Pine Rocklands

FNAI Global Rank:	**G1**
FNAI State Rank:	**S1**
Federally Listed Species in S. FL:	**10**
State Listed Species in S. FL:	**103**

Pine rocklands. *Original photograph courtesy of U.S. Fish and Wildlife Service.*

Pine rocklands are unique to southern Florida and the Bahamas. In Florida they are found on limestone substrates on the Miami Rock Ridge, in the Florida Keys, and in the Big Cypress Swamp. Pine rocklands are dominated by a single canopy tree, South Florida slash pine (*Pinus elliottii* var. *densa*), a diverse hardwood and palm subcanopy, and a very rich herbaceous layer. The flora of pine rocklands is composed of a diverse assemblage of tropical and temperate taxa. Many endemic plant taxa are also found in this community. It is a fire maintained community, requiring periodic fires to eliminate invading hardwoods, assist in nutrient cycling, and to reduce duff layers. Pine rocklands also provide critical foraging and nesting habitat for a diverse array of wildlife, including five federally listed animal species. While significant areas of pine rocklands are now protected within preserves such as Everglades NP, Big Cypress National Preserve, and the National Key Deer Refuge, pine rockland fragments are still threatened on the Miami Rock Ridge and in the Florida Keys. Pine rocklands have been heavily impacted by outright destruction, conversion to agriculture, fire suppression, exotic plant and animal invasions, collecting pressure on plants and animals, and alterations to hydrology. Significant work has now been initiated to control exotic plant taxa in pine rocklands, although much research needs to be conducted on restoring heavily degraded sites.

Synonymy

The following terms have been applied in whole or in part to plant communities of South Florida which are included in this account of pine rockland: 414-other coniferous forest (Florida Department of Administration 1976); South Florida flatwoods (Soil and Water Conservation Service 1989); pine forest (Duever *et al*. 1979); southern slash pine forest (Ward 1979); rockland pine forest (Davis 1943); pineland (Correll and Correll 1982). The FLUCCS code for the pine rocklands community includes: 411 (pine flatwoods), and 434 (hardwood/conifer mixed) (during regeneration).

Distribution

Pine rocklands are found in southern Florida, the Bahamas, and Cuba. In Florida, they were historically found on limestone substrates in Miami-Dade County along the Miami Rock Ridge from approximately North Miami Beach south and west to Long Pine Key in what is now Everglades NP. Pine rocklands in the Florida Keys are now restricted to the Lower Keys. Significant tracts of pine rocklands occur on Big Pine Key, No Name Key, Little Pine Key, Cudjoe Key, and Upper Sugarloaf Key in Monroe County. They also occcur in the Big Cypress National Preserve in Collier County. Alexander (1953) has shown that a small area of pine rockland once existed in the Upper Keys on Key Largo, but has since undergone succession to rockland hammock. Some pinelands in areas of limestone outcropping in Broward County may also be referable to this community. The largest remaining contiguous areas of pine rockland are found in the Long Pine Key area of Everglades NP in Miami-Dade County, on Big Pine Key in Monroe County, and in the Big Cypress National Preserve in Collier County (Figure 1). Small pine rockland fragments also persist along the Miami Rock Ridge from Florida City north to approximately Southwest 32nd Street in Miami-Dade County.

The pine rocklands of the Miami Rock Ridge have been divided into three separate regions by Robertson (1955) following soil patterns. He termed the northern end of the ridge with extensive sandy pockets “Northern Biscayne Pinelands,” which extend south to approximately S.W. 216 Street. To the south, “Redland” soils predominate and these pinelands are termed “Southern Biscayne Pinelands.” These pinelands extend south to Long Pine Key. “Long Pine Key,” wholly within Everglades NP, was considered the third region. It contains very few soil deposits and is of lower elevation.

Description

Pine rockland is a savanna-like forest on limestone outcrops with a single canopy species, South Florida slash pine, and a diverse understory of shrubs and herbs. It is a fire-maintained community requiring periodic burns every 3 to 7 years (Snyder *et al.* 1990). This community is often found in association with rockland hammock and short hydroperiod freshwater wetland communities.

Vegetative Structure and Composition

The flora of pine rocklands is influenced by the community’s proximity to the tropics as well as its peninsular connection to mainland Florida (Robertson 1953, Snyder 1986, Snyder *et al*. 1990). K. Bradley and R. Hammer (unpublished data) have recorded 374 native plant taxa in pine rocklands of Miami-Dade County, outside of Everglades NP. Although species diversity and richness varies geographically for pine rockland communities, the Richmond tract in Miami-Dade County contains 260 taxa of native plants (DERM 1994), the Navy Wells Pineland Preserve contains 172 taxa, and the Tamiami Pineland Preserve contains 163 taxa.

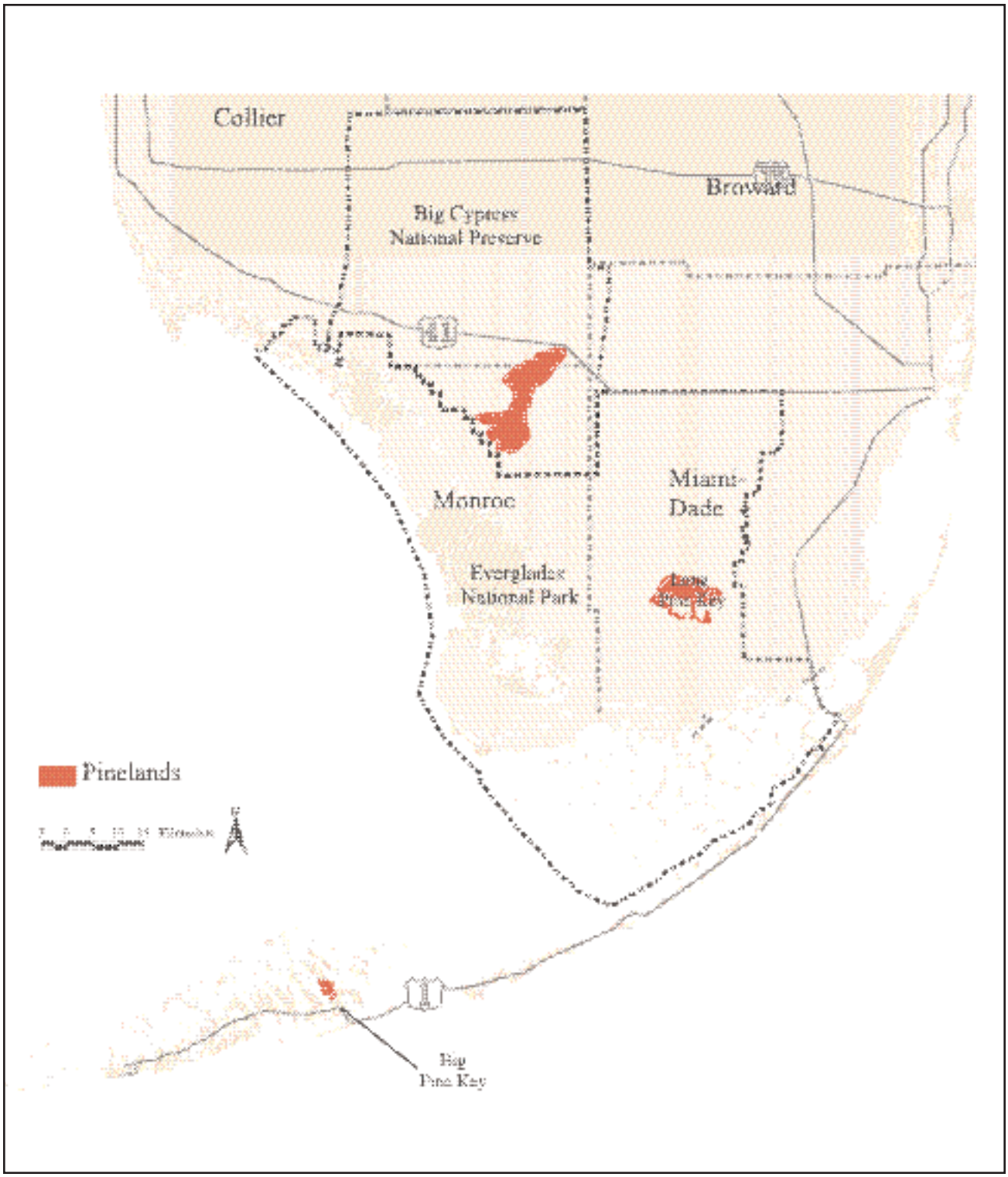

Figure 1. Distribution of the largest remaining contiguous areas of pine rocklands (adapted from Snyder *et al.* 1990.).

A high degree of vascular plant endemism is observed in the pine rockland community. In a 1977 survey of the 186 species noted in Miami-Dade and Monroe county pine rocklands, 30 species were only found in pine rockland communities in Miami-Dade County (exclusive of Everglades NP), and nine of these were endemic to the pine rockland community (Loope *et al.* 1979). Approximately 31 plant taxa which occur in pine rocklands are currently treated as endemic to South Florida (Table 1); 13 of these taxa occur in additional plant communities such as marl prairies or rockland hammocks (*e.g.* Blodgett's wild-mercury (*Argythamnia blodgettii)*, pineland clustervine (*Jacquemontia curtissii),* and false-leadplant (*Dalea carthagenensis* var. *floridana*)). Many taxa which were formerly considered to be endemic have been found in other regions such as peninsular Florida, the Bahamas, or Cuba [*e.g.* Blodgett's ironweed (*Vernonia blodgettii),* Florida gamagrass (*Tripsacum floridanum*)*,* Florida white-tops (*Rhynchospora floridensis*)], or are no longer considered to be taxonomically distinct (*e.g. Polygala boykinii* var. *sparsifolia),* and pineland-privet (*Forestiera segregata* var. *pinetorum*).

Many plant taxa reach their northern or southern limits in the pine rocklands of South Florida. Taxa with their entire United States distribution in South Florida which are limited to pine rocklands include Bahama sachsia (*Sachsia polycephala*)*,* pineland daisy (*Chaptalia albicans*)*,* quailberry (*Crossopetalum ilicifolium*), and shrub eupatorium (*Koanophyllon villosum*). A number of species in pine rocklands are disjunct from sandhill communities in central Florida. These include *Asclepias viridis, Cyperus filiculmis, Desmodium marilandicum,* dollarweed (*Rhynchosia reniformis*), Gray's beakrush (*Rhynchospora grayi*)*,* green-eyes (*Berlandiera subacaulis*)*, Rhynchosia michauxii,* Tracy's bluestem (*Andropogon tracyi*)*,* and *Zornia bracteata*. These taxa are primarily found in deposits of sand in the northern Biscayne pinelands, although *Asclepias viridis* can also be found on Big Pine Key.

The overstory of pine rocklands is open and dominated by a canopy of South Florida slash pine ranging in height from 20 to 24 m (65.6 to 79.2 ft) (Snyder *et al.* 1990). In the lower Keys the pine trees are smaller and the subcanopy includes *Thrinax* and *Coccothrinax*. Slash pine densities in pine rocklands have been reported at 453 to 1,179 pines/ha (185-477 pines/acre) on Long Pine Key (Snyder 1986), and 90 pines/ha (36 pines/acre) in the Turner River Area of Big Cypress National Preserve (Gunderson *et al.* 1982). This canopy provides a source of pine needles for fine fire fuel. The pine canopy ignites rarely, typically after long periods of fire suppression. Germination occurs during October, November, and December, with survival highest when optimal soil moisture is present the following dry season (McMinn 1970). The seedlings remain in the grass stage for 2 to 5 years. Growth occurs over a period of approximately 10 months from February to November (Langdon 1963). There is little to no subcanopy. However, hardwoods that may occur in the subcanopy include live oak (*Quercus virginiana*), wild-tamarind (*Lysiloma latisiliquum*), and willow-bustic (*Sideroxylon salicifolium*). These species are more abundant in areas where natural fire is suppressed (Snyder *et al*. 1990, DERM 1995) and in pine rocklands in close proximity to tropical hardwood hammocks (Loope and Dunevitz 1981).

More than 90 taxa of shrubs occur in pine rocklands, comprising a mix of tropical and temperate taxa. Those pinelands in proximity to hammocks have more hammock shrub taxa present, such as gumbo-limbo (*Bursera simaruba*), inkwood (*Exothea paniculata*), and wild-tamarind (Loope *et al.* 1979).

Dominant taxa in the shrub layer vary depending on location, soils, and elevation (Snyder *et al.* 1990, Loope *et al.* 1979). Fifteen species of shrubs may be present in pine rocklands throughout South Florida. These include cabbage palm (*Sabal palmetto*), coco-plum (*Chrysobalanus icaco*), myrsine (*Rapanea punctata*), saw palmetto (*Serenoa repens*), southern sumac (*Rhus copallinum*), strangler fig (*Ficus aurea*), swamp-bay (*Persea palustris*), wax-myrtle (*Myrica cerifera*), white indigo berry (*Randia aculeata*), and willow-bustic (Snyder *et al*. 1990). Pine rocklands near prairies or transverse glades have less of a shrub layer, but pineland acacia (*Acacia pinetorum*) and *Solanum verbascifolium* may occur in the shrub layer of pine rocklands in these areas. Some wetland taxa such as buttonbush (*Cephalanthus occidentalis*), coastal plain willow (*Salix caroliniana*), elderberry (*Sambucus canadensis*), pond-apple (*Annona glabra*), and pond cypress (*Taxodium ascendens*) may also be present (Snyder *et al*. 1990). Running oak (*Quercus pumila),* shiny blueberry (*Vaccinium myrsinites)*, and staggerbush (*Lyonia fruticosa*) are common in pinelands of central and northern Miami-Dade County in association with deposits of sand and loam.

Almost all pine rocklands have an understory palm component. The most common species is saw palmetto. On the Miami Rock Ridge, silver palm (*Coccothrinax argentata*) may occur, although it is rare toward the south (*e.g.* Long Pine Key). In the Florida Keys, thatch palm (*Thrinax morissii*) and silver palm are common, and reach heights of several meters, much higher than palms on the Miami Rock Ridge or Big Cypress. In areas with a longer hydroperiod and/or a layer of calcareous or loamy soil, cabbage palm (*Sabal palmetto*) may become abundant (Duever *et al*. 1979).

Hardwood species that occur in Big Cypress National Preserve and Miami Rock Ridge pinelands, but not in the Florida Keys pinelands, include buckthorn (*Sideroxylon reclinatum*), dahoon holly (*Ilex cassine*), live oak, and varnish leaf (*Dodonaea angustifolia*) (Snyder *et al*. 1990). Additional tropical species that are found in the Florida Keys as well as Miami Rock Ridge pinelands include locust berry (*Byrsonima lucida*), long-stalked stopper (*Psidium longipes*), pineland croton (*Croton linearis*), pineland strongback (*Bourreria cassinifolia*), rough velvetseed (*Guettarda scabra*), silver palm, and wild sage (*Lantana involucrata*) (Snyder *et al*. 1990). Tropical taxa that only occur in the Florida Keys pinelands include *Dodonaea elaeagnoides,* few-flowered holdback (*Caesalpinia pauciflora*), Key's partridge-pea (*Chamaecrista lineata* var. *keyensis*)*,* pisonia (*Pisonia rotundata*), pride-of-Big Pine (*Strumpfia maritima*), and small flowered lily-thorn (*Catesbaea parviflora*).

Shrub density and the abundance of tropical hardwoods is lower in the Southern Biscayne pinelands than in Long Pine Key (Loope *et al.* 1979). The shrub layer northward into the Northern Biscayne pinelands more closely resembles pine flatwoods as a result of the amount of sandy soils in this area.

The herbaceous layer in pine rocklands is very diverse, with a combination of grasses, ferns, sedges, and forbs. When the shrub layer in pine rockland areas is sparse, the herbaceous layer is more diverse. The herbaceous layer, like

the shrub layer, is composed of both temperate and tropical species with perennials much more common than annuals. Temperate species are most common in the Miami Rock Ridge and Big Cypress pinelands (Snyder *et al*. 1990). Typical widepread herbs and graminoids include *Schizachyrium sanguineum, S. gracile, Andropogon longiberbis, A. glomeratus* var. *pumilus,* candyweed (*Polygala grandiflora*), creeping morning-glory (*Evolvulus sericeus*), pineland heliotrope (*Heliotropium polyphyllum*), rabbit-bells (*Crotalaria rotundifolia*), and thistle (*Cirsium horridulum*).

Herbs found only in pine rocklands with deep sand layers, primarily towards the northern portions of the Miami Rock Ridge include *Aeschynomene viscidula*, *Andropogon gyrans* var. *gyrans, Asclepias verticillata*, big threeawn (*Aristida condensata*), *Cyperus filiculmis,* hair sedge (*Bulbostylis ciliatifolia*), *Lechea sessiliflora, Lechea torreyi, Liatris chapmanii*, *Palafoxia integrifolia, Polanisia tenuifolia,* procession flower (*Polygala incarnata*)*, Pteroglossaspis ecristata, Seymeria pectinata, Stylisma villosa,* tiny polygala (*Polygala smallii*)*, Tragia urens,* and wiregrass (*Aristida beyrichiana*). The wetter sands in the Big Cypress support *Helenium pinnatifidium, Pluchea rosea*, small butterwort (*Pinguicula pumila*), and yellow colicroot (*Aletris lutea*). Herbaceous species restricted to the pine rocklands on the Miami Rock Ridge include Brickell-bush (*Brickellia mosieri*)*,* pineland daisy*,* and rockland morning-glory (*Ipomoea tenuissima*). Tropical herbaceous species are most commonly found in pine rocklands in the southern portions of the Miami Rock Ridge, Long Pine Key, and the Florida Keys, while the Big Cypress has a stronger temperate component. The herbaceous layer in the Florida Keys is less diverse than elsewhere with fewer species recorded (Snyder *et al*. 1990). Most herbs in the pine rocklands of the Florida Keys are also found on the mainland. Exceptions include Key's deltoid spurge (*Chamaesyce deltoidea* ssp. *serpyllum*), and *Evolvulus grisebachii.*

Soils, Hydrology and Climate

Pine rockland occurs on relatively flat, moderately-to well-drained terrain. Because limestone bedrock is at or very near the surface, soils are generally small accumulations of sand, marl, and organic material in depressions and crevices in the rock surface. Drainage varies according to the porosity of the limestone substrate, but it is generally rapid. Consequently, most sites are wet for only short periods following heavy rains. During the rainy season, however, some sites may be shallowly inundated by very slow-flowing surface water for up to 60 days per year (FNAI and Florida Department of Natural Resources 1990).

Each of the three regions where pine rocklands occur in Florida has unique geological attributes. In Miami-Dade County, the community is associated with the Miami Rock Ridge, a formation of Miami oolitic limestone which extends for 70 miles from northeastern Miami-Dade County to the Mahogany Hammock region of Everglades NP (DERM 1993, 1994). The surface is often irregular with solution holes up to several meters in width and depth. Organic materials and humus accumulate in these solution holes (Snyder *et al.* 1990).

The elevation of the Miami Rock Ridge varies from greater than 7 m above sea level in the Miami area to less than 2 m above sea level in the Long Pine

Key area of Everglades NP with an average elevation of approximately 3 m, varying in width from 6.4 to 16 km (4 to 10 miles) (Davis 1943, USDA 1947). Where the ridge is evident in the Mahogany Hammock area of Everglades NP, it is covered largely by marl soil (Snyder, *et al.* 1990). Elevations in the limestone formations found in the Keys are significantly lower, from 1 to 2 m above sea level.

The depth and composition of pine rockland soils varies from almost non-existent in the Long Pine Key area, to very little exposed rock found in the Northern Biscayne pinelands. Where soil is present, it is a fine reddish-brown sandy loam, slightly acidic with less than10 percent organic matter. The soils and rooting medium found in solution holes may contain 30 to 50 percent organic matter. Soils in the Northern Biscayne pinelands area are quartz sands classified as Opalocka sand-rock outcrop complex. South of this area, the soils are rockier and classified as Card Sound rock outcrop series (USDA 1996). Soils in the lower Keys pine rocklands are classified as Key Vaca very gravely loam. These soils are well drained with a water table from 1 to 2 m (USDA 1996). Soil mapping has not been performed for Collier County, so little information is available on Big Cypress pine rockland soils (Snyder *et al*. 1990). S. Woodmansee (The Institute for Regional Conservation, personal communication 1998) has conducted extensive soil tests of pine rockland soils on the Miami Rock Ridge and has found that all pine rockland soils are slightly basic.

Rainfall in the pine rockland community varies from over 163 cm (64 inches) average annual in the northwest portion of Miami-Dade County to between 122 and 143 cm (48 and 56 inches, respectively) average annual in the rest of the county. Mean rainfall in the Florida Keys pine rocklands is 102 cm (40 inches), but is variable from island to island. The majority of this precipitation (75 percent) occurs between June and September (DERM 1995).

The hydroperiod in Long Pine Key and Big Cypress pine rocklands can range from about 20 to 60 days/year (Duever *et al*. 1979), but in pine rocklands on the Miami Rock Ridge outside of Everglades NP and most of the pine rocklands on Big Pine Key, the water table seldom reaches the surface. Under current conditions, the mean water table in Long Pine Key pine rocklands is reported at 0.6 to 2.0 m below the surface during the dry season and 0.3 to 1.0 m below the surface during the wet season (Olmsted and Loope 1984).

Temperature also plays an important role in pine rocklands. Because the large constituent of tropical and subtropical plants are more exposed to below-freezing temperatures in the relatively open understory, they are more likely to succumb to freeze damage than conspecifics in the sheltered rockland hammocks. Thus, below-freezing temperatures help reduce tropical hardwood encroachment in pine rocklands (FNAI and Florida Department of Natural Resources 1990).

Wildlife Diversity

Except for some birds and bats, most vertebrate animal species found in pine rocklands are temperate in origin (Snyder *et al.* 1990). While plant species can be transported by birds, ocean currents, or wind from the Caribbean, most animal species had to travel to South Florida by land, and a land bridge has never connected South Florida with the Caribbean. Pine rocklands provide food, cover,

roosting, and nesting sites to a wide variety of wildlife species. Fifteen species of vertebrates are endemic to South Florida rocklands (Snyder *et al.* 1990), and many of these utilize pine rocklands as habitat. Ten of these are mammals and five are reptiles. There are no endemic birds found in pine rocklands (Snyder *et al.* 1990).

It has been noted that rockland habitats, including pine rocklands, contain a lower diversity and abundance of wildlife than similar habitats to the north (Robertson and Kushlan 1984). Snyder *et al.* (1990) cite "the peninsula effect" of reduced species diversity in all vertebrate groups. Habitat disturbance has been implicated with low breeding bird populations, although reduced densities have also been found in isolated, undisturbed areas of the Big Cypress National Preserve (Patterson *et al.* 1980.).

The almost-year-round relative dryness of pinelands in the Big Cypress National Preserve has been cited as an important factor for wildlife in this community (Duever *et al.* 1979). Characters which are important to wildlife include open areas for sunning, soaring space, and a high amount of grassy forage.

Robertson and Kushlan (1984) report breeding bird densities in pine rocklands of 3 to 15.5 species, and between 5.5 and 55.5 breeding birds per ha . The most common included pine warbler (*Dendroica discolor),* red-bellied woodpecker (*Melanerpes carolina),* eastern meadowlark (*Sturnella magna),* northern mockingbird (*Mimus polyglottos),* eastern kingbird (*Tyrannus tyrannus),* bobwhite (*Colinus virginianus),* eastern bluebird (*Sialia sialis),* loggerhead shrike (*Lanius ludovicianus),* and common grackle (*Quiscalus quiscula)* on Long Pine Key and red-bellied woodpecker, gray kingbird (*Tyrannus dominicensis),* and northern cardinal (*Cardinalis cardinalis)* in the Florida Keys.

Dalrymple (1988) reports 22 species of reptiles and amphibians collected in traps in pine rocklands on Long Pine Key. Among the most common species collected were green anole (*Anolis carolinensis*), southern leopard frog (*Rana sphenocephala*), southern toad (*Bufo quercicus*), black racer (*Coluber constrictor),* and southeastern five-lined skink (*Eumeces inexpectatus*).

Some West Indian vertebrates are also found in pine rockland communities, however, it is unknown if these were introduced by humans. Present opinion indicates that all but the reef gecko were introduced. The greenhouse frog (*Eleutherodactylus planirostris*), Cuban treefrog (*Osteopilus septentrionalis*), reef gecko (*Sphaerodactylus notatus*), and brown anole (*Anolis sagrei*) are representative of these West Indian species (Snyder *et al*. 1990). The Bahamian bark anole (*Anolis distichus*), Jamaican fruit bat (*Artibeus jamaicensis*), and Florida mastiff bat (*Eumops glaucinus floridanus*) are examples of recent natural colonizers of pine rockland habitat (Snyder *et al*. 1990).

The Big Cypress (=mangrove) fox squirrel (*Sciurus niger avicennia*), Florida panther (*Puma (=Felis) concolor coryi*), and Florida black bear (*Ursus americanus floridanus*) use pine rockland habitats, but are also found in other plant communities as well (Snyder *et al*. 1990). The American kestrel (*Falco sparverius*), brown-headed nuthatch (*Sitta pusilla*), eastern bluebird (*Sialia sialus*), and summer tanager (*Piranga rubra*) formerly bred in pine rocklands of the Miami Rock Ridge, but are no longer found there (Snyder *et al*. 1990). These species, with the exception of the American kestrel and the hairy woodpecker (*Picoides villosus),* are still found in the pine rocklands of the Big Cypress National Preserve (Snyder *et al*. 1990).

Invertebrate species found in pinelands include ants, skippers, butterflies, and arachnids. The ants originate from North America while many of the butterflies and skippers are West Indian in origin. Typical butterflies include Bartram's hairstreak (*Strymon acis bartrami*), Florida leaf wing (*Anaea troglodyta floridalis*), rockland grass skipper (*Hesperia meskei*), and sawgrass skipper (*Euphyes pilatica klotsi*) (Minno and Emmel 1993). Other invertebrates include ogre-faced spider (*Dinopsis spinosa*), silver argiope (*Argiope argentata*), and vinegaroons (*Mastigoproctus giganteus*).

Wildlife Species of Concern

Federally listed species that depend upon or utilize pine rocklands in South Florida include: Key deer (*Odocoileus virginianus clavium),* Kirtland's warbler (*Dendroica kirtlandii*), bald eagle (*Haliaeetus leucocephalus*), eastern indigo snake (*Drymarchon corais couperi*), and Florida panther. The pine rocklands in the Big Cypress region and Long Pine Key provide habitat for eastern indigo snakes and Florida panthers. The Key deer can be found utilizing the pine rocklands on Big Pine Key. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

State listed animals occurring in pine rocklands include Big Pine Key ringneck snake (*Diadophis punctatus acricus*), red rat snake (*Elaphe guttata guttata*), and gopher tortoise (*Gopherus polyphemus*). Rare animals known from this community include Florida atala butterfly (*Eumaus atala*), Florida leafwing butterfly (*Anaea troglodyta floridalis*), and rim rock crowned snake (*Tantilla oolitica).* Refer to Appendix C for a list of other species that utilize the pine rockland communities.

The **Florida atala** was at one time believed to be extirpated in South Florida due to over collecting of its food plant the coontie (*Zamia pumila*), and habitat loss. It has reappeared and is locally common due to its host plant being grown as an ornamental in gardens and nurseries. This butterfly naturally occurs in tropical hardwood hammocks and pinelands. Surveys should be completed to determine the distribution and abundance of the Florida atala. Conservation actions should include prescribed burning to maintain the Florida atala's natural habitat.

The **Big Pine Key ringneck snake** is known only from pine rocklands on Big Pine Key, and is known from a variety of habitats including pine rocklands. This species is neither widespread nor common and could become endangered if suitable habitat is not preserved. The pine rockland habitat and the Big Pine Key ringneck snake will continue to decline as the human population increases throughout the Florida Keys unless suitable habitat is preserved.

Red rat snake. *Original photograph by Barry Mansell.*

The **lower Keys populations of red rat snakes** live in pine woods and mangrove forests (Weaver 1992). They are primarily nocturnal, hide under rocks and logs, and will burrow into loose sand. The red rat snake is being threatened by the increasing development activities that are occurring throughout the Florida Keys. Although the red rat snake population in the Keys was documented as declining before the recent surge of development, the numbers appear to be stable and locally abundant. The lower Keys population of red rat snake has been listed as a species of special concern by the State. Although the numbers appear to be stable, the paucity of field work makes estimates of population sizes questionable. Conservation actions should continue to include the preservation of suitable habitat, including pine rocklands.

The **Florida leafwing** butterfly is locally abundant on Big Pine Key and Long Pine Key (Minno and Emmel 1993) and occurs in rocky pinelands of southern Miami-Dade County (Minno and Emmel 1994). The Florida leafwing lays its eggs on its host plant, the woolly croton *(Croton linearis*). After hatching, the males perch on the foliage at the edge of clearings and feed on the leaves. The restricted habitat of this endemic species is declining due to urbanization on the mainland and in the Keys (Minno and Emmel 1994). Hurricane Andrew dealt an additional blow to the already stressed southern Miami-Dade County Florida leafwing population. Although fire is critical to this species, land management should avoid burning large tracts at one time, and create a mosaic of habitat with differing fire regimes. Remaining habitat in the Keys and southern Miami-Dade County should be preserved to continue the existence of the Florida leafwing.

Plant Species of Concern

Federally listed plant species that depend upon or utilize pine rocklands in South Florida include: Garber's spurge (*Chamaesyce garberi*), deltoid spurge

(*Chamaesyce deltoidea* ssp. *deltoidea*), tiny polygala (*Polygala smallii*), small's milkpea (*Galactia smallii*), and crenulate lead-plant (*Amorpha crenulata*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. There are 84 State listed plant taxa that occur in pine rocklands. With the exception of Garber's spurge and tiny polygala, all of the listed plant species listed here are found only in Miami-Dade County. Garber's spurge is found primarily in pine rocklands and coastal areas of the Florida Keys, but has been found at the Charles Deering Estate and in Everglades NP. Tiny polygala is found in xeric to mesic habitats along the east coast from Miami-Dade County to St. Lucie County. Carter's mustard (*Warea carteri*), which is typically associated with scrub, sandhill, and scrubby flatwood habitats, was historically recorded in pine rocklands in the Coral Gables area. It has not been seen there in decades.

More than 90 plant species of concern have been recorded in pine rocklands (Appendix C). Most State listed plant taxa occurring in pine rocklands occur on the Miami Rock Ridge (88 percent). Pine rocklands of the Florida Keys contain 49 percent, while only 17 percent are found in the Big Cypress (Table 2). Some of the rarest State listed species which occur in pine rocklands include Brickell-bush (*Brickellia mosieri*), Carter's orchid (*Basiphyllaea corallicola*), Grisebach's bindweed *(Evolvulus grisebachii),* false-leadplant (*Dalea carthageninsis* var. *floridana*), pride-of-Big Pine (*Strumpfia maritima*), narrow-leaved hoary pea (*Tephrosia angustissima* var. *angustissima*), and coral hoary pea *(T. angustissima* var. *corallicola).* Several State listed pine rockland endemic taxa should be considered for possible Federal listing: Blodgett's wild mercury (*Argythamnia blodgettii*), Brickell-bush, Carter's small flowered flax (*Linum carteri* var. *carteri*), false lead-plant, few-flowered crab grass (*Digitaria pauciflora*), Florida lantana (*Lantana depressa* var. *depressa*), key's deltoid spurge, pineland milk-pea (*Galactia pinetorum*), and sand flax (*Linum arenicola*). One endemic pine rockland plant is now thought to be extinct: the narrow-leaved hoary-pea. Mrs. Britton's shadow-witch orchid (*Ponthieva brittoniae*) (McCartney 1997), Flor De Pasmo (*Bletia patula),* and Bahama manjack (*Cordia bahamensis)* are believed to be extirpated in South Florida.

The endemic **Blodgett's wild mercury** can be found in low, moist limestone areas near the margins of pine rocklands in South Florida, extending into the Keys. To conserve the Blodgett's wild mercury, pine rocklands should be preserved. This plant is rapidly declining due to the increasing pressures of residential and commercial development on its specialized habitat type. The State has listed the Blodgett's wild mercury as an endangered species.

The State endangered **Carter's small-flowered flax** is endemic and can be found in mowed pine rocklands in Miami-Dade County. As with any other endangered plant species that requires pine rocklands as its specialized habitat, it is extremely endangered due to the high rate of residential and commercial development that is occurring throughout the Miami area.

The **Florida lantana** is listed by the State as an endangered species due to its declining pine rockland habitat that is occurring throughout its narrow range of Miami-Dade County. Only twelve elemental occurrences of var. *depressa* have

been documented, all in Miami-Dade County. This species has been rapidly declining due to commercial and residential development that is occurring throughout its range. In order for this species to avoid extinction, efforts must be made to preserve existing pine rockland habitat.

The **sand flax** is endemic to Miami-Dade and Monroe counties. This plant can be found in solution pits and shallow soils of semi-shaded ephemeral pools on limerock in open pine rocklands, pineland clearings, and adjacent roadsides (Long and Lakela 1971). Fire suppression reduces the amount of open areas required by the sand flax. This plant is State listed as endangered due to the extreme degree of threats that are occurring as a result of development and natural occurrences. The sand flax should be managed in a manner that incorporates fire as a tool to preserve and create open habitat.

The ecotone between pine rocklands and tropical hardwood hammocks is very important habitat for many plant taxa and is discussed in the Tropical Hardwood Hammock account.

Ecology

Fire is required for the maintenance of the pine rockland community. It influences vertical structure and species composition, controls the invasion and growth of hardwood species, allows light to reach understory and herbaceous plants, and allows for pine regeneration. Although some have reported that fire also controls the ratio of pineland to hammock under natural conditions (*e.g.* Snyder *et al*. 1990), others (Olmsted *et al.* 1983) state that the size and shape of hammocks remain relatively constant over time. Regardless, under conditions of fire suppression, hardwoods will invade pine rockland and eventually shade out pine rockland understory species. For this reason, this plant community has been termed a "fire subclimax" community, since hardwood development is kept in check by fire (FWS 1988b; DERM 1994, 1995).

Pine rockland fires are surface fires that have minimal effects on the pine canopy. The primary source of natural fire in pine rockland systems is lightning (Snyder 1986). The majority of lightning-caused fires occur between May and September, with larger fires in the early part of the wet season (Snyder 1986). The shortest fire interval could be 2 to 3 years, the longest interval 10 to 15 years with most researchers in agreement that pine rocklands typically burn twice per decade (Snyder *et al.* 1990). Hofstetter (1973) estimates a proper fire frequency at 3 to 7 years, although it has been suggested that a fire interval of 3 to 7 years may be too frequent for young pines to attain a large enough size to survive a fire (Olmsted and Loope 1984).

The South Florida slash pine is very resistant to fire. Seedlings of the South Florida slash pine have the ability to resprout from the root collar after a surface burn, while the northern variety is without this adaptation (Ketcham and Bethune 1963). It also has long needles which shield apical buds, and a thick bark which protects the inner bark and cambium (Byram 1948, Hare 1965). Hofstetter (1973) reports an 87 percent mortality of seedlings under 1.5 m (5 ft) tall, and approximately 50 percent mortality of saplings 2 to 6 m (6.6 to 19.8 ft) tall. Pine seedlings have better survival rates in areas of low duff accumulation, and seedling establishment can be improved when fires occur

soon before seed release, typically in October (Klukas 1973, Snyder 1986). If fires occur after seed release then seeds are killed (Snyder 1986).

Many herbs and shrubs resprout or grow rapidly after fire, and shrubs are seldom killed by a single fire (Snyder 1986). Fire may also stimulate flowering in these taxa. Fire response may vary dramatically depending on the time of year of the fire event (Snyder *et al*. 1990). Gunderson *et al.* (1983) report that in a study of fire effects on 36 pine rockland plant species, 21 showed no alteration in post-fire flowering or fruiting patterns. Species with reduced flowering or fruiting activity included the eight hardwood shrubs. Six species exhibited an increase in flowering and fruiting activity in the 9 months following a fire. Snyder (1986) showed that hardwood recovery was not affected by season of burning. Instead, recovery was affected by fire intensity. Gunderson *et al.* (1983) report that fruiting of shrub species is reduced after a fire, and that repeated burning may also exhaust root reserves. Almost all herbs in pine rocklands are perennials which resprout quickly after fires. Snyder (1986) reported that herbs regained their pre-fire biomass 7 months after a dry-season burn and 1 year after a wet-season burn. Annuals or biennials which do not resprout following fire include false-foxglove (*Agalinis fasciculata*) and tiny polygala.

The theoretical successional relationship between pine rockland and tropical hardwood hammocks has been much discussed (see Olmsted *et al.* 1983). It has been reported that in the absence of fire, pine rockland will succeed to tropical hardwood hammock in 20 to 30 years (Alexander 1967, Wade *et al*. 1980, Loope and Dunevitz 1981, Snyder *et al*. 1990), but that succession may be slowed if less hammock is present in the vicinity of the pine rockland (Loope and Dunevitz 1981). Olmsted *et al.* (1983), however, reported that hammock size and shape stays "remarkably" constant over time. Since fire is a natural function in the South Florida Ecosystem, virtually all hammock expansion into pine rocklands in the absence of fire would have to be attributed to anthropogenic factors.

Status and Trends

In Miami-Dade County, this relatively high elevation community was one of the first to be developed. Land clearing commenced during the late 1800s and early 1900s and continued unabated until 1984, when Miami-Dade County passed the Tree Protection Ordinance which provided some protection to upland forests. Prior to modern settlement, this vegetative community covered approximately 65,450 ha (161,660 acres) in Miami-Dade County. As a consequence of development, the north-south distribution of pine rocklands along the Miami Rock Ridge has been reduced by more than 12 miles. Approximately 8,029 ha now remain in Everglades NP. A 1975 inventory (Shaw 1975) recorded 2,132 ha (5,268 acres) in forest fragments of 2 ha (5 acres) or more outside of Everglades NP. A 1978 inventory reported a further 25 percent reduction (Loope *et al.* 1979). DERM (1995) reported that in 1990, 375 pine rockland fragments totaling nearly 1,780 ha (4,400 acres) remained. These fragments averaged only 4.9 ha (12.1 acres) in size, and ranged from 0.4 ha (1 acre) to 345 ha (853 acres). Acreage

of pine rockland on Big Pine Key was reduced from 1,049 ha (2,592 acres) in 1955 to 701 ha (1,732 acres) in 1989 (Folk 1991, Folk *et al*. 1991). In some cases, this habitat loss has been the direct cause of plant extirpations [*e.g.* Carter's warea *(Warea carteri*)*, Cordia bahamensis, Bletia patula*].

During the 20th century, extensive logging took place on the Miami Rock Ridge, the Florida Keys, and Big Cypress pine rocklands. The majority of the pine rocklands in Everglades NP were logged prior to establishment of this park in the late 1930s and early 1940s, although it appears that approximately 1,667 ha (4119 acres) were spared. This is probably because the pines in those areas were too small or were in areas that were difficult to reach (Olmsted *et al.* 1983). Logging began in the Big Cypress region around 1900, with a peak in logging activity in the 1940s to the mid 1950s (Duever *et al.* 1979). According to Duever *et al.* (1979), the only virgin stands of pine rocklands remaining in Big Cypress National Preserve are in the northern and eastern edges of the "Interior Pinelands" (between Tamiami Trail and Alligator Alley). By the turn of the century, citrus and other fruit trees were being planted in cleared pine rocklands in Miami-Dade County. Row crops, although originally planted in marl prairies, were planted in pine rocklands when application of the newly invented rock plow began in 1954 (Olmsted *et al.* 1983, Loope *et al*. 1979, Snyder *et al*. 1990). In addition, some areas were scraped, and then abandoned (DERM 1994). Some of these scraped sites are now dominated by native vegetation.

The majority of remaining pine rocklands outside of the Florida Keys have now been acquired and are no longer threatened by development. Large areas of pine rocklands are protected in Everglades NP, Big Cypress National Preserve, and the National Key Deer Refuge. Other areas with pine rocklands on the mainland include several conservation areas on the Miami Rock Ridge which are managed by Miami-Dade County Park and Recreation Department, and the Miami-Dade County Environmentally Endangered Lands Program. The largest of these sites however is only 121 ha (300 acres) in size. A significant amount of pine rockland is still threatened by development in the Keys (C.R. Kruer, personal communication 1998).

Pine rocklands once dominated the landscape in eastern Miami-Dade County and were associated with a mosaic of marl prairies which transected them. Other communities such as swale and coastal marsh surrounded them, and other habitats such as tropical hardwood hammocks were embedded within them. Fragmentation of pine rocklands and their artificial separation from other communities has had very serious effects on both the pinelands and the wildlife that utilize them. Fragmentation, for instance, may make it difficult for certain migratory bird species to survive in the developed landscape.

In addition to outright habitat loss and its associated fragmentation effects, the process of urbanization and rural development itself has caused significant negative effects to pine rocklands. The development of roads, among other things, has increased access of natural areas, including pine rocklands, to collectors of bromeliads, ferns, orchids, butterflies, and palms.

While collecting pressure on these groups has been much more intense in tropical hardwood hammocks, large excavated holes where mature silver palms once occurred is a common sight in pine rocklands. Roads also lead to wildlife mortality from automobile traffic, including that of the Florida panther

(FWS 1998a), and presumably even rare invertebrates such as the atala and Florida leaf-wing butterflies.

Although it has not been well studied, pine rocklands have probably been affected by reductions in the mean water table. It has been suggested that a lowered water table may also have been a factor in the massive die-off of South Florida slash pine following Hurricane Andrew (DERM 1995). Oberbauer *et al.* (1997) report that water limits the growth of South Florida slash pines in Miami-Dade County, and that the water status of slash pines has declined relative to 25 to 30 years ago. Their results did not confirm, however, that water stress was the primary factor in post-hurricane pine mortality. Some plant species that were formerly present in low-elevation pine rocklands on the Miami Rock Ridge (*e.g.*, *Eriocaulon ravenelii*) have been extirpated.

Sea level rise is also reducing acreage of pine rockland in the Florida Keys. Alexander (1953) hypothesized that the pine rocklands of Key Largo disappeared because of sea-level rise, resulting in invasion of a tidal swamp community. Ross *et al.* (1994) conducted a thorough study of the effects of sea-level rise on Sugarloaf Key, finding that sea-level rise was responsible for a reduction in area from 88 ha (217 acres) before 1935 to 30 ha (74 acres) in 1991.

Exotic plant taxa have also significantly affected pine rocklands. At least 277 taxa of exotic plants are now known to invade pine rocklands in South Florida (Appendix D). Impacts of exotic plant species have been particularly severe in pine rocklands on the Miami Rock Ridge.

The exotic tree Brazilian-pepper (*Schinus terebinthifolius)* is the most widespread and one of the more invasive species. It is probably present in every pine rockland fragment in Miami-Dade County, and is also well established in the pine rocklands of Everglades NP, Big Cypress National Preserve, and the Florida Keys. If left uncontrolled in a fire-suppressed pineland, it will form a dense, monospecific canopy, almost completely eliminating native vegetation (Loope and Dunevitz 1981). Burma reed (*Neyraudia reynaudiana*), a large woody grass, is one of the most worrisome invaders. This fire-tolerant grass is now present in almost all pine rockland fragments of the Miami Rock Ridge. It is only slightly established in the pine rocklands of Everglades NP, and has not been documented in pine rocklands of the Big Cypress National Preserve or the Florida Keys. This grass will form dense stands, out competing native vegetation, and alter the fire regime in sites where it invades. Melaleuca (*Melaleuca quinquenervia*), primarily an invader of wetlands, can be a problem in lower pinelands of the Big Cypress National Preserve. Other troublesome exotic pest plants in pine rocklands include earleaf acacia (*Acacia auriculiformis*), natal grass (*Rhynchelytrum repens*), shrub verbena (*Lantana camara*), and tongue tree (*Albizia lebbeck*). Hybrids between native and exotic plant taxa have also begun to appear (*e.g. Lantata depressa* x *L. camara*) (Hammer 1996), ultimately threatening native species with extirpation or extinction.

Exotic animals have also impacted pine rocklands. Introduced species that occur in South Florida rocklands include seven mammals, about 30 birds, four amphibians, and 25 reptiles (Snyder *et al*. 1990). Armadillo (*Dasypus novemcinctus*), black rat (*Rattus rattus*), fire ants (*Solenopsis invicta*), and hog (*Sus scrofa*), as well as domestic cats *(Felis domesticus)*, have all been found in

South Florida pine rocklands. Feral and domestic cats prey on resident and migratory land birds. The 15 species of parrots, parakeets, and other psittacines which have been recorded as nesting in the wild in South Florida (Snyder *et al.* 1990), are most certainly dispersing seeds of exotic plants.

Fire suppression has had considerable negative impacts on pine rockland communities. Most pine rockland fragments of the Miami Rock Ridge have undergone some degree of fire suppression. Fire-suppressed sites often take on a characteristic appearance. They have a dense edge dominated by Brazilian-pepper and exotic vines (*e.g. Jasminum* spp.). In the center Brazilian-pepper is also common, the saw palmetto understory becomes very dense and tall, and several other hardwoods may also reach heights of several meters (*e.g.* West Indian-lilac [*Tetrazygia bicolor*], willow bustic). A thick duff layer accumulates and eventually results in the appearance of humic soils rather than mineral soils. The herbaceous layer is reduced to sporadic occurrences of a few shade-tolerant species with patchy distributions (*e.g.* bestraw [*Galium hispidulum*], *yellowroot* [*Morinda royoc*]). Diversity is considerably reduced in these fragments (Loope and Dunevitz 1981). In addition, winter burning may have had adverse impacts on pine rocklands.

A variety of contaminants could affect pine rocklands and their constituent fauna. Mosquito spraying is a problem to many species of invertebrates, including the atala and Florida leafwing butterflies, and numerous other invertebrates. This in turn, reduces food availability for land birds.

Recently, another type of threat to this vegetative community became apparent. In August of 1992, Hurricane Andrew hit southern Miami-Dade County. This hurricane had sustained winds in excess of 233 km/h (145 mph) with vortices up to 322 km/h (200 mph). Ninety-nine percent of the pine rocklands located in Miami-Dade County were impacted by this storm event. Within one year of the event, many adult trees were dead, outbreaks of *Ips* beetles (including *I. calligraphis, I. avulsus,* and *I. grandicollis*) had been reported, and two species of weevil (*Hylobius pales, Pachylobius picivorus*) had attacked juvenile trees (DERM 1995). The outbeak has been attributed to the combination of wind damage and drought following a very dry spring, making the trees more susceptible to infestation. In a fall 1993 follow-up survey of Miami-Dade County pine rocklands, only two of 18 sites had living mature pines (DERM 1995). The loss of the pines has affected the fire fuel production, and could allow invasive species to further impact pine rocklands in this area (DERM 1993). The hurricane also flooded some interior non-tidal wetlands on Big Pine Key in Monroe County, subjecting some low-lying pines to salt stress and mortality.

Management

Most pine rocklands outside of the Florida Keys are now protected from development. On the Miami Rock Ridge in Miami-Dade County, many pine rockland parcels are still privately owned. Development of many of these pine rocklands, however, regulated under the Natural Forest Community ordinance. Prior to development a permit is required from the Miami-Dade County Department of Environmental Resources Management. Many parcels, however, are not covered by this ordinance, including the federally owned properties in the

Richmond Pineland complex (DERM 1994). In the Keys, pine rocklands continue to be developed (C.R. Kruer, personal communication 1998).

Acquisition of the remaining pine rocklands outside of the Florida Keys is nearing completion, although the Miami-Dade County Environmentally Endangered Lands Program still has a number of significant ongoing projects. The need for protection of pine rocklands on the Miami Rock Ridge has been well illustrated by Loope *et al*. (1979) and Loope and Dunevitz (1981). Miami-Dade County should be encouraged to complete these acquisitions as soon as possible. In the Florida Keys, land acquisition is still ongoing through CARL, and the Monroe County Land Authority (C.R. Kruer, personal communication 1998). The CARL program has several active programs in the Florida Keys, and should be stimulated to complete its purchases there as soon as possible. SOR also has some significant projects in the lower Keys. Pine rockland habitat on Big Pine Key and Cudjoe Key is at risk from various factors including hydrologic alteration due to residential withdrawls of the water table and canal dredging.

In both Miami-Dade County and the Florida Keys, cooperation with landowners of pine rocklands is essential to the long-term protection of this natural community. In 1979, Miami-Dade County enacted the Environmentally Endangered Lands Covenant Program which reduces taxes for owners of pine rocklands and tropical hardwood hammocks who agree not to develop these systems and to manage them for a period of 10 years. This program is still ongoing and protects many pine rockland sites. Unfortunately, no similar system exists in Monroe County, where a significant amount of pine rockland is still in private ownership. Monroe County should be encouraged to adopt a program similar to the Environmentally Endangered Lands Covenant Program to help prevent the destruction and/or deterioration of privately held pinelands. In particular, these remaining pine rocklands are critical habitat for Key deer (FWS 1998b). In addition to the Environmentally Endangered Lands Covenant program, Miami-Dade County also has the Forest Resources Program within DERM which provides private and public owners of pine rocklands and tropical hardwood hammocks with technical assistance, including the preparation of management plans, herbicide training, prescribed fire coordination, plant identification workshops, and site-specific consultations (J. Klein, DERM, personal communication 1998). The Forest Resources Program is also collaborating with the Boy Scouts of America to link private sites with Eagle Scout projects, and is exploring several mechanisms to provide monetary support for management on private lands. This kind of program should also be encouraged in the Florida Keys. The USDA Farm Service Agency also has an "Environmental Quality Incentive Program," a cost sharing program for restoration and management of natural communities taken out of agricultural production.

The DERM Forest Resources Program also has regulatory authority over pine rocklands and tropical hardwood hammocks, and is charged with enforcing regulations which provide partial protection for pine rocklands on the Miami Rock Ridge. This includes authority over all natural forest communities in Miami-Dade County, including county, and city-owned parcels. In the Florida Keys, most regulatory authority is found in the local comprehensive plan, which is enforced by the Department of Community Affairs (C.R. Kruer, personal communication

1998). Property owners now compete for 255 permits per year through the Rate of Growth Ordinance that assigns good and bad points for presence of natural areas and endangered species (C.R. Kruer, personal communication 1998). Neither regulatory program totally precludes development.

Until recently, management of pine rockland preserves outside of Everglades NP has been minimal, and many pine rockland preserves have become degraded due to invasions by exotic plants, invasions by exotic, feral, and domestic animals, fire exclusion, anthropogenic fires, unauthorized use (including bicycles), illegal dumping, improper siting of interpretive trails and facilities, poaching of animals, collecting of plants, drainage, flooding and saltwater intrusion, mosquito spraying, and drift of pesticides from agricultural and commercial operations. Massive pine mortality has also occurred in pine rockland fragments impacted by Hurricane Andrew in 1992. More effort must be made to reduce these and other types of negative impacts on pine rockland preserves.

Following acquisition and the prevention of further disturbance, the most important step in recovery is to restore existing degraded pine rocklands through active management, and, with a few exceptions, this process is still in its formative stages. Where possible, connections between pine rocklands and surrounding natural communities such as tropical hardwood hammocks and freshwater wetlands should be re-established. Roads and fire breaks which separate pine rocklands from hammock edges, marl prairies and other surrounding communities should be removed, and prescribed fire should be used as a tool to re-establish historic hammock edges. Roads which dissect and fragment pine rocklands should be removed and restored, except where they are needed as fire breaks. Where possible, the water table should also be restored to approximate its historic condition. This includes raising the water table on the Miami Rock Ridge. Exotic plant species must be controlled with the ultimate goal of extirpating as many exotic taxa as possible, and restoring historic pineland structure and composition. When possible, outlying populations of exotic plant species should be treated as a way of limiting expansion (Moody and Mack 1988). Exotic animals must be removed from natural areas, and domestic pets prevented from entering pine rocklands. Animal removal must be sensitive to the needs of indigenous wildlife which might be affected by certain chemical control methods. Efforts should also be made to control unauthorized use including off-trail hiking. Land managers must also be vigilant against contamination of sites from mosquito spraying, and pesticide drift from commercial and agricultural operations. Finally, special emphasis should be placed on the reintroduction of extirpated species within their historic ranges.

Everglades NP has had an ongoing management program in pine rocklands since 1958 (Olmsted *et al.* 1983) when a prescribed burn program was initiated. Although winter burning was done historically, the park began a program of summer burning in 1981 (Doren *et al.* 1993). The park has also been active in controlling exotic pest plants, primarily Brazilian pepper. The obvious and most important actions for pine rockland maintenance, protection, restoration, and enhancement, focus on control of exotic plant species and appropriate fire management regimes (Loope *et al*. 1979).

The most aggressive campaign to restore pine rockland fragments is being conducted by DERM and the Miami-Dade County Park and Recreation

Department, Natural Areas Management Section (NAM). DERM prepared a pine rockland restoration plan following Hurricane Andrew (DERM 1995). This plan focuses future pineland restoration efforts on establishment of a grass/forb understory in these communities to provide supplemental fine fuels. This effort is a result of adult pine mortality from Hurricane Andrew. It is believed that the fine fuels are needed to provide the correct temperature for pine rockland fires and provide proper conditions for pine regeneration. A grassy understory produces less smoke when burned, and is easier to extinguish in urban fragmented forests.

The Miami-Dade County program has been very active since Hurricane Andrew in 1992, and has completed a substantial amount of management work in a number of pinelands including The Charles Deering Estate, Nixon Smiley Pineland, Larry and Penny Thompson Park, Ludlam Pineland, and Trinity Pineland (L. McDonald, Miami-Dade County Parks and Recreation Department, Natural Areas Management Section, personal communication 1998). These larger sites have management plans which include recommendations for the control of exotic plants, and the implementation of prescribed burning programs (*e.g.* Miami-Dade County Park and Recreation Department 1993, 1994). Initial work has also been completed in pine rocklands at a number of other sites. This work has resulted from a multi-agency collaboration including the Miami-Dade County Park and Recreation Department, DERM, Fairchild Tropical Garden, Ecohorizons, Inc., and The Nature Conservancy. On going technical assistance has been provided by the Institute for Regional Conservation.

Several agencies in Miami-Dade County including the Miami-Dade County Parks and Recreation Department, DERM, American Forests, and the Division of Forestry have also been active in outplanting pine seedlings to pine rockland fragments where mature pines were killed after Hurricane Andrew (L. McDonald, personal communication 1998).

In the Florida Keys, significant work on exotic plant control has now been initiated in pine rocklands. Florida Audubon Society and the Florida Keys Invasive Exotics Task Force have recently completed a Keys-wide exotic species mapping project which clearly demonstrates the problems with exotics in the Keys, including pine rocklands (C. Kruer, Florida Audubon Society, personal communication 1998). DEP has recently allocated $170,000 to the control of exotics in uplands in the Keys, but this is primarily being used to control exotics on north Key Largo (L. Flynn, The Nature Conservancy, personal communication 1998), which lacks pine rocklands. In the future, the Florida Keys Invasive Task Force will attempt to negotiate conservation agreements with private landowners to conduct exotic control programs on private lands (which now act as seed sources), and expand existing projects which utilize volunteers to control exotic species (L. Flynn, personal communication 1998). Prescribed burning in pine rocklands in the Florida Keys, however, has been sporadic and controversial. Research on prescribed fire in pine rocklands in the lower Florida Keys is currently being conducted by M. Ross *et al.* (M. Ross, Florida International University, personal communication 1998).

Once pine rocklands are restored, they must be maintained in perpetuity. In pinelands within the developed area, the effect of fragmentation will continue to be felt *ad infinitum*, including species extirpations due to small population sizes. In preserves of all sizes, seed rain from exotic plant taxa, and invasions by exotic animal species (including feral and domestic pets) will continue. Natural fire will

be dysfunctional, and prescribed fire will have to be used to maintain pine rocklands and tropical hardwood hammock edges. Infestations by beetles and other insects may be pronounced. The water table must be monitored to insure that pine rocklands are not dewatered or flooded. Contaminants, including pesticides, must be continuously monitored. Managers must counter these negative trends through active management: species populations must be monitored and augmented if necessary; prescribed fire must be used as a management tool; preserves must be monitored for re-establishment of known exotic species and the establishment of new species, and these plants and animals must be removed before they can become well established; water management agencies must be lobbied to continue providing the proper quantity of water; and, preserves must be protected from pesticides and other contaminants.

Potentially, pine rocklands can also be restored where they have been destroyed, although considerable research is needed in this area. Numerous scrape-down sites exist in southern Miami-Dade County where the soil surface was removed and the terrain leveled by a bulldozer. At many of these sites, pine rockland herbs have recovered and now dominate the site, although exotic plant species, especially grasses, have recently begun to invade these sites.

Potentially, pine rocklands can also be created from scratch. Native plant enthusiasts have been promoting the use of native plants and the restoration of native plant communities in South Florida since the early 1970s, and pine rocklands are one of the natural communities which people have attempted to create *de novo*. Efforts to create pine rocklands within the built environment began as early as 1987 (H. Block, personal communication 1998). Almost all attempts to create pine rocklands have been by homeowners and schools. While the establishment of pine rockland herbs and shrubs (including palms) can be accomplished fairly easily, the long-term establishment of South Florida slash pine has been problematic. After a number of years of growth, most pines become sick and die. This may be due to a lack of mycorrhizal fungi in the pine roots (*e.g.* Sylvia 1997). Pine rockland is also a challenging natural community to create because it requires fire, and the use of fire within a residential environment is almost totally precluded. Fire analogs (such as trimming of shrubs and raking of pine needle duff) have been explored, but will require more attention if this type of community restoration is to be effective.

In the early 1990s, The Association of Florida Native Nurseries published a "common-sense" guide to xeric landscaping with Florida Native Plants which included a preliminary list of recommended species for pine rockland (Jameson and Moyroud 1991). Miami-Dade County has recently published "The Landscape Manual" (Miami-Dade County Department of Planning, Development, and Regulation 1996), which includes a brief community description, a list of recommended plants for pine rockland creation, and a table including cultural requirements and tolerances. G. Gann of the Institute for Regional Conservation has developed preliminary guidelines for pine rockland creation, but these have not yet been published. Guidelines for the rescue of pine rockland plants from development sites have also been developed (Hammer 1997). Pine rockland creation guidelines should be completed and expanded to include pine rockland creation in the Florida Keys, and refined to provide specific guidelines for distinct floristic sub-regions (*e.g.* southern Miami-Dade County *vs.* Big Pine Key).

One of the downsides of the trend in landscaping with native plants is that some species are being distributed outside of their historic range, where they can become established and, potentially, invasive. For example, the mahogany (*Swietenia mahagoni*), which is native to the upper Florida Keys and the southern edge of the mainland, has been widely distributed in cultivation throughout southeastern Florida. It now has begun to naturalize throughout southeastern Florida and poses a threat to several natural communities, including pine rocklands. Other native species naturalizing outside of their historic range include bitterbush (*Picramnia pentandra*) (Avery and Loope 1980), butterfly sage (*Cordia globosa*), coffee colubrina (*Colubrina arborescens*), redberry stopper (*Eugenia confusa*) (Avery and Loope 1980), and twinberry stopper (*Myrcianthes fragrans*). In South Florida, native species have very specific natural ranges, and these ranges must be respected within the restoration planning context.

Research is also a critical component of pine rockland recovery, especially applied research that pertains to the recovery of the ecosystem. Loope and Dunevitz (1981) provided a review of research relating to pine rocklands on the Miami Rock Ridge up to that time. Recent research on pine rocklands has been conducted by Armentano *et al.* (1995), Kernan (1997), Oberbauer *et al.* (1997), Ross and Ruiz (1996), and Ross *et al.* (1997) and includes work on hurricane-related mortality of South Florida slash pines, wind-throw of slash pine caused by Hurricane Andrew, and research on endemic plants in the Florida Keys and the Miami Rock Ridge. Current research on pine rocklands includes: the effects of season of burning and proper fire-return intervals in pine rocklands on Big Pine Key (M. Ross, personal communication 1998), research on the restoration of 1.6 ha (four acres) of pine rockland on Big Pine Key (M. Ross, personal communication 1998); research on micorrhizal fungi and its role in pine rockland restoration (J. Fisher, personal communication 1998); research on plant-animal interactions and the effects of fragmentation on the pollination of pine rockland plants on the Miami Rock Ridge (S. Koptur, Florida International University, personal communication 1998); research on hurricane effects on mortality of South Florida slash pines (R. Doren, Everglades NP, personal communication 1998).

Finally, formal and informal public awareness programs to promote pine rockland conservation are very important and should be promoted. Everglades NP, and the National Key Deer Refuge have excellent facilities interpreting the importance of pine rocklands. Miami-Dade County has also produced a plant guide of common pine rockland plants with a forward describing the importance of the pine rockland community (Austin, no date).

Table 1. Endemics occurring in pine rocklands

Species	Community
Amorpha herbacea var. crenulata	Freshwater Marshes
Argythamnia blodgettii	Tropical Hardwood Hammocks
Brickellia mosieri	
Chamaecrista lineata var. keyensis	
Chamaesyce conferta	Freshwater Marshes
Chamaesyce deltoidea ssp. adhaerens	
Chamaesyce deltoidea ssp. deltoidea	
Chamaesyce deltoidea ssp. pinetorum	
Chamaesyce deltoidea ssp. serphyllum	
Chamaesyce garberi	Beach Dune, Tropical Hardwood Hammocks
Chamaesyce porteriana	Tropical Hardwood Hammocks
Dalea carthagenensis var. floridana	Tropical Hardwood Hammocks, Coastal Strand
Digitaria pauciflora	Freshwater Marshes
Elytraria caroliniensis var. angustifolia	Freshwater Marshes, Mesic Flatwoods
Galactia pinetorum	
Galactia smallii	
Hedyotis nigricans var. floridana	
Jacquemontia curtisii	Hydric and Mesic Flatwoods
Lantana depressa var. depressa	
Linum arenicola	Freshwater Marshes
Linum carteri var. carteri	
Linum carteri var. smallii	Freshwater Marshes
Melanthera parvifolia	
Phyllanthus pentaphyllus var. floridanus	
Poinsettia pinetorum	
Ruellia succulenta	Freshwater Marshes
Sabal miamiensis	Scrubby Flatwoods
Sideroxylon reclinatum ssp. austrofloridense	
Spermacoce terminalis	
Tephrosia angustissima	
Tragia saxicola	

Table 2. Distribution of listed plant species in pine rocklands

Species	Miami Rock Ridge	BICY	Florida Keys
Aletris bracteata	X	X	X
Alvaradoa amorphoides	X		
Amorpha herbacea var. crenulata	X		
Argythamnia blodgettii	X		X
Basiphyllaea corallicola	X		X
Bletia purpurea	X	X	X
Bourreria cassinifolia	X		X
Brickellia mosieri	X		
Byrsonima lucida	X		X
Catopsis berteroniana	X		
Chamaesyce deltoidea ssp. adhaerens	X		
Chamaesyce deltoidea ssp. deltoidea	X		
Chamaesyce deltoidea ssp. pinetorum	X		
Chamaesyce deltoidea ssp. serphyllum			X
Chamaesyce garberi	X		X
Chamaecrista lineata var. keyensis			X
Chamaesyce pergamena	X	X	X
Chamaesyce porteriana	X		X
Chaptalia albicans	X		
Coccothrinax argentata	X		X
Colubrina arborescens	X		
Colubrina cubensis var. floridana	X		
Crossopetalum ilicifolium	X		X
Crossopetalum rhacoma	X		X
Cynanchum blodgettii	X		X
Cyperus floridanus	X		
Dalea carthagenensis var. floridana	X		
Digitaria dolichophylla	X		X
Digitaria pauciflora	X		
Dodonaea elaeagnoides			X
Ernodea cokeri	X		
Evolvulus grisebachii			X
Galactia smallii	X		

Table 2. Distribution of listed plant species in pine rocklands *cont.*

Species	Miami Rock Ridge	BICY	Florida Keys
Glandularia maritima	X		
Hypelate trifoliata			X
Ipomoea microdactyla	X		
Ipomoea tenuissima	X		
Jacquemontia curtissii	X	X	X
Jacquinia keyensis	X		X
Jacquemontia pentanthos			X
Koanophyllon villosum	X		
Lantana canescens	X		
Lantana depressa	X		
Linum arenicola	X		X
Linum carteri var. carteri	X		
Linum carteri var. smallii	X	X	
Manilkara jaimiqui ssp. emarginata			X
Melanthera parvifolia	X	X	X
Ocimum campechianum	X		
Odontosoria clavata	X		X
Phyla stoechadifolia	X		
Pisonia rotundata			X
Pithecellobium keyense	X		X
Poinsettia pinetorum	X		X
Polygala smallii	X		
Ponthieva brittonae	X		
Psidium longipes	X		X
Psychotria ligustrifolia	X		
Pteris bahamensis	X	X	X
Pteroglossaspis ecristata	X		
Rhynchosia parvifolia	X		X
Sachsia polycephala	X		X
Scutellaria havenensis	X		X
Selaginella eatonii	X		
Senna mexicana var. chapmanii	X		X
Smilax havanensis	X		X
Solanum verbascifolium	X		
Spermacoce terminalis	X		X
Spiranthes torta	X		X
Strumpfia maritima			X

Table 2. Distribution of listed plant species in pine rocklands *cont.*

Species	Miami Rock Ridge	BICY	Florida Keys
Stylosanthes calcicola	X		X
Tephrosia angustissima	X		
Tephrosia angustissima var. corallicola	X		
Thrinax morrisii			X
Thrinax radiata			X
Tillandsia balbisiana	X	X	X
Tillandsia fasciculata var. densispica	X	X	X
Tillandsia flexuosa	X	X	X
Tillandsia utriculata	X	X	X
Tillandsia variabilis	X	X	X
Tragia saxicola	X		
Trema lamarckianum	X		
Tripsacum floridanum	X	X	X
Vernonia blodgettii	X	X	X
Warea carteri	X		

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Restoration of Pine Rocklands

Restoration Objective: Maintain the structure, function, and ecological processes of pine rocklands, and prevent any further loss, fragmentation, or degradation of this community in South Florida.

Restoration Criteria

Given that pine rocklands occur as ecotonal communities or as "islands" in a larger matrix of another natural community type, restoration of this community type implies protection and restoration of surrounding and adjacent communities.

Pine rocklands may be considered restored when: (1) a reserve design is developed that identifies intact pine rockland habitat essential for maintaining biodiversity and self-sustaining populations of imperilled species; (2) the reserve design is effected to protect this community through land acquisition or cooperative agreements with landowners; (3) the effects of disturbance in degraded pine rocklands are reversed by active management; (4) any further loss, fragmentation, and degradation of this community has been prevented; (5) ecological linkages to adjacent communities are restored and preserved; (6) management is implemented to benefit the large number of species that depend upon pine rocklands as habitat; (7) invasive exotic species are reduced to non-threatening levels; and (8) landscape-level habitat diversity is restored.

Community-level Restoration Actions

1. Prevent further destruction or degradation of existing pine rocklands.

1.1. Acquire pine rocklands threatened with development. Complete acquisitions in Miami-Dade County under the Environmentally Endangered Lands Program. Encourage CARL, Save our Rivers, Preservation 2000, the Monroe County Land Authority and the Federal government to complete acquisition projects in the lower Florida Keys. Pine rocklands owned by the Federal government should be designated conservation areas.

1.2. Promote conservation easements and landowner agreements. Support the Miami-Dade County Environmentally Endangered Lands Covenant Program and assistance for private landowners of pine rocklands under DERM's Forest Resources Program. Encourage the development of similar programs in the Monroe County.

1.3. Enforce regulatory protection of pine rocklands. Encourage Miami-Dade and Monroe counties to improve regulations protecting pine rocklands, creating language which enables agencies to initiate upland mitigation banks.

1.4. **Prevent degradation of existing preserves containing pine rocklands.** Work with Federal, State, county, and municipal agencies and non-governmental organizations to prevent further degradation of existing preserves from exotic plant and animal species (including feral and domesticated pets), fire exclusion, anthropogenic fires, unauthorized site uses, illegal dumping, improper siting of facilities (including interpretive trails), poaching of animals, collecting of plants, hydrologic modifications including drainage, flooding and salt-water intrusion, and damage from pesticides and other contaminants.

2. Restore existing degraded pine rocklands through active management.

2.1. **Restore connections between and among pine rocklands and surrounding natural communities.** Roads and fire breaks that separate pine rocklands from tropical hardwood hammocks and other connecting natural communities should be removed. Roads which dissect and fragment pine rocklands should be removed and restored, except as they are needed as fire breaks.

2.2. **Restore natural fire regimes.** Pine rocklands that have been degraded due to fire exclusion can be restored with prescribed fires. Each protected pine rockland site should have a fire management plan prepared specifically for it. Management plans should specifically include allowing natural, lightning-ignited fires to burn through pine rockland preserves whenever possible. In addition, plans should specify how and when prescribed fires should be ignited if natural fires are inadequate to meet management objectives. Prescribed burning should occur during the proper season. Fires should be allowed to burn freely into tropical hardwood hammock edges when conducted during the proper fire season and with adequate moisture to protect the hammock interior. Control unauthorized anthropogenic fires.

2.3. **Where possible, restore the water table to its historic levels**. Rehydrate pine rocklands affected by drainage on the Miami Rock Ridge.

2.4. **Control exotic plants and animals.** Develop control programs that eliminate, to the extent possible, exotic plants and animals from pine rocklands, including outlying populations. Ensure that control measures are not deleterious to native species.

2.5. **Restore areas impacted by anthropogenic fires, unauthorized site uses, illegal dumping, and the improper siting of facilities.** Pine rocklands that have been impacted by misuse should be restored. Facilities such as interpretive trails that endanger populations of rare plants or animals should be closed, removed, and restored.

2.6. **Protect pine rocklands from point and non-point source pollution** including mosquito control spraying, and drift from agricultural and commercial operations. Allow species which have been impacted from contaminants to recover naturally or with assistance.

2.7. **Reintroduce species which have been extirpated within their historic ranges.** Develop plans to reintroduce plant and animal species which have been extirpated from South Florida where appropriate and only within historic ranges. Augment populations and establish new populations of rare species which have been impacted by habitat loss, poaching, collecting pressure, *etc.*, to ensure the long-term persistence of the species in South Florida.

3. **Maintain pine rocklands in a natural condition in perpetuity.**

   3.1. **Continue to maintain connections between and among pine rocklands and other natural communities**, such as tropical hardwood hammocks.

   3.2. **Continue to use prescribed fire to maintain pine rockland/tropical hardwood hammock ecotones.** Develop and budget for prescribed fire programs in adjacent natural communities.

   3.3. **Continue to monitor the water table to ensure that pine rocklands are provided with adequate moisture.** Ensure that water levels are maintained at their historic levels, where possible.

   3.4. **Continue to monitor for and control exotic plant and animal species.**

   3.5. **Continue to control public use and eliminate improper use**, such as mosquito spraying and drift from agricultural and commercial operations.

   3.6. **Monitor and correct for both point source and non-point source pollution**, especially in outlying areas before they become populated.

   3.7. **Monitor and correct for negative population trends among important pine rockland species.** Each preserve containing pine rocklands should have a specific monitoring plan that will alert managers to extirpations or downward trends in populations of selected pine rockland species, including endemic species, listed species, and keystone species.

4. **Recreate pine rocklands where they have been destroyed by human activities.**

   4.1. **Explore opportunities to utilize natural regeneration** as a method to restore connections between and among pine rocklands and other natural communities, as well as to expand the total area of pine rocklands.

   4.2. **Explore opportunities to utilize secondary pine rocklands** as habitat for wildlife.

5. **Create pine rocklands where natural communities have been destroyed by human activities.**

   5.1. **Encourage the use of pine rocklands as landscape models within the built landscape.**

   5.2. **Refine guidelines and specifications for pine rockland creation.** Promote the development of refined pine rockland creation guidelines and the development of specifications for all applicable areas of South Florida, including species lists which clearly articulate that species should only be out-planted within their historic ranges.

   5.3. **Discourage the use of pine rocklands species outside of their historic ranges.** Many pine rockland and tropical hardwood hammock species have been promoted for landscape use within South Florida. Unfortunately, many of there species have been and are being planted outside of their historic ranges. Some species are now escaping from cultivation and invading natural areas. The use of native species only within their natural ranges should be encouraged.

6. **Connect existing pine rocklands by acquiring lands for conservation between them.** Land acquisition, landowner agreements or conservation easements should be used to prevent development of lands between existing conservation areas and to restore lands where possible. Lands acquired as connectors between conservation areas containing pine rocklands need not include pine rocklands. Historically, pine rocklands existed as a dominant habitat type with

other habitat types embedded or surrounding them. Opportunities to use landscapes such as canal banks and roadsides as greenways dominated by native vegetation should be explored.

7. **Encourage community-level research.** More research is needed on wildlife habitat needs in terms of pine rockland functions and biodiversity, pine rockland creation and recreation methods, sea-level rise in the Florida Keys, and historical hydrology of pine rocklands.

8. **Monitor land management actions.** All management actions should be monitored to determine their effectiveness, and changes should be made to management activities as appropriate. Managers should have a plan for monitoring relative population levels of selected plant and animal species.

9. **Increase public awareness.** Public understanding and approval are required for any conservation effort to be successful. Public announcements should highlight land acquisition projects such as Miami-Dade County's Environmentally Endangered Lands Program and CARL. Environmental education programs in South Florida should be encouraged to distribute materials or develop lesson plans on pine rockland habitats, pine rockland species and the importance of maintaining natural biodiversity.