History of South Florida Pine Rocklands and How They Have Been Negatively Affected by Fire Suppression and Fragmentation.

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As the world's forests continue to disappear, natural areas manager must increasingly become expert in the "art and science" of maintaining urban forest fragments (Janzen 1998). Although the composition of such remnants differs from that of intact forests, (Laurence and Bierregaard 1997), many of these scattered pieces play a vital role in conserving regional native plant richness. In fact, small fragments (<40 ha) have been shown to contain species richness rivaling or even exceeding that of the large preserves. (Possley 2008) Pine rocklands are an ecosystem found exclusively in southern Florida, the Bahamas, and Cuba. South Florida Pine rocklands sit upon oolitic marine limestone outcroppings that were created during the mid-Pleistocene geologic period, somewhere between 2.6 million and 12,000 years ago. There are three distinct geologic formations: the Miami, Key Largo and Tamiami limestones (Hoffmeister 1974). The rocklands also occur in three distinct geographical locations that are correlated with the geological formations. See Attached Map. Oolitic limestone is comprised of small rounded particles called oolites. The oolites are created by layers of calcite being deposited around a smaller particle and rolled back and forth in calm shallow water. These ooids became cemented together when sea level fell, exposing the Pleistocene around 130,000 YPB (Perkins 1977). Only a shallow layer of this rock near the surface is fully hardened. A few feet below the surface the oolites are weakly cemented together. These surficial limestone outcroppings created the Miami Rock Ridge. The three different geographical locations sit on different types of limestone. The largest outcrop is the Miami rock ridge, comprised of Miami limestone, which occupies a broad area from Miami to Homestead and narrows westward through the Long Pine Key area of the Everglades National Park. (Meyers 1990) The highest elevation in this portion of the Pine rocklands is about 4 meters above sea level, decreasing down to less than 2 meters above sea level. These rock outcrops in the Florida Keys are two different types of limestone. The upper Keys represent outcrops of the Key Largo limestone, and the lower Keys represent outcrops of the Miami limestone. Most of the elevations of the Keys outcroppings are 1 to 2 meters above sea level. The third region of outcropping is the southeastern area of the Big Cypress Swamp. This area has outcroppings of Tamiami limestone. The outcroppings are most extensively exposed around Pinecrest near their southern end, but they extend for many kilometers north (Meyers 1990).

Tamiami limestone is more fossiliferous than the Miami limestone and is considered to be older (Hoffmeister 1974). The Key Largo limestone, which underlies the Florida Keys, is formed from consolidated reef corals and associated rubble and is considered to be contemporaneous with the Miami oolite. This limestone covers a small area in comparison with the other two formations and was apparently formed by a patch reef-sand shoal complex during a period of high sea level, between 200,000 and 130,000 YBP (Perkins 1977)

The soils of pine rocklands differ greatly from the deep, sandy soils elsewhere in the state. Rockland soils are noted for their scarcity, and this is particularly apparent where fire has removed litter and understory vegetation. A Soil survey for Monroe County was not completed until 1995, while Dade and Collier counties were completed in 1954 and 1958 respectively. These soil surveys predate the advent of current soil taxonomy, so that the nomenclature is archaic, though mapping units such as “Rockdale” and “Rockland” are quite descriptive. (Meyer

1990.) In the pine rocklands of Big Pine Key the soild surface is almost entirely limestone, varying in character from a solid surface interrupted by solution holes to an uneven surface covered by loose rocks. Occasional shallow depressions in the rock surface contain fine, reddish-brown, sandy loam. These residual soils are slightly acid and have less than 10 percent organic matter (Snyder 1986). North and west of Homestead such soils are more common and are responsible for the name "Redlands" given to the area (Meyers 1990). All the pine rocklands have good internal drainage and remain saturated only when flooded by high water tables.

Pine rocklands contain the highest plant diversity of any other habitat. See attached plant list. Remaining pine rockland fragments of Miami-Dade County are extremely important for conserving the unique plant richness in South Florida. Florida pine rocklands contain 98 state listed and 16 federal listed vascular plant species (Gann et al. 2006). Furthermore, this plant community has a high degree of endemism, with 41 vascular plant taxa endemic to Florida and 25 species found only in pine rocklands of Florida (Gann et al. 2006). Most of these endemic plant species require a fire return interval of less than five years to maintain their habitat (Robertson 1954). The canopy of a typical pine rockland is dominated by one species of tree. This tree is the South Florida Slash Pine (*Pinus eliotti var. densa*). In pine rocklands in the lower Keys there may be a subcanopy that includes *Thrinax* and *Coccothrinax*. If a pine rockland is located near a tropical hardwood hammock it may also have a subcanopy that includes: Live oak (*Quercus Virginia*), wild-tamarind (*Lysiloma latisiliquum*), willow-bustic (*Sideroxylon* *salicifolium*), gumbo-limbo (*Bursera simaruba*), and inkwood (*Exothea paniculata*)(US Fish and Wildlife Service 1998). In rocky pinelands that have not burned for many years, the hardwood shrubs grow to form a subcanopy, as in the case of some of the lower Key pinelands (e.g. Cudjoe Key). In many of the pineland remnants on the Miami rock ridge, the past several decades of fire suppression have allowed the development of a subcanopy. All pine rocklands have an understory that includes palms. The most common species is saw palmetto (*Serenoa repens*), but silver palm (*Coccothrinax argentata*), thatch palm (*Thrinax morissii*), and cabbage palm (*Sabal palmetto*) can also be seen. Some of the common shrubs that can be present in Pine rocklands throughout South Florida 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*), and white indigo berry (*Randia aculeate*) (Snyder *et al* 1990). The herbaceous layer of the pine rockland can be the most diverse layer depending on the density of the shrub layer. More than 250 indigenous herbaceous species have been recorded in this ecosystem (many are listed in Loope et al., 1979) Typical fire adapted herbaceous species include: *Angedenia sagrae, Melanthera parvifolia, Jacquemontia curtissii, Crossopetalum ilicifolium, Acalypha chamaedrifolia, Cassia deeringiana, Crotalaria pumila, Andropogon cabanissii, Anemia adiantifolia, Aamia pumila, Schizachyrium sanguineum, Schizachyrium gracile, Andropogon longiberbis, Andropogon glomeratus var. pumilus,* Candyweed *(Polygala grandiflora*), creeping morning-glory (*Evolvulus sericeus*), pineland heliotrope (*Heliotropium polyphyllum*), rabbit-bells (*Crotalaria rotundifolia*), and thistle (*Cirsium horridulum*) (U.S. Fish and Wildlife Service 1998).

Most pine rockland herbaceous plants are perennials with the ability to recover and re-spout very quickly after a fire. However, some plant species have been lost. The Tephrosia angustissima is presumed extinct; it was described as endemic to the pine rocklands (Small 1933), but no plants of the species have been found for several decades (Meyer 1990). Several epiphytes, including *Rhipsalis baccifera, Brassia caudata, Macradenia lutescens*, have been extirpated from south Florida, primarily due to overcollecting. Several other species could be lost as well. The endemic plants *Polygala smallii* and *Amorpha crenulata* are known from only a few populations each (Meyer 1990).

Fire is necessary for the pine rockland ecosystem to function correctly. Fire is required for the maintenance of rockland pine forest and controls, at least in part, the relative dominance of upland habitats by pineland hammock. (Myers 1990) This system is called a "fire subclimax" community and fire is needed to prevent succession into hammock. Fire also: promotes flowering of herbaceous species and fruit production of woody species, improves nutritional quality of plants for animals, enhances nutrient cycling of some elements and elevates soil pH, maintains required habitat conditions for fire-adapted plant and animal species, results in a more heterogeneous and divers habitat—if natural fires are patchy—leaving pockets of unburned areas, prohibits wildfire conditions from developing (i.e. vast accumulation of highly-flammable, dead vegetation) (Tanner 1997). Wade et al. (1980) and Robertson (1955) reviewed fire effects in south Florida pine rocklands and they determined that fires in rockland pine forests are fires that consume only litter, duff, pine needles and some understory vegetation. The fire burns too low and the South Florida slash pine canopy is too open to support a crown fire. Historically, lightning usually starts fires in surrounding graminoid wetlands and sweep into the pinelands. (Myers 1990) Pine rocklands burn easily because the fuel load and conditions are favorable. Pine needles and saw palmettos accumulate on or near the ground and decompose slowly. The herbaceous layer also contributes a small amount of fuel and keeps the pine needles from matting to the ground. The rough rocky outcroppings also prevent matting. The open canopy and the prevention of matting allows for rapid drying of the fuel load, so fires are possible within a day after rain (Myers 1990). If fires are suppressed the pine rockland may succeed into a hammock, with hardwoods invading. Once hardwoods invade, these hammocks do not burn as easily. Hammocks have hardwood leaf litter lying directly on moist ground and little herbaceous fuel. The herbaceous layer will not exist anymore due to the shade of the hardwoods. The shaded, microclimate of hammocks is not conducive to fire spread. A fire with flames greater than I meter burning through pine rocklands can reach a hammock margin and die out within seconds (Meyer 1990). 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). Pineland plants show obvious adaption to fire. The South Florida slash pine is very resistant to fire (U.S. Fish and Wildlife Service 1998). Its resistance comes from the ability to resprout at the root collar, long needles that shield the apical buds, and thick bark that protects the cambium. Most prescribed fires, and natural fires as well, kill few large trees. Fires often prune lower branches and may even scorch off all the needles, but the pine trees generally recover. The seedlings are fire adapted as well. They have thicker stems and are more fire resistant than other slash pine seedlings (Ketcham and Bethume, 1963), but there is still high seedling mortality from fires. Pine seedling establishment is improved when fires occur soon before seed release (Klukas, 1973; Snyder, 1986). Plants in the pine rockland are fire-adapted as well. The coontie (*Zamia pumila*), for example, has underground stems that store nutrients that are used as energy to resprout new leaves following fire. While the aboveground portion of hardwood shrubs is usually killed by fires, all species can resprout from below ground within a few months (Robertson, 1953: Hofstetter, 1974). Robertson (1953) found a 0-10 percent mortality rate in nine hardwood species after a December fire. Some species such as sumac, are prolific root sprouters; most species resprout from near the base of the stem. Because individual stems often send up multiple sprouts, a fire can actually result in a temporary increase in the number of hardwood stems (Meyers 1990). Topkilling by fires typically eliminates fruiting for one or two years after burning (Meyers 1990). There is no massive mortality of shrubs followed by a regeneration from seed, as in some chaparral species (Keeley and Keeley 1981) However, seedlings of a varnish leaf and sumac have been observed in the first year after a fire and must be derived from a soil seed bank (Meyer 1990). Shrub layer palms experience little mortality as well. Generally all the expanded leaved are killed by fires, but the apical buds are unaffected and new leaf and flower stalk production continues unabated. Palms with developed trunks are susceptible to fire damage but, because of their internal anatomy, die only if repeated fires burn through the trunk and cause the tree to fall over (Meyer 1990). Many of the plants grow very rapidly after a fire and are seldom killed by a single fire (Snyder *et al.* 1990). Fires can also stimulate flowering in some plants. The pineland herbaceous layer responds to fire with rapid regrowth and increased flowering (Robertson 1953, 1962). Many species flower infrequently except in recently burned pineland. (Meyers 1990). This includes grasses such as: *Tripsacum floridanum, Imperata brasiliensis, Andropogon cabanissii, Liatris tenuifolia, Stenadrium dulce,* and *Ipomea microdactyla* (Herndon 1987). *Hypoxis* also flowers more profusely in recetly burned pineland than in long-burned habitat (Herndon 1987). Plants do respond differently depending on the time of year of the fire. It may increase or decrease flowering and fruiting patterns. For example, the endemic *Schizachyrium rhizomatum* flowers much more profusely after a spring burning than after a fall or winter burning (Snyder and Ward 1987). Fire can also shift the blooming periods for some species, but is most noticeable in plants with the shortest blooming periods. A summer fire, for example, can change the flowering period of *Liatris gracilis* from September and October to December and January (Meyers 1990) The most pronounced effect of fire, however, is to stimulate and synchronize the reproductive activity of herbaceous species. For several months following burning, all individuals of a given species flower simultaneously. In an unburned pine rockland, many of these same species would not bloom, and those that did would only occasionally flower at the same time as nearby plants of the same species. Intensity and frequency also affects the plants response to fire. Too many fires or an intense fire will kill plants and trees. Pineland fires do not result in significant changes in species composition because almost all species are perennials that survive and recover in place. However, the relative importance in terms of cover or biomass shifts initially from hardwoods to herbs because herbs respond more quickly. As the post-fire period lengthens, the development of larger hardwoods and the accumulation of litter shift the balance back in favor of hardwoods (Snyder 1986). The time of year at which these fires occurred would also have affected the forest structure and dynamics. It is known that the season of burning influences flowering of herbaceous species and the establishment of pine seedlings. Elsewhere in the Southeast, the mortality and regrowth of hardwood understories have been shown to depend on season burning (Lewis and Harshbarger 1976), but some studies in rockland pine forests have been ambiguous on this point (Snyder 1986).

If fire is suppressed, within two to three decades, the pine rocklands become tropical hardwood hammocks with a relict overstory of pines (Robertson 1953). The hardwood shrubs develop a closed canopy, a more humid microclimate is developed, a thick organic detritus layer accumulates and the characteristic herbaceous flora of the pineland disappears. This is the basic sequence proposed for the development of hammock islands in pineland (Safford 1919; Simpson 1920). Alexander and Dickson (1972) estimated that in the lower Keys it may take fifty years for hardwoods to overgrow pine rocklands completely, because of the water-limited productivity.

A fundamental question concerning the fire ecology of south Florida pinelands involves the fire regime before settlement by Europeans: how frequently and at what time of year did pinelands burn before the fire pattern was affected by drainage, artificial barriers such as roads and canals, and accidental or intentional ignition by humans? (Meyer 1990) Reconstructing the fire history of south Florida from physical evidence such as fire scars has not been possible (Taylor 1980) . An alternative has approach is to infer the answer from observations from present day fire patterns. The upper limit of natural fire frequency can be inferred from the time it takes endemic herbaceous plants to be shaded out by the development of a closed hardwood layer; the lower limit, from the time it takes for sufficient fuel to accumulate. In the Miami rock ridge these limits are approximately ten to fifteen years and two to three years (Meyers 1990). Such extremes in fire frequency would result in difference in forest structure and dynamics. More frequent fires would produce open savanna-like stands with relatively little hardwood growth and a heavy herbaceous layer. Pine regeneration would occur in small patches where on or a few canopy trees died. In contrast, if fires were suppressed, it would result in greater litter accumulation, a heavier fuel load, less herbaceous growth. The high fuel loads would result in more intense fires that would kill canopy trees in patches hectares in size (Meyers 1990). The presettlement fire frequency was probably somewhere between these two extremes and undoubtedly varied considerably during history. Before development, most natural wildfires were relatively frequent, burned at low intensity and impacted large areas because of natural fire breaks (rivers and wetlands) were spread out (Tanner 1997). Since many of the areas surrounding the pine rocklands have been developed, fire suppression is common. Lightning is the only nonanthropogneic source of fire ignition, and is common in south Florida (Taylor 1980). Lightning strikes and lightning caused fires occur mainly during the rainy season (May through October), but larger fires tend to occur in the earlier part of the season before the water levels are highest and in years when the onset of the summer rains are delayed. Oppositely, human caused wild fires are most common in November through May, with the greatest area burned with conditions are usually driest (April and May) (See attached figure Taylor and Rochefort 1981) Prescribed burns in the Everglades National Park until 1980 was mainly done in the cooler months of October to April under mild burning conditions (Taylor 1981); since that time is has been done mostly during the rainy season. It is difficult to know for certain what the presettlement fire regime was due to the face that Indians lived here thousands of years before European settlers. They may have burned at times other than lightning season. 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 (U.S. Fish and Wildlife Service 1998). Suppression allows invasive exotic plants into the ecosystem, the saw palmetto understory grows dense, and hardwoods begin to grow. All of these factors begin to shade out the herbaceous plants and the suppression causes succession into a different ecosystem called a hammock. Suppression also allows for a thick layer of organic material (duff) to accumulate and the soils will appear humic rather than mineral. Also, the oolitic limestone outcroppings will become covered in a thick layer of duff. When the natural frequency of fire is disrupted, dry plant material accumulates and fuels a more severe fire. A fire's intensity in an overgrown, unmanaged pine rockland increases beyond the beneficial point for the ecosystem, overheating the soil, damaging root systems, burning into the pine canopy, destroying seeds, and killing plants.

The earliest settlers in south Florida were concentrated in the Florida Keys. Key West was the largest city in the region from the time of its settlement in the 1820s through the early years of the twentieth century (Meyers 1990). The pine rocklands in the Keys were exploited extensively during this period. The valuable timbers, especially mahogany, were logged out first. Many of the early settlers used slash-and-burn agriculture around homesteads within the rocklands (Meyers 1990). The most intensive exploitation of the hammocks and rocklands during this period was for firewood and charcoal. As Key West grew, its need for fuel grew correspondingly, and this fuel was supplied by hammock trees (Small 1917). In Miami Dade County, the Rock Ridge is higher than the surrounding ground and is generally well drained. These characteristics lead it to be one of the first areas to be developed. Pinelands and glades were used as range for livestock. Large solution holes within pinelands (“banana holes”) were often planted by homesteaders (Harshbergber, 1914). Limited logging of the pinelands occurred until the Florida East Coast Railroad reached Miami in 1896. Industrial logging then began, and the pinelands were clear-cut over the next fifty years (Meyers 1990). While land clearing started in the late 1800s, it continued unabated until 1984. Finally, in 1984 Miami-Dade County passed the Tree Protection Ordinance which gave some protection to the pine rocklands. The earliest industry in the Miami region was the preparation of flour from the root and stemstock of coontie. This industry which lasted from 1840 through 1925 reduced the abundance of coontie in the Miami area but probably had little effect on the rockland ecosystem. The pine rocklands were cleared for several different uses. The invention of the rock plow in 1954 allowed for the rocky outcroppings to be pulverized and create a rocky soil for agricultural use. Sisal (*Agave sisalana*), coconut palms, pineapple, and the commercial plantings of tropical tree cops were developed around the turn of the century. (Dorn 1956) All were planted in the newly created farmland. The most important crops were grapefruit, limes, mangoes, and avocadoes. The groves were generally established on the well drained rocklands. Row crops, citrus trees, and other fruit trees were planted and as the land was developed farmers moved farther and farther west clearing more pine rocklands. It is estimated that pine rocklands originally covered 185,000 acres of Miami-Dade County. Today there are less than 4,000 acres outside of Everglades National Park and less than 1,600 acres are protected in public park and preserves. This can be seen in the attached map.

Invasive plant species are invading pine rocklands. Brazilian Pepper (*Schinus terebinthifolius*) is the most widespread invader. It is probably present in every pine rockland fragment in Miami-Dade County, and is also well established in the pine rocklands of Everglades National Park, Big Cypress National Preserve, and the Florida Keys. (U.S. Fish and Wildlife Service 1998) Fire suppression allows the Brazillian Pepper to grow uncontrolled and shade out the understory of herbaceous plants. Once saplings reach 1 meter high, most are able to survive fire (Loope 1981). The low water-holding capacity and lack of nutrients in plowed pineland "soils" are countered by liberal irrigation and chemical fertilization. Upon abandonment, the physical and chemical alterations of the soil, along with fire suppression (Orth and Conover 1975) result in successional vegetation that bears little resemblance to the native pineland and is often dominated by the invasive exotic *Schinus terebinthifolius*. Burma reed (*Neyraudia reynaudiana*) is another invader that is present in almost all pine rockland fragments of the Miami Rock Ridge. This large woody grass, will form dense stands that are fire tolerant. It too out competes native vegetation and shades out the herbaceous understory. Other ornamentals that have invaded the pine rocklands of south Florida are: *Bischofia javanica, Schefflera actinophylla, Colubrina asiatica, Syngonium sp*. and *Sansevieria sp.*

Passive protection is not sufficient to preserve the pine rockland system. Pinelands must be burned regularly, and both the small size of the remaining rocklands and the presence of residential and commercial development on the borders of the preserves greatly restrict burning programs (Meyers 1990).Everglades National Park has had an ongoing management program in pine rocklands since 1958 (Olmsted *et al* 1983) when a prescribed burn program was initiated. Until recently, there has not been much management outside of Everglades NP. The Department of Environmental Resource Management and the Miami-Dade County Parks and Recreation Department, Natural Areas Management Section have aggressively restored and maintained pine rockland ecosystems since Hurricane Andrew in 1992 (DERM1995). Some of the maintenance and restoration responsibilities include: prescribed burns, removal of exotic and domestic animal species, preventing illegal dumping, preventing plant collecting, preventing drift of herbicide and pesticide, and preventing unauthorized use (including bicycles). In pyrogenic forests, an additional effect of fragmentation is the loss of the natural fire regime that is vital to maintain the system (Noss and Csuti 1997). As fire suppression becomes the norm, re-introducting fire to urban fragments poses a whole new suite of social issues (Davis 1990), while the major ecological issue becomes succession to a non-pyric community, threatening biodiversity in a system (Leach and Givinish 1996; Heuberger and Putz 2003; Varner et al. 2005). In fire suppressed urban forest fragments, populations of rare species become extremely difficult to maintain. The “art and science” of management enters when managers must combines both species-based and process-based management (Hobbs 2007). Land managers face the conflicting goals of re-introducing fire to the landscape for the good of overall biodiversity while trying not to extirpate rare species that may be vulnerable to fire (Possley 2008). Further complicating the issue, land management budgets are usually so woefully inadequate that money must be carefully allocated to only the most effective techniques (Laurence and Bierregaard 1997). It is, therefore, crucial that land managers adapt their restoration techniques to be as effective as possible (Possley 2008). Restoration strategies employed in the Miami-Dade County Natural Areas Management plan include controlling invasive plant species infestations and conduction regular burns. However, prescribed burns are often unfeasible due to development. Miami-Dade County is a matrix of roads buildings, and agricultural fields with a population of more than 2.4 million (U.S. Census Bureau 2004). Since its 1991 inception, the County’s Natural Areas Management Division has maintained a fire prescribed program in its pine rocklands, yet weak public support has been a persistent barrier to its success (Possley 2008). Further management challenges are presented by the small size of pine rockland fragments, which poses acquisition, protection, and management issues. Of the 51 Miami-Dade pine rockland preserves, 45 are < 40 hectare in size and 32 of those are < 10 hectares. The County’s Natural Areas Management Division conducts manual hardwood reduction treatments as a surrogate for capturing some of the ecological benefits off frequent fires (Possley 2008). This process provides two purposes it reduces hardwood canopy and prepares the pine rockland canopy for possible future prescribed fire by removing vegetation that is less likely to burn. Whether it is achieved through fire or manual treatment, the target structure for pine rockland forests managed by Miami-Dade County is one in which hardwoods are reduced in stature and cover, palms occupy approximately 25% or the midstory cover, and shrub gaps contain a diverse mosaic of understory grasses and forbs (Maguire 1995). Reasons for this target vegetation structure include promoting diverse understory flora, increasing fine fuels (thereby reducing smoke output), and preventing hot burning fires that kill young pine trees (Maguire 1995). There are other factors affecting the health of the pine rockland ecosystem too, such as: sea level rise, hurricanes, and a lower water table. After Hurricane Andrew many pines were lost because the hurricane’s wind weakened the trees and an invasion of beetles followed. Fires are a necessary part of the maintenance of the ecosystem, but many of the fragmented pine rocklands are surrounded by development. An alternative to burning (such as trimming of shrubs and raking of pine needle duff) has been explored, but study is need to determine if this type of restoration is effective (US Fish and Wildlife Service 1998). This may clear the density to allow sunlight to the herbaceous layer; it does not recycle the nutrients back into the soil. It also does not provide the fire that these fire that these plants have evolved to live with. The study produced by Possley (2008) was to examine effectiveness of their restoration practices. Patterns in pine rockland plant diversity were studied over an eight year period. See attached map for the location of the 18 study plots in 16 of Miami-Dade County’s managed pine rockland preserves. Three environmental factors that were believed to be influences on plant species composition were examined. Changes in abundance and cover of both rare native species and non-native plant invasive plant species between sampling periods were examined. The goals of the study were to: (1) elucidate some of the underlying factors that affect plant species composition, (2) determine whether fire management affects plant species richness and floristic composition within this time period, and (3) reveal any possible rare plant species losses or invasive plant species increases (Possley 2008).

The environmental criteria that was studied in the Possley (2008) study included major geographic region (based on edaphic factors), recent fire frequency, and fragment size. For major geographic regions, the work or O'brien (1998) was used. In that study, he spatially defined three distinct geographic regions of Miami-Dade pine rockalnd forest that were previously suggested by Robertson (1955) and Snyder et al. (1990). For classification in this study soil type was correlated with soil characteristics. O'Brien (1998, as well as Robertson (1955) and Snyder et al. (1990) all suggested that plant community composition changes along this gradient. Possley (2008) hypothesized that fragments receiving multiple fires from 1995 to 2003 would have greater native plant species richness and significantly different floristic composition than unburned or less frequently burned fragments. Possley (2008) also predicted that fragment size would also be positively associated with plant species richness, per the theory of island biogeography (MacArthur and Wilson 1967). Although fragment size has been shown to be a reliable predictor of plant species richness in many different systems (e.g. Honnay et al. 199; Gillespie 2005), it has not been supported in other studies (Robinson et al. 1992; Holt et al. 1995) and its over-use has been criticized as irrelevant for planning and managing preserves (Saunders et al. 1991). In addition to the predictions mentioned Possley (2008) wanted to utilize the dataset to examine the changes in abundance and cover of both abundance and cover of both rare native plant species between 1995 and 2003. It has been shown that richness of native pineland understory plant species can be increased through fire management (Brockway and Lewis 1997; Sparks et al. 1998) and thinning of overstory vegetation (Maschinski et al. 2005). Additionally, it is generally accepted that biological invasions can reduce native biodiversity (Elton 2000: Simberloff 2005). Thus, if management is to maximize native biodiversity on Miami-Dade County preserves has been successful, Possley (2008) expected to see decreased abundance and cover of non-invasive plant species, coupled with unchanged or increased abundance and cover of rare native plant species. Sampling methods were set, plots were measured, and sampling units were taken. Between 1995 and 2003 native plant species increased by an average of 4.5 species per plot. Fragment size had a positive influence on native plant species richness in understory plots (Possley 2008). However, there was a wide range in native plant species richness among small preserves. Presence and cover of rare native plant species in managed plots increased over sampling period in many cases, but this was significant for only one species, federally endangered *Galactia smallii*) (Possley 2008). Study plots contained 14 Florida endangered plant species. From 1995 to 2003, only three of these 14 rare species decreased in number of plot occurrences (Possley 2008). No plants were lost from the study over this period: and four previously unrecorded rare species were recorded. Invasive plant species were not a major component of the study, but the majority of the non-native cover was Brazilian Pepper (*Schinus terebinthiflious*) and *Neyraudia* *reynaudiana*(Possley 2008). Invasive plant cover percentage did fall during the study, but was not statistically significant.

The (Possley 2008) study showed that native plant species is very high in Miami-Dade County's fragmented pine rockland preserves. The documentation of 182 and 187 native taxa in the 162 selected plots (totaling 0.016 ha) is high when compared to one study in Everglades pine rocklands, where DeCoster et al. (1999) found a maximum of 128 species in a 0.1-ha plot (Possley 2008). While in the Possley (2008) study the native plant richness did not change greatly between sampling periods, native plant richness on a per-plot basis increased significantly. This was accounted to several factors. Natural Areas Management practices that commenced in 1991, such as removal of non-native invasive plant species and native hardwoods as well as prescribed burning, were likely to have favored the biologically rich pine rockland understory (Possley 2008). In addition, observer influence could explain part or all of the increase in native plant richness. During the study there was repeated manual reduction of hardwoods by Miami-Dade County in 1995, 1997, 1999, 2002, and most intensively in 2003. There was also a prescribed burn in 2001. At the conclusion of the study the prescribed burn had not yet promoted the recovery of the diverse pine rockland understory. Overall, Possley (2008) believed that significant change in pine rockland plant species richness occurs over a longer time span than the length of the study, but was not able to prove it with the existing dataset.

Even with the slow response time of the plant species richness, Possley (2008) noted that even in the relatively short eight-year span of the study, the number of fires received by study plots affected floristic composition. Certain plant species appears to be much more affected by recent fires than others. Although there was a positive correlation between fragment size and native plant species richness, Possley (2008) theorized the relationship might have been stronger there was data on mid-sized pine rockland preserves in Miami-Dade County. Close to 95% of pine rockland preserved are < 40 hectares in size. All remaining preserves are >80 hectares, except for one newly acquired 54-hectare unit that contains some pine rockland. Small fragments had a wide variance in total number of plant species they supported (Possley 2008). Many of the smallest preserves in the study (<15) hectares had levels of plant species richness that approached or exceeded those plots in larger preserves. The dataset from Possley (2008) highlights the importance of conserving even the small fragments and indicates that preserve size is one of the factors influencing plant species richness, along with soil type, hydrology, fire history, and disturbance (Possley 2008). Along with the increased cover of the federally endangered *Galactia smallii* as well as the increased occurrences of 11 other rare plant species suggests pine rockland preserves in Miami-Dade County are being managed in a positive way supporting floristic diversity (Possley 2008).

Possley (2008) suggest some factors influencing species assemblage and suggest directional trends for cover of both rare native species and non-native species in managed preserves. Fire history influenced native species assemblage. While fragmentation makes management more difficult, it had little effect on native plant diversity. Possley (2008) showed that significant loss of native diversity did not occur during the eight-year time scale of the study. This showed the ecological value that exists in urban fragments, even when they are small and fire-suppressed, emphasizing the importance of acquisition, preservation, and restoration of the parcels.

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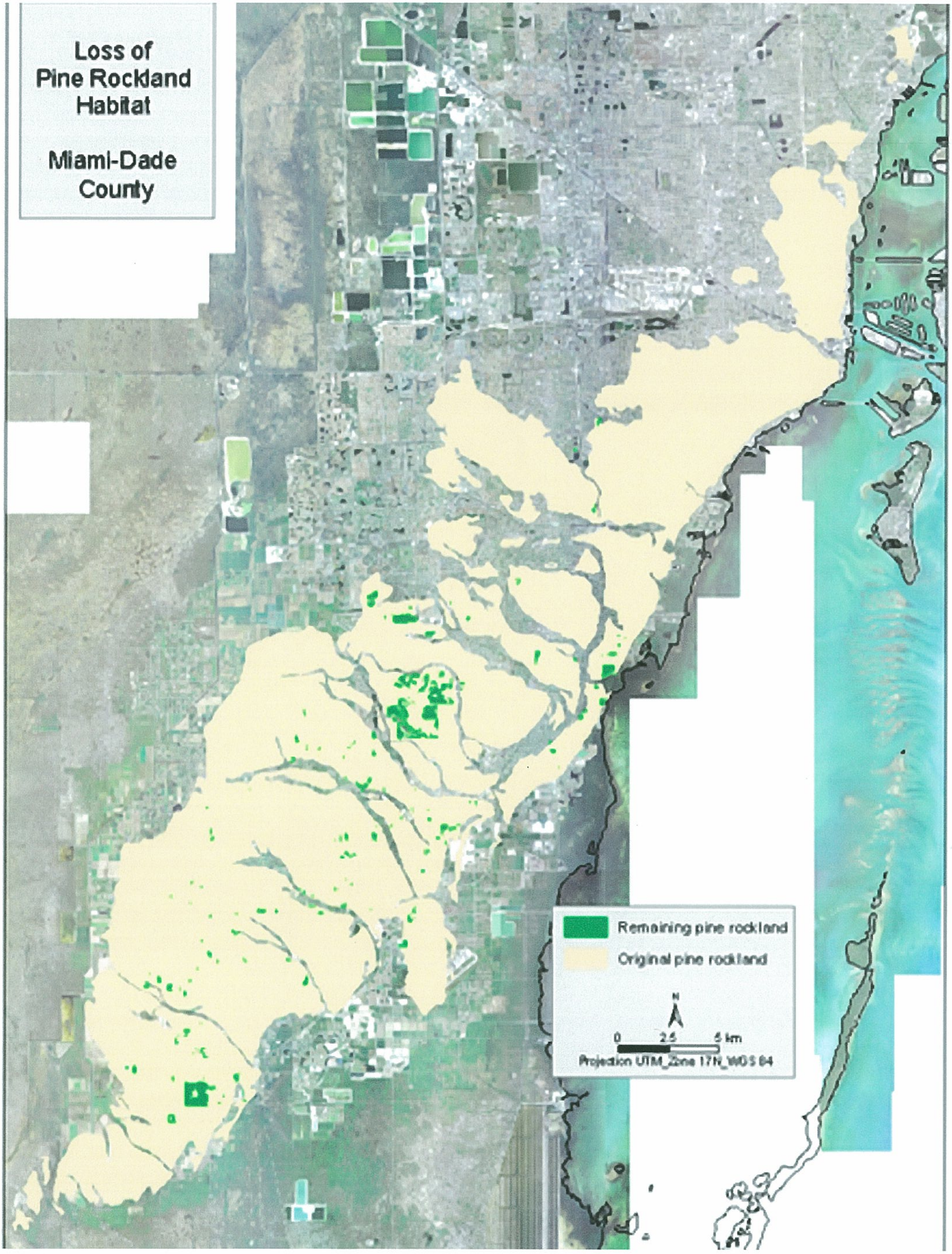

Loss of
Pine Rockland
Habitat

Miami-Dade
County
Remaining pine rockland
Original pine rockland
N
0
2.5
5 km
Projection UTM_Zone 17N_WGS 84

Appendix. Distribution of woody plant species native to rockland hammocks (H) and pinelands (P) of southern Florida

		Florida Keys		Miami Rock Ridge				
Scientific Name	Common Name	UK	LK	—	LP	RL	NB	Big Cypress
Trees and Shrubs								
Acacia farnesiana	sweet acacia	—	P	—	—	—	P	—
Acacia pinetorum	pineland acacia	—	P	H	P	—	—	—
Acer rubrum var. *tridens*[a,b]	red maple	—	—	—	—	—	—	H
Alvaradoa amorphoides	alvaradoa	—	—	H	P	P	—	—
Amorpha crenulata	crenulate lead plant	—	—	—	—	—	P	—
Amyris elemifera	torchwood	H	—	H	—	—	—	H
Annona glabra[b]	pond apple	H	P	H	P	P	P	H
Ardisia escallonioides	marlberry	H	P	H	P	P	—	H
Asimina reticulata[a]	pawpaw	—	—	—	—	—	—	P
Ateramnus lucidus	crabwood	H	—	H	—	—	—	—
Avicennia germinans[b]	black mangrove	H	H	—	—	—	—	—
Baccharis angustifolia[a]	false willow	—	P	H	—	—	—	—
Baccharis glomeruliflora[a]	groundsel tree	—	H	H	P	P	P	H
Baccharis halimifolia[a]	groundsel tree	H	H,P	H	P	P	P	P
Befaria racemosa[a]	tarflower	—	—	—	—	—	—	P
Bourreria cassinifolia	smooth strongbark	—	P	—	P	P	P	—
Bourreria ovata	strongbark	H	H	—	—	—	—	—
Bourreria succulenta	rough strongbark	H	—	—	—	—	—	—
Bumelia celastrina var. *angustifolia*	saffron plum	H	H,P	—	P	—	—	—
Bumelia reclinata	buckthorn	—	—	H	P	P	P	H,P
Bumelia salicifolia	willow bustic	H	H,P	H	P	P	P	H,P
Bursera simaruba	gumbo limbo	H	H,P	H	P	P	—	H
Byrsonima lucida	locust berry	H	H,P	H	P	P	P	—
Caesalpinia pauciflora	—	—	P	—	—	—	—	—
Callicarpa americana[a]	beauty berry	H	—	H	P	P	P	H,P
Calyptranthes pallens	pale lidflower	H	—	H	—	—	—	H
Calyptranthes zuzygium	myrtle-of-the-river	H	—	H	—	—	—	—
Canella winterana	cinnamon-bark	H	—	—	—	—	—	—
Capparis cynophallophora	Jamaica caper	H	—	—	—	—	—	—
Capparis flexuosa	limber caper	H	H	—	—	—	—	—
Casasia clusiifolia	seven-year apple	H	—	—	—	—	—	—
Cassia chapmanii	Bahama senna	—	H,P	H	P	P	P	P
Cassia ligustrina	—	H	—	H	—	—	—	—
Catesbaea parviflora	—	—	P	—	—	—	—	—
Celtis laevigata[a]	sugarberry	—	—	H	—	—	—	H
Cephalanthus occidentalis[a,b]	buttonbush	—	—	H	P	P	—	H
Chrysobalanus icaco	coco plum	H	P	H	P	P	P	H,P
Chrysophyllum oliviforme	satinleaf	H	H,P	H	P	—	—	H
Citharexylum fruticosum	fiddlewood	H	—	H	P	P	—	H
Clusia rosea	pitch apple	—	H	—	—	—	—	—
Coccoloba diversifolia	pigeon plum	H	H,P	H	P	—	—	H
Coccoloba uvifera	sea grape	H	H,P	—	—	—	—	—
Colubrina arborescens	coffee colubrina	—	—	H	P	—	—	H
Colubrina cubensis	Cuba colubrina	—	—	H	P	—	—	—
Colubrina elliptica	soldierwood	H	—	—	—	—	—	—
Conocarpus erecta	buttonwood	H	H,P	H	P	P	—	—
Cordia globosa	—	H	—	—	—	—	—	H
Cordia sebestena	Geiger tree	H	H	—	—	—	—	—
Cornus foemina[a,b]	stiff cornel	—	—	—	—	—	—	H
Crossopetalum rhacoma	rhacoma	H	H,P	H	P	P	—	—
Croton linearis	pineland croton	—	P	—	P	P	P	—
Cupania glabra	cupania	—	H	—	—	—	—	—
Diospyros virginiana[a]	persimmon	—	—	H	P	—	—	H,P
Dodonaea viscosa	varnish leaf	H	—	H	P	P	P	P
Drypetes diversifolia	milkbark	H	H,P	—	—	—	—	—
Drypetes lateriflora	Guiana plum	H	—	H	—	—	—	H
Erithalis fruticosa	black torch	H	H,P	—	—	—	—	—
Erythrina herbacea[a]	coral bean	—	—	H	—	—	—	H
Eugenia axillaris	white stopper	H	H,P	H	P	P	—	H,P
Eugenia confusa	redberry stopper	H	—	H	—	—	—	H
Eugenia foetida	Spanish stopper	H	H,P	H	—	—	—	—
Eugenia rhombea	red stopper	H	—	—	—	—	—	—
Eupatorium villosum	—	—	—	H	P	P	—	—
Exostema caribaeum	princewood	H	H	—	—	—	—	—
Exothea paniculata	inkwood	H	H	H	P	P	—	H
Ficus aurea	strangler fig	H	H,P	H	P	P	P	H,P
Ficus citrifolia	shortleaf fig	H	H,P	H	P	P	P	H,P

(*continued*)

Scientific Name	Common Name	Florida Keys		Miami Rock Ridge				Big Cypress
		UK	LK	—	LP	RL	NB	
Forestiera segregata var. *pinetorum*	pineland olive	—	P	H	P	P	—	—
Guaiacum sanctum	lignum vitae	H	—	—	—	—	—	—
Guapira discolor	blolly	H	H,P	H	P	P	—	—
Guettarda elliptica	velvetseed	H	H,P	H	P	P	—	—
Guettarda scabra	rough velvetseed	H	H,P	H	P	P	P	—
Gyminda latifolia	false boxwood	—	H	—	—	—	—	—
Hamelia patens	scarletbush	H	H	H	—	—	—	H
Hippomane mancinella	manchineel	—	H,P	—	—	—	—	—
Hypelate trifoliata	white ironwood	H	P	H	P	—	—	—
Ilex cassine[a]	dahoon	—	—	H	P	P	P	H,P
Ilex glabra[a]	gallberry	—	—	—	—	—	—	P
Ilex krugiana	tawnyberry holly	—	—	H	P	P	—	—
Jacquinia keyensis	joewood	H	H,P	H	P	—	—	—
Krugiodendron ferreum	black ironwood	H	H	H	—	—	—	H
Laguncularia racemosa[b]	white mangrove	H	H,P	—	—	—	—	—
Lantana involucrata	wild sage	H	H,P	H	P	P	P	—
Lyonia fruticosa[a]	staggerbush	—	—	—	—	—	P	P
Lysiloma latisiliqua	wild tamarind	H	—	H	P	P	—	H
Magnolia virginiana[a,b]	sweet bay	—	—	H	P	—	—	H
Manilkara bahamensis	wild dilly	H	H,P	—	—	—	—	—
Mastichodendron foetidissimum	mastic	H	—	H	—	—	—	H
Maytenus phyllanthoides	gutta-percha mayten	H	—	—	—	—	—	—
Metopium toxiferum	poisonwood	H	H,P	H	P	P	P	H,P
Morus rubra[a]	red mulberry	—	—	H	—	—	—	H
Myrcianthes fragrans	twinberry stopper	H	—	H	P	P	—	H
Myrica cerifera[a]	wax myrtle	—	H,P	H	P	P	P	H,P
Myrsine guianensis	myrsine	H	H,P	H	P	P	P	H,P
Nectandra coriacea	lancewood	H	—	H	—	—	—	H
Persea borbonia[a]	red bay	H	P	H	P	P	P	H,P
Pinus elliottii var. *densa*	S. Fla. slash pine	—	H,P	H	P	P	P	P
Piscidia piscipula	Jamaica dogwood	H	H,P	H	—	—	—	—
Pisonia rotundata	pisonia	—	H,P	—	—	—	—	—
Pithecellobium guadalupense	blackhead	—	P	—	—	—	—	—
Pithecellobium unguis-cati	cat's claw	H	H	H	—	—	—	—
Prunus myrtifolia	West Indies cherry	—	—	H	—	—	—	—
Psidium longipes	long-stalked stopper	—	H,P	H	P	P	P	—
Psychotria ligustrifolia	Bahama wild coffee	H	—	—	—	—	—	—
Psychotria nervosa	wild coffee	H	H,P	H	P	P	—	H
Psychotria sulzneri	wild coffee	—	—	H	—	—	—	H
Quercus laurifolia[a]	laurel oak	—	—	—	—	—	—	H
Quercus minima[a]	dwarf live oak	—	—	—	—	—	P	P
Quercus pumila[a]	running oak	—	—	H	—	—	P	P
Quercus virginiana[a]	live oak	H	—	H	P	P	P	H,P
Quercus virginiana var. *geminata*[a]	sand live oak	—	—	—	—	—	P	P
Randia aculeata	indigo berry	H	H,P	H	P	P	P	H,P
Reynosia septentrionalis	darling plum	H	H,P	—	—	—	—	—
Rhizophora mangle[b]	red mangrove	H	H,P	—	—	—	—	—
Rhus copallina[a]	sumac	—	P	H	P	P	P	H,P
Salix caroliniana[a,b]	willow	—	—	H	P	P	P	H,P
Sambucus canadensis[a,b]	elderberry	—	—	H	—	—	P	H
Sapindus saponaria	soapberry	H	—	H	—	—	—	—
Savia bahamensis	maiden bush	—	H	—	—	—	—	—
Schaefferia frutescens	Florida boxwood	H	—	—	—	—	—	—
Schoepfia chrysophylloides	gray twig	H	—	H	—	—	—	H
Simarouba glauca	paradise tree	H	H	H	—	—	—	H
Solanum bahamense	Bahama nightshade	H	—	—	—	—	—	—
Solanum donianum[b]	—	—	H,P	H	P	—	—	—
Solanum erianthum	potato-tree	H	H,P	H	—	—	—	H
Sophora tomentosa	necklace pod	—	P	—	—	—	—	—
Strumpfia maritima	—	—	P	—	—	—	—	—
Swietenia mahagoni	mahogany	H	—	H	—	—	—	—
Taxodium ascendens[a,b]	pond cypress	—	—	H	—	—	—	P
Tetrazygia bicolor	tetrazygia	—	—	H	P	P	P	—
Trema lamarckiana	West Indies trema	H	—	—	—	—	P	—
Trema micrantha	Florida trema	—	H,P	H	P	P	P	H,P
Vaccinium myrsinites[a]	shiny blueberry	—	—	—	—	—	P	P
Vallesia glabra	pearl berry	H	—	—	—	—	—	—
Viburnum obovatum[a,b]	black haw	—	—	—	—	—	—	H
Ximenia americana	tallowwood	H	H	H	—	—	P	H
Zanthoxylum fagara	wild lime	H	—	H	—	—	—	H

(*continued*)

Appendix (continued)

Scientific Name	Common Name	Florida Keys		Miami Rock Ridge				Big Cypress
		UK	LK	—	LP	RL	NB	
Vines and Scandent Shrubs								
Ampelopsis arborea[a]	pepper vine	—	—	H	—	—	—	H
Berchemia scandens[a,b]	rattan vine	—	—	—	—	—	—	H
Caesalpinia bonduc	yellow nicker	—	H	—	—	—	—	—
Caesalpinia crista	gray nicker	H	—	—	—	—	—	—
Chiococca alba	snowberry	H	H	H	—	—	—	H
Cissus sicyoides	possum grape	—	—	H	—	—	—	H
Dalbergia brownei	—	H	—	—	—	—	—	—
Dalbergia ecastophyllum	fishpoison vine	H	—	H	—	—	—	—
Gouania lupuloides	chew stick	H	—	—	—	—	—	H
Hippocratea volubilis	doctor vine	H	—	H	—	—	—	—
Parthenocissus quinquefolia[a]	Virginia creeper	H	H	H	—	—	—	H
Pisonia aculeata	devil's claw	H	H	H	—	—	—	H
Smilax spp.[a]	greenbrier	H	H,P	H	P	P	P	H,P
Tournefortia hirsutissima	—	—	—	H	—	—	—	H
Tournefortia volubilis	soldier vine	H	H	—	—	—	—	H
Toxicodendron radicans	poison ivy	H	H,P	H	P	P	P	H,P
Vitis spp.[a]	grape	H	—	H	—	—	—	H
Vitis rotundifolia[a]	muscadine	H	H	H	P	—	—	H,P
Palms								
Coccothrinax argentata	silver palm	H	H,P	H	P	P	P	—
Pseudophoenix sargentii	buccaneer palm	H	—	—	—	—	—	—
Roystonea elata	royal palm	—	—	H	—	—	—	—
Sabal palmetto[a]	cabbage palm	H	H,P	H	P	P	P	H,P
Serenoa repens[a]	saw palmetto	H	H,P	H	P	P	P	H,P
Thrinax morrisii	Key thatch palm	H	H,P	—	—	—	—	—
Thrinax radiata	Florida thatch palm	H	H,P	—	—	—	—	—

Sources: Distributions are based on Alexander (1958a, 1967b), Dickson (1955), Gunderson and Loope (1982b), Hilsenbeck (1976), McGuire and Brown (1974), Olmsted et al. (1980, 1983), Phillips (1940), Robertson (1955), Weiner (1979), and observations of the authors.

Note: UK = Upper Keys; LK = Lower Keys; LP = Long Pine Key; RL = Redlands; NB = Northern Biscayne.

a. Species with distributions mainly north of south Florida.

b. Species of solution holes or ecotones; more characteristic of other habitats.

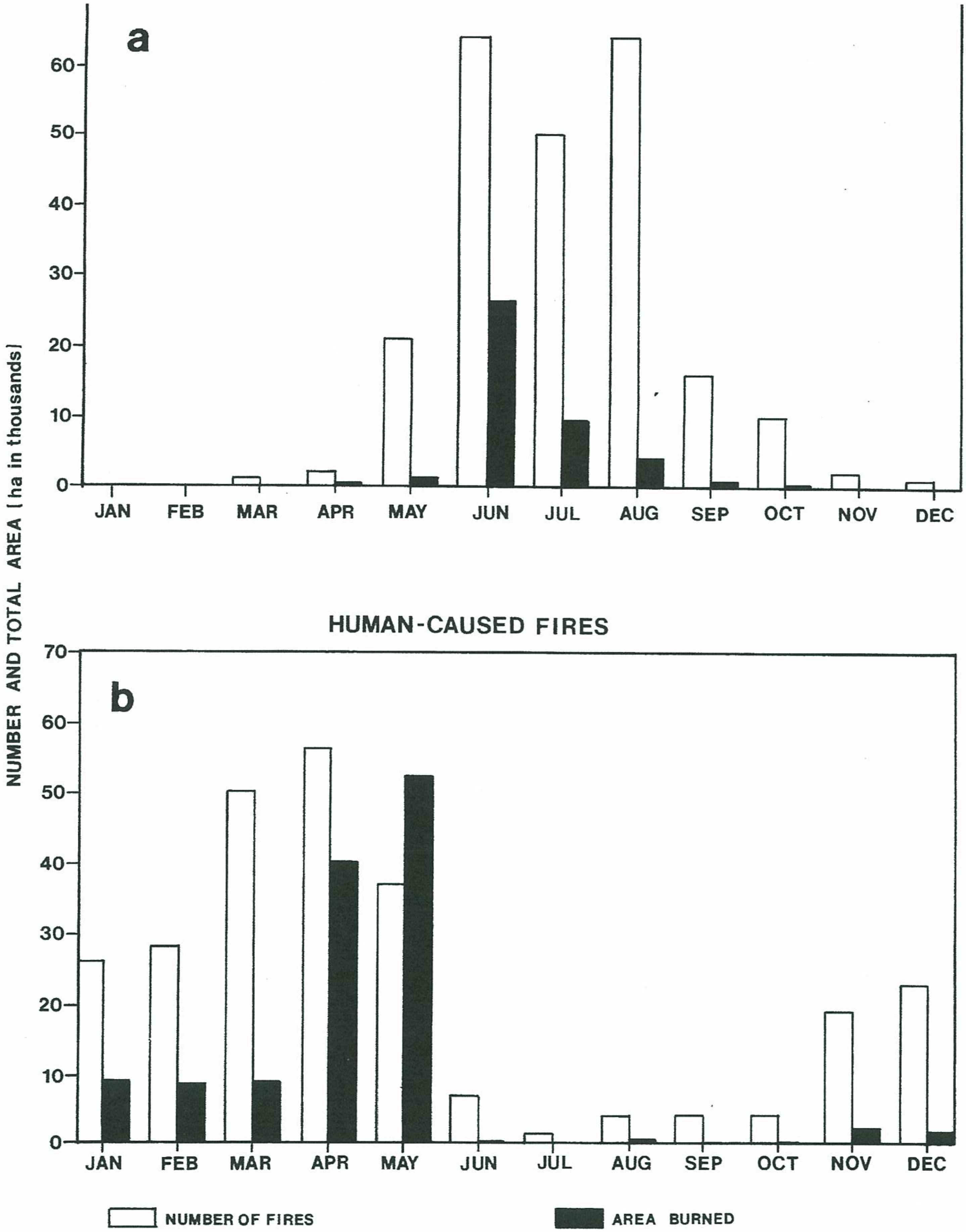
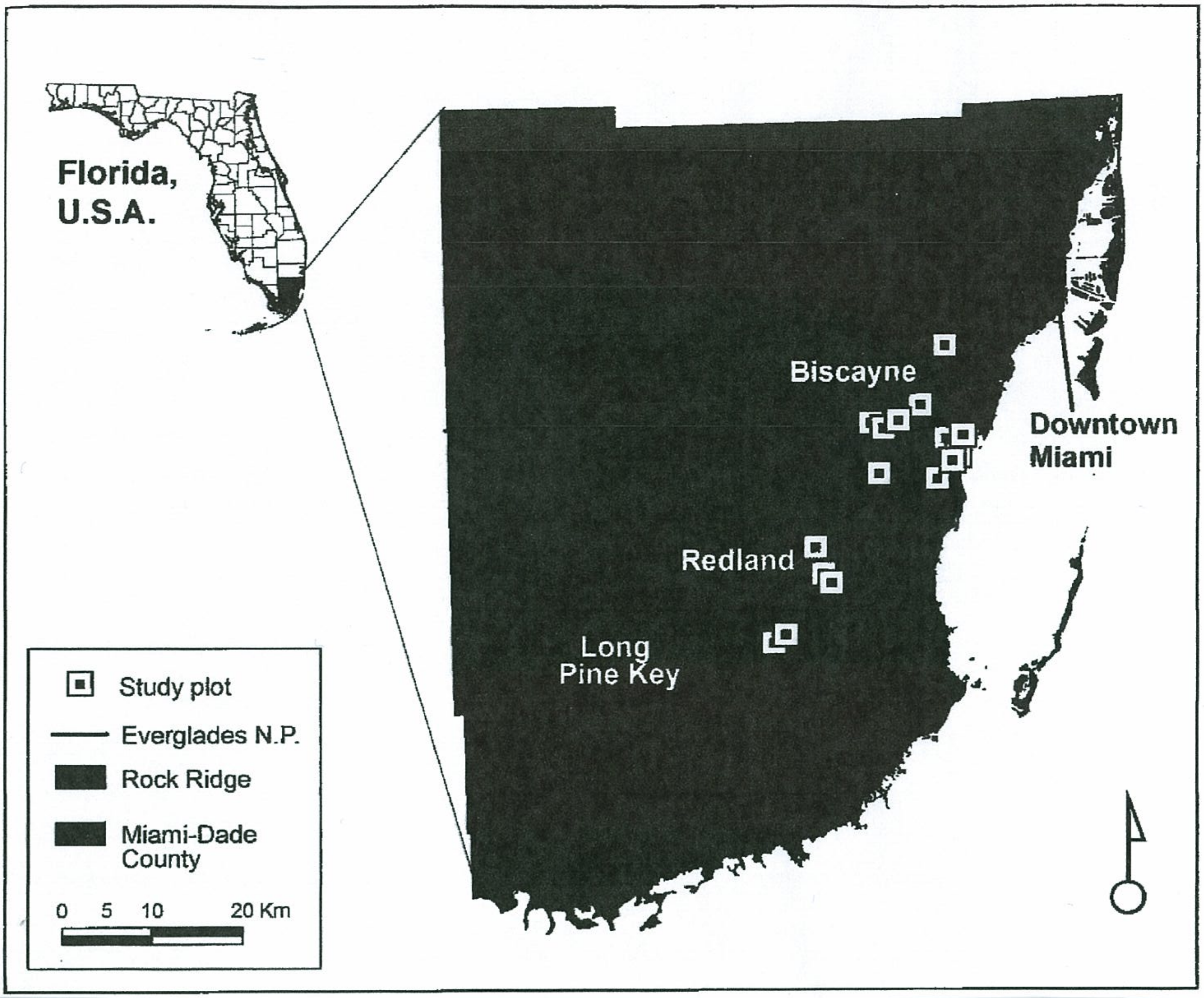


Fig. 8.13. Monthly distribution of (*a*) lightning fires and (*b*) human-caused fires (excluding prescribed fires) in Everglades National Park recorded from 1948 to 1981. The data are derived from Taylor (1981) and Doren and Rochefort (1984).


Florida,
U.S.A.
Biscayne
Downtown
Miami
Redland
Long
Pine Key
Study plot
Everglades N.P.
Rock Ridge
Miami-Dade
County
0 5 10 20 Km