic distance and identity measures (Nei, 1972) were calculated for each pair of populations.

Results

Within the range of SFSP 19 of the 21 (90.5%) allozyme loci were polymorphic in at least one population (Table 2). Only Gdh and Pgi1 were monomorphic in all 16 populations. The percentage of the loci polymorphic within each population ranged from 57.1% (BPK) to 90.5% (LPK) and averaged 72.6% across all 16 populations. The number of alleles per polymorphic locus ranged from 2.46 (BROW) to 2.92 (BPK) with a population mean of 2.68, while there were 3.16 alleles per polymorphic locus for the species as a whole. Genetic diversity values (H_e) were uniform across all populations with NOCY2 having the highest value (0.242) and BROW the lowest (0.202). The mean genetic diversity per population was 0.227 and for the species taken as a whole it was 0.235. In 15 of the 16 populations the expected heterozygosity values (H_e) were higher than the observed heterozygosity. The slight deficit of observed heterozygosity was also indicated by the mean F_{IS} value (0.024) across all of the polymorphic loci (Table 3).

There were very few differences in the levels of genetic diversity between populations from rockland and sandy soils (Table 2). The mean proportions of polymorphic loci (P) were nearly identical (73.8% vs 71.4%) as were the overall values (90.5% for both soil types). The

rockland populations did have slightly more alleles per polymorphic locus (mean $A_p = 2.73$ vs 2.64) and overall several more alleles were present in the rockland populations. [$A_p = 3.16$ (60 alleles) vs 2.84 (54 alleles)]. The six alleles that were unique to the rockland populations all occurred at very low frequencies (0.006 or less). There were no alleles unique to the sandy soil populations. These additional alleles increase the mean levels of genetic diversity within the rockland populations (0.232 vs 0.221). Taken as a whole the rockland populations had slightly more genetic diversity (0.240 vs 0.228).

As with most members of the genus *Pinus* the majority of the genetic diversity in this species resides within its individual populations (Hamrick et al., 1992). The G_{ST} value obtained for SFSP was especially low (0.028), however, indicating that there is a high amount of gene flow among all of its populations. The estimate of gene flow obtained from the genetic structure data (ie G_{ST}) indicated that N_m (the number of migrants per generation) was 8.7 . Typically a N_m value of 4.0 is considered to be high and above that value genetic drift plays a small role in shaping the genetic structure of the species.

Because the sampling design included two soil types it was possible to partition the total genetic diversity into three components; within populations, among populations within soil types and among soil types. Of the total among population component 15% was due to soil type and 85% was among populations within a soil types. For the total data set (ie 16 populations) 15 of the 19 polymorphic loci had significant differences ($P < 0.05$) in allele frequencies among populations. When the populations from the rockland and sandy soil types are pooled and compared only 10 loci had significantly different allele frequencies. Although there are statistically significant differences at several loci, the differences in allele frequencies are small and probably don't represent biologically important differences. The largest difference in allele frequencies between the rockland and sand populations was approximately 0.12 .

Genetic identities among populations were quite high (mean $I = 0.987$, Table 2). There were also very few differences among the populations in their average genetic identities values with the other 15 populations. The lone exception is population *SUG* whose mean genetic identity with the other populations was 0.971 , still high by most standards. It is interesting that population *SUG* is located on Sugarloaf Key and is one of the most isolated populations of SFSP.

Conclusions

South Florida slash pine has a high level of genetic diversity as measured by these allozyme traits and the vast majority of its genetic variation occurs within rather than among its populations. Furthermore, although there are statistically significant differences in allele frequencies among its populations, the actual differences in allele frequencies are small and probably are not biologically important. There are even smaller differences in allele frequencies between the rockland populations and populations from sandy soils. Only 0.4% of the total genetic diversity occurs among populations representing the two soil types. This

result is undoubtedly due to the relatively small geographic scales involved, the close proximity of the rockland and sandy populations to one another, and the ability of conifer trees to distribute pollen over long distances. Both populations BPK and SUG had somewhat lower than average P values, an observation that is consistent with the more isolated nature of these two populations. However, a large proportion of the genetic diversity that is found within the species occurs within these two isolated populations.

Readers of this report should interpret the data presented here with some caution. The general consensus is that variation at allozyme loci are not subject to intense natural selection pressures. Thus, on a limited geographic scale such as south Florida, gene flow would be expected to be of predominant importance in shaping the genetic structure of the species. Other genetically controlled traits that are subject to more intense selection pressures (eg. growth rate, tree form, insect and disease resistance, drought tolerance etc.) would be expected to demonstrate more differentiation among populations and perhaps between the two soil types.

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Table 1. Population names, soil types, locations, and ownership of the 16 populations analyzed in this study. Forty-eight individuals were analyzed from each site except BROW where only 24 individuals were collected.

<u>Soil type/population</u>	<u>Collection Site</u>	<u>Ownership</u>
<u>Sandy soils</u>		
LEEC	Lee Co.	? Private
HEND	Hendry Co.	? Private
COLL	Collier Co.	? Private
PUIS	Du Puis	State
THOM	North Dade	St. Thomas Univ., Broward Co. Parks
BROW	Broward Co.	Broward Co. Parks
NOCY1	North Big Cypress	Big Cypress
NOCY2	North Big Cypress	Big Cypress
<u>Rocky soils</u>		
BICY	Lostman's Pine	Big Cypress
SUG	Sugarloaf Key	US Dept. Interior
BPK	Big Pine Key	US Dept. Interior
SMRR	So. Miami Rock Ridge	Private
NWLL	Navy Wells	Dade Co. Parks Dept.
CMRR	Central Miami Rock Ridge	Federal, Private
NMRR	No. Miami Rock Ridge	State/Dade Co.
LPK	Long Pine Key	NPS/ Everglades NP

Table 2. Levels of genetic diversity in populations of *Pinus elliottii* var *densa*. P = percent polymorphic loci, Ap = number of alleles per polymorphic locus, Ho = observed heterozygosity, He = Hardy-Weinberg expected heterozygosity and I = mean genetic identity.

Population	P(%)	Ap	Ho	He	I
Sandy Soils					
LEEC	76.2	2.56	0.227	0.219	0.988
HEND	81.0	2.65	0.224	0.230	0.989
COLL	81.0	2.65	0.203	0.216	0.989
PUIS	71.4	2.80	0.200	0.225	0.989
THOM	66.7	2.79	0.211	0.219	0.987
BROW	61.9	2.46	0.190	0.202	0.984
NOCY1	76.2	2.56	0.189	0.213	0.988
NOCY2	76.2	2.63	0.214	0.242	0.987
mean	73.8	2.64	0.208	0.221	0.988
total within sandy type	90.5	2.84	-	0.228	-
Rockland Soils					
BICY	76.2	2.81	0.215	0.228	0.987
SUG	66.7	2.71	0.232	0.237	0.971
BPK	57.1	2.92	0.224	0.228	0.986
SMRR	71.4	2.73	0.232	0.237	0.989
NWLL	76.2	2.63	0.231	0.241	0.988
CMRR	71.4	2.73	0.229	0.241	0.988
NMRR	61.9	2.69	0.209	0.222	0.989
LPK	90.5	2.58	0.216	0.225	0.990
mean	71.4	2.73	0.224	0.232	0.986
total within rockland type	90.5	3.16	-	0.240	-
overall mean	72.6	2.68	0.216	0.227	0.987
Total within species	90.5	3.16	-	0.235	-

Table 3. Distribution of genetic diversity within and among populations of *Pinus elliottii* var *densa* by polymorphic allozyme locus. H_T = total genetic diversity; H_S = mean genetic diversity within populations; F_{IS} = inbreeding coefficient within populations; G_{ST} = proportion of genetic diversity found within populations.

Locus	Number of alleles	H_T	H_S	F_{IS}	G_{ST}
ADH	2	0.020	0.020	-0.024	0.013
PGM1	4	0.348	0.335	0.036	0.038
PGM2	3	0.013	0.013	-0.019	0.013
TPI1	3	0.501	0.482	0.034	0.038
TPI2	4	0.013	0.013	-0.020	0.015
DIA1	3	0.024	0.024	-0.023	0.013
PGI2	6	0.510	0.495	0.039	0.029
FE1	3	0.436	0.407	-0.014	0.067
FE2	4	0.462	0.455	0.010	0.017
6PGD1	3	0.587	0.567	0.094	0.034
6PGD2	3	0.028	0.027	-0.033	0.021
IDH	2	0.444	0.433	-0.006	0.024
SKDH	5	0.499	0.488	0.058	0.021
AAT1	4	0.336	0.329	-0.082	0.021
AAT2	2	0.028	0.027	-0.053	0.037
AAT3	3	0.127	0.118	0.170	0.070
F16D2	2	0.026	0.026	0.063	0.026
MDH1	2	0.032	0.032	-0.020	0.004
MDH2	<u>2</u>	<u>0.500</u>	<u>0.485</u>	<u>0.235</u>	<u>0.029</u>
mean	3.16	0.260	0.251	0.024	0.028

mean G_{ST} among sand populations = 0.021

mean G_{ST} among rockland populations = 0.024

mean G_{ST} among soil types = 0.004 (15% of total G_{ST})

mean G_{ST} among populations within soil types = 0.024 (85% of total G_{ST})

Appendix 5: Partial list of pine rockland stands in Dade County, sorted by soil type. Data from DERM (1993a). This list contains all sites greater than seven acres. Those sites below seven acres are primarily county-owned.

Sites with Opalocka Sand-Rock Outcrop Soils

SITE CODE	SITE NAME	Size (ac.)	Publicly Owned?	Acquisition List?	Pre-Andrew		Soil Type	Sec.	Town.	Ran.
					Mature Pines % Freq.	Young Pines % Freq.				
391	Richmond Pine Rocklands	853	Y	N	0.5	0.1	Opalocka	35	55	39
370	Tamiami Pineland Preserve	112	Y	N	0.7	0.1	Opalocka	14	55	39
65	Deering Estate	100	Y	N	0.9	0.2	Opalocka	26	55	40
3	Boystown	90	N	Y	0.9	0.2	Opalocka	10	55	39
161	Goulds Pineland Preserve (CARL)	62	Y	Y	0.9	0.3	Opalocka	13	56	39
144.05	Quail Roost Preserve (CARL-EEL)	48	Y	Y	1	0.7	Opalocka	10	56	39
372	Corporate Industrial Park @ Kendall	40	N	N			Opalocka	14	55	39
6	EEL Tamiami Complex Add'n	32	N	Y	0.8	0.4	Opalocka	13	55	39
58	Ludlum Pineland / FPL Easement	31	Partial	N	1	0.8	Opalocka	23	55	40
52	Rockdale Pineland Preserve (CARL)	27	Y	N	0.9	0.6	Opalocka	21	55	40
80	Deering Estate Add'n (CARL)	21	Y	N	0.5	0.4	Opalocka	35	55	40
403	NFC Map 33D	20	N	N	0.9	0	Opalocka	5	56	39
220	South Goulds/NFC Map35E	20	N	N	1	0.4	Opalocka	24	56	39
14	Wilkins / Pierson (CARL-EEL)	20	N	Y	0.7	1	Opalocka	32	55	39
18	Eachus/ Map 22A	17	N	N	1	0.2	Opalocka	34	55	39
369	Manfred Retreat Map 19B	17	N	N	0.4	0.3	Opalocka	36	55	38
15.04	West of Childs	16	N	N	0.2	0.5	Opalocka	32	55	39
132	Calderon Pineland (EEL) Map 32a	15.7	N	Y	1	0.7	Opalocka	3	56	39
224	Sw 124 ave/245 St., many owners	15.5	N	N	0.8	0.1	Opalocka	24	56	39
368	Trinity Pineland Preserve (CARL)	15	Partial	Y	0.9	0.1	Opalocka	35	54	40
153	Private Site	15	N	N	1	0.6	Opalocka	11	56	39
81.02	Burger King Site, Old Cutler	15	N	N	0.4	0.3	Opalocka	35	55	40
397	Girl Scouts Camp Choe / Map26B	15	N	N	0.8	0.6	Opalocka	30	55	40
401.04	West of Map 33A	14	N	N	1	0	Opalocka	5	56	39
182	NFC Map 32P	14	N	N	0.8	0.4	Opalocka	13	56	39
160	Goulds Stone Church / Map 32A	13	N	N	0.9	1	Opalocka	13	56	39
303	NFC Map 32B	12.5	N	N	1	0	Opalocka	14	56	39
136.02	NFC Map33C	12.5	N	N	0	0.3	Opalocka	4	56	39
366	A.D. Barnes Park	12	Y	N	0.9	0.7	Opalocka	14	54	40
66	Weeks (EEL Covenant)	12	N	N	1	0.2	Opalocka	26	55	40
31.06	East of M-D South on 107 Av.	11	Y	N	0.9	0.2	Opalocka	6	55	40
177	Medloch	10.5	N	N	1	0.2	Opalocka	15	56	39
15	Childs map21B	10	N	N	0.2	0.4	Opalocka	32	55	39
388	Eureka and Newton	10	N	N			Opalocka	33	55	39
302	School Board on SW216 St.	10	Y	N	0	0	Opalocka	14	56	39
276.5	East part of Whispering Pines	10	N	Y	1	0.2	Opalocka	3	56	40
148	NFC Map32E	10	N	N	0.8	0.4	Opalocka	11	56	39
371.5	Near Tamiami Map 20C	10	N	N			Opalocka	14	55	39
276	Whispering Pines (EEL) Map 36B	9.5	N	N	0.8	0.2	Opalocka	3	56	40
78.5	Bill Sadowski Park	9	Y	N	0.8	0	Opalocka	34	55	40
3.5	Boystown (southeast, not EEL)	9	N	N	1	0	Opalocka	10	55	39
25	South of Baptist Hosp	9	N	N	1	0.3	Opalocka	4	55	40
404	Hall (EEL Covenant) Map33A	8	N	N	1	0	Opalocka	7	56	39
16.02	Private Site	8	N	N	1	0.4	Opalocka	32	55	39
287	NFC Map 37A	8	N	N	0.4	0.8	Opalocka	17	56	40
145	Near Quail Roost / map32C	7.5	N	N	1	0	Opalocka	10	56	39
277	Whispering Pines (EEL) (Eastridge)	7.5	N	Y	1	0.7	Opalocka	3	56	40
398	Ned Glenn Preserve (School Board)	7.5	Y	N	0.5	0.5	Opalocka	4	56	40
167	Near Goulds Pineland	7.5	N	N	1	0.2	Opalocka	13	56	39
48	Pine Shore Park	7.5	Y	N	0.6	0.9	Opalocka	18	55	40
85	Private Site	7	N	N	0.8	0.3	Opalocka	11	56	38
144.02	Part of Quail Roost CARL Site	7	Y	N	0.8	0.8	Opalocka	10	56	39
26	Turnpike	7	N	N	0.6	0.4	Opalocka	5	55	40
61	USDA (No stand)	6.5	Y	N	0.9	0	Opalocka	24	55	40
283	BlkCrkFor / east	5.5	Y	Y	0.7	0.2	Opalocka	7	56	40
32	Ron Ehman Park	5	Y	N	0.9	0.5	Opalocka	9	55	40
399	Tropical Park	5	Y	N	0.7	0	Opalocka	22	54	40
56	Coral Reef Park	4.5	Y	N	0.7	0.5	Opalocka	22	55	40
284	Black Creek Forest, west (EEL)	4.5	N	Y	0.6	0.5	Opalocka	7	56	40
453	School Board, Site in Goulds	4	Y	N	0.6	0	Opalocka	18	56	40
63	USDA (south stand)	3.5	Y	N	0.7	0.6	Opalocka	24	55	40
424.5	Fairchild, Montgomery Found.	3	N	N	0.8	0	Opalocka	18	55	41
154	Rock Pit # 77	3	Y	N	1	0	Opalocka	11	56	39
367	Girl Scout Little House, So. Miami	3	N	N	1	0.2	Opalocka	25	54	40
79	Bill Sadowski Park (NE part)	2.5	Y	N	1	0.4	Opalocka	34	55	40
82	Hardy Matheson Preserve (pine)	2	Y	N	1	0.4	Opalocka	7	55	41
398.5	Whisp. Pine Pk	2	Y	N	1	0.4	Opalocka	4	56	40
20	Coral Pine Pk	1.5	Y	N	1	0.4	Opalocka	2	55	40

Total Opalocka Outcrop Soil Acreage = 1963

*Acquisition Pending

Sites on Cardsound Rock Outcrop Series Soils

SITE CODE	SITE NAME	Size (ac.)	Publicly Owned?	Acquisition List?	Pre-Andrew		Soil Type	Sec.	Town.	Ran.
					Mature Pines % Freq.	Young Pines % Freq.				
415	Navy Wells Preserve	300	Y	N	0.9	0.8	Cardsound	28	57	38
252	Camp Owaissa Bauer	70	Y	N	0.9	0	Cardsound	30	56	39
338	NFC Map 42B	50	N	N	1	0.3	Cardsound	23	57	38
255.04	Owaissa Add'n / Country Ridge	49	Partial	Y	0.9	0.7	Cardsound	31	56	39
352	Sunny Pines (EEL NW-42)	38	Y	Y	0.7	0	Cardsound	34	57	38
199.03	NFC Map 34B	37	N	N	1	0	Cardsound	21	56	39
188	NFC Map 33F	25	N	N	0.8	0	Cardsound	16	56	39
275	Moody Dr. School Board Site (CARL)	22.5	Y	Y	0.8	1	Cardsound	35	56	39
344	Florida City Pineland (CARL)	22	Partial	Y	0.8	0.8	Cardsound	25	57	38
365	Seminole Wayside Park	22	Y	N	0.7	0.2	Cardsound	8	57	39
419	Palm Avenue Pines (CARL)	20	Partial	Y	0.9	0.2	Cardsound	21	57	38
426	Navy Wells Complex, Site #39 (EEL)	20	*N	Y	0.9	0.3	Cardsound	28	57	38
265	Old Dixie/Hattie Bauer	20	N	N	0.9	0.8	Cardsound	33	56	39
312	NFC Map 38C	19	N	N	1	0.2	Cardsound	10	57	38
421	U.S.A. Map 30A	18.5	Y	N	1	0.1	Cardsound	14	56	38
297.05	NFC Map 38A	18	N	N	1	0.2	Cardsound	2	57	38
329	NW-2 (Schl Bird)	18	N	Y	1	1	Cardsound	15	57	38
273	Dade Heights / Map 36D	18	N	N	1	1	Cardsound	35	56	39
295.05	West Biscayne (CARL)	17	N	Y	1	0.8	Cardsound	2	57	38
330	NFC 38B	17	N	N	1	0.5	Cardsound	15	57	38
237	NFC Map 34K	16	N	N	1	0	Cardsound	28	56	39
310	Glancy/ Map 40A	16	N	N	0.9	0.4	Cardsound	9	57	38
354	Notre Dame Univ/ Map 43B	15	N	N	1	0.6	Cardsound	2	57	39
315	NFC Map 38E	14	N	N	0.8	0	Cardsound	10	57	38
435	NFC Map 38A	13	N	N	1	0	Cardsound	1	57	38
222.04	In Princeton	12.5	N	N	1	0.2	Cardsound	24	56	39
306	NFC Map 34A	12	N	N	1	0.4	Cardsound	32	56	39
175.01	Silver Palms Groves (north portion)	12	Y	Y	1	0	Cardsound	15	56	39
323	Residential, near NW-2 EEL	12	N	N	0.8	0.2	Cardsound	14	57	38
425	Private Site	12	N	N	0.9	0.4	Cardsound	7	57	39
99	Plat-All, Inc (EEL Covenant)	12	N	N	0.8	0	Cardsound	24	56	38
345	Navy Wells, site #23 (EEL)	11	N	Y	0.2	0	Cardsound	25	57	38
417	NFC Map 31B	10.5	N	N	0.9	0.5	Cardsound	36	56	38
255.03	Near Country Ridge/ Map 34B	10	N	N	0.4	0.5	Cardsound	31	56	39
360	Near Navy Wells	10	N	N	1	0	Cardsound	27	57	38
126	Coop Ext. TREC Center	10	Y	N	0.9	0.6	Cardsound	35	56	38
360	Ingram Site on SW 288 St. (CARL)	10	N	Y	1	0.3	Cardsound	6	57	39
268	Old Dixie	9	N	N	1	0.2	Cardsound	33	56	39
111	NFC Map 31B	9	N	N	1	0	Cardsound	26	56	38
235	Campanile EEL Covenant	9	N	N	1	0.3	Cardsound	27	56	39
112	NFC Map 31A	9	N	N	0.7	0.1	Cardsound	28	56	38
106	Private Site	8	N	N	1	0	Cardsound	28	56	38
296	West of Co-op Extension	8	N	N	0.9	0.2	Cardsound	2	57	38
354.05	Near HAFB	8	N	N	1	0.6	Cardsound	2	57	39
326	Private Site	8	N	N	0.6	0.7	Cardsound	14	57	38
332	South of NW-2	8	N	N	0.9	0.5	Cardsound	22	57	38
422	Blakeslee (EEL Covenant) Map 30B	8	N	N	1	0	Cardsound	14	56	38
241	Boyscout Camp/NFC Map 34H	8	N	N	0.4	0.6	Cardsound	28	56	39
324	West of Florida City	8	N	N	0.7	0	Cardsound	14	57	38
97	Rock Pit (5823)	8	Y	N	0.9	0	Cardsound	23	56	38
108.02	NFC Map 31C	8	N	N	1	0	Cardsound	26	56	38
336.02	Rock Pit #39	8	Y	N	1	0.2	Cardsound	20	57	38
101	Private Site	8	N	N	0.7	0.2	Cardsound	24	56	38
207	Private Site	7.5	N	N	1	0	Cardsound	22	56	39
413	map 42I	7	N	N	0.8	0.4	Cardsound	26	57	38
307	Private Site	7	N	N	1	0.3	Cardsound	14	56	39
123.6	Private Site	7	N	N	1	0.4	Cardsound	35	56	38
175.02	Silver Palm Grove (south portion)	4.5	Y	Y	1	0.9	Cardsound	15	56	39

Total Cardsound Series Soil Acreage = 1194

*Acquisition Pending

Appendix 6: Classification Scheme for GIS Mapping of Pine Rocklands

During DERM's study of the Richmond Pine Rocklands (DERM 1994), various layers of spatial information (vegetation cover types, fuel loading, and forest structure) were developed for purposes of determining management priorities. The cover types for pine rocklands listed below were developed such that a stand could be rapidly classified, then later mapped using GIS technology.

VEGETATION COVER TYPES

Native-dominated habitats

The following cover types are typically found in areas with intact substrate; or, if disturbed, then the disturbance is more than 25 years old.

1. **Pine Rockland:** Hardwood cover is less than 30%, exotic cover is less than 30%, and the substrate has been minimally altered.
2. **Pine Rockland with *Neyraudia*:** Pine rocklands with *Neyraudia* cover greater than 30%.
3. **Pine Rockland with Brazilian Pepper:** Pine rocklands with *Schinus* cover greater than 30%.
4. **Pine Rockland with Mixed Exotics:** Pine rocklands with mixed exotic cover greater than 30%.
5. **Pine Rockland with Modified Substrate:** These areas show signs of severe substrate modification (scraping or blading) but have been recolonized by predominantly native plant species. These areas usually are dominated by graminoids and forbs, and have very few native palms or hardwoods.
6. **Successional Pine Rockland:** Pine rocklands with greater than 30% cover by native hardwoods.
7. **Transitional Pine Rockland:** Pine rocklands with species indicative of transition to wetland.
8. **Hardwood Hammock:** Areas containing a cover of predominantly native hardwood trees.

Exotic-dominated areas

The following cover types are typically found in areas with recent soil disturbance.

1. **Mixed Exotics:** Areas containing a mixture of exotic plants, most commonly combinations of *Neyraudia*, *Schinus*, *Pennisetum*, *Albizia*, *Ricinus*, *Bischofia*, *Leuceana*, or *Casuarina*, with frequently a ruderal understory component.
2. **Exotic Monocultures:** In these areas, one exotic species dominates the vegetative cover, frequently exceeding 90% cover. Other native or exotic may be present in low numbers. Examples include "Dense *Neyraudia*", "Dense Brazilian Pepper", and "Dense Australian Pine".

PINE ROCKLAND FOREST STRUCTURE

Each management area is searched for the existence of living pine trees in all size classes. Management areas are labeled by listing each tree size class present. PEVD is an abbreviation for *Pinus elliottii* var. *densa*.

1. **PEVD 0:** Trees in the categories below occur at densities less than the densities listed below.
2. **PEVD 1:** Seedlings up to the grass stage (1 meter tall) with density greater than 25 seedlings per acre on average.
3. **PEVD 2:** Emergent grass stage (saplings) up to trees of cone bearing size (approximately between 1 meter and 6 meters tall) with density greater than 25 trees per acre.
4. **PEVD 3:** Trees of cone-bearing size and greater (over 6 meters) at a density greater than 10 trees per acre.
5. **Combinations:** Management units with more than one size class of pine are labeled accordingly. For example, a management unit with a PEVD 1,2,3 label contains an uneven-aged stand with all pine size classes, whereas a unit labeled PEVD 3 would contain only mature trees.

PINE ROCKLAND FUEL LOADING

The fuel loading categories below were selected to discriminate between three types of areas: areas that will not burn, areas that will burn, and areas that will burn with great intensity. Due to the dynamic nature of flammable fuels, annual reassessment of management areas is required. Fuels are classified by their size, which directly relates to speed at which the dry. The amount of dry, non-living fine fuels contributes significantly to ability of a vegetated area to ignite and carry fire. Fine fuels (one hour fuels) are those fuels less than 1/4 inch in diameter. They are called one hour fuels because they are very sensitive to moisture changes. Fine fuels in pine rocklands are needles, grass, small twigs, and dry palm fronds. Fuels can be continuous or discontinuous in arrangement. Bare patches of rock and sandy are clues that the fine fuels are discontinuous.

1. **F1 (Low fuel load):** Fine fuels lacking or fine fuels very discontinuous, mineral soils exposed. Fire-altering exotics (*Neyraudia*) lacking or less than 30% in cover. Areas with F1 fuels may not carry fire. Wildfires may not be a threat unless wind and moisture conditions are extreme. Frequently, these areas have low fuel loading because they have recently burned. These areas will need little site preparation prior to reforestation.
2. **F2 (Moderate fuel load):** Fine fuels continuous, moderate to heavy fuels very discontinuous; or, low fine fuels with fire-altering exotics (*Neyraudia*) prominent component (ie. > 30% cover) of understory; or, transverse glades with continuous fine grassy fuels. Areas with F2 fuels will burn readily and pose concern for wildfires. These areas will need to be burned prior to reforestation. The "Dense *Neyraudia*" cover type is considered an F2 fuel.
3. **F3 (Heavy fuel loading):** Continuous fine fuels present combined with *Neyraudia* above 30% cover or heavy, continuous moderate-heavy (10-1,000 hour fuels, ie. fuels greater than 1' in diameter). Areas with F3 fuels will burn readily and have potential to produce intense wildfires. These areas will need to be burned prior to reforestation.