The Ecological Communities

Contents **Page**

High Pine 3-3
Florida Scrub/Scrubby Flatwoods/Scrubby High Pine 3-31
Beach Dune/Coastal Strand/Maritime Hammock 3-69
Mesic Temperate Hammock 3-95
Tropical Hardwood Hammock.....3-121
Pine Rocklands.....3-161
Pine Flatwoods
    Mesic Pine Flatwoods 3-195
    Hydric Pine Flatwoods.....3-231
Dry Prairie 3-279
Cutthroat Grass Communities 3-347
Freshwater Marshes/Wet Prairies.....3-399
Forested Wetlands.
    Flowing Water Swamps 3-455
    Pond Swamps.....3-479
    Seepage Swamps 3-499
Mangroves 3-519
Coastal Salt Marsh 3-553
Seagrasses.....3-597
Nearshore and Midshelf Reefs.....3-623

High Pine

FNAI Global Rank:	**G2/G3**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**15**
State Listed Species in S. FL:	**35**

High Pine. *Original photograph courtesy of The Nature Conservancy.*



Longleaf pine savannas, characterized by a nearly continuous ground cover of wiregrass (*Aristida beyrichiana*) and widely spaced longleaf pines (*Pinus palustris*), once covered most of the pre-settlement uplands of the southeastern United States from Virginia to Texas and south to Central Florida. These savannas included both high pine and pine flatwoods, similar plant communities at opposite ends of the moisture gradient. Today the longleaf pine savanna is almost extinct, the result of harvesting all original-growth longleaf pines and decades of fire suppression. In South Florida, the high pine community is extinct except for a few small, isolated fragmentary remnants that are not large enough to be self-sustaining or to support the full complement of native species. Most South Florida sites where high pine formerly occurred are now occupied by citrus orchards, strip mines or other human development. Remaining high pine sites are small and have been degraded by fire suppression. They now are dominated by invasive off-site species such as sand pine (*Pinus clausa*), or by species formerly restricted to the shrub layer such as turkey oak (*Quercus laevis*).

Prospects for restoring high pine to its former range in the South Florida Ecosystem appear remote.

Synonymy

The longleaf pine savannas of the southeastern United States were called “pine barrens” by the first European settlers (Williams 1837). Later, the lower, more mesic savannas came to be called “pine flatwoods” and the higher, better-drained areas, “high pine” (*e.g.* Whitney 1896). Beginning in the 1940s, Laessle (1942, 1958) and others from the University of Florida in Gainesville began referring to the plant community as “sandhills,” perhaps because they were uncomfortable using the term “high pine” for a community then largely lacking pine trees due to lumbering and fire suppression. Means and Campbell (1982) introduced the term “clayhills” for the same

community on clay-based soils, because they were uncomfortable using the term "sandhills" for a plant community on clay soils. Others have called the community longleaf pine/turkey oak, longleaf pine/wiregrass, longleaf pine ridge lands, and longleaf pine savanna. High pine sites that have been severely degraded by fire exclusion and lumbering have been called "turkey oak barrens," "turkey oak sandhills" and even "turkey oak scrub." Myers (1990), thankfully, restored the term "high pine" in his very thorough account of the community. We continue to use the term "turkey oak barrens" for former high pine sites that now lack a wiregrass ground cover and are dominated by tree-sized turkey oaks (*Quercus laevis*).

Plant communities intermediate between high pine and Florida scrub can be called "scrubby high pine," analogous to "scrubby flatwoods," which is intermediate between pine flatwoods and Florida scrub. Scrubby high pine has been known by many names, including "Caribbean pine-turkey oak" (Laessle 1967), "slash pine-turkey oak" (Douglas and Layne 1978), "southern ridge sandhills" (Abrahamson *et al.* 1984), "yellow sand scrub" (Christman 1988a), "natural turkey oak barrens" (Christman and Judd 1990), "hickory scrub" (Main and Menges 1997), and "blackjack lands" or "blackjack ridges" by 19th century land surveyors cited in Myers (1990). The FLUCCS code for the high pine community includes: 412 (longleaf pine/xeric oak).

Distribution

Longleaf pine savannas (high pine and pine flatwoods) once covered more than 29 million ha (71.6 million acres, over 70 percent of the upland area) on the southeastern coastal plain from southeastern Virginia to eastern Texas and south to central Florida (Croker 1979, Noss 1988, Means and Grow 1985). Today, only about 1 million ha (2.5 million acres, less than 3 percent of the original) remains. According to Myers (1990), the historic southern limit of the high pine community corresponded to the end of the sand ridges in peninsular Florida, reaching Martin County on the east coast, Lee County on the west coast and Highlands County in the interior.

Within the South Florida Ecosystem high pine formerly occupied much of the center of the Lake Wales Ridge in Polk and northern Highlands counties (Figure 1). Most of this area is now occupied by citrus groves and commercial development. It appears that lands with yellow sands on the southern half of the Lake Wales Ridge ("southern ridge sandhills" of Abrahamson *et al*. 1984, "hickory scrub" of Main and Menges 1997) and on the eastern flank of the Lake Wales Ridge ("natural turkey oak barrens" of Christman and Judd 1990) supported scrubby high pine rather than high pine (Christman 1988a, 1988b, 1995; Myers and Boettcher 1987, Myers 1990).

Today, small remnant vestiges of high pine still occur in Polk County at Bok Tower Gardens, Mountain Lake and around Babson Park. None is large enough to be self-sustaining or to support many of the native high pine vertebrate species (GFC 1994). The Florida Natural Areas Inventory has records for five high pine remnants in Polk County, one in Osceola County (on the Polk county line) and one in Highlands County. The Osceola and Polk County sites range from 2 to 45 ha (5 to 111 acres). The best stand of high pine

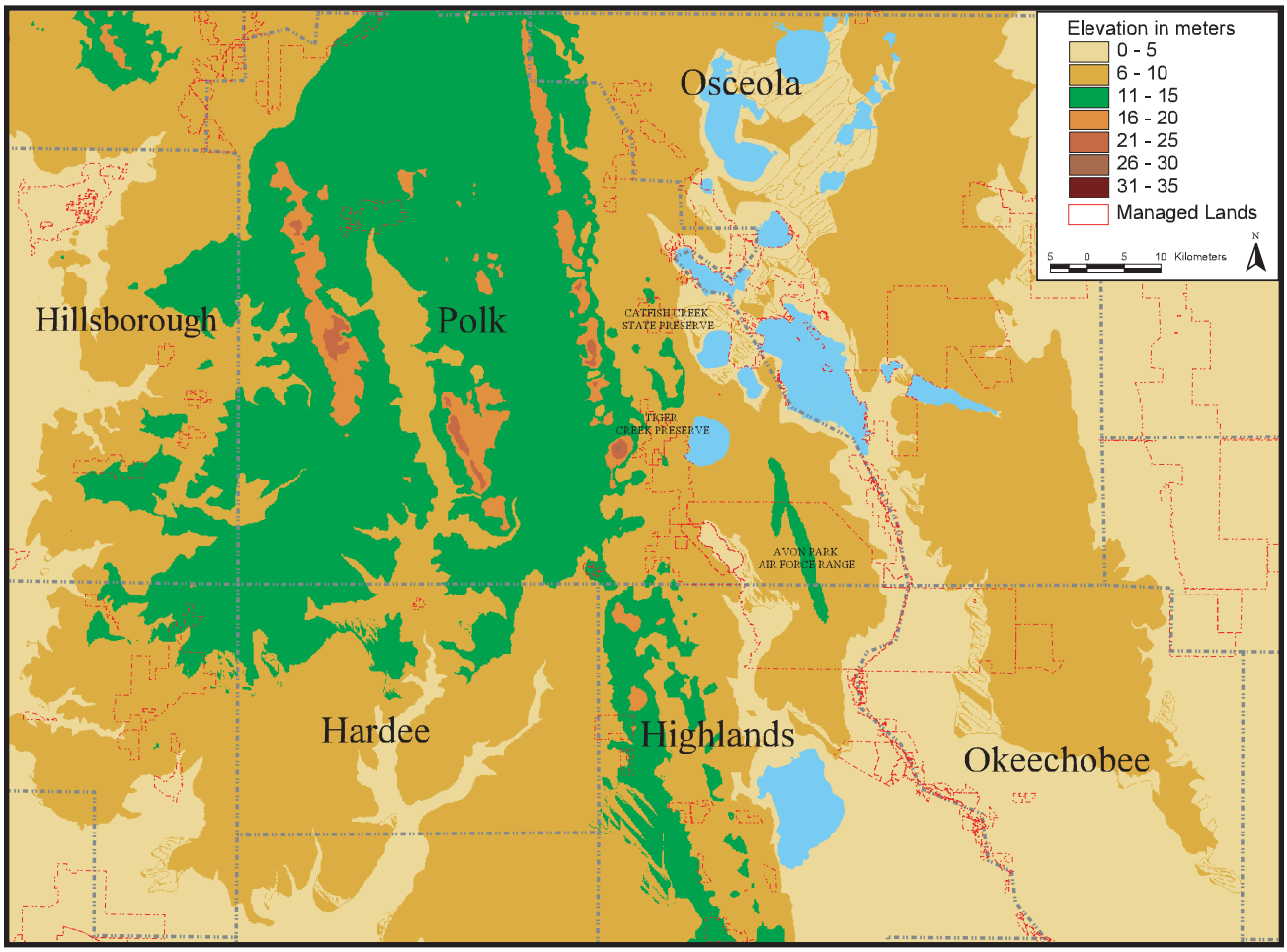


Figure 1. The distribution of high pine in South Florida north of Lake Okeechobee.

remaining in the South Florida Ecosystem covers about 440 ha (1,087 acres) on the Bombing Range Ridge within the Avon Park AFR. FNAI has no records of high pine for any of the other counties in the South Florida Ecosystem.

According to Jim Beever (GFC, personal communication 1998) there are areas of longleaf pine along the Peace River in DeSoto and Hardee counties that are high and dry enough to qualify as high pine. These occupy ridges within pine flatwoods communities. A small area of high pine occurs on a ridge along Horse Creek near Ona in Hardee County. Unfortunately, this site is part of a proposed phosphate strip mine (J. Beever, GFC, personal communication 1998).

Scrubby high pine occurs throughout Florida where it usually is associated with peaks in high pine or pine flatwoods communities or narrow bands along steep slopes between high pine and wetlands. It sometimes occurs as an ecotone between scrub and high pine. In northern Florida and the Panhandle, scrubby high pine is uncommon, generally occurring in small isolated patches. Within the South Florida Ecosystem, however, scrubby high pine once dominated much of the southern Lake Wales Ridge in the vicinity of Lake Placid, and especially in four regions on the eastern flank of the ridge near Catfish Creek, Tiger Creek, Carter Lake and (formerly) Bear Hollow (Christman 1988a). High pine and scrubby high pine apparently were the native plant communities of choice for citrus growers on the Lake Wales Ridge.

Description

The longleaf pine savannas of the southeastern United States occupy lands ranging from flat, poorly drained (even seasonally flooded) to extremely well-drained high and dry ridges. The lower, more mesic savannas are called pine flatwoods and the higher, drier stands are known as high pine. The two communities are at opposite ends of a wetness continuum, are similar in appearance, have similar fire regimes, and share many plant and animal species. Ridges within extensive areas of pine flatwoods often support more xeric species and could be considered high pine, just as low areas within high pine support flatwoods species.

The original high pine community was readily recognized by the continuous ground cover of grasses and the widely spaced longleaf pines. Today there is no virgin or old-growth high pine remaining in Florida. Examples of second growth high pine that come close to matching descriptions from early naturalists (*e.g.*, Bartram 1791, Williams 1837) can be seen at Riverside Island in the Ocala National Forest and at The Nature Conservancy's Janet Butterfield Brooks Preserve in Hernando County. There is another, smaller example near Thomasville, Georgia.

High pine communities can occur on a variety of soils, from coarse, sterile sands to fertile calcareous or phosphatic clays to rich loamy soils underlain by clays (Myers 1990). Studies by Laessle (1958, 1967) and Kalisz *et al*. (1986) have shown that there are no consistent differences in the physical or chemical properties of scrub and high pine soils. The two strikingly different plant communities are maintained by differences in fire regimes. The influence of soil type apparently is secondary or even insignificant (Myers 1990).

The original high pine community in Florida was dominated by wiregrass and

piney woods dropseed (*Sporobolus junceus*). Numerous other grasses, sedges and forbs were present as well, some making their aboveground appearances only after fire. Typical herbaceous species include wiregrass, piney woods dropseed, yellow buttons (*Balduina angustifolia*), silkgrass (*Pityopsis graminifolia*), green eyes *(Berlandiera subacaulis*), deer tongue (*Carphephorus corymbosus*), scrub dayflower (*Commelina erecta*), summer farewell (*Dalea pinnata*), blazing star (*Liatris tenuifolia*), and queen's delight (*Stillingia sylvatica*). There was no canopy or subcanopy in the original high pine savanna. Widely spaced longleaf pines, up to a meter in diameter, were the only large trees. (Some high pine communities in South Florida may have had South Florida slash pine (*Pinus elliottii* var. *densa*) instead of longleaf pine.) Turkey oak, blue jack oak (*Q. incana*), post oak (*Q. stellata*) and sand live oak (*Q. geminata*) were usually present in scattered, often multi-stemmed clumps kept low and shrubby by frequent fires. Other woody plants typical of high pine include palafoxia (*Palafoxia integrifolia*), Chapman's oak (*Q. chapmanii*), and myrtle oak (*Q. myrtifolia*). Table 1 is a list of plant species that are typically found in peninsular Florida high pine communities. It was compiled for this report from six published and unpublished species lists from high pine sites in peninsular Florida.

Most remaining high pine communities in South Florida have been degraded by logging, fire exclusion, feral hog rooting, and cattle grazing, and appear quite different today. A typical high pine site in Florida today is characterized by extensive areas of bare ground littered with dead turkey oak leaves, scattered clumps of wiregrass, widely scattered longleaf pines, and a dominant midstory of turkey oak trees. Such a community usually is referred to as turkey oak barrens, and is often invaded by scrub species such as sand pine, garberia (*Garberia heterophylla*) and rosemary (*Ceratiola ericoides*) if seed sources are nearby. Turkey oak barrens usually support a subset of the original high pine species and some scrub species as well (Campbell and Christman 1982).

Scrubby high pine is a naturally occurring plant community that is floristically and functionally intermediate between high pine and scrub. Scrubby high pine usually contains longleaf pine or south Florida slash pine, turkey oak and scattered clumps of wiregrass, and has yellow sand, all conditions typical of high pine. However scrubby high pine also contains typical scrub species, such as sand pine, the evergreen scrub oaks, garberia, and rosemary, and it supports several species that are restricted or nearly restricted to it such as scrub hickory (*Carya floridana*), scrub buckwheat (*Eriogonum longifolium* var. *gnaphthalifolium*), pigeonwing, Lewton's polygala, and the scrub balms (*Dicerandra* spp.) (Christman 1988a, 1988b, Christman and Judd 1990). Scrubby high pine easily can be confused with man-made turkey oak barrens but references from the 18th and 19th centuries (cited in Myers 1990) attest to the natural occurrence of scrubby high pine long before the original longleaf pine savannas were logged. Scrubby high pine appears to be associated with topographically diverse landscapes where long-term fire-return intervals have been exceedingly variable (Myers and Boettcher 1987, Christman 1988b, Myers 1990).

Wildlife Diversity

Typical mammalian species in high pine include the Florida mouse (*Podomys floridanus*), Sherman's fox squirrel *(Sciurus niger shermani*), and pocket gopher *(Geomys pinetis)*. Typical birds are the pine warbler (*Dendroica pinus*), Bachman's sparrow (*Aimophila aestivalis*), and brown-headed nuthatch (*Sitta pusilla*). Typical reptiles are the gopher tortoise (*Gopherus polyphemus*), southeastern five-lined skink (*Eumeces inexpectatus*), eastern coachwhip (*Masticophis flagellum*), Florida pine snake (*Pituophis melanoleucus mugitus)*, and black racer (*Coluber constrictor*). Typical amphibians include the pine woods treefrog (*Hyla femoralis*), the gopher frog (*Rana capito*), and the spadefoot toad (*Scaphiopus holbrooki*). An extensive list of high pine reptiles and amphibians is provided by Campbell and Christman (1982) and Mushinsky (1985). Stout and Corey (1995) list vertebrates and invertebrates commonly captured in the high pine community. Engstrom (1993) provides lists of the characteristic birds and mammals of the longleaf pine savanna.

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the high pine community in South Florida include: the red cockaded woodpecker (*Picoides borealis*), sand skink (*Neoseps reynoldsi*), bluetail mole skink (*Eumeces egregius lividus)*, and eastern indigo snake (*Drymarchon corais couperi*). Biological accounts and recovery plans for these species are included in "The Species" section of this recovery plan. Several State listed species occur in the high pine community. These include: the Sherman's fox squirrel, Florida mouse, Florida pine snake, gopher tortoise, short-tailed snake (*Stilosoma extenuatum*), and gopher frog (Appendix C). The high pine community is important for these and other wildlife species of concern, as it provides cover, food, roosting, or nesting in well drained, white to yellow sands.

The primary habitat for the **Sherman's fox squirrel** is the fire maintained, mature longleaf pine-turkey oak, high pine and flatwoods communities (Humphrey 1992). Although the total population size of the fox squirrel is unknown, its numbers have been proportionally declining with habitat loss resulting from fire suppression and development. Longleaf pine seeds and turkey oak acorns are considered to be the fox squirrel's primary diet. Nesting usually occurs in large oaks and often contains Spanish moss *(Tillandsia usneoides)*, which provides insulation (Humphrey 1992). The specialized habitat of the remaining fox squirrels is greatly threatened due to increasing pressures of agricultural, commercial, and residential development. Habitat preservation and reclamation, including prescribed fire management, of large areas (at least 25 km^2, or 9.7 sq mi) of heterogeneous, natural high pine habitat are the most needed conservation actions for the Sherman's fox squirrel (Humphrey 1992). The State has listed the fox squirrel as a species of special concern.

The **red-cockaded woodpecker** prefers open, frequently burned, mature longleaf pine, sparse midstory communities (Rodgers *et al.* 1996). These mature high pine areas provide a food source and roosting and nesting habitat necessary to sustain red-cockaded woodpeckers. Red-cockaded woodpeckers

feed primarily on arthropods by scaling back the bark of trees in their preferred pine-dominated habitats (Rodgers *et al.* 1996). Population surveys have determined that although suitable habitat in privately owned forests could be inhabited by red-cockaded woodpeckers, these mature forests are rapidly declining as a result of fire suppression, development, and timber production. The majority of the existing red-cockaded woodpecker populations are fragmented and occur on Federal lands. The fragmented high pine forests are incompatible with sustaining large or stable populations of red-cockaded woodpeckers. Currently, the FWS has the red-cockaded woodpecker listed as endangered under the ESA. The State has the red-cockaded woodpecker listed as threatened. Despite the protected legal status of red-cockaded woodpecker, the population has continued to decline throughout South Florida, principally as result of habitat deterioration (Rodgers *et al.* 1996). Habitat preservation and reclamation, including prescribed fire management of old-growth pines, should be one of the conservation actions for the red-cockaded woodpecker. Measures should also be taken to prevent further fragmentation of suitable habitat by creating corridors of old-growth pines between population centers.

The **southeastern American kestrel** *(Falco sparverius paulus)* uses high pine communities for nesting and foraging habitat. Although no systematic statewide surveys have been completed to estimate the current population size, it can be expected that the southeastern American kestrel population decline will continue in conjunction with the loss of foraging and nesting habitat due to timber harvest of the high pine forests. Data from the FWS' Breeding Bird Survey also suggests a declining kestrel population in Florida between 1966 and 1979 (Rodgers *et al.* 1996). Kestrels are found nesting predominately in longleaf pine snags, but also can be found in sand pines, turkey oaks, live oaks *(Quercus virginiana)*, and in post oaks (Rodgers *et al.* 1996). These nesting habitats preferred by southeastern American kestrels have declined and are continuing to decline rapidly throughout Florida. Loss of nesting snags due to agricultural conversion and developmental pressures appears to be the dominant factor affecting kestrels'decline. Habitat preservation of both nesting and foraging habitat is crucial to the conservation of the southeastern American kestrel. Currently, the State has the southeastern American kestrel listed as threatened.

The **gopher tortoise** is considered a keystone species in the high pine community because its deep burrows provide sites for nesting, feeding, refuge from fire and predators, and protection from high temperatures and desiccation for hundreds of other species (Landers and Speake 1980, Diemer 1992, Enge *et al.* 1997). Gopher frogs (*Rana capito*), Florida mice (*Podomys floridana*), and eastern indigo snakes (*Drymarchon corais couperi*) are variously dependent on tortoise burrows. The spoil in front of a gopher tortoise burrow provides germination sites for plants and essential microhabitat for fossorial reptiles such as mole skinks (*Eumeces egregius*), and crowned snakes (*Tantilla relicta*). Over 300 species of invertebrates, 36 reptiles and amphibians, 19 mammals, and 7 birds have been found in gopher tortoise burrows (Cox *et al.* 1987, Jackson and Milstrey 1989, Brandt *et al*. 1993, Kent and Snell 1994,



Gopher Tortoise. *Original photograph by Dawn Jennings.*

Diemer 1992). Some of the arthropods, such as the gopher cricket (*Ceuthrophilus* spp.) and scarab beetles (*Aephodius* spp., *Copris* spp., and *Onthophagus* spp.) are obligate commensals that occur nowhere except in gopher burrows (Deyrup and Franz 1994). Overall, gopher tortoise burrows provide a diversity of microhabitats that engenders a higher species richness (both plant and animal) for the high pine community.

The **eastern indigo snake** can be found in a variety of habitats in South Florida ranging from swamps to xeric uplands, including high pines. It can often be found in high pines in association with gopher tortoise burrows as oviposition sites in high pines. Eastern indigo snakes require large tracts of land for survival which leads to its declining numbers. Habitat loss, overcollecting for the pet trade, and mortality resulting from gassing tortoise burrows for rattlesnake collection are responsible for the placement of the eastern indigo snake on the State and Federal threatened list. Large and unaltered expanses of land must be preserved in order to protected the eastern indigo snake.

According to radio telemetry studies, the **Florida pine snake** occupies well drained, xeric sites, including longleaf pine-turkey oak associations. This snake is extremely fossorial and is often found associated with the tunneling system of the pocket gopher and, to a lesser extent, the gopher tortoise (Moler 1992). There have been serious declines in the numbers of Florida pine snake in the last 20 years due to habitat alteration, excessive collecting, and road mortality. Fire management and preservation of high pine habitats are the most needed conservation actions for the Florida pine snake. The Florida pine snake is currently listed by the State as a species of special concern.

The endemic **short-tailed snake** is chiefly restricted to longleaf pine-turkey oak plant associations, but can also be found in upland hammock and sand pine scrub (Moler 1992). Although little is known about this cryptic species, we know it is



Short-tailed snake. *Original photograph by Joseph Wasilewski.*

a burrower and is seldom seen above ground outside of the spring and fall seasons. The short-tailed snake's specialized habitat of well-drained soils is under tremendous pressures by agriculture, building construction, and timbering/clearcutting of longleaf pines and sand pine scrub. Obvious conservation measures must include preservation and enhancement of these rapidly declining habitat communities. The short-tailed snake is currently listed as threatened by the State.

The **sand skink** is listed as a threatened species by the State and the FWS. This species is restricted to the microhabitats of loose sand and sunny exposures primarily in the rosemary scrub habitat of central Florida. In addition, it can be found inhabiting sand pine scrub, oak scrub, scrubby flatwoods, "turkey oak barrens" (Moler 1992), and was reported from definite high pine (sand hills) sites by Telford (1962) in ecotonal areas between high pine and sand pine forest in the Ocala NF. Because sand skinks spend most of their time 1 to 8 cm (0.5 to 3.0 in) beneath the surface of well-drained sandy soils, they cannot tolerate dense ground cover or heavily rooted vegetation. This habitat has already seen much destruction as a result of agriculture and residential development. Although the sand skink is threatened with extinction due to its losing battle with humans for its habitat, it is often abundant in the remnant habitat that exists. Since the specialized habitat of the sand skink is rapidly declining, conservation actions should be taken to preserve large tracts of high pine and scrub communities.

Plant Species of Concern

Federally listed plant species that depend upon or utilize the high pine community in South Florida include: Britton's beargrass (*Nolina brittoniana*), tiny polygala (*Polygala smallii*), Carter's mustard (*Warea carteri*), scrub

buckwheat (*Eriogonum longifolium* var. *gnaphalifolium*), Florida bonamia (*Bonamia grandiflora*), papery whitlow-wort (*Paronychia chartacea*), wide-leaf warea (*Warea amplexifolia*), pigeon wings (*Clitoria fragrans*), Lewton's polygala (*Polygala lewtonii*), Florida ziziphus (*Ziziphus celata*), and scrub plum (*Prunus geniculata*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. The State listed pine pinweed (*Lechea divaricata*) can also be found utilizing the high pine community.

The **wide-leaf warea** is a plant endemic to the high pine (or sandhill) habitat. Clasping warea is limited to dry, open longleaf pine woods, longleaf pine/turkey oak woods, or live oak/bluejack oak woods that occur on well-drained, sterile, white to yellowish sands on the Lake Wales Ridge. It does not generally occur in weedy areas and requires fire management to facilitate its growth. Conservation actions for the wide-leaf warea should include fire management and preservation of high pine habitat. This species is currently listed as endangered by the State and the FWS.

The **scrub plum** prefers dry, sunny, nutrient-poor sites found in its native habitat of high pine and scrub oak communities. The scrub plum has been listed as endangered by the State and the FWS due to its rapidly declining habitat. The habitat type lends itself to numerous threats due to fire suppression and developmental pressures. Fire, or equivalent artificial disturbance, appears to be necessary for perpetuation of the species. The scrub plum readily resprouts after a fire or mechanical disturbances and colonizes the sunny openings created by the disturbances.

Ecology

Forests, scrubs and savannas are general terms for plant communities that are dominated by trees, shrubs, or grasses, respectively. The differences in vegetative structure are the result of the frequency of fire, which historically was determined by the local topography or "lay of the land," and by the flammability of the vegetation itself. In Florida, natural, lightning-caused fires occur at an average rate of more than 1,000 fires/year (Komarek 1964), and before modern man created settlements, transportation corridors, and farms, fires burned across the landscape until they ran out of fuel or reached aquatic or wetland firebreaks.

In southeastern North America, large expanses of flat land and rolling hills offered little impediment to the movement of lightning-caused fires and historically supported savannas dominated by various flammable grasses, especially wiregrass, and including widely spaced longleaf pines, or in the southern third of the Florida peninsula, South Florida slash pine. Historically, savannas experienced fire-return intervals of 1 to 10 years. The plant species composition and even the physical appearance of a savanna (except for the above-ground parts of the grasses, forbs and shrubs which are temporarily burned off) are little changed by the frequent fires. Savannas, therefore, are not disclimax communities and fires in savannas are not disturbances but rather predictable, regular features of the local climate.

Longleaf pines are uniquely adapted to existence in a fire-maintained landscape. The bark is thick and relatively fireproof. The limbs are high on the

trunk, above the flames. The needles are long and when they fall they tend to drape on encroaching shrubs causing them to be engulfed in fire. Longleaf seedlings remain in the "grass" stage for up to 20 years during which time they develop a strong root system while the vulnerable apical meristem is protected from fire in a thick sheath of needles. At some point the longleaf seedling bolts rapidly and within a few weeks the tender growing tip is raised 2 to 4 m (6 to 13 ft) above the ground and is once again safe from ground fires. Typically longleaf pines are vulnerable to death by fire only during the brief bolting phase.

Fires in the high pine community typically consume only the grasses and above-ground portions of woody shrubs. High pine fires tend to be relatively cool and slow burning compared to the catastrophic conflagrations typical of scrub. They usually occur during the season of most frequent lightning, in Florida from May through September, which corresponds with the growing season for the plants.

If fires are excluded from high pine, the woody shrubs grow larger and eventually dominate the site, shading out the grasses and forbs. Turkey oak barrens are former high pine sites in which the turkey oaks (and sometimes blue jack oaks) attain tree size. At its extreme, such a degraded community becomes a pioneer xeric hammock, with large sand live oaks and laurel oaks (*Quercus hemispherica*) replacing the turkey oaks. Such a community has almost no herbaceous vegetation ground cover, and almost none of the original high pine species.

Not to be confused with man-made turkey oak barrens is scrubby high pine, which is a natural community characterized by a combination of high pine and scrub species. Myers (1990) cites several 18th and 19th century descriptions of areas within the larger high pine landscape that were dominated by turkey, blue jack or post oaks. Scrubby high pine appears to be maintained by a highly irregular fire regime in which periods of frequent fire favor high pine species and other periods of less frequent fire allow proliferation of scrub species at the expense of wiregrass and longleaf pine. The constantly shifting pattern of fire return intervals allows both kinds of plants to coexist over the long term.

High pine is a stable, climax community characterized by a preponderance of "K-selected" species. That is, most high pine plant and animal species are long-lived with low reproductive rates. Long-term survival for populations of typical high pine plant and animal species depends more on each individual living a long time rather than producing a large number of offspring every year. Adult mortality is low. Some examples include wiregrass, which is almost unknown to reproduce in nature either sexually or asexually (Hebb 1957, 1971; Clewell 1986, 1989; Myers 1990); longleaf pines which live for centuries and whose recruitment is highly episodic (Platt *et al.* 1988 and numerous references therein), gopher tortoises which don't reach sexual maturity until 10 to 20 years of age (Diemer 1992), and red-cockaded woodpeckers, which nest only in living pine trees more than 60 years of age and require a year or more to construct the nesting cavity (Rudolph and Conner 1991).

High pine animals tend to have large home ranges. Individual eastern indigo snakes range over 50 to 100 ha (124 to 247 acres) (Moler 1992); Florida pine snakes are known to range over 12 to 96 ha (30 to 237 acres); in Florida,

a single family unit of red-cockaded woodpeckers requires 140 to 200 ha (346 to 494 acres) or more (DeLotelle *et al.* 1987, Wood 1996). For this reason the Florida GFC will not condone public acquisition of high pine communities deemed too small to support viable populations of native vertebrates: "To ensure the long-term viability of all sandhill vertebrate species, tracts less than 2,025 ha (5,000 acres) should not be acquired, unless they are contiguous with extensive publicly-owned lands" (GFC 1994).

Status and Trends

Florida has experienced more than an 88 percent loss of high pine since European settlement (Kautz *et al*. 1993). Most of the South Florida Ecosystem is outside the original range of high pine. Where high pine did occur (primarily on the central portion of the Lake Wales Ridge) nearly all has been eliminated and replaced with citrus groves or residential development. In South Florida the Florida scrub community is endangered, but the high pine community essentially is extinct. There are no stands of high pine within the South Florida Ecosystem large enough to meet the Florida GFC's criteria for public acquisition (GFC 1994).

All of the vertebrate species that are characteristic of high pine in Florida are declining in numbers and most are protected as threatened or endangered. Some of these species may be able to persist in degraded high pine sites or in other xeric habitats. The gopher tortoise is capable of persisting in other xeric habitats if illegal hunting is curtailed. The indigo snake is actually more common in wetland communities, but often uses gopher tortoise burrows for winter refuge. The Florida mouse, endemic to Florida, occurs in scrub habitats as well as high pine. The pocket gopher is able to thrive in heavily disturbed former high pine, including improved pastures and road shoulders. In South Florida, the red-cockaded woodpecker has been all but extirpated in high pine and the last populations, now nearing extinction as well, are confined to pine flatwoods. The Sherman's fox squirrel still occurs in high pine communities where domestic dogs and cats have not yet become dominant.

Management

Under natural conditions, the high pine community burned on average every 1 to 8 years (Robbins and Myers 1992, Christensen 1981). Such frequent burning prevented the establishment of hardwood trees, and maintained the open, park-like aspect of the savanna community. Unlike fires in scrub, fires in high pine are low-intensity, easy to ignite and easy to control. Land managers in Florida have been "firing" the pine savannas since Florida's original inhabitants, 12,000 years ago (Robbins and Myers 1992). Data from charcoal and fossil pollen found in lake sediments indicate that fires have occurred in South-central Florida for at least the last 50,000 years (Watts and Hansen 1988).

The intact high pine community is easily managed with growing season prescribed fires. Most herbaceous plant species native to the high pine community flower (and presumably produce seed) more profusely after growing season fires than they do after dormant season fires (Robbins and

Myers 1992, Streng *et al*. 1993). Growing season fires result in higher rates of top-kill and complete kill of the oaks and other hardwood species (Streng *et al*. 1993). Fires in the dormant season tend to result in increased biomass of hardwood trees. The Florida DEP, the Florida chapter of The Nature Conservancy, and the FWS and the USFS are experienced at prescribing fires in Florida high pine communities.

It has been demonstrated, especially on Florida state parks, that reintroduction of frequent growing season fires into degraded high pine (*i.e*., turkey oak barrens) will return the site to high pine in less than a decade. In most cases, the reintroduction of growing season fires is all the management necessary to restore high pine on turkey oak-dominated sites. In some cases it may be necessary to kill turkey oaks that have become too large to be killed by normal fires. This can be done by girdling and/or herbicide treatment.

Robbins and Myers (1992) suggest determining seasonal burn schedules and fire return intervals in managed high pine by random. They even provide a table of randomly generated numbers between 1 and 10 for managers to use in scheduling prescribed burns. Their purpose is to avoid an artificially uniform schedule of burning, but attentive, on-the-ground managers can probably devise a better way to determine when a site should be burned.

Myers (1990) admonished land managers to not overlook four important aspects of prescribed burning in high pine: (1) Maintain variability in season, frequency and regularity of burning both within and between sites; (2) recognize the natural variability in high pine sites, from the typical open wiregrass savanna to scrubby high pine associations that are transitional to Florida scrub; (3) maintain ecotones; and (4) recognize that other, adjacent communities, such as cutthroat grass glades, seepage meadows, and seepage slopes, were dependent on fires that originated in high pine and pine flatwoods. Some of these communities have changed to bayheads and gallberry or titi thickets because, like scrub, the connectivity between them and the pinelands has been severed and they no longer are exposed to fire.

Healthy, intact high pine communities, with their continuous ground cover of grasses and frequent fires, generally are not susceptible to invasion by exotic species. However, some degraded high pine sites have been invaded by the exotic cogongrass (*Imperata cylindrica*), which is difficult to eradicate and may exclude some native high pine species (Simons 1990). Cogongrass may hinder efforts to restore high pine. Various combinations of burning, herbicide application and mechanical removal have been used to control cogongrass, but more research is needed.

Table 1. Vascular plants of high pine in peninsular Florida.

The species are arranged in decreasing order of frequency of occurrence and importance on six published and unpublished plant species lists compiled from high pine communities in the Welaka area, Putnam County (Laessle 1942), Gold Head Branch State Park, Clay County (White and Judd 1985), the Ordway Preserve, Putnam County (Franz and Hall 1990), 2 sites in Polk and Osceola counties (Bridges and Reese 1996), the Avon Park Air Force Range, Highlands County (FNAI 1996), and a site in Osceola County (FNAI 1998). Species received a score of 1 for each list on which they occurred with the following two adjustments: Laessle (1942) ranked the plants from the Welaka area high pine site as dominant, common, frequent or rare and these were given scores of 1.5, 1, 0.5 and 0.25, respectively. Bridges and Reese (1996) ranked 35 species on their list as characteristic or restricted to high pine, and these were given scores of 1.5. Scores were summed and the species listed in decreasing order. The number of lists on which each species occurred is in parentheses.

* = introduced.

Aristida beyrichiana (6)	*Quercus geminata (5)*
Pinus palustris (6)	*Smilax auriculata (5)*
Balduina angustifolia (6)	*Stillingia sylvatica (5)*
Pityopsis graminifolia (6)	*Tephrosia chrysophylla (5)*
Bulbostylus ciliatifolia (6)	*Palafoxia integrifolia (5)*
Quercus laevis (6)	*Aster tortifolius (5)*
Sporobolus junceus (6)	*Chapmannia floridana (4)*
Carphephorus corymbosus (5)	*Cnidosculous stimulosus (5)*
Commelina erecta (5)	*Lygodesma aphylla (5)*
Dalea pinnata (5)	*Polygonella gracilis (5)*
Liatris tenuifolia (5)	*Sorghastrum secundum (5)*
Licania michauxii (5)	*Pterocaulon virgatum (5)*
Opuntia humifusa (5)	*Bulbostylus warei (4)*
Lechea deckertii (4)	*Yucca flaccida (4)*
Phoebanthus grandiflorus (4)	*Andropogon brachystachyus (3)*
Quercus chapmanii (4)	*Andropogon floridanus (3)*
Stylisma patens (4)	*Andropogon gyrans (3)*
Quercus myrtifolia (4)	*Andropogon virginicus var. glaucus (3)*
Andropogon ternerius (4)	*Aristida purpurascens var. purpurascens (3)*
Asclepias tuberosa (3)	*Berlandiera subacaulis (3)*
Chrysopsis scabrella (4)	*Cuthbertia graminea (3)*
Crotalaria rotundifolia (4)	*Cyperus filiculmis (3)*
Cyperus retrorsus (4)	*Dychoriste oblongifolia (3)*
Eryngium aromaticum (4)	*Eriogonum tomentosa (3)*
Galactia elliottii (4)	*Galactia regularis (3)*

Helianthemum corymbosum (4)	*Indigofera caroliniana (3)*
Paspalum setaceum (4)	*Myrica cerifera (3)*
Polanisia tenuifolia (4)	*Pinus clausa (3)*
Pteridium aquilinum (4)	*Polypremum procumbens (3)*
Schizachyrium scoparum (4)	*Selaginella arenicola (3)*
Schrankia microphylla (4)	*Serenoa repens (3)*
Seymeria pectinata (4)	*Tillandsia usneoides (3)*
Stipulicida setacea (3)	*Aeschynomene viscidula* (3)*
Tragia urens (4)	*Asclepias verticillata (3)*
Trichostema dichotomum (4)	*Asimina obovata (3)*
Elephantopus elatus (4)	*Aster concolor (3)*
Hedyotis procumbens (4)	*Cassia chamaecrista (3)*
Triplasis americana (4)	*Centrosema virginianum (3)*
Vaccinium myrsinites (4)	*Chamaesyce cordifolia (3)*
Croton argyranthemus (3)	*Aster undulatus (2)*
Cuthbertia ornata (2)	*Befaria racemosa (2)*
Dicanthelium acicular (3)	*Buchnera americana (2)*
Paronychia hernarioides (2)	*Ceratiola ericoides (2)*
Quercus incana (2)	*Chrysopsis gossypina (2)*
Rhynchospora megalocarpa (2)	*Crotonopsis linearis (2)*
Stylosanthes biflora (3)	*Dicanthelium ensifolium var. unciphyllum (2)*
Ximenia americana (2)	*Dicanthelium portoricense (2)*
Astragalus obcordatus (3)	*Digitaria villosa (2)*
Cassia nictitans (3)	*Eragrostis virginica (2)*
Diospyros virginiana (3)	*Eragrostris refracta (2)*
Gaylussacia dumosa (3)	*Eriogonum longifolium var. gnaphalifolium (2)*
Penstemon multiflorus (3)	*Eupatorium compositifolium (2)*
Rhus copallina (3)	*Fimbristylus puberula (2)*
Tephrosia florida (3)	*Froelichia floridana (2)*
Tillandsia recurvata (3)	*Gratiola hispida (2)*
Agalinis filifolia (2)	*Hedyotis uniflora (2)*
Amsonia ciliata (2)	*Hieracium gronovii (2)*

Andropogon virginicus var. virginicus (2)	*Hieracium megacephalon (2)*
Aristida condensata (2)	*Hypericum tetrapetalum (2)*
Aristida gyrans (2)	*Krameria lanceolata (2)*
Aristida spiciformis (2)	*Lachnocaulon beyrichianum (2)*
Asimina incarna (2)	*Lechea sessiliflora (2)*
Asimina reticulata (2)	*Liatris pauciflora (2)*
Ludwigia maritima (2)	*Andropogon virginicus (2)*
Lyonia fruticosa (2)	***Bonamia grandiflora (2)***
Lyonia lucida (2)	*Ceanothus microphyllus (2)*
Orbexilum lupinellum (2)	*Cenchrus gracillimus (2)*
Paronychia americana (2)	*Clitoria mariana (2)*
Paronychia chartacea (2)	*Cyperus globulosus (2)*
Paronychia patula (2)	*Desmodium strictum (2)*
Pinus elliottii var. densa (2)	*Dicanthelium malacon (2)*
Piriqueta caroliniana (2)	*Dicanthelium ovale (2)*
Polygonella robusta (2)	*Galactia volubilis (2)*
Polymnia uvedalia (2)	*Gymnopogon ambiguus (2)*
Psoralea canescens (2)	*Hypoxis juncea (2)*
Quercus minima (2)	*Lechea torreyi (2)*
Rhynchosia difformis (2)	*Lespedeza hirta (2)*
Rhynchospora grayi (2)	*Liatris chapmanii (2)*
Rhynchospora intermedia (2)	*Liatris gracilis (2)*
Schizachyrium sanguineum (2)	*Lonicera sempervirens (1)*
Scleria pauciflora (2)	*Opuntia pusilla (1)*
Tephrosia virginiana (2)	*Piptochaetium avenacioides*
Verbesina heterophylla (2)	*Polygala grandiflora (2)*
Vernonia angustifolia (2)	*Polygonella polygama (1)*
Viola septemloba (2)	*Schoenocaulon dubium (2)*
Vitus rotundifolia (2)	*Sisyrhinchium nashii (2)*
Xyris caroliniana (2)	*Solidago chapmanii (2)*
Stylodon carneus (2)	*Scutellaria multiglandulosa (1)*
Tephrosia hispidula (2)	*Andropogon virginicus var. decipiens (1)*

Vaccinium stamineum (2)	*Anthaenantia villosa (1)*
Warea carteri (1)	*Aristida mohrii (1)*
Aristolochia serpentaria (2)	*Aristida purpurascens var. virgata (1)*
Arnoglossum floridanum (2)	*Aristida rhizomophora (1)*
Asclepias amplexicaulus (2)	*Aristida simpliciflora (1)*
Asclepias humistrata (2)	*Asimina pygmaea (1)*
Aster walteri (2)	*Aster adnatus (1)*
Bulbostylus stenophylla (2)	*Aster dumosus (1)*
Bumelia reclinata (2)	*Aureolaria pectinata (1)*
Callicarpa americana (2)	*Axonopus affinis (1)*
Conyza canadensis (2)	*Axonopus furcatus (1)*
Desmodium viridiflorum (2)	*Bumelia tenax (1)*
Diodea teres (2)	*Cacalia floridana (1)*
Garberia heterophylla (2)	*Carphephorus odoratissimus (1)*
Gelsemium sempervirens (2)	*Carphephorus paniculatus (1)*
Ilex glabra (2)	*Carya floridana (1)*
Krigia virginica (2)	*Cassytha filiformis (1)*
Lyonia ferruginea (2)	*Castanea pumila (1)*
Magnolia grandiflora (2)	*Chionanthus pygmaeus (1)*
Phoradendrom serotinum (2)	*Chrysopsis mariana (1)*
Quercus stellata (2)	*Clematis reticulata (1)*
Ruellia carolinensis (2)	*Crataegus lepida (1)*
Cuscuta pentagona (1)	*Hupericum reductum (1)*
Cyperus nashii (1)	*Hypericum hypericoides (1)*
Cyperus retrofractus (1)	*Hypericum reductum (1)*
Dalea feayi (1)	*Hypoxis curtissii (1)*
Desmodium ciliare (1)	*Ilex ambigua (1)*
Desmodium floridana (1)	*Ilex opacum (1)*
Desmodium marilandicum (1)	*Juncus dichotomus (1)*
Desmodium tenuifolium (1)	*Juncus scirpoides (1)*
Dicanthelium ensifolium var. breve (1)	*Juniperus silicicola (1)*
Dicanthelium strigosum var. glabrescens (1)	*Lechea cernua (1)*

Digitaria cognata (1)	*Lechea minor (1)*
Digitaria gracillima (1)	*Lechea mucronata (1)*
Elephantopus nudatus (1)	*Linaria floridana (1)*
Eragrostris elliottii (1)	*Lolium perenne* (1)*
Eragrostris spectabilis (1)	*Lupinus diffusus (1)*
Erigeron strigosus (1)	*Nolina brittoniana (1)*
Eryngium yuccifolium (1)	*Osmanthus megacarpus (1)*
Euphorbia cordifolia (1)	*Palafoxia feayi (1)*
Euthamia tenuifolia (1)	*Panicum acuminata (1)*
Galactia mollis (1)	*Panicum anceps (1)*
Gymnopogon chapmanianus (1)	*Panicum clandestinum (1)*
Helenium flexuosum (1)	*Panicum virgatum (1)*
Helianthemum nashii (1)	*Parthenocissus quinquefolia (1)*
Helianthus radula (1)	*Paspalum notatum* (1)*
Paspalum plicatulum (1)	*Stylisma abdita (1)*
Persea humilis (1)	*Tephrosia spicata (1)*
Phlox nivalis (1)	*Tillandfsia fasciculata var. densispica (1)*
Pluchea rosea (1)	*Tillandsia utriculata (1)*
Polygala lewtonii (1)	*Toxicodendron pubescens (1)*
Polygala setacea (1)	*Tradescantia roseolens (1)*
Prunus geniculata (1)	*Trichostema setaceum (1)*
Pyrrhopappus carolinianus (1)	*Utricularia subulata (1)*
Quercus falcata (1)	*Vaccinium darrowii (1)*
Quercus hemispherica (1)	***Warea amplexifolia (1)***
Quercus inopina (1)	*Xyris brevifolia (1)*
Rhynchelytrum repens (1)	*Xyris jupicai (1)*
Rhynchosia reniformis (1)	*Agerantina jucunda (1)*
Rhynchosia tomentosa (1)	*Bulbostylis barbata* (1)*
Rhynchospora fernaldii (1)	*Centrosema floridana (1)*
Rubus cuneifolius (1)	*Desmodium canescens (1)*
Sabal etonia (1)	*Eupatorium album (1)*
Salvia azurea (1)	*Eupatorium mohrii (1)*

Schizachyrium niveum (1)	*Euphorbia exserta (1)*
Scutellaria arenicola (1)	*Gaillardia aestivalis (1)*
Silphium compositum (1)	*Gaylussacia nana (1)*
Sisyrhinchium xerophyllum (1)	*Gaylussacia tomentosa (1)*
Solidago fistulosa (1)	*Helianthemum carolinianum (1)*
Solidago odora (1)	*Heterotheca subaxilaris (1)*
Oxalis stricta (1)	*Prunus serotina (1)*
Phaseolus sinuatus (1)	*Pteroglossapsis ecristata (1)*
Physalis arenicola (1)	*Salvia lyrata (1)*
Sceleria ciliata (1)	*Setaria geniculata (1)*
Schizachyrium hirtiflorum (1)	*Smilax glauca (1)*
Scleria triglomerata (1)	*Spermolepis divaricata (1)*
Smilax bona-nox (1)	*Toxicodendron radicans (1)*
Acalypha gracilens (1)	*Vaccinium arboreum (1)*
Andropogon tracyi (1)	*Zornia bracteata (1)*
Aristida tenuispica (1)	
Asclepias tomentosa (1)	
Eupatorium capillifolium (1)	
Eustachys petraea (1)	
Gnaphalium obtusifolium (1)	
Haplopappus divaricatus (1)	
Lechea divaricata (1)	
Leptoloma cognatum (1)	
Matelea pubiflora (1)	
Monarda punctata (1)	
Oenothera laciniata (1)	
Onosmodium virginianum (1)	
Panicum hemitomon (1)	
Phytolacca americana (1)	
Prunus angustifloia (1)	

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Restoration of High Pine

Restoration Objective: Maintain and enhance the structure, function, and composition of the high pine community to ensure the long-term survival in the wild of all plant and animal species that depend upon this community for their existence.

Restoration Criteria:

High pine in South Florida may be considered restored when: (1) existing high pine habitat is preserved through land acquisition; Federal, State or local management actions; and/or private cooperative agreements; (2) prescribed fire or other management techniques are used to restore suitable habitat; (3) any further loss, fragmentation, and degradation of high pine habitat has been prevented; (4) appropriate ecosystem management plans have been prepared, funded, and implemented for long-term perpetuation of the high pine community; and (5) protection of high pine is adequate to ensure self-sustaining populations of endemic, rare, and imperilled species that use this community.

Community-level Restoration Actions

1. **Prevent further destruction or degradation of existing high pine communities**.

    1.1. **Secure high pine sites through land acquisition, landowner agreements, and conservation easements.** The highest priority should be placed on preventing development of remaining high pine sites. This is best accomplished by land acquisition, but other methods of preventing development such as conservation easements are sometimes useful. So much of South Florida's original high pine has already been irretrievably lost, that if any high pine tracts can be located they should be acquired for preservation.

    1.2. **Control public use.** Inappropriate public uses such as off-road vehicle racing and trash dumping should be prevented with signs and fences if necessary.

    1.3. **Enforce existing regulations.** Regulations against taking protected species must be enforced.

2. **Restore existing degraded high pine communities.**

    2.1. **Permit the reintroduction of natural fires or prescribe controlled burns.** High pine communities that have been degraded because of fire exclusion can be restored with prescribed fires. Each protected site should have a fire management plan prepared specifically for it. Management plans should specifically include allowing natural, lightning-ignited fires to burn through high pine 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.

2.2. **Encourage maintenance and recovery of natural ecotones.** Ecotones are important elements of any natural landscape and should receive special attention in natural area management plans. Fire breaks and roads should be placed well away from ecotones. Ecotones that have been degraded by existing roads and fire breaks should be restored.

2.3. **Eliminate or control exotic and off-site species.** Some high pine communities are infested with cogongrass. This invasive exotic should be controlled with herbicides and mechanical treatments.

2.4. **Reintroduce locally extirpated species.** Red-cockaded woodpeckers and wide-leaf warea should be reintroduced into appropriate high pine sites from which they have been extirpated. High pine sites are considered appropriate if all the critical requirements (*e.g.*, old growth longleafs for red-cockaded woodpeckers) of the species are met.

2.5. **Eliminate any sources of pollution**.

2.6. **Control public use.** High pine communities that have been degraded by inappropriate public use can only be restored by eliminating that public use. Signs and fences may be necessary to discourage off-road vehicle use, trash dumping, and illegal plant and animal harvesting.

3. **Maintain high pine communities in a natural condition in perpetuity.**

3.1. **Continue to prescribe natural fires or controlled burns.** Continue planning for natural lightning-ignited fires to be allowed to burn. Prescribe controlled burns when natural fires are inadequate to meet management objectives.

3.2. **Continue to control exotic species.**

3.3. **Continue to control public use.**

3.4. **Monitor for negative population trends among important high pine animal and plant species.** Areas of high pine within ecological preserves should have specific monitoring plans that will alert managers to extirpations or downward trends in populations of selected species, including endemic species, listed species, and keystone species.

3.5. **Monitor and correct for any point source or non-point source pollution**.

4. **Restore high pine where it has been destroyed by human activities such as mining or farming**. Most of the citrus groves on the Lake Wales Ridge were established on high pine sites. Today many of these groves are being abandoned. We may have the opportunity to restore high pine on some of these sites, although we do not yet know how to do this.

5. **Create high pine in regions where it has been destroyed by human activities**. It may be possible to create high pine on former strip mines, although this has not yet been attempted.

6. **Connect existing high pine preserves 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.

7. **Encourage research on ground cover restoration.** In northern Florida The Nature Conservancy and the Florida DEP are restoring high pine on turkey oak barrens sites where the ground cover is still at least partly intact. On sites where the ground cover has been completely destroyed, high pine restoration is still not feasible. We need to learn how to restore wiregrass on former citrus groves and strip mines where it has been eliminated.

8. **Monitor habitat and ecological processes.**

   8.1. **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 site-specific plan for monitoring vegetation response to prescribed fires and other land management actions.

   8.2. **Monitor for negative population trends among important high pine plant and animal species**. Each high pine preserve should have a monitoring plan that will alert managers to extirpations or downward trends in relative population levels of selected plant and animal species.

   8.3. **Monitor and correct for any point source or non-point source pollution.**

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 Florida's (CARL) program and Preservation-2000.

Florida Scrub

Including Scrubby Flatwoods and Scrubby High Pine

FNAI Global Rank:	**G2/G3**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**32**
State Listed Species in S. FL:	**100**

Florida scrub. *Original photograph courtesy of The Nature Conservancy.*



Florida scrub is a plant community easily recognized by the dominance of evergreen shrubs and frequent patches of bare, white sand. With more than two dozen threatened and endangered species dependent upon scrub, the entire community is itself endangered. Recovery of the community and its associated plants and animals will depend upon land acquisition and effective land management.

Synonymy

Florida scrub in its various phases has been called xeric scrub, sand scrub, big scrub, sand pine scrub, oak scrub, evergreen oak scrub, dune oak scrub, evergreen scrub forest, slash pine scrub, palmetto scrub, rosemary scrub, and rosemary bald. Florida scrubs may be classified as coastal or interior. Scrubs are often named by the dominant plant species, as in rosemary scrub, sand pine scrub, palmetto scrub, or oak scrub. Some authors have confused closed-canopy forests of sand pine trees with scrub. Scrubs that are very recent in origin, usually a result of man's activities, are called pioneer scrubs. Communities intermediate between scrub and pine flatwoods have been called dry or xeric flatwoods but now are referred to as scrubby flatwoods. Communities intermediate between scrub and high pine have been called southern ridge sandhills, hickory scrub, yellow sand scrub, turkey oak scrub, turkey oak barrens, and natural turkey oak barrens, but probably are best referred to as scrubby high pine. The FLUCCS code for the scrub community include: 413 (sand pine), 421 (xeric oak), and 441 (coniferous plantations).

Distribution

Coastal Florida scrub occurs sporadically on barrier islands and dunes and ridges along the Atlantic Coast in Florida and Georgia and along the Gulf Coast in Florida and Alabama (Myers 1990, Wharton 1978). On the northern Gulf Coast, coastal scrubs occur on several barrier islands

and on a narrow band along the coast from Franklin County to just across the state line in Baldwin County, Alabama. There are only a handful of coastal scrubs on the Gulf coast of the Florida peninsula. Among these are scrubs in the vicinity of Cedar Keys in Levy County, near WeekiWatchee in Hernando County, near Palma Sola in Manatee County, and near Bonita Springs, Naples and Marco Island in Lee and Collier counties. On the Atlantic coast of the Florida peninsula, scrubs occur (or formerly occurred) from St. John's County south to Miami-Dade County, where they occupy dunes and ridges immediately inland from coastal strand.

Within the South Florida Ecosystem, coastal scrubs occur in Indian River, St. Lucie, Martin, Palm Beach, and Broward counties on the Atlantic Coast, and Lee and Collier counties on the Gulf Coast. Coastal scrub formerly occurred in Miami-Dade County.

Interior Florida scrub occur sporadically on well-drained sandy ridges on the Georgia Fall Line and within the Florida peninsula from Kingsley Lake, Clay County south to Immokalee, Collier County (Myers 1990, Wharton 1978). Most interior Florida scrubs are associated with north-south tending ridges that were formed by wind and wave action during periods of higher sea level. The expansive stands of sand pine in the Ocala NF in Lake and Marion Counties are forests, not scrub, and occupy a landscape with yellow sand that may have supported high pine savanna during the earlier Holocene.

Within the South Florida Ecosystem, interior Florida scrub occurs on the Lake Wales, Winter Haven, Lake Henry, Lakeland, and Bombing Range ridges (White 1970) in Polk, Osceola, and Highlands counties; on lesser ridges within the Osceola Plain and Eastern Valley in Osceola, Okeechobee, Indian River, St. Lucie, and Martin counties; and scattered on small rises in Hardee, DeSoto, Glades, Hendry, and Collier counties (Figure 1).

Scrubby flatwoods is a scrub-like association often occurring on drier ridges in typical flatwoods or near coasts. The understory species of this vegetation type are similar to those of sand pine scrub, but the sand pine is replaced by slash pine or longleaf pine. Scrubby flatwoods occur throughout Florida, including the panhandle and northern peninsula where scrub is rare or nonexistent. Scrubby flatwoods occupy slightly higher and better-drained areas than pine flatwoods. Scrubby flatwoods are common on the Archbold Biological Station and formerly occupied much of the western flank of the Lake Wales Ridge. This community is especially well-developed on the low north-south tending ridges in Osceola and Okeechobee counties.

Scrubby high pine occurs throughout Florida where it usually is associated with peaks in high pine communities or narrow bands along steep slopes between high pine and wetlands. It sometimes occurs on well-drained sandy peaks within pine flatwoods communities. In northern Florida and the panhandle, the community generally occurs in small isolated patches. Within the South Florida Ecosystem, however, scrubby high pine once dominated much of the southern Lake Wales Ridge, especially in four regions on the eastern flank including areas around Catfish Creek, Tiger Creek, Carter Lake and (formerly) Bear Hollow (Christman 1988a). High pine and scrubby high pine (called southern ridge sandhills by Abrahamson *et al.* 1984, and others) apparently were the native plant communities of choice for citrus growers on the Lake Wales Ridge.

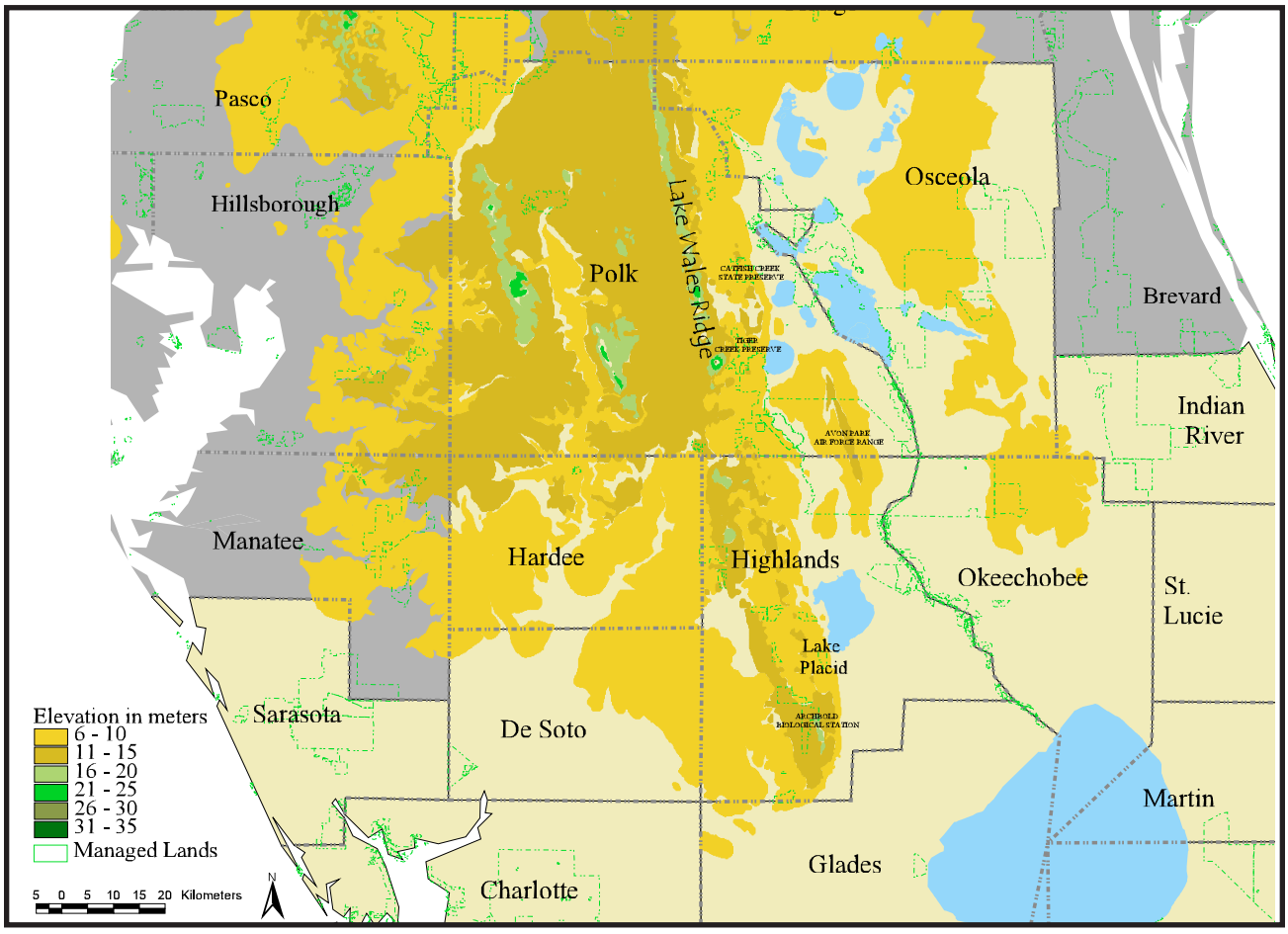


Figure 1. Conservation lands and topography in South Florida north of Lake Okeechobee.

Description

There is no single plant species that occurs in all Florida scrubs and not in other habitats as well, yet the community is easily recognized. Florida scrub can be identified by the dominance of several species of woody shrubs, especially myrtle oak or scrub oak (*Quercus myrtifolia* or *Q. inopina*), sand live oak (*Q. geminata*), Chapman's oak (*Q. chapmanii*), crookedwood (*Lyonia ferruginea*), saw palmetto (*Serenoa repens*) and Florida rosemary (*Ceratiola ericoides*); the absence of a tree canopy; the absence of a continuous vegetative ground cover; and the absence of longleaf pine (*Pinus palustris*), wiregrass (*Aristida beyrichiana*), and turkey oak (*Q. laevis*). When sand pines (*Pinus clausa*) are present in scrub they do not form a continuous canopy but occur as scattered individuals or clumps of individuals. Most scrubs occur on white sand and patches of bare sand with or without scattered clumps of ground lichens.

Scrub soils are derived from quartz, slightly to strongly acidic, very low in nutrients, and moderately to excessively well-drained. They are classified as entisols (soils with little or no horizon development) (Myers 1990). Scrub soils are practically devoid of organic matter, silt and clay. Scrub soils range from the pure white, excessively leached St. Lucie Fine Sand, to moderately leached Paola and Orsino sands that are characterized by a white surface and a yellowish subsoil.

Scrubs often occupy ecotones between longleaf pine savannas (high pine or pine flatwoods) and wetlands, and conditions within a single scrub may grade from xeric to mesic. Scrubs on the most excessively drained sites often are dominated by Florida rosemary and referred to as rosemary balds. Sand pine scrubs have scattered individuals or clumps of sand pines and oak scrubs are dominated by one or more of the shrubby oaks.

Scrubby flatwoods is floristically and functionally intermediate between pine flatwoods and scrub, and sometimes (but not necessarily) occurs as an ecotone between them (Abrahamson and Hartnett 1990). Scrubby flatwoods differs from scrub by the presence of scattered wiregrass and a preponderance of flatwoods species such as fetterbush (*Lyonia lucida*), wax myrtle (*Myrica cerifera*), and gallberry (*Ilex glabra*). Shrubby oaks, including sand live oak, Chapman's oak, and myrtle oak or scrub oak, are often dominant and slash pine, sand pine or longleaf pine may be present. Plant species typical of scrubby flatwoods that may be considered indicators of the community include tarflower (*Befaria racemosa*), scrub St. John's wort (*Hypericum reductum*), and pennyroyal (*Piloblephis rigida*). Scrubby flatwoods is more mesic than scrub, has a higher water table (Abrahamson *et al.* 1984) and the vegetation is more dense. Scrubby flatwoods is drier that flatwoods and almost never has standing water (Abrahamson *et al*. (1984). It has been suggested that scrubby flatwoods sometimes captures pine flatwoods sites that have been logged and protected from fire (see Myers 1990).

Scrubby high pine, called "southern ridge sandhills" by Abrahamson *et al.* (1984), "yellow sand scrub" by Christman (1988a), "natural turkey oak barrens" by Christman and Judd (1990), "hickory scrub" by Main and Menges (1997), "Caribbean pine-turkey oak" by Laessle (1967), "slash pine-turkey oak" by Douglas and Layne (1978), and "blackjack lands" or "blackjack ridges" by 19th century land surveyors cited in Myers (1990) is a rare, naturally

occurring plant community that is floristically and functionally intermediate between scrub and high pine. Scrubby high pine contains longleaf pine or south Florida slash pine (*Pinus elliottii* var. *densa*), turkey oak and scattered wiregrass, and has yellow sand, conditions typical of high pine. However scrubby high pine also contains typical scrub species, such as sand pine, evergreen scrub oaks, garberia (*Garberia fruticosa*), and rosemary, and it supports several species that are nearly restricted to it or reach their greatest abundances in it such as scrub hickory (*Carya floridana*), scrub beargrass (*Nolina brittoniana*), pigeonwing (*Clitoria fragrans*), Lewton's polygala (*Polygala lewtonii*), and the scrub balms (*Dicerandra* spp.) (Christman 1988a, 1988b; Christman and Judd 1990). Scrubby high pine easily is confused with man-made turkey oak barrens but references from the 18th and 19th centuries (cited in Myers 1990) attest to the natural occurrence of scrubby high pine long before the original longleaf pine savannas were logged. Scrubby high pine appears to be associated with topographically diverse landscapes where long-term fire-return intervals have been exceedingly variable (Myers and Boettcher 1987, Christman 1988b, Myers 1990).

Narrow bands of scrubby high pine often occur as ecotones on steep slopes between high pine and wetland communities. (Note that on more gentle slopes high pine usually grades almost imperceptibly into pine flatwoods.) Scrubby high pine also occurs on ridges or peaks within high pine communities perhaps because the soils there are too well-drained to support a continuous ground cover of the wiregrass needed to carry frequent fires. The community also occurs on rolling hills interspersed with ponds and marshes, especially on the Lake Wales Ridge (Christman 1988a). Scrubby high pine apparently was always uncommon in central and northern Florida, but formerly was common on the southern Lake Wales Ridge where, prior to its almost complete conversion to citrus orchards, it occupied sites with extremely well-drained sands and extremely varied topography (Christman and Judd 1990, Myers 1990).

Species Diversity

Table 1 lists the vertebrates that are characteristic of Florida scrub. All are endemic to the State of Florida. Other xeric-adapted species that are almost always encountered in scrub include the Florida mouse (*Podomys floridana*), the short-tailed snake (*Stilosoma extenuatum*), the scrub lizard (*Sceloporus woodi*), the rufous-sided towhee (*Pipilo erythrophthalmus*), the gopher tortoise (*Gopherus polyphemus*), the Florida worm lizard (*Rhineura floridana*), other subspecies of mole skinks (*Eumeces egregius* sspp.), and the crowned snakes (*Tantilla relicta* spp.). Although these animals are typically encountered in scrub, none are entirely restricted to the community; rather they are animals adapted to xeric habitats in general (Campbell and Christman 1982).

There are also many species of invertebrates that are endemic to Florida scrub. Deyrup (1989) listed 46 species of insects and spiders believed to be restricted to scrub, including 20 species restricted to scrub within the South Florida Ecosystem.

Table 2 provides a list of characteristic and occasional plant species known to occur in interior scrub, coastal scrub, scrubby flatwoods, and scrubby high pine. Many of these are listed as endangered or threatened by the FWS and are treated in "The Species" section of this recovery plan. Among the scrub endemic plants that are not federally listed are the scrub milkweed (*Asclepias curtissii*), Florida rosemary (*Ceratiola ericoides*), garberia (*Garberia heterophylla*), scrub rockrose (*Helianthemum nashii*), scrub holly (*Ilex cumulicola*), nodding pinweed (*Lechea cernua*), scrub hickory (*Carya floridana*), scrub palm (*Sabal etonia*), and sand pine (*Pinus clausa*), all of which are fairly widespread in Florida scrub. Some of these, such as sand pine, Florida rosemary, and garberia often invade disturbed high pine sites (turkey oak barrens) and probably are not in need of protection. Others, such as scrub milkweed, nodding pinweed, scrub palm and scrub rockrose may be more restricted to scrub and scrubby flatwoods and therefore in greater danger of extinction.

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize Florida scrub, scrubby flatwoods, or scrubby high pine in South Florida include: the Florida panther (*Puma (=Felis) concolor coryi*), Florida scrub-jay (*Aphelocoma coerulescens*), Kirtland's warbler (*Dendroica kirtlandii*), eastern indigo snake (*Drymarchon corais couperi*), blue-tailed mole skink (*Eumeces egregius lividus*), and sand skink (*Neoseps reynoldsi*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. These species are also included in Appendix C.

The **Florida mouse** (*Podomys floridanus*) is the only species of mammal entirely restricted to Florida. Florida mice occur in open scrub, scrubby flatwoods, scrubby high pine and high pine communities where they live in burrows, especially those of the gopher tortoise. Characteristics of the habitat that favor Florida mice are similar to those that favor the Florida scrub-jay (Layne 1992). The Florida mouse is larger than other deer mice and its closest relatives apparently are in southern Mexico (Layne 1992). The Florida mouse is listed as a species of special concern by the State of Florida because of habitat loss throughout its limited range in the central peninsula.

The **sand skink** (*Neoseps reynoldsi*) is listed as a threatened species by the State and the FWS. This species is restricted to the microhabitats of loose sand and sunny exposures primarily in the rosemary scrub habitat of central Florida. In addition, it can be found inhabiting sand pine scrub, oak scrub, scrubby flatwoods, "turkey oak barrens" (Moler 1992), and was reported from definite high pine (sand hills) sites by Telford (1962) in ecotonal areas between high pine and sand pine forest in the Ocala NF. Because sand skinks spend most of their time 1 to 8 cm (0.5-3.0 in) beneath the surface of well-drained sandy soils, they cannot tolerate dense ground cover or heavily rooted vegetation. This habitat has already seen much destruction as a result of agriculture and residential development. Although the sand skink is threatened due to loss of



Florida mouse. *Original photograph by Barry Mansell.*

habitat, it is often found in the remnant habitat that exists. Since the specialized habitat of the sand skink is rapidly declining, conservation actions should be taken to preserve large tracts of scrub and high pine communities.

The **gopher tortoise** (*Gopherus polyphemus*) is a state listed species that occurs in scrub, as well as other upland communities (Appendix C). Its deep burrows provide sites for nesting, feeding, refuge from fire and predators, and protection from high temperatures and desiccation for hundreds of other species (Landers and Speake 1980, Diemer 1992, Enge *et al.* 1997). Gopher frogs (*Rana capito*), Florida mice (*Podomys floridana*), and eastern indigo snakes (*Drymarchon corais couperi*) are variously dependent on tortoise burrows. The spoil in front of a gopher tortoise burrow provides germination sites for plants and essential microhabitat for fossorial reptiles such as mole skinks (*Eumeces egregius*), and crowned snakes (*Tantilla relicta*). Over 300 species of invertebrates, 36 reptiles and amphibians, 19 mammals, and 7 birds have been found in gopher tortoise burrows (Cox et al. 1994, Jackson and Milstrey 1989, Brandt *et al*. 1993, Kent and Snell 1994, Diemer 1992). Some of the arthropods, such as the gopher cricket (*Ceuthrophilus* spp.) and scarab beetles (*Aephodius* spp., *Copris* spp., and *Onthophagus* spp.) are obligate commensals that occur nowhere except in gopher burrows (Deyrup and Franz 1994). Overall, gopher tortoise burrows provide a diversity of microhabitats that engenders a higher species richness (both plant and animal) for the high pine community. Gopher tortoises are listed as species of special concern by Florida and are declining throughout the state because of habitat loss and illegal harvesting for food.

The **Florida scrub lizard** (*Sceloporus woodi*) occurs only in central and south-central peninsular Florida and along both coasts in South Florida where it is

restricted to scrub and scrubby high pine communities. Scrub lizards occur in open, sandy habitats and are often seen running along the ground, in contrast to their many relatives in western North America which are decidedly arboreal. The Florida scrub lizard is extremely endangered where it occurs in coastal scrubs in South Florida, and is already extinct or nearly so in southwest Florida (DeMarco 1992). In Ocala NF, and where its habitat persists on the Lake Wales Ridge, the species is still common.

The **Florida gopher frog** (*Rana capito aesopus*) most typically occurs in scrub and high pine communities where it lives almost exclusively in gopher tortoise burrows. They venture out at night to feed on arthropods, spiders and other frogs, and can sometimes be seen perched at the burrow entrance on rainy or cloudy days. Following heavy rains in spring or summer, gopher frogs migrate up to a mile to spawn in isolated wetland ponds. When the tadpoles transform in 3-5 months, they must leave the water and find a tortoise burrow of their own. The gopher frog is listed as a species of special concern by Florida and is the only listed amphibian in the South Florida Ecosystem.

The **Highlands tiger beetle** (*Cicindela highlandensis*) was known only from two scrubs on the southern Lake Wales Ridge, both of which have been destroyed by development (Deyrup 1989). No doubt there are many more scrub invertebrates yet to be described, and many that will go extinct before they are described.

Plant Species of Concern

Federally listed species that depend upon or utilize the scrub community in South Florida include: four-petal pawpaw (*Asimina tetramera),* Florida bonamia (*Bonamia grandiflora*), fragrant prickly-apple (*Cereus eriophorus* var. *fragrans*), pygmy fringe-tree (*Chionanthus pygmaeus*), Florida golden aster (*Chrysopsis floridana*), Florida perforate cladonia *(Cladonia perforata*), pigeon wings (*Clitoria fragrans*), short-leaved rosemary (*Conradina brevifolia*), Avon Park harebells (*Crotalaria avonensis*), Garrett's mint (*Dicerandra christmanii*), scrub mint (*Dicerandra frutescens*), Lakela's mint (*Dicerandra immaculata*), scrub buckwheat (*Eriogonum longifolium* var. *gnaphalifolium*), snakeroot (*Eryngium cuneifolium*), Highlands scrub hypericum (*Hypericum cumulicola*), scrub blazing star (*Liatris ohlingerae*), scrub lupine (*Lupinus aridorum*), Britton's beargrass (*Nolina brittoniana*), papery whitlow-wort (*Paronychia chartacea*), Lewton's polygala (*Polygala lewtonii*), tiny polygala (*Polygala smallii*), wireweed (*Polygonella basiramia*), sandlace (*Polygonella myriophylla*), scrub plum (*Prunus geniculata*), Carter's mustard (*Warea carteri*), and Florida ziziphus *(Ziziphus celata).* Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. The State listed pine pinweed (*Lechea divaricata*) also occurs in the scrub community (Appendix C).

The **Florida ziziphus** is a spiny shrub that occurs on the fringe of turkey oak *(Quercus laevis)* sandhills or yellow sand oak-hickory scrub communities, and is endemic to the Lake Wales Ridge. The Florida ziziphus prefers excessively

drained, nutrient-poor soils in the high pine habitat or the transitional zone between scrubby flatwoods and high pine (DeLaney *et al.* 1989, Burkhart *et al.* 1997). The plant grows vigorously in the more open sites of high pine and pastures, where there is full sun or a light canopy. Conservation measures for this plant should include habitat preservation, captive propagation, reintroduction of this plant into unoccupied, suitable habitats, and land management of the scrubby flatwoods and high pine communities. The Florida ziziphus is currently listed as endangered by the State and the FWS.

Lewton's polygala (*Polygala lewtonii*) prefers the transitional habitat that occurs between oak scrub and high pine communities. Lewton's polygala responds favorably to highly variable fire frequencies. It resprouts quickly and there is an increase in seedling recruitment. With the continued decline of both oak scrub and high pine communities due to agricultural and residential pressures, the Lewton's polygala will also continue to decline. Conservation actions should include habitat acquisition and implementation of appropriate land management of oak scrub and high pine communities. Due to the rapid decline of its habitat, the Lewton's polygala has been listed as endangered by the State of Florida and the FWS.

The **nodding pinweed** *(Lechea cernua)* prefers habitat in the scrub and scrubby flatwoods communities. This plant responds positively to fire and soil (sand) disturbance. This Florida endemic plant has only been found throughout the south and central counties. The nodding pinweed has been and is currently under a great threat due to its rapidly declining habitat caused by agricultural, residential and commercial development. The State has listed the nodding pinweed as threatened due to its declining habitat.

Florida perforate cladonia is a federally endangered lichen endemic to the Florida high white sand scrub communities. This plant is restricted to the open, well-drained, and nutrient-poor soils that are associated with sand pine *(Pinus clausa),* and the Florida rosemary *(Ceratiola ericoides)*. Due to the increasing pressure of land conversions to citrus and residential development, scrub habitat and the Florida perforate cladonia continues to decline. Since the cladonia is presumed to be a slow growing and recolonizing plant, conservation actions should be taken to include preservation and to establish a fire regime that occurs frequently. The frequent fire cycle will reduce fuels enough to prevent large, complete fires, thus leaving bare patches of sand that can serve as refugia. Furthermore, conservation actions should protect the sites from vehicle and heavy foot traffic.

Ecology

Plant communities that are dominated by shrubs are called scrubs and differ in many ways from communities dominated by trees, which are called forests, and those dominated by grasses or grass-like plants, which are called savannas. These differences in vegetative structure are the result of the frequency of fire, which historically was determined by the local topography or "lay of the land," and by the flammability of the vegetation itself. In Florida, natural, lightning-

caused fires occur at an average rate of more than 1,000 fires/year (Komarek 1964), and before modern man created settlements, transportation corridors, and farms, these fires burned across the landscape until they ran out of fuel or reached aquatic or wetland firebreaks.

Forests develop on steep slopes, in ravines, or on peninsulas and islands where the local topography acts as a natural break to the progression of lightning-ignited fires. Fires rarely burn into Florida hammocks and when they do they generally consume only the litter on the forest floor (Platt and Schwartz 1990). Fire return intervals in Florida hammocks are generally longer than 100 years.

In southeastern North America, large expanses of flat land and rolling hills offered little impediment to the movement of lightning-caused fires and historically supported savannas dominated by various flammable grasses and including widely spaced longleaf pine (*Pinus palustris*) or, in the southern third of the Florida peninsula, South Florida slash pine (*P. elliottii* var. *densa*). The higher and drier savannas are called high pine (sometimes "sandhills") and the lower, wetter sites are referred to as pine flatwoods. Historically, savannas experienced fire-return intervals of 1 to 10 years. The plant species composition and even the physical appearance of a savanna (except for the above ground part of the grass which is temporarily burned off) are little changed by the frequent fires. Savannas, therefore, are not disclimax communities and fires in savannas are not disturbances but rather predictable, regular features of the local climate.

Scrubs became established in topographically intermediate areas with intermediate fire-return intervals usually varying from 10 to 80 years. More mesic scrubs usually experience shorter fire-return intervals because fuels accumulate faster there than in drier scrubs. Some extremely xeric rosemary scrubs are thought to burn very rarely (Myers 1990). When scrubs do burn, the fires are usually very intense, consuming the shrubs and trees, in contrast to the low-intensity surface fires typical of savannas. Fire in scrub is a major stand-replacing disturbance that removes all aboveground vegetation and restarts plant growth, usually with the same combination of species.

Once established, the natural vegetation of a community tends to perpetuate itself. For example, savannas are carpeted with highly flammable grasses and dry pine needles which tend to ignite readily and frequently, thus excluding woody plants, whereas scrubs are characterized by patches of bare sand and almost inflammable evergreen shrubs which are unlikely to burn for decades, thereby favoring woody shrubs which in turn shade the ground or release allelopathic toxins (Richardson and Williams 1988) that exclude flammable grasses.

Forests, savannas and scrubs may be further characterized as hydric, mesic or xeric. Thus forests include swamps, mesophytic forests and xeric hammocks; savannas include marshes, pine flatwoods and high pine; and scrubs include shrub bogs, gallberry flats and xeric scrubs. Most authors restrict the term "Florida scrub" to the xeric scrubs only, and we follow that convention here.

Coastal scrubs differ from interior scrubs in their geologic age, species composition, response to disturbance, and management needs (Christman 1988a, Fernald 1989, Johnson and Muller 1993). Coastal scrubs appear to be

maintained at least in part by periodic wind disturbance, especially hurricanes, whereas interior scrubs are maintained by periodic fires. Coastal scrubs are much younger than scrubs on the Lake Wales Ridge, and support few endemic species.

When scrubs are prevented from burning for a long time, some of the oaks may grow up to tree size. If these oaks become dominant and in effect capture the site, the community becomes a pioneer xeric hammock, a man-made community that usually retains a subset of scrub species but lacks most of the typical hammock species. Most pioneer hammocks can be restored to scrub with growing season fires (Abrahamson and Abrahamson 1996) which, unlike dormant season fires, will top-kill many of the oaks (S. Morrison, The Nature Conservancy, personal communication 1995a; 1995b).

When sand pines are present in scrub they do not form a continuous canopy but occur as scattered individuals or clumps of individuals. Occasionally sand pines so dominate a scrub site that it becomes a sand pine forest, with many of the typical scrub forbs, shrubs, and animals suppressed or eliminated. Sand pines are killed by fire, however, and the stand returns to scrub following a burn. If conditions after a fire are favorable for sand pine seedling survival, another sand pine forest may develop and overtop the ephemeral scrub again. Sand pines release their seeds following the heat of a killing fire, but survival of the seedlings is dependent upon adequate soil moisture for several weeks after germination (Myers *et al.* 1987). Even without a killing fire, sand pine forests will revert to scrub when the sand pines, which rarely live beyond 80 years (Cooper 1973), start dying off. Removal of the sand pines by harvesting also will return the site to scrub, as will a burn in sand pines too young to have produced seeds (less than 5 years old).

When all native vegetation has been removed from a savanna or hammock as by plowing, and the site then abandoned, a pioneer scrub may develop. This man-made community usually is dominated by the most invasive weed and scrub species, such as blackberry (*Rubus* spp.), laurel oak (*Q. hemisphaerica*), Florida rosemary, sand pine, and sand live oak. With continued fire suppression the site will become dominated by large oaks. It is not known if such a site can be returned to the original plant community.

Following the removal of longleaf pines and the exclusion of fire, high pine savanna usually is replaced by turkey oak barrens, a man-made community dominated by turkey oak with scattered remnant clumps of wiregrass, remnant longleaf pines, and areas of bare yellow sand. Often sand pine and Florida rosemary invade if a seed source is nearby. Turkey oak barrens should not be confused with scrub or with scrubby high pine.

Status and Trends

Xeric uplands in South Florida have declined in distribution and quality as a result of anthropogenic actions (Kautz 1993, Kautz *et al*. 1993, Center for Plant Conservation 1995). These declines have been attributed to loss of habitat to agricultural, commercial, and residential development, fragmentation of habitat, and altered fire regimes and hydrology. Historically, natural fire regimes were the driving force in maintaining xeric upland communities. During early settlement

of Florida, more frequent but less intense fires altered some scrubs, and more recently, suppression of fires has altered scrubs by increasing fire return intervals. Since European settlement, there has been an estimated 60 percent reduction in the aerial coverage of scrub throughout Florida (Kautz 1993, Center for Plant Conservation 1995, Enge *et al*. in press).

The scrub communities in South Florida have experienced greater losses than other areas of the state. By the early 1980s an estimated 66 percent of scrub habitat had been lost within the Lake Wales Ridge alone (Christman 1988a). Since Christman's estimate, severe freezes during 1983 and 1985 resulted in the abandonment of citrus groves in central Florida and establishment of new groves in South Florida, particularly within scrub habitat along the Lake Wales Ridge. Additionally, more scrub in the northern portions of the Lake Wales Ridge has been lost due to residential and commercial expansion south of Orlando (Fernald 1989).

Scrub communities along the Atlantic Coastal Ridge have also been destroyed, severely fragmented and degraded. Historically, these communities formed a nearly continuous band from Brevard County to Broward County (Davis 1967). Today, coastal scrubs on the Atlantic Ridge exist as fragmented islands surrounded by developed or disturbed lands. Virtually all remaining significant scrub tracts that are not currently protected are proposed for development, or are for sale (Fernald 1989).

In addition to the destruction of scrub communities caused by conversion to agricultural, residential, and commercial purposes, human uses have fragmented the remaining upland habitat. Anthropogenic features such as roads, railroads, and commercial and residential development often act as firebreaks which limit the dispersal of fire, reduce fire intensity and increase fire-return intervals. Unfortunately, the use of fire for land management purposes has been limited by the public's intolerance of fire and strict limitations on particulate air emissions (Brown 1989, Cortner *et al.* 1990).

The dependency of xeric upland plant communities on periodic fire is well-documented, but many patches have not been burned for many years, and many are now overgrown or have been invaded by more mesic, fire-intolerant vegetation (Givens *et al*. 1984). In cases where fire has been excluded for long periods, the functions and values of xeric habitats have been degraded, and many of the plant and animal species typical of these fire-maintained habitats have been reduced or extirpated. Habitat suitability, and persistence of pyrogenic species may decline as quickly as 5 to 10 years or may last as long as 100 years since the last fire depending on the community and species (Myers 1985, Breininger and Schmalzer 1990, Johnson and Abrahamson 1990, Menges and Kohfeldt 1995, Abrahamson and Abrahamson 1996, Hawkes and Menges 1996).

The effects of habitat fragmentation on species richness have been exhaustively studied (MacArthur and Wilson 1967, Diamond 1975, 1978; Simberloff and Abele 1976, 1982; Zimmerman and Bierregaard 1986). For most groups, large habitat patches in close proximity to each other provide for the greatest species diversity and minimize extinction probabilities. On the contrary, small patches that are isolated are less likely to preserve species that would otherwise be common in the mosaic of communities that existed before isolation. Since at least the Pleistocene, Florida scrub has been characterized by an insular,

discontinuous distribution, but the degree of habitat fragmentation seen today is unprecedented and certainly will cause increases in extinction rates among scrub plants and animals.

Non-native plant species are rarely a significant threat to Florida scrub. The widespread exotic, natal grass (*Rhynchelytrum repens*), sometimes colonizes along the edges of Florida scrub, but has not been reported to be a nuisance. Bahiagrass (*Paspalum notatum*) has been planted in some Lake Wales Ridge scrubs where it seems to persist and exclude recovery of native scrub species. Bahiagrass has proven difficult to eradicate. A few exotic plant species have established in coastal scrubs on the Atlantic Coastal Ridge (Table 1, Appendix E).

Management

Scrub

Because scrub is a fire-dependent community that is adapted to periodic destruction by fire only to increase in stature until the next fire, its physical structure and appearance varies with the length of time since the last fire. The density and growth rate of vegetation in scrub are related to the length of time since the last fire and the amount of available moisture, the latter varying with depth to the water table and with soil characteristics between and within scrubs. Mesic scrubs and more mesic parts of large scrubs recover faster following fire than xeric scrubs (Schmalzer and Hinkle 1992). Furthermore, natural fires probably rarely burned all of a scrub at once, but created, instead, a mosaic of scrub habitat types with differing intervals since last burned. Therefore there is no single way a natural scrub should always appear, and there is no specific fire-return interval applicable to all scrubs. A healthy, natural scrub will be devoid of living, above ground vegetation immediately after a fire, densely stocked with 2 to 4 m tall oaks before the next fire, and rarely homogeneous. Nevertheless managers should have guidelines to determine when a scrub should be burned in order to prevent it from growing into a pioneer hammock. Such a “rule of thumb,” using the habitat requirements of the Florida scrub-jay was suggested by Christman (1995).

The Florida scrub-jay (*Aphelocoma coerulescens*) is a federally threatened species that is restricted to and dependent upon the Florida scrub habitat (FWS 1990). The Florida scrub-jay can be used as an indicator species for healthy, natural scrub, and its preferred habitat as the management goal for portions (but not all) of managed scrub.

Since natural scrubs usually consist of a mosaic of different scrub microhabitats maintained by different time periods since last burned, differences in soil characteristics, and differences in elevation, scrub management should seek to emulate this heterogeneity, and not impose an artificial uniformity of (for example) preferred scrub-jay habitat throughout. (Some scrub species have microhabitat requirements quite different from those of scrub-jays.) As a basic starting point for decisions regarding scrub management, we suggest that a scrub should be deemed in need of management when more than 50 percent of the scrub

area that could theoretically support scrub-jays has become unsuitable to do so because of vegetative growth since the last fire. (The 50 percent figure is admittedly arbitrary and subject to adjustment.)

According to Cox (1987), preferred scrub-jay habitat consists of scrub with oaks 1 to 3 m tall covering 50 to 75 percent of the area, open patches of bare sand covering 10 to 30 percent of the area, and no more than 20 percent canopy cover by trees. These conditions also are ideal for most scrub-adapted reptiles (Campbell and Christman 1982), including the sand skink (*Neoseps reynoldsi)* (Christman 1992), and Florida scrub lizard (*Sceloporus woodi)* (Jackson 1973), as well as most scrub endemic shrubs and forbs (Christman and Judd 1990, references in Richardson 1989).

Whenever more than one-half of a scrub can be characterized by (1) woody vegetation greater than 3 m in height, (2) areas of bare sand covering less than 10 percent of the ground, or (3) canopy cover greater than 20 percent, the scrub should be treated with prescribed fire or, if possible, a natural fire should be allowed to burn through the scrub. Managers must be flexible, of course. Some rosemary balds for example might never be characterized by woody vegetation more than 3 m tall, or bare sand areas falling below 10 percent cover, or shrubs forming a subcanopy covering more than 20 percent of the total area. Nevertheless, these scrubs might still be in need of periodic fire to maintain rare endemic scrub plants (Menges and Kimmich 1996, Quintana-Ascencio and Morales-Hernandez 1997).

If the management goal for scrubs is to maintain and restore natural communities, prescribed fires in scrub should be set in the growing season in adjacent upland communities and allowed to burn with the wind through the scrub and into natural wetland firebreaks.

Head fires die out variably as they enter the ecotone with wetlands and this maintains the natural variability of the ecotone. Head fires leave some areas intensely burned, some areas lightly burned, and some unburned, creating the habitat mosaic that insures the survival of all scrub species (Christman *et al*. 1979). Backing fires, in contrast, tend to burn the ground cover more completely and homogeneously, and to burn hotter at ground level, possibly killing animals and plant seeds near the soil surface. Furthermore, backing fires are difficult to sustain in scrub unless fuels are especially dry.

On the other hand, backing fires are easier to control. In cases where maximum control of the prescribed fire is imperative, backing fires may have to be used. Backing fires have been used successfully in scrub at The Nature Conservancy's Saddle Blanket Lakes Scrub Preserve in Polk County. A sand pine scrub there was ignited during very dry conditions in May with a wind speed of less than 4 mph, and the desired results were achieved by the backing fire (S. Morrison, TNC, personal communication 1995a).

Scrubs should be burned in the growing season because that is the period during which most lightning fires occur (Abrahamson *et al.* 1984a) and as a result the scrub plants and animals have become adapted to that regime (Abrahamson 1984b, Platt *et al*. 1988, Abrahamson 1995). In the scrubs and sand pine forests of the Ocala NF in Marion County, for example, 80 percent of the "wildfires" over a 50-year period occurred between the months of February and June (Cooper 1973).

The best time to burn Florida scrub is in March, April, or May (Robbins and Myers 1992, S. Morrison, The Nature Conservancy, personal communication 1995b, J. Thorsen, USFS, personal communication 1995, Main and Menges 1997).

Long-unburned scrub cannot be managed with winter fires such as formerly were prescribed in high pine or turkey oak barrens. Indeed, such fires, if they can be sustained at all, appear to hasten the degradation of scrub and its conversion to pioneer hammock by eliminating much of the ground layer but little of the larger woody vegetation (Abrahamson and Abrahamson 1996). Whereas growing season fire in sand pine forest or pioneer hammock will kill the sand pines and above-ground parts of the oaks, thus favoring scrub, fire in the dormant season will burn little but the ground litter (S. Morrison, The Nature Conservancy, personal communications 1995a; 1995b).

The timing of subsequent prescribed fires in scrub should be variable because no single fire-return interval could support the diversity of fire-recovery strategies and habitat preferences observed in native scrub species (Christman, *et al.* 1979, Ostertag and Menges 1994, Abrahamson and Abrahamson 1996). For example, most of the scrub oaks and other woody shrubs simply resprout from below ground within days following a fire (Abrahamson 1984b); in contrast, Florida rosemary is killed by fire and its seeds, already stored in the soil, germinate 1 to 3 years post-fire, with the new seedlings then requiring 10 to 15 years to produce seeds (Johnson 1982); the seeds of sand pine are released when the tree burns to death and germinate within days and periodically thereafter for 2 to 3 years after fire, then take 5 to 7 years to produce seeds again (Fowells 1965, Abrahamson 1984b); the fruticose lichens, *Cladonia* spp. and *Cladina* spp., take decades to re-establish following their death from fire (Buckley and Hendrickson 1988, personal observation); the scrub composite, *Balduina angustifolia* (yellow buttons), is an annual or sometimes biennial (Cronquist 1980) that is killed by fire, depending upon seeds already present in the soil for its recovery (personal observation); the scrub pinweeds, *Lechea* spp., may be absent or nearly so before fire, but appear in abundance within months after a fire (Johnson and Abrahamson 1990); and the relative abundances of scrub reptiles have been shown to vary with time since sand pine regeneration (Christman *et al.* 1979). Main and Menges (1997) provide a table with fire-return intervals that have been suggested for the various plant communities at Archbold Biological Station.

Prescribed fires are best ignited along existing roads and allowed to burn up to and through the scrub and into natural wetland firebreaks. Roads that have been routed through natural ecotones should not be used as firebreaks because this perpetuates the disturbance caused by the road, further reducing the ecological value of the ecotone. Ecotones are important habitats for many plant and animal species, some reaching their greatest abundances there, and some dependent upon them. Ecotones are transitory boundaries between ecosystem structures and functions, and sometimes serve as natural firebreaks. They should never be disturbed if natural systems management is a goal. Existing roads and firebreaks that have been constructed through natural ecotones should be abandoned and the ecotones allowed to recover.

Even worse than roads are the plowed ditches or “fire lines” that managers and fire fighters formerly dug for control of prescribed and natural fires. These ditches damage wildlife habitat and disrupt hydrology and natural soil

processes. Existing fire ditches should be restored to original grade. Written fire prescriptions should require restoration of any fire line ditches that might be plowed for emergency containment.

If artificial firebreaks, either baselines (where the fire is started) or control lines (meant to stop the spread of the fire), must be constructed, they should be temporary, created by various combinations of mowing, crushing, burning, or fire suppressant foam. Rollerchopping with heavy drums should be avoided because it can adversely affect animal habitats and soil processes, damage plant roots and rhizomes upon which scrub regeneration is dependent, and create habitat for invasive species (W. Thomson, The Nature Conservancy, personal communication 1995). Rollerchopping with empty roller drums may be acceptable where mowing is impractical.

Successful prescribed burns in sand pine scrub at Archbold Biological Station in Highlands County and in sand pine forest in the Ocala NF in Marion County were preceded by the ignition of linear backfires to establish burned strips that would serve as baselines and control lines (Abrahamson 1984a, Custer and Thorsen, no date). At Saddle Blanket Lakes Scrub Preserve, temporary firebreaks were constructed by mowing, then burning the mowed strips. At Yamato Scrub in Palm Beach County, Doren *et al.* (1987) created control lines and baselines in sand pine forest by dropping all standing sand pines and using an empty roller chopper to crush the vegetation in a 30 to 50 m wide strip encircling the burn site. In sand pine forest at Blue Springs SP in Volusia County, managers removed the standing sand pines and mowed the remaining vegetation to create temporary firebreaks (W. Thomson, The Nature Conservancy, personal communication 1995).

The required width of control lines can be determined from the predicted fire behavior as modeled by the fire prediction computer program, BEHAVE (Andrews 1986), using the National Forest Fire Laboratory fuel model for chaparral/high pocosin/mature shrub (NFFL model 4, Anderson 1982). There is no fuel model specific for Florida scrub, but the chaparral model was found to describe adequately successful prescribed burns in sand pine forest in Palm Beach County (Doren *et al.* 1987), and in sand pine forest in the Ocala NF, Marion County (Custer and Thorsen, no date). The chaparral fuel model probably could be adapted for scrub (which lacks an overstory of pine trees) as well (R. Roberts, DEP, personal communication 1995).

To reduce predicted flame height and the potential for downwind spotting (and thus the required width of the control lines), Doren *et al.* (1987) used an empty roller chopper to crush 30 to 50 m wide parallel strips perpendicular to the prescribed wind direction. This created alternating bands of chopped and unchopped fuel which was allowed to dry for 10-15 days prior to the burn. The burn was accomplished by first igniting the downwind edge of the crushed perimeter, then moving upwind to each crushed strip and igniting them in turn so that the fire burned with the wind toward the next already burning crushed strip. This pattern resulted in alternately black lining and head firing parallel strips across the entire area (Doren *et al.* 1987).

Scrub at Oscar Scherer SRA in Sarasota County was mowed with a Brown tree cutter prior to burning (Smyth 1991). On Merritt Island, managers used a Brown tree cutter, a D-6 Caterpillar with a V-blade, or a roller chopper to

prepare strips and blocks within several long-unburned oak scrubs prior to burning (Schmalzer *et al.* 1994). After drying for a week or two the crushed strips were easily ignited with a drip torch. By the time the heading fire reached the uncut scrub it had built up sufficient intensity to carry into the standing vegetation (F. Adrian, FWS, personal communication 1995). Managers at Merritt Island reported that the Brown tree cutter provided the best results, producing the best fuel bed with almost no soil disturbance.

Many scrubs adjoin turkey oak barrens or high pine upslope and grade into wetlands downslope. The best way to burn these scrubs is to ignite head fires in the turkey oak barrens and allow the fires to burn into and through the scrubs and then go out in the wetlands downslope. Certainly this is how the scrubs burned before modern man's influence, and this is the fire regime under which the plants and animals have evolved and to which they are adapted. Backing fires could also be used, but conditions must be especially dry to burn scrub with a backing fire.

Experience at The Nature Conservancy's Tiger Creek Preserve in central Florida has shown that when it is dry enough to ignite a scrub, it may be too dry to use natural wetlands as a firebreak because the duff and humus in the wetland/scrub ecotone may catch fire and smolder for weeks, causing unacceptable smoke problems on adjacent lands (S. Morrison, The Nature Conservancy, personal communication 1995b).

Certainly the humus and duff in wetlands, and especially in wetland ecotones, burned under natural conditions prior to management by modern man. Today's accumulation of surface organic matter in the ecotones around wetlands probably is greater than at most times in the past, and no doubt has lead to an increase in forested communities at the expense of scrub and savanna. Reduction of duff exposes bare mineral soil, which favors establishment of fire-dependent plant species. Some reduction of accumulated duff in wetland/scrub ecotones should be a goal of natural systems management.

On the other hand, if smoke from smoldering duff and humus is deemed unacceptable, managers may wish to pre-burn above ground vegetation in wetland firebreaks when it is possible to do so without igniting the humus, then burn the scrub toward the wetland on a later, drier, date when the scrub will burn. By pre-burning the wetland firebreak when the Keech/Byram Drought Index (Keech and Byram 1968) is less than 350, managers can reduce fuel there without igniting the humus (Melton 1989).

In general, prescribed fires in Florida scrub should be ignited early in the growing season (March to May) while the vegetation is still relatively dry. If igniting the duff within the wetland firebreak must be avoided, the scrub should be burned when the wetlands are flooded and the duff is fireproof but the scrub itself is dry enough to burn. Prescribed fires in scrub that will not depend on available wetlands for firebreaks can be set anytime between March and July.

The computer modeling program, RXWINDOW (Andrews and Bradshaw 1990) can be used to determine the best environmental conditions (fuel moisture and wind) for burning scrub based on the desired results of the burn (tree mortality, flame length, rate of spread, and intensity). The program requires input of a specific fuel model for the habitat type to be burned, but there is no fuel model for Florida scrub. The National Forest Fire Laboratory fuel model for

chaparral/high pocosin/mature shrub (NFFL model 4, Anderson 1982) was found to describe adequately prescribed burns in sand pine forest in Palm Beach County (Doren *et al.* 1987) and in Marion County (Custer and Thorsen, no date). The model has not been tested with scrub, which differs from sand pine forest in the absence of a canopy of mature sand pine trees.

Mechanical disturbance alone has been suggested as an alternative to prescribed fire in scrub when the latter is too dangerous or smoke would be an unacceptable nuisance (Fernald 1989). Scrubs that have been chopped or mowed (but not root-raked) seem to regenerate as if they had been burned, but further study is needed. Campbell and Christman (1982) and Greenberg *et al.* (1995) were unable to document significant biological differences between mechanically disturbed and burned sand pine forests in the Ocala NF, but both studies were poorly controlled. Biologists at Jonathan Dickinson SP currently are studying the advantages and disadvantages of mechanical techniques versus prescribed burning versus combinations of both in Florida scrub (R. Roberts, DEP, personal communication 1995).

The science of prescribed burning in Florida scrub is in its infancy and few publications are available. The only published summary of actual prescribed burning in Florida scrub is Schmalzer *et al*. (1994). The papers by Doren *et al*. (1987) and Custer and Thorsen (no date) are the only summaries of actual prescriptions for burns in sand pine forest. All three papers include detailed descriptions of the methods used and results obtained in actual prescribed burns. The new Archbold Biological Station fire management plan (Main and Menges 1997) is one of the best examples of a managed area burn plan.

The best sources for information about prescribed fire in Florida scrub are the people who have actually burned scrubs. Prescribed fires have been conducted in scrubs (or sand pine forests) at Archbold Biological Station in Highlands County (information source: Eric Menges), Tiger Creek, Catfish Creek, and Saddleblanket Lakes Nature Conservancy Preserves in Polk County and Lake Apthorpe Nature Conservancy Preserve in Highlands County (sources: Steve Morrison and Geoff Babb), Yamato Scrub in Palm Beach County (sources: Robert Doren and Richard Roberts), Wekiva Springs State Park in Orange County (source: Rosi Mulholland), Disney Wilderness Preserve in Osceola County (source: Walt Thomson), Jonathan Dickinson SP in Martin County (source: Richard Roberts), Blue Springs SP in Volusia County (source: Walt Thomson), Oscar Scherer SRA in Sarasota County (source: J. Smyth), Ocala NF in Marion County (sources: Jim Thorsen and George Custer), and Merritt Island NWR in Brevard County (sources: Paul Schmalzer and Fred Adrian). Those experienced with fire in scrub emphasize that plow lines are usually ineffective and attempts at control by people, equipment, and tools after the fire has escaped are often futile (Doren *et al*. 1987). The best control is prior planning.

Successful prescribed burns in South Florida scrubs will depend on thorough planning, careful preparation, using a variety of control techniques including existing wetland firebreaks, prior blacklining, mowing wide firebreaks, overstory removal, and possibly fire suppressant foam and hose layouts with sprinklers, and above all, experienced and reliable fire crews and equipment. Fire crews should first develop and improve their scrub-burning skills on small units with large adjoining wetlands.

Scrubby Flatwoods

Prescribed burning is easier in scrubby flatwoods communities than in scrub. The vegetation typically is more dense and carries a fire more readily. Scrubby flatwoods communities tend to recover more quickly from fire because higher levels of soil moisture allow the shrubs to grow faster. Fire return intervals in scrubby flatwoods typically range between 8 and 30 years. Scrubby flatwoods are often inhabited by Florida scrub-jays, therefore managers can use the scrub-jay habitat requirements to determine when a scrubby flatwoods should be burned.

Scrubby High Pine

Historically, fire return intervals in scrubby high pine probably were more variable than in other pyrogenic communities (Christman 1988a, Myers and Boettcher 1987). That is why the community is able to retain scrub-adapted species that cannot tolerate frequent fires on a long-term basis as well as high pine-adapted species that must have frequent fires. Both types of plants are able to persist even though conditions are not optimal for either. Fires at too frequent intervals can turn scrubby high pine toward high pine (S. Morrison, The Nature Conservancy, personal communication 1995a). Fires at too infrequent intervals can turn scrubby high pine toward xeric hammock. Through the centuries the community probably fluctuated between periods when it was more like high pine and periods when it was more like scrub.

Scrubby high pine is not Florida scrub-jay habitat so managers cannot use scrub-jay habitat requirements as a rule of thumb for determining when scrubby high pine should be burned. Instead, managers must be able to make on-the-ground decisions regarding when and what portions of a scrubby high pine community are in need of prescribed fire. The goals are to prevent the development of a continuous tree canopy (fire too rare); to prevent the development of a continuous ground cover (fire too frequent); to prevent the loss of woody species that resprout after fire (fire too frequent); to prevent the loss of woody and herbaceous species that reseed after fire (fire too rare). The best strategy for prescribing burns in scrubby high pine probably is to keep the burn units small, vary the timing and methodology as much as possible, and carefully evaluate the results of each burn.

Table 1. Characteristic vertebrates of South Florida scrub, scrubby flatwoods and scrubby high pine. Federal status: T=threatened; MC=FWS species of management concern. Species or subspecies in boldface are endemic to the State of Florida. Unless otherwise noted, listed birds nest in scrub. Modified from Christman 1988a and Mushinsky and McCoy 1995.

SPECIES	FEDERAL STATUS	COMMENTS
MAMMALS		
southeastern shrew, Sorex longirostris		
short-tailed shrew, Blarina brevicauda		
least shrew, Cryptotis parva		
eastern yellow bat, Lasiurus intermedius		
evening bat, Nycticeius humeralis		
nine-banded armadillo, Dasypus novemcinctus		
cottontail rabbit, Sylvilagus palustris		
Florida mouse, Podomys floridana	MC	
oldfield mouse, Peromyscus polionotus		
cotton mouse, Peromyscus gossypinus		
golden mouse, Ochrotomys nuttalli		
spotted skunk, Spilogale putorius		
BIRDS		
southeastern American kestrel, Falco sparverius paulus	MC	
mourning dove, Zenaida macroura		
common ground-dove, Columbina passerina		
eastern screech owl, Otus asio		
common nighthawk, Chordeilas minor		
Chuck-Will's-widow, Caprimulgus carolinensis		
Florida scrub-jay, Aphelocoma coerulescens	T	nearly endemic to scrub
tufted titmouse, Parus bicolor		
blue-gray gnatcatcher, Polioptila caerulea		
ruby-crowned kinglet, Regulus calendula		winter resident
northern mockingbird, Mimus polyglottos		
gray catbird, Dumetalla carolinensis		winter resident
brown thrasher, Toxostoma rufum		
northern parula, Parula americana		
pine warbler, Dendroica pinus		
yellow-rumped warbler, Dendroica coronata		winter resident
palm warbler, Dendroica palmarus		winter resident
common yellowthroat, Geothlypis trichas		winter resident

SPECIES	FEDERAL STATUS	COMMENTS
northern cardinal, Cardinalis cardinalis		
rufous-sided towhee, Piplio erythrophthalmus		
chipping sparrow, Spizella passerina		winter resident
REPTILES		
gopher tortoise, Gopherus polyphemus	MC	
Florida worm lizard, Rhineura floridana		
scrub lizard, Sceloporus woodi	MC	nearly endemic to scrub
slender glass lizard, Ophisaurus attenuatus		
six-lined racerunner, Cnemidophorus sexlineatus		
peninsula mole skink, Eumeces egregius onocrepis		
blue-tailed mole skink, Eumeces egregius lividus	T	endemic to Lake Wales Ridge
southeastern five-lined skink, Eumeces inexpectatus		
sand skink, Neoseps reynoldsi	T	nearly endemic to scrub
rough green snake, Opheodrys aestivus		
southern black racer, Coluber constrictor priapus		
eastern coachwhip, Masticophis flagellum		
corn snake, Elaphe guttata		
scarlet kingsnake, Lampropeltis triangulum elapsoides		
Florida scarlet snake, Cemophora c. coccinea		
short-tailed snake, Stilosoma extenuatum	MC	
crowned snake, Tantilla relicta		
eastern coral snake, Micrurus fulvius		
pygmy rattlesnake, Sistrurus miliarius		
AMPHIBIANS		
greenhouse frog, Eleutherodactylus planirostris		introduced
eastern spadefoot toad, Scaphiopus holbrooki		
southern toad, Bufo terrestris		
oak toad, Bufo quercicus		
pinewoods treefrog, Hyla femoralis		
narrow-mouthed toad, Gastrophryne carolinensis		
gopher frog, Rana capito	MC	

Table 2. Plants of South Florida scrub.

Plants of South Florida Scrub. * = introduced species. Species in boldface are endemic to Florida scrub or habitats intermediate between scrub and high pine or scrub and flatwoods. Federal Status: E = Endangered; T = Threatened; O = Occasional in community; C = Characteristic of community. Modified from Steinberg 1980, Abrahamson *et al.* 1984, Christman 1988a, Fernald 1989, Austin 1993, and unpublished site survey data on file at FNAI, Tallahassee, Florida.

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Ambrosia artemisiifolia (Asteraceae)			O		
Amorpha herbacea (Fabaceae)		O			
Andropogon arctatus (Poaceae)		O			
Andropogon brachystachyus (Poaceae)		C			
Andropogon floridanus (Poaceae)		C	C	O	
Andropogon glomeratus var. glaucopsis (Poaceae)		O			
Andropogon ternarius var. cabanisii (Poaceae)		O			
Andropogon tracyi (Poaceae)		C		O	
Andropogon virginicus var. glaucus (Poaceae)		C			O
Andropogon virginicus var. virginicus (Poaceae)		O			
Aristida condensata (Poaceae)		O			
Aristida gyrans (Poaceae)		C	C	O	
Aristida spiciformis (Poaceae)		O			O
Aristida beyrichiana (Poaceae)		O	O	C	C
Aristida tenuispica (Poaceae)		O	O		
Asclepias curtissii (Asclepiadaceae)		C	C	C	
Asclepias humistrata (Asclepiadaceae)		O			O
Asclepias pedicellata (Asclepiadaceae)		O	O		O
Asclepias tomentosa (Asclepiadaceae)		O			
Asclepias tuberosa (Asclepiadaceae)		C	O		O
Asclepias feayi (Asclepiadaceae)		C		O	O
Asimina obovata (Annonaceae)		C		O	C
Asimina pygmaea (Annonaceae)		O		O	
Asimina reticulata (Annonaceae)		O	C	O	

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Asimina tetramera (Annonaceae)	E		C		
Balduina angustifolia (Asteraceae)		C	C	O	C
Befaria racemosa (Ericaceae)		C	O	C	O
Bidens pilosa (Asteraceae)			O		
Bonamia grandiflora (Convolvulaceae)	T	C			C
Bulbostylus ciliatifolia (Cyperaceae)		C	O	O	O
Bulbostylus warei (Cyperaceae)		C	C	O	O
Bumelia lacuum (Sapotaceae)		C			
Bumelia lanuginosa (Sapotaceae)		O			
Bumelia reclinata var. reclinata (Sapotaceae)		O			
Bumelia tenax (Sapotaceae)		C	O	C	O
Calamintha ashei (Lamiaceae)		C			
Calamintha coccinea (Lamiaceae)		O			O
Callicarpa americana (Verbenaceae)			O		O
Callitres columellaris* (Cupressaceae)			O		
Carphephorus corymbosus (Asteraceae)		O	O	C	
Carya floridana (Juglandaceae)		C	C		C
Carya glabra (Juglandiaceae)		O			
Cassia chamaecrista (Fabaceae)		O	C		
Cassytha filiformis (Lauraceae)			C		
Casuarina spp.* (Casuarinaceae)			O		
Catharanthus roseus* (Apocynaceae)		O	O		
Ceratiola ericoides (Empetraceae)		C	C		C
Chamaesyce cumulicola (Euphorbiaceae)			C		
Chamaesyce hyssopifolia (Euphorbiaceae)		O			
Chapmannia floridana (Fabaceae)		C		O	C
Chionanthus pygmaeus (Oleaceae)	E	C			C
Chrysopsis scabrella (Asteraceae)		O	C	C	C
Cladina evansii (Cladoniaceae)		C	C	C	C
Cladina subtenuius (Cladoniaceae)		C	C	C	C
Cladonia calycantha (Cladoniaceae)		C		O	
Cladonia leporina (Cladoniaceae)		C	C	C	C

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Cladonia perforata (Cladoniaceae)	E	C	C		
Cladonia prostrata (Cladoniaceae)		C	C	O	C
Cladonia subsetacea (Cladoniaceae)		O			
Clitoria fragrans (Fabaceae)	T	O			C
Clitoria mariana (Fabaceae)			O		O
Cnidoscolus stimulosus (Euphorbiaceae)		C	O	O	O
Commelina erecta (Commelinaceae)		C	O	C	C
Conradina brevifolia (Lamiaceae)	E	C			
Conradina grandiflora (Lamiaceae)		C	C	C	
Conyza canadensis (Asteraceae)		O		O	O
Crataegus lepida (Rosaceae)		C			
Crotalaria avonensis (Fabaceae)	E	C			
Crotalaria rotundifolia (Fabaceae)		O	O		O
Croton argyranthemus (Euphorbiaceae)		O			O
Croton glandulosus (Euphorbiaceae)		O	O		
Crotonopsis linearis (Euphorbiaceae)		O	O		O
Cuthbertia ornata (Commelinaceae)		O	C		C
Cyperus compressus (Cyperaceae)			O		
Cyperus retrorsus (Cyperaceae)		C	O	C	C
Dalea carnea (Fabaceae)			O		
Dalea feayi (Fabaceae)		C	C		O
Dalea pinnata (Fabaceae)		O			O
Dicanthelium sabulorum (Poaceae)		O	O		
Dicerandra christmanii (Lamiaceae)	E				C
Dicerandra frutescens (Lamiaceae)	E				C
Dicerandra immaculata (Lamiaceae)	E		C		
Dicranum condensatum (Dicranaceae)		C		C	
Diodea teres (Rubiaceae)		C	O		
Elaphantopus elatus (Asteraceae)		O	O	C	
Eriogonum longifolium var. gnaphalifolium (Polygonaceae)	T	O			C
Eriogonum tomentosum (Polygonaceae)		O			O
Ernodea littoralis (Rubiaceae)			O		

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Eryngium aromaticum (Apiaceae)			O	C	
Eryngium cuneifolium (Apiaceae)	E	C			
Erythrina herbacea (Fabaceae)			O		
Euphorbia c.f. floridana (Euphorbiaceae)		C		C	
Euphorbia polyphyla (Euphorbiaceae)		C	O	O	
Froelichia floridana (Amaranthaceae)		O	O		O
Galactia elliottii (Fabaceae)		C	O	C	C
Galactia regularis (Fabaceae)		O	O	O	O
Galactia volubilis (Fabaceae)		O	O	O	
Galium hispida (Rubiaceae)		O		O	
Garberia heterophylla (Asteraceae)		C		C	C
Gaylussacia dumosa (Ericaceae)		C	O	C	C
Gaylussacia frondosa (Ericaceae)		O			O
Gaylussacia tomentosa (Ericaceae)		O			O
Gratiola hispida (Scrophulariaceae)		C	O	O	
Hamelia patens (Rubiaceae)			O		
Hedyotis nigricans (Rubiaceae)			O		
Hedyotis procumbens (Rubiaceae)		C	O		
Helianthemum carolinianum (Cistaceae)		O			O
Helianthemum corymbosum (Cistaceae)		C	C	O	O
Helianthemum nashii (Cistaceae)		C	C	C	O
Helianthus debilis (Asteraceae)			O		
Heterotheca subaxillaris (Asteraceae)		O	O		
Hypericum cumulicola (Hypericaceae)	E	C		O	
Hypericum gentianiodes (Hypericaceae)		O	O		
Hypericum hypericoides (Hypericaceae)		O		O	
Hypericum reductum (Hypericaceae)		C	C	C	
Hypoxis juncea (Hypoxidaceae)		O		C	
Ilex ambigua (Aquifoliaceae)		C			O
Ilex cumulicola (Aquifoliaceae)		C		O	C
Ilex glabra (Aquifoliaceae)		O	O	C	
Krigia virginica (Asteraceae)		O			

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Lachnocaulon anceps (Eriocaulaceae)		O		C	
Lachnocaulon minus (Eriocaulaceae)		O		C	
Lantana sp.			O		
Lechea cernua (Cistaceae)		C	C	O	
Lechea deckertii (Cistaceae)		C	C	O	O
Lechea divaricata (Cistaceae)		O	C	O	
Lechea minor (Cistaceae)		O			
Lechea sessiliflora (Cistaceae)		O			
Lechea torreyi (Cistaceae)		O			
Liatris chapmanii (Asteraceae)		O	C		O
Liatris garberi (Asteraceae)			O		
Liatris laevigata (Asteraceae)		C		O	O
Liatris ohlingerae (Asteraceae)	E	C		O	O
Liatris tenuifolia (Asteraceae)		O	O	O	C
Licania michauxii (Chrysobalanaceae)		C	C	C	C
Linaria floridana (Scrophulariaceae)		C	C		O
Lupinus aridorum (Fabaceae)	E	C			O
Lupinus diffusus (Fabaceae)		O	C		C
Lygodesma aphylla (Asteraceae)		C	O	O	
Lyonia ferruginea (Ericaceae)		C		C	C
Lyonia fruticosa (Ericaceae)		C	C	C	O
Lyonia lucida (Ericaceae)		O	C	C	
Monotropa uniflora (Ericaceae)		C	C		
Myrica cerifera (Myricaceae)		O	O	C	
Nolina brittoniana (Agavaceae)	E	C		C	C
Oncidium bahamense (Orchidaceae)			C		
Opuntia humifusa (Cactaceae)		C	C		C
Opuntia stricta (Cactaceae)			C		
Osmanthus americanus (Oleaceae)		O			C
Osmanthus megacarpus (Oleaceae)		C			C
Palafoxia feayi (Asteraceae)		C	C	C	C
Palafoxia integrifolia (Asteraceae)		O	O	O	C

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Panicum breve (Poaceae)		C		C	O
Paronychia americana (Caryophyllaceae)		C	C		C
Paronychia chartacea (Caryophyllaceae)	T	C		O	
Paronychia herniarioides (Caryophyllaceae)		C			O
Persea borbonia (Lauraceae)		O	O	O	
Persea humilis (Lauraceae)		C	C	C	
Phyllanthus abnormis (Euphorbiaceae)			O		
Physalis viscosa (Solanaceae)			O		
Piloblephis rigida (Lamiaceae)		O	O	C	
Pinus clausa (Pinaceae)		C	C	C	C
Pinus elliottii (Pinaceae)		C	O	C	C
Pinus palustris (Pinaceae)		O	O	C	C
Piriqueta caroliniana (Turneraceae)		O	O		
Pityopsis graminifolia (Asteraceae)		C	C	O	C
Poinsettia cyathophora (Euphorbiaceae)			O		
Polanisia tenuifolia (Capparaceae)		C	C		C
Polygala grandiflora (Polygalaceae)		O		O	
Polygala incarnata (Polygalaceae)		O			
Polygala lewtonii (Polygalaceae)	E	O			C
Polygala polygama (Polygalaceae)		O			
Polygonella basiramia (Polygonaceae)	E	C		O	
Polygonella ciliata (Polygonaceae)		C	C		O
Polygonella gracilis (Polygonaceae)		C	C	O	O
Polygonella myriophylla (Polygonaceae)	E	C			O
Polygonella polygama (Polygonaceae)		C	C	C	C
Polygonella robusta (Polygonaceae)		C	C		C
Polypremum procumbens (Loganiaceae)		C		O	O
Prunus geniculata (Rosaceae)	E	C			C
Psoralea canescens (Fabaceae)		O			
Pterocaulon virgatum (Asteraceae)		O	O	O	O
Pteroglossappis ecristata (Orchidaceae)		O	O		
Quercus chapmanii (Fagaceae)		C	C	C	C

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Quercus geminata (Fagaceae)		C	C	C	C
Quercus incana (Fagaceae)			O		
Quercus inopina (Fagaceae)		C		C	
Quercus laevis (Fagaceae)		O	O		C
Quercus minima (Fagaceae)		O	O	O	
Quercus myrtifolia (Fagaceae)		C	C	O	C
Quercus pumila (Fagaceae)		O	O	O	
Quercus virginiana (Fagaceae)			O		
Rhus copalina (Anacardiaceae)		O	O	O	
Rhynchelytrum repens* (Poaceae)		O	O	O	
Rhynchosia cinerea (Fabaceae)		O			O
Rhynchospora intermedia (Cyperaceae)		O	O	O	
Rhynchospora megalocarpa (Cyperaceae)		C	C	C	C
Richardia scabra (Rubiaceae)		O			
Sabal etonia (Arecaceae)		C	C	C	C
Sabal palmetto (Arecaceae)			O	O	
Schinus terebinthifolius* (Anacardiaceae)			O		
Schizachyrium niveum (Poaceae)		C		O	O
Schrankia microphylla (Fabaceae)		C	O	O	O
Scleria ciliata (Cyperaceae)			O	O	
Selaginella arenicola (Selaginellaceae)		C	C	C	C
Serenoa repens (Arecaceae)		C	C	C	C
Seriocarpus bifoliatus (Asteraceae)				O	
Seymeria pectinata (Scrophulariaceae)		C	C	O	
Sisyrinchium xerophyllum (Iridaceae)		C	C	C	O
Smilax auriculata (Smilacaceae)		C	O	C	O
Smilax laurifolia (Smilacaceae)			C		
Solidago chapmanii (Asteraceae)		C	O		O
Stillingia sylvatica (Euphorbiaceae)		C	O		C
Stipa avenaciodes (Poaceae)		C			
Stipulicida setacea (Caryophyllaceae)		C	C		O
Stylisma abdita (Convolvulaceae)		C			C

NAME (FAMILY)	FEDERAL STATUS	INTERIOR SCRUB	COASTAL SCRUB	SCRUBBY FLATWOODS	SCRUBBY HIGH PINE
Stylisma patens (Convolvulaceae)		C			
Stylisma villosa (Convolvulaceae)		O	C		O
Tephrosia chrysophylla (Fabaceae)		C			C
Tillandsia balbisiana (Bromeliaceae)		O	C		
Tillandsia fasciculata (Bromeliaceae)		O	O		O
Tillandsia flexuosa (Bromeliaceae)		O	O		
Tillandsia paucifolia (Bromeliaceae)		O	O		
Tillandsia pruinosa (Bromeliaceae)			O		
Tillandsia recurvata (Bromeliaceae)		C	C	O	O
Tillandsia setacea (Bromeliaceae)		O	O	O	O
Tillandsia usneoides (Bromeliaceae)		C	O	O	C
Tillandsia utriculata (Bromeliaceae)		O	C		O
Tradescantia roseolens (Commelinaceae)		C		O	O
Tragia smallii (Euphorbiaceae)		O			O
Tragia urens (Euphorbiaceae)		O			O
Trichostema dichotomum (Lamiaceae)		C	O	C	C
Triphora gentianoides (Orchidaceae)			O		
Usnea strigosa (Usneaceae)		C		C	C
Vaccinium arboreum (Ericaceae)		O			O
Vaccinium darrowii (Ericaceae)		C	O	C	C
Vaccinium myrsinites (Ericaceae)		C	C	C	C
Vaccinium stamineum (Ericaceae)		O	O	O	O
Vitis aestivalis (Vitaceae)			O		
Vitis munsoniana (Vitaceae)		C	O	O	O
Vitis shuttleworthii (Vitaceae)			O		
Warea carteri (Brassicaceae)	E	O	C	C	C
Woodwardia virginica (Blechnaceae)			O		
Ximenia americana (Olacaceae)		C	C		C
Xyris caroliniana (Xyridaceae)		O		C	
Yucca filamentosa (Agavaceae)		O		O	O
Zamia pumila (Cycadaceae)			O		
Ziziphus celata (Rhamnaceae)	E	C			

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Restoration of Scrub, Scrubby Flatwoods and Scrubby High Pine

Restoration Objective: Maintain and enhance the structure, function, and composition of the scrub community, and increase the spatial extent of scrub as habitat throughout South Florida to insure the long-term survival in the wild of all plant and animal species that depend upon this community for their existence.

Restoration Criteria

Scrub in South Florida may be considered restored when: (1) existing scrub habitat is preserved through land acquisition; Federal, State or local management actions; and/or private cooperative agreements; (2) when prescribed fire or other management techniques are used to restore suitable habitat from overgrown scrub; (3) when any further loss, fragmentation, and degradation of scrub habitat has been prevented; (4) when appropriate ecosystem management has been prepared, funded, and implemented for long-term perpetuation of the scrub community; and (5) when protection of scrub is adequate to ensure endemic, rare, and imperilled species that use this community have self-sustaining populations.

Community-level Restoration Actions

1. **Prevent further destruction or degradation of existing scrub communities.**

   1.1. **Secure scrub sites through land acquisition, landowner agreements, and conservation easements**. The highest priority should be placed on preventing development of remaining scrub sites. This is best accomplished by land acquisition, but other methods of preventing development such as conservation easements are sometimes useful. So much of South Florida's original scrub has already been irretrievably lost that most remaining scrub tracts should be acquired for preservation. Scrubs on the acquisition lists for Florida's CARL program for the FWS Lake Wales Ridge NWR should be acquired first. In addition, scrubs identified by Fernald (1989) and the strategic habitat conservation area scrubs identified by Cox et al. (1994) should be acquired.

   1.2. **Control public use**. Indiscriminate use of off-road vehicles and illegal sand mining have contributed to the degradation of many South Florida scrubs. These and other inappropriate public uses must be discouraged if we are to prevent further degradation of existing scrubs. Signs and fences may be required.

   1.3. **Enforce existing regulations**. Regulations against collecting threatened and endangered species must be enforced.

2. Restore existing degraded scrubs.

2.1. Permit the reintroduction of natural fires or prescribe controlled burns, and/or mechanical disturbance treatments. Scrubs that have been degraded because of fire exclusion can be restored with prescribed fires and/or mechanical disturbance treatments. Each protected scrub site should have a fire management plan prepared specifically for it. Management plans should specifically include allowing natural, lightning-ignited fires to burn through scrub 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. The use of mechanical disturbance instead of or in addition to fire may be appropriate in some cases.

2.2. Encourage maintenance and recovery of natural ecotones. Ecotones are important elements of any natural landscape and should receive special attention in scrub management plans. Fire breaks and roads should be placed well away from ecotones. Ecotones that have been degraded by existing roads and fire breaks should be restored.

2.3. Eliminate or control exotic and off-site species. Some scrubs on the Lake Wales Ridge have been planted to bahiagrass (*Paspalum notatum*) for cattle forage. This turf-forming grass excludes native scrub species and persists even when burned. Mechanical soil scarification and/or chemical herbicide treatments might be necessary to reduce bahiagrass ground cover. Some coastal scrubs on the Atlantic Coast Ridge have been colonized by exotic plant species. These infestations tend to be small, localized, and probably easy to eliminate compared to exotic plant problems in other communities.

2.4. Reintroduce locally extirpated species. Because of past management practices, some scrub plant and animal species may have disappeared from existing degraded scrubs. These species can be reintroduced if natural recolonization is unlikely.

2.5. Eliminate any sources of pollution to the scrub site.

2.6. Control public use. Scrubs that have been degraded by inappropriate public use can only be restored by first eliminating that public use. Signs and fences may be necessary to discourage off-road vehicle use. In some scrubs on the Lake Wales Ridge, illegal sand mining has seriously degraded habitats.

3. Maintain scrub communities in a natural condition in perpetuity.

3.1. Continue to prescribe natural fires, controlled burns and/or mechanical disturbance treatments. Continue planning for natural lightning-ignited fires to be allowed to burn. Prescribe controlled burns and/or mechanical treatments when natural fires are inadequate to meet management objectives.

3.2. Continue to control exotic species. Exotic plant species rarely invade interior scrub, but coastal scrubs, especially on the Atlantic Coast Ridge, are sometimes susceptible to invasion by exotics. These probably can be controlled by mechanical means without the need for chemical herbicides.

3.3. Continue to control public use. Scrubs acquired for conservation of biotic resources must be protected from inappropriate public use. Sand mining, off-road vehicle use, and rare plant collecting are not compatible with scrub preservation.

3.4. Monitor for negative population trends among important scrub plant species. Each scrub preserve should have a specific monitoring plan that will alert managers

to extirpations or downward trends in populations of selected scrub species, including endemic species, listed species, and keystone species.

3.5. Monitor and correct for any point source or non-point source pollution.

4. **Recreate scrub where it has been destroyed by human activities such as mining or farming**. In Polk County efforts to recreate scrub where it had been totally destroyed on former strip mines have been promising, but less than satisfactory so far. The research, monitoring, and efforts should continue.

5. **Create scrub in regions where scrub has been destroyed by human activities**. In Osceola County, researchers have attempted to create a scrub by spreading top soil from a scrub that was being destroyed by development onto a former cow pasture. The effort has been promising but so far less than satisfactory. The research and the efforts should continue.

6. **Connect existing scrub preserves 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. Lands acquired as connectors between scrub preserves need not be scrubs. Historically, scrubs existed as "islands" in a matrix of other community types, and this pattern should be maintained as much as possible.

7. **Encourage community level research**.

7.1. Encourage research on prescribed burning in scrub. As more and more Florida scrubs are placed under management for ecological conservation the use of prescribed fire to manage scrub will become increasingly necessary. Unfortunately, there has been little prescribed burning in Florida scrub to date and there are no formal guidelines available. The National Forest Fire Laboratory does not have a fuel model for Florida scrub. Currently the U. S. Forest Service in the Ocala NF is developing a fuel model specific for sand pine forest (J. Thorsen, USFS, personal communication 1995). However, it is doubtful if such a model will describe adequately fire behavior in scrub, which lacks an overstory of sand pine trees. Managers need a fuel model for the various phases of Florida scrub.

FWS has funded DEP at Jonathan Dickinson SP to develop optimum pre-treatment methods for prescribed burning in coastal scrub and sand pine forest, and to compare stand replacement by mechanical disturbance versus prescribed burning (R. Roberts, DEP, personal communication 1995). Similar studies in Lake Wales Ridge and other interior scrubs are needed.

7.2. Encourage research on alternatives to prescribed burning. In cases where prescribed burning cannot be accomplished due to proximity of roads or other human development, mechanical disturbance may be an acceptable alternative. FWS has funded a study at Archbold Biological Station to compare the effects of mechanical treatment with prescribed fire on listed Lake Wales Ridge plants and their habitats. Similar studies in various scrub types and in other areas of South Florida are needed.

8. **Monitor habitat and ecological processes.**

8.1. Monitor land management actions. All management actions should be monitored to determine their effectiveness, and changes should be made to management activities as appropriate. Each scrub preserve should have a specific monitoring plan

to assist managers with decisions regarding prescribed burning and other land management actions.

8.2. **Monitor for negative population trends among important scrub plant and animal species.** Each scrub preserve should have a specific monitoring plan that will alert managers to extirpations or downward trends in populations of selected scrub species, including endemic species, listed species, and keystone species.

8.3. **Monitor and correct for any point source or non-point source pollution**.

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 Florida's Conservation and Recreational Lands (CARL) program and Preservation-2000. Federal initiatives such as the new Lake Wales Ridge NWR should be advertised. Environmental education programs in South Florida should be encouraged to distribute materials or develop lesson plans on scrub habitats, scrub species, and the importance of maintaining natural biodiversity. Educators and potentially interested organizations should be made aware of available resources such as brochures, slide programs, and video tapes from Archbold Biological Station, GFC, and others. Schools and the interested public should know about internet sites that feature Florida scrub.

Beach Dune, Coastal Strand and Maritime Hammock

FNAI Global Rank:	**G3/4**
FNAI State Rank:	**S1/2**
Federally Listed Species in S. FL:	**16**
State Listed Species in S. FL:	**50**

Beach dune/coastal strand.
Original photograph by Ann Johnson.



The beach dune and coastal strand communities in South Florida are the closest communities to the high-energy shoreline. Within this high-energy zone, there are a number of daily, naturally occurring events such as: wave action, sand burial, and salt spray. Closest to the coast, the upper beach is regularly disturbed by waves of high tides or storms and regularly recolonized by driftline annuals and trailing perennials such as railroad vine (*Ipomoea pes-caprae*). Above the reach of annual wave action is the foredune, built by coarse, rhizomatous grasses; primarily sea oats (*Uniola paniculata*), that thrive under constant burial from sand blown off the beach. Beyond the zone of constant sand burial are the dwarfed trees and shrubs of the coastal strand. The species growing in this zone are kept at a low stature by salt spray, which kills the upward-growing leader shoots. Species composition within the coastal strand communities that are located on the Gulf and Atlantic coasts differ. These differences need to be taken into account prior to restoration plantings.

Maritime hammocks are low forests of evergreen broadleaved trees found inland from coastal strand communities on the Atlantic coast and from coastal grassland communities on the Gulf coast. The canopy may be composed of trees with either temperate affinities (*Quercus virginiana, Sabal palmetto, Persea borbonia*) or (usually on more calcareous substrates) of trees with tropical affinities (*Bursera simarouba, Ficus aurea, Coccoloba uvifera*). In both cases in South Florida the understory is composed primarily of tropical shrubs and small trees. Although they share some widespread coastal tree species, forests on nearby tropical coasts of the Bahamas, Cuba, and the Yucatan Peninsula do not appear to have the same structure and composition as tropical maritime hammocks in South Florida (Correll and Correll 1982, Sauer 1967, Moreno-Casasola and Espejel 1986).

Synonymy - Beach Dune/Coastal Strand

This description also includes several other coastal communities of lesser extent, *i.e*., coastal grassland, coastal interdunal swale, and coastal rock barren (FNAI 1990 and Federal Department of Natural Resources (FDNR) 1990). These communities are mapped under "coastal strand" and "barren and urban land" categories on the Florida Land Cover map (GFC 1992); in the latest draft of The Nature Conservancy's classification (Weakley *et al*. 1998) they are subsumed under the following alliances: *Uniola paniculata* subtropical herbaceous alliance, *Muhlenbergia filipes* herbaceous alliance, *Fimbristylis castanea-Scirpus pungens* seasonally flooded herbaceous alliance, *Coccoloba uvifera* shrubland alliance, *Sophora tomentosa-Forestiera segregata* shrubland alliance, *Serenoa repens* wooded shrubland alliance. The FLUCCS codes for beach dune and coastal strand include: 310 (herbaceous), and 720 (sand other than beaches), respectively.

Synonymy - Maritime Hammock

This description includes the shell mound community (FNAI 1997 and FDNR 1990). The FLUCCS codes for this community include: 425 (tropical hardwoods), and 427 (live oak). In the most recent draft of The Nature Conservancy classification (Weakley *et al*. 1998) they are found under the following alliances: *Quercus virginiana-Sabal palmetto* forest alliance; *Bursera simarouba-Coccoloba diversifolia-Ocotea coriacea-Eugenia axillaris* forest alliance; *Sabal palmetto-Coccoloba uvifera* forest alliance.

Distribution - Beach Dune/Coastal Strand

The beach dune community occurs on the first dunes above the beach, which are most often built by sea oats. This herbaceous zone is found on sandy shores around the Gulf of Mexico from eastern Mexico north of the Yucatan Peninsula (Sauer 1967, 1982) to Florida, including Cuba and the Bahamas (Correll and Correll 1982), and extending northward up the Atlantic coast to Virginia (Stalter and Lamont 1997). In South Florida, the herbaceous zone and sandy coasts are continuous along the Atlantic coast from the Sebastian Inlet, Indian River County, south to Cape Florida, Miami-Dade County, and along the Gulf coast from Lido Key, Sarasota County, south to Cape Romano, Collier County (Johnson *et al*. 1992, Johnson and Muller 1992). Between Collier and Miami-Dade counties, beaches are discontinuous, being found at two sites on the Florida Keys (Kruer 1992), four sites on the islands west of Key West, including the Marquesas (Kruer 1992) and the Dry Tortugas (Davis 1942), on Cape Sable, and on a few of the larger outer islands of the Ten Thousand Islands (Johnson and Muller 1992).

The zone immediately inland from the herbaceous zone may be occupied by shrubs (coastal strand community), grasses (coastal grassland and coastal interdunal swale communities), or by a sparse stand of stunted shrubs and cacti on bare limestone substrate (coastal rock barren community). Coastal strand is found along both the Atlantic and Gulf coasts of South Florida, but is most

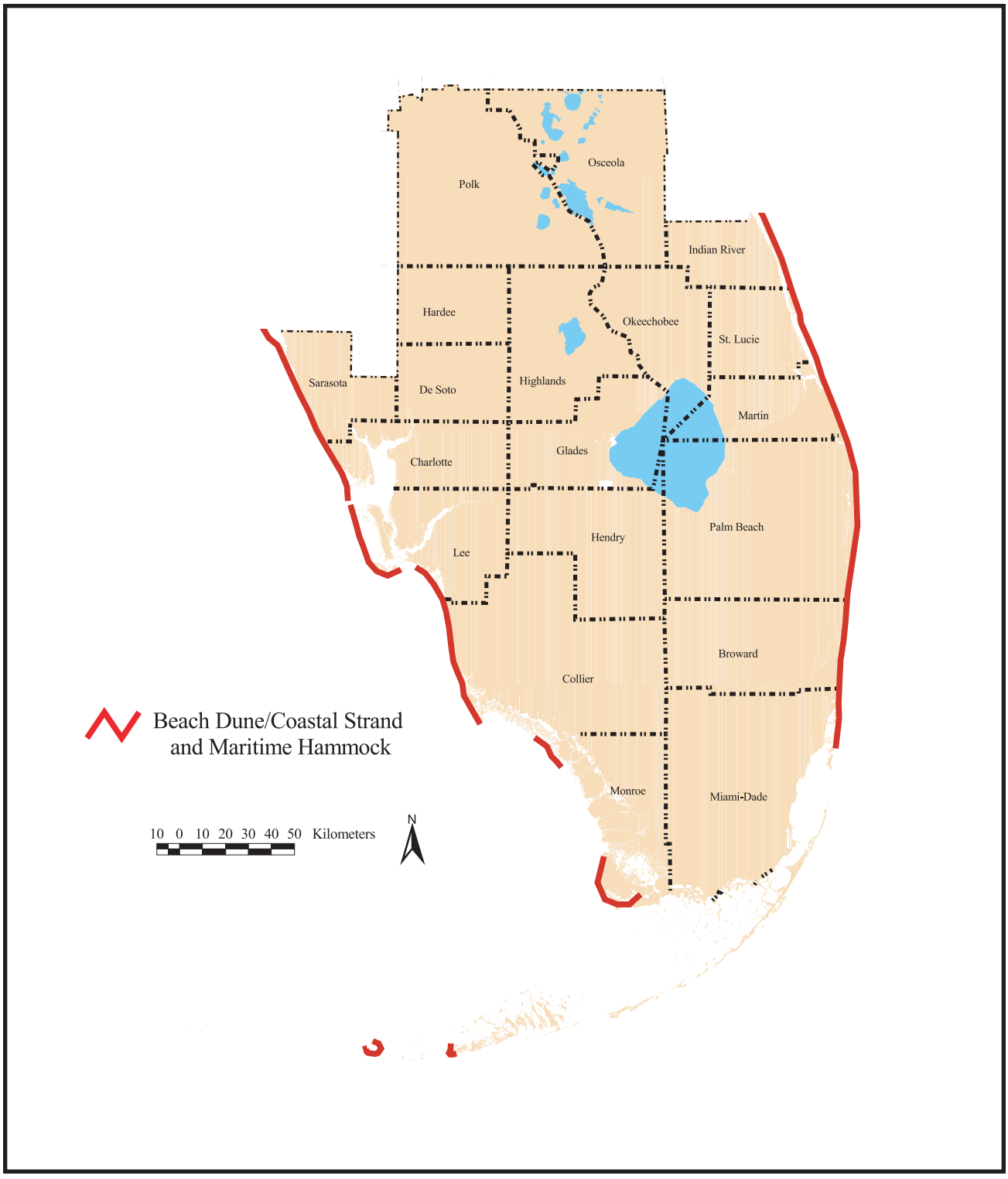


Figure 1. The distribution of beach dune, coastal strand and maritime hammock in South Florida (adapted from Myers and Ewel 1990).

common and continuous along the Atlantic coast; coastal grassland and coastal interdunal swale communities are found primarily on Cape Sable and the broader barrier islands of the Gulf coast, *i.e*., Cape Romano, Canon, Keewaydin, North Captiva, Cayo Costa, Don Pedro and Knight Islands (Johnson and Muller 1992, Herwitz 1977, Morrill and Harvey 1980), and formerly on Sanibel, Captiva, Little Gasparilla, and Gasparilla Islands (Cooley 1955, Morris *et al*. 1979). The coastal rock barren community is known from four sites in the Florida Keys (Kruer 1992).

Distribution - Maritime Hammock

Maritime hammocks characterized by a canopy of Virginia live oak (*Quercus virginiana*) occur north along the Atlantic coast to Virginia, and west along the Gulf coast to Texas (Bellis 1995, Weakely *et al*. 1998). On the east coast, tropical species appear in the understory of these oak-dominated forests in Florida around the latitude of Daytona Beach, Volusia County, and on the west coast at Tarpon Springs, Pasco County. On calcareous substrates, such as shell mounds, tropical species may form the canopy of coastal forests as far north as Levy and Volusia counties on the west and east coasts of Florida, respectively. In South Florida, maritime hammocks extend south on the sandy barrier islands to Cape Florida, Miami-Dade County on the Atlantic side, and Cape Romano, Collier County, on the Gulf side. They may also occasionally be found along the mainland shores of the lagoons and bays separating the barriers from the mainland. In Monroe County they are also found in scattered locations on Ten Thousand Islands and Cape Sable. In the Florida Keys they are replaced by the more diverse tropical hardwood hammock community (refer to the tropical hardwood hammock account) including coastal berms or limestone substrate.

Description - Beach Dune

The beach dune community is a predominantly herbaceous community of wide-ranging coastal specialists. It occurs on the upper beach and foredune, or first dune above the beach, which is built by perennial rhizomatous grasses growing upward from year to year as they are buried by sand blown inland off the beach. Sea oats is the most commonly encountered dune-former, a tall coarse grass capable of rapid lateral spread, forming a relatively sparse stand of tillers with internodes up to one foot apart (Wagner 1964). Two less common dune-forming grasses are beach cordgrass (*Spartina patens*) and bitter panicum (*Panicum amarum* var. *amarulum*). Several shrubs *(Helianthus debilis, Croton punctatus*, *Scaevola plumieri*, and *Iva imbricata*) can often be found growing between the widely spaced leaves in a patch of sea oats, along with two less frequent coastal shrubs, *Argusia gnaphalodes* and *Suriana maritima*. The upper beach in front of the sea oats foredune is a less stable habitat, being disturbed by seasonal or storm high tides annually or at least every few years, and is colonized by trailing vines: *Ipomoea pes-caprae*, *I. imperati*, *Canavalia rosea*, and on the Atlantic coast: *Alternanthera maritima* and *Okenia hypogaea*, by low, spreading, halophytic grasses: *Paspalum distichum, Sporobolus virginicus*, and by driftline annuals: *Cakile lanceolata*, *Salsola kali* and *Atriplex pentandra* (Johnson and Muller 1993).

The discontinuous beaches of the Keys, the islands west of Key West, and the Ten Thousand Islands, which tend to be formed largely of shell fragments rather than quartz sands, have the same set of species as the mainland beaches, with a higher representation of the more tropical component, *i.e., Suriana maritima, Argusia gnaphalodes, Ambrosia hispida, Hymenocallis latifolia*, and *Sesuvium portulacastrum* (Kruer 1992, Davis 1942).

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the beach dune community in South Florida include: southeastern beach mouse (*Peromyscus polionotis nivieventris*), roseate tern (*S. dougallii dougallii*), piping plover (*Charadrius melodus*), loggerhead sea turtle (*Caretta caretta*), green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), Kemp's ridley sea turtle (*Lepidochelys kempii*), and hawksbill sea turtle (*Eretmochelys imbricata*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. In addition, other species use the beach dune community in South Florida for loafing, foraging, and nesting (refer to Appendix C).

The endemic **southeastern beach mouse** which is restricted to sea oats dunes, was formerly abundant from Ponce (=Mosquito) Inlet, Volusia County to Hollywood Beach, Broward County. In South Florida, it is now restricted to scattered localities in Indian River and St. Lucie counties, although it still has stable populations in the northern portion of its range, and is federally listed as threatened (FWS 1998). On the Gulf coast, the Chadwick Beach cotton mouse (*Peromyscus gossypinus restrictus*), described from the dunes near Englewood in Charlotte County, has been determined to be extinct (Repenning and Humphrey 1986).

The Caribbean population of the federally threatened **roseate tern** nests on limestone or shell rubble in the lower Keys and the Dry Tortugas. The species has an unstable breeding site distribution that is dependent on islands with open sandy or broken coral nesting areas, a lack of mammalian and avian predators, and minimal disturbance by humans. Roseate terns are also known to nest on roofs of buildings in Florida (Smith 1996). A moderate amount of suitable natural breeding habitat remains in the Caribbean population range; however, much of the Florida Keys' natural habitat has been greatly reduced or degraded by natural or anthropogenic factors.

Many shorebirds use beaches in South Florida for nesting or wintering or both. Florida is the main wintering ground of the federally threatened **piping plover** which breeds in northern North America. Formerly seen wintering in all South Florida counties except Martin, this species is now absent from Indian River, Palm Beach, and Broward counties and has become rare in Miami-Dade and Sarasota counties (FWS 1998).

The **southeastern snowy plover** (*C. alexandrinus tenuirostris*), which is State-listed as threatened (GFC 1997), both breeds and winters along the Gulf coast of Florida and the larger Caribbean islands, and in South Florida breeds from Charlotte to Collier counties (Gore and Chase, 1989).



Least tern. *Original photograph by Barry Mansell.*

American oystercatchers (*Haematopus palliatus*) are State-listed as species of special concern. They inhabit the Atlantic coast of Florida from the north Florida line south to Palm Beach County. Oystercatchers are also found on the Florida Gulf coast from Collier County north to the Suwannee River. They utilize beach, sandbar, mudflat, and mollusk beds for feeding and roosting. They feed on small fish and a variety of marine invertebrates. Oystercatchers prefer large, sparsely vegetated sand areas for nesting, but will also nest in wrack and marsh grass. They are vulnerable to human disturbance, habitat loss, and mammalian predation.

The **least tern** (*Sterna antillarum*) is state-listed as threatened. It nests throughout Florida's coasts except for the salt marshes of the Big Bend area and the mangrove-lined southwestern coast. Historically, least tern nesting took place on the ground, in open sandy places where vegetation covered less than 20 percent of the area. Shoreline development and human disturbance have altered much of the natural least tern nesting habitat. Least terns have been sighted nesting on roofs of buildings in Palm Beach County (P. Davis, Palm Beach County, personal communication 1998).

Black skimmers (*Rynchops niger*) are State-listed as a species of special concern. They nest along the coastal areas of Florida from Escambia to Collier County on the Gulf coast and from Nassau to Broward County on the Atlantic coast. Nesting colonies are located on dredge-material islands, natural sandbars, small coastal islands, and beaches with little vegetation, generally within sight of open water. They usually feed in estuary areas, with small fish being the predominant prey. Black skimmers need undisturbed, sandy beaches and islands for nesting and rearing their young. Least terns and black skimmers that formerly nested on bare sand beaches have turned to rooftops and spoil islands for nesting as increased human use has rendered the mainland beaches in South Florida unsuitable.

Bare sand beaches are utilized for nesting by **sea turtles**. Four federally listed species of sea turtles nest on South Florida beaches. These include: **loggerhead**, **green**, **hawksbill,** and **leatherback** sea turtles. The **Kemp's ridley** sea turtle has nested once in Lee County, and has had a few false crawls in Palm Beach County. The most frequent nester in South Florida, the loggerhead, has a worldwide distribution with three major nesting areas: in the Arabian Sea, in Australia, and in the southeastern United States. Although turtles nest on beaches from North Carolina to the Florida panhandle, during the 1997 nesting season, roughly 84 percent of the 66,445 nests recorded throughout Florida were found from Brevard to Broward counties (DEP 1998). Of this total, Brevard County had the highest overall nesting activity at 38 percent, with the second highest occurring in Palm Beach County at 18 percent (DEP 1998). Major nesting beaches in South Florida include: Hutchinson Island, Jupiter Island, and northern Palm Beach County (from Tequesta to Singer Island) (P. Davis, Palm Beach County, personal communication 1998). South Florida (Indian River to Sarasota counties) accounted for approximately 56 percent of the loggerhead sea turtle nesting during the 1997 season (DEP 1998). Sea turtles typically nest at night from March through November, with incubation lasting approximately 55 days. Although not all beaches are monitored 7 days a week, sea turtle nest densities in South Florida during the 1997 season were approximately 1 nest per 117 km of beach surveyed. Threats to sea turtle nests in this region are both man-made (physical disturbance, including burial by beach nourishment projects; high raccoon predator populations; lights near the coast which disorient hatchlings) and natural (coastal erosion causing cliffing and invasion by the exotic Australian pine whose root mats interfere with nest excavation) (FWS 1998).

Plant Species of Concern

Federally listed species that depend upon or utilize the beach dune community in South Florida include the beach jacquemontia (*Jacquemontia reclinata*). The biological account and recovery tasks for this species are included in "The Species" section of this recovery plan. Refer to Appendix C for a list of other plant species that utilize the beach dune community in South Florida.

Sanibel lovegrass (*Eragrostis tracyi*) is a state endangered, delicate annual grass that occasionally reaches a height of 40 cm (16 inches) (usually less). It occurs on the Florida coast southwest in Lee County northward to Mound Key, and found nowhere else in the world. Habitat requirements for this grass are flexible and can be found in many disturbed or pioneering sites including coastal dune, coastal strand, and maritime hammock environments.

Sea lavender (*Tournefortia gnaphalodes*) is a shrub which reaches 2 m (6.6 ft) in height. The plant has many dense, fleshy branches which often give it a clumped appearance. It has slender light gray leaves from 4 to 12 cm (1.6 to 4.8 inches) long. This shrub occurs throughout the Caribbean, but in Florida is found only along the east coast from Brevard County southward to the Keys. Coastal construction has extirpated this plant at many previously documented sites. The State of Florida has designated the sea lavender as an endangered species.



Remirea maritima **(beachstar.)** *Original photograph courtesy of Florida Natural Areas Inventory.*

The state endangered **burrowing four-o'clock** (*Okenia hypogaea)* is an annual with deep taproots and stems that spread out over the soil surface. It is often found with sand covering the plant in a thick coat. In Florida, burrowing four-o'clock is found in only a few locations along the southeast coast, but is also found on the Mexican Gulf coast. The plant is restricted to the ocean side of coastal dunes, often being the closest plant to the water's edge.

The **beach-star** (*Remirea maritima*) is a small perennial herb with stems arising at intervals along the elongated stolon. Its numerous leaves, overlapping at the base with recurved leaf blades, give this plant a star-like appearance. Although widely distributed in the tropics, it is found in Florida only along the southeastern coast (especially south of Martin County). The plant's former range was from Vero Beach southward to Miami-Dade County, but beach development has extirpated this plant from former sites, especially in Miami-Dade County. This species has been designated as an endangered species by the State of Florida.

The **bay cedar** (*Suriana maritima*) is a densely branched shrub or small tree which reaches a height of 8 m. Its leaves are fleshy blades from 1 to 4 cm (0.4 to 1.6 inches) in length. The state endangered bay cedar is found in coastal beaches, sand dunes and sandy thickets throughout South Florida, including the keys of Florida Bay and the lower Florida Keys.

Description - Coastal Strand

The most commonly encountered community behind the herbaceous dune zone is a shrubby community known as coastal strand. On the Atlantic coast, coastal strand occurs as a dense, flat-topped (salt spray-pruned) community of evergreen shrubs which shows increasing abundance of tropical species as one goes south along the coast. The zone nearest the beach is usually occupied by a mixture of saw palmetto (*Serenoa repens)* and a shrubby form of sea grape *(Coccoloba*

uvifera). As one goes inland, the canopy grades upward and is formed by a mixture of shrubs, usually including *Sabal palmetto* (dwarfed)*, Forestiera segregata, Persea borbonia*, *Chrysobalanus icaco*, and *Rapanea punctata.* The associates of these widespread species change as one goes southward. From Indian River to St. Lucie County their common associates are *Sideroxylon tenax, Myrcianthes fragrans*, and *Quercus virginiana* (dwarfed); from Martin to Miami-Dade County their associates change to tropical species, such as *Eugenia foetida* and *Pithcellobium keyense* (Johnson and Muller 1993).

On the Gulf coast, the area behind the foredune is usually occupied by an open stand of grasses or trailing shrubs with scattered islands of taller shrubs surrounding a few cabbage palms in their center. These shrub islands of the coastal strand community are composed of many of the same tropical species found on the Atlantic coast (*Forestiera segregata, Rapanea punctata, Randia aculeata, Chiococca alba, Lantana involucrata)*, plus several shrubs or small trees more commonly, if not exclusively, found on the Gulf coast and the Florida Keys, i.e., *Jacquinia keyense, Pithecellobium unguis-cacti, Sideroxylon celastrina*, and *Piscidia piscipula*. Coastal shrubs with a low trailing growth habit [*Ernodea littoralis, Ambrosia hispida, Chiococca parvifolia = C. alba,* Wunderlin (1996)] are also more abundant in the open backdune communities on the Gulf than they are in the denser, shrubby backdune thicket communities on the Atlantic coast of South Florida (Johnson and Muller 1992, Cooley 1955, Herwitz 1977).

The coastal grassland community in which these shrub islands occur is generally of two types: on newer sand deposits it is composed of a variety of tall grasses (*Muhlenbergia capillaris, Spartina patens, Schizachyrium semiberbe, Andropogon glomeratus, Aristida patula*, *etc.*, plus occasional remnant patches of *Uniola paniculata*). This type is well developed on Cape Sable and the newer southern part of Cannon Island. In older, more stable portions of the broad barrier islands fronting Pine Island Sound, *e.g.,* Cayo Costa, North Captiva, and formerly Captiva and Sanibel (Cooley 1955), coastal grassland consists of a short, dense sward of hairy grama grass, *Bouteloua hirsuta*, a western disjunct which is also a dominant species in Texas and on the western high plains (Kuchler 1964). This community is well preserved on state-owned land on Cayo Costa and North Captiva islands.

The coastal interdunal swale community is associated with the newer type of coastal grassland which develops on the ridges as a barrier island accretes as a series of low ridges and swales. It generally consists of graminoid species such as *Fimbristylis castanea, F. spathacea, Spartina patens*, and *Paspalum distichum*, with occasional halophytic species (*Juncus roemerianus, Avicennia germinans*) if tidal influence is present (Johnson and Muller 1992).

The coastal rock barren community occurs on Key Largo limestone and is marked by an abundance of spiny species including, *Acanthocereus pentagonus*, *Opuntia stricta*, and *Agave decipiens*, plus a great variety of other weedy herbs and shrubs (Kruer 1992). It appears to develop after disturbance, whether man-made or natural, and probably would not be recognized as a separate community except for the presence of several rare plants, notably *Chamaesyce garberi*, *Opuntia triacantha*, and *Indigofera mucronata* var. *keyensis.*

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the coastal strand community in South Florida include: Lower Keys rabbit (*Sylvilagus palustris hefneri*), southeastern beach mouse, eastern indigo snake (*Drymarchon corais couperi*), and Kirtland's warbler (*Dendroica kirtlandii*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

Gopher tortoise (*Gopherus polyphemus*), a species State-listed as threatened, may form dense populations in coastal grassland (Johnson and Muller, 1992). Gopher tortoises are large terrestrial turtles, averaging 23 to 28 cm (9.2 to 11.2 inches) in carapace length. In Florida, the gopher tortoise occurs in all 67 counties, but its distribution in the southern peninsula is limited and increasingly fragmented by unsuitable habitat and urbanization. They require well-drained loose soil for burrowing, adequate low-growing herbs for foraging, and open sunlit sites for nesting. Gopher tortoise populations are declining primarily due to urbanization and other habitat-altering land uses.

Plant Species of Concern

Federally listed plant species that depend upon or utilize the coastal strand community in South Florida include: Garber's spurge (*Chamaesyce (=Euphorbia) garberi*), and Key tree-cactus (*Pilosocereus* (=*Cereus*) *robinii*). The biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

The endemic **Atlantic coast Florida lantana** (*Lantana depressa* var. *floridana*) occurs in the coastal strand community. This species is a low-growing shrub that occurs in the natural (storm overwash) or man-made openings in the dense shrub layer. The Atlantic coast Florida lantana is a small shrub with prostrate or erect branches, and leaves up to 3.5 cm (1.4 inches) long. The State of Florida has classified *Lantana depressa* var. *floridana* as an endangered species.

The **coastal vervain** (*Verbena* (=*Glandularia*) *maritima*) is a endangered perennial with rose-purple flowers, nearly hairless creeping stems, and deeply incised or toothed leaves from 2 to 4 cm (0.8 to 1.6 inches) in length. In addition to the coastal strand community, it also occurs in the coastal dune and pine rockland communities.

The **Florida semaphore cactus** (*Opuntia corallicola* (=*spinosissima*)) is an endemic, distinct species (Austin *et al*. 1998, Gordon and Kobisiak 1998) presently known from a single remaining wild population of fewer than 15 mature plants at The Nature Conservancy's Torchwood Hammock Preserve on Little Torch Key. According to Small (1930), it formerly occurred on Big Pine Key and Key Largo; neither the number of individuals nor the size of those populations were described. Cactus hobbyists were thought to have eliminated this species in the late 1970s, but it was rediscovered at the Torchwood Hammock Preserve site during the mid 1980s (Austin *et al*. 1998). The State of Florida has listed the Florida semaphore cactus as an endangered species.

Coastal grassland on Cayo Costa and North Captiva islands are home to some of the few populations of non-hybridized, state endangered **Gulf coast Florida**

lantana (*Lantana depressa* var. *sanibelensis*) (Johnson and Muller 1992, Sanders 1987). Similar in appearance to the Atlantic coast Florida lantana (*Lantana depressa* var. *floridana*), this coastal shrub, is highly endemic to southwestern Florida.

The coastal rock barren community supports the growth of the state endangered **Key's Joe-jumper** (*Opuntia triacantha).* This species has nearly prostrate, irregularly branched stems, with loosely attached joints 4 to 8 cm (1.6 to 3.2 inches) long and 3 to 4 cm (1.2 to 1.6 inches) wide. Spines vary from one to six in number and are 4 cm (1.6 inches) long. It is distributed from Florida to the West Indies, including Puerto Rico and the Virgin islands.

The **Key's indigo** (*Indigofera mucronata* var. *keyensis*) is an endemic herbaceous perennial vine currently known only from the upper Florida Keys (Isley 1990). This species is shade intolerant and requires periodic burning to reduce competition from woody vegetation. Its historic distribution once included Lower and Upper Matecumbe keys where it is now extirpated. Threats to the Key's indigo include loss of habitat as a result of development, fire suppression, and exotic plant invasion. The plant can be identified as having five leaflets opposite on its leaf stalk; pink to salmon flowers and stems with small appressed, straight hairs.

Description - Maritime Hammock

Maritime hammocks with a temperate canopy are generally short forests (10 to 12 m) with a monotonous canopy of *Quercus virginiana*, *Sabal palmetto*, and *Perrea borbonia*, plus a structurally diverse understory of woody species including small trees and tall and short shrubs which do not form clear layers. Commonly encountered species include *Ardisia escallonioides, Rapanea punctata, Myrcianthes fragrans, Zanthoxylum fagara, Z. clava-herculis, Eugenia axillaris, E. foetida, Psychotria nervosa*, and *Serenoa repens* (Johnson *et al*. 1992). South of northern Palm Beach County most maritime hammocks have a tropical canopy composed of a greater variety of trees, including the three most common mentioned above plus: *Mastichodendron foetidissimum, Guapira discolor, Coccoloba diversifolia, Simarouba glauca*, and *Metopium toxiferum*. *Sabal palmetto* continues south as an important component of the canopy and subcanopy; the understory shrubs are also the same southward, except for *Myrcianthes fragrans* which does not continue south of St. Lucie County. As one goes southward in Palm Beach County more tropical species appear, including silver palm (*Coccothrinax argentata*) and blackbead (*Pithecellobium keyense*). The barrier islands of southern Palm Beach, Broward, and Miami-Dade counties were developed early in the century and Alexander (1958), in describing a soon-to-be-destroyed hammock near Pompano Beach containing 21 species of tropical trees, referred to the hammock community in this region as essentially "extinct". The best remaining examples of this community can be found at JD MacArthur Beach State Park, Ocean Hammock Park, and Gumbo Limbo Nature Center in Palm Beach County (P. Davis, Palm Beach County, perssonal communication 1998), and at the Bartlett Estate (Bonnet House) south of Hugh Taylor Birch State Park in Broward County.

On the Gulf coast of South Florida maritime hammocks with a temperate canopy of live oak and cabbage palm may be found from Sarasota to Collier counties. As on the east coast, maritime hammocks with tropical canopies occur on calcareous substrates. Composition of canopy and understory of temperate hammocks on the Gulf coast is similar to hammocks on the Atlantic coast; composition of tropical maritime hammock canopies is also similar to those on the Atlantic, but somewhat less diverse. Although one species, *Piscidia piscipula*, is found on the Gulf and not on the Atlantic coast, six tree species found on the Atlantic are not found on Gulf coast: *Amyris elemifera, Guapira discolor, Krugiodendron ferreum, Metopium toxiferum, Ocotea coriacea*, and *Zanthoxylum coriaceum* (Wunderlin *et al*. 1996; Table 1). Two Atlantic species are replaced on the Gulf by related species in the same genus. *Pithecellobium unguis-cati* replaces *P. keyense* and *Harrisia aboriginum* replaces *Harrisia simpsonii* from Lee County northward (Wunderlin *et al*. 1996). Another difference, noted by Harper (1927), is that west coast hammocks tend to have more spiny species (*Acanthocereus pentagonus, Agave decipiens, Yucca aloifolia, Opuntia stricta*) in the understory than do east coast hammocks. The best examples of maritime hammocks are found on the inland side of Cayo Costa and North Captiva Islands just above the mangrove fringe. Other good examples of temperate maritime hammock are found on "inner barrier islands" that characterize this coast. These develop when an inlet severs the tip of an island from the remainder and subsequent coastwise growth of outer barrier causes it to overlap its former tip, allowing the development of hammock on the now protected inner island. Such hammock development has occurred on Petersen Island and Whiddon Key at Port Charlotte State Recreation Area in Charlotte County and on Cannon and Johnson Islands at the south end of Keewaydin in Collier County. One of the best developed tropical hammocks in the Gulf coast is found on a shell mound on Josselyn Island in Pine Island Sound, Lee County (Johnson and Muller 1992).

Among animals dependent on maritime hammocks, populations of the insular cotton rat (*Sigmodon hispidus insulicola*), found in tidal marshes and on hammock edges on Captiva, Sanibel, and Pine Islands in Lee County, are apparently secure enough not to require state-listing as are populations of the lower Keys cotton rat (*S. h. exputus*) which is found in similar coastal habitats (Humphrey 1992). Migrating songbirds that funnel down the Atlantic coast of Florida on their way to South America use the coastal hammock and strand communities for food and shelter. The northern prairie warbler (*Dendroica discolor*) and indigo bunting (*Passerina cyanea*) are declining species that use the peninsular migration route (Enge *et al*. 1997).

Wildlife Species of Concern

Federally listed species that depend upon or utilize the maritime hammock community in South Florida include: Florida panther (*Puma (=Felis) concolor coryi*), eastern indigo snake, bald eagle (*Haliaeetus leucocephalus*), and Kirtland's warbler. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. For a list of other species that utilize the maritime hammock community please refer to Appendix C.

Florida prairie warblers (*Dendroica discolor paludicola*) utilize the maritime hammock community. They are approximately 12 cm (4.72 in) long overall, and

weigh about 6 to 8 grams (0.21-0.28 oz). There is no overall population estimate for the Florida prairie warbler. Its local abundance ranges from rare to common. Because the species nests almost entirely in mangroves, it is reasonable to infer that its numbers have declined somewhat as mangroves have been cleared or otherwise rendered unusable for nesting. Development pressures continue to be strong in the high-growth coastal zone of the southern peninsula.

The **peregrine falcon** (*Falco peregrinus*) is federally listed as endangered due to its similarity of appearance with the endangered *Falco peregrinus anatum. Falco peregrinus* can be found utilizing the maritime hammock community while migrating through Florida. The species feeds primarily on birds, and rarely on small mammals, fish, lizards, and insects. Threats include: falconers robbing nests, shooting by hunters, and food chain contamination from use of persistent pesticides. Peregrine falcon reintroductions have been fairly successful in the United States. Populations of peregrine falcons are estimated to be 1,593 breeding pairs in the United States and Canada. In recognition of this species' recovery, the FWS has proposed to remove *Falco peregrinus anatum*, and consequently *Falco peregrinus* from the endangered and threatened species list (63 FR 45446). A final decision will be made following the receipt of public comments.

Plant Species of Concern

Although there are no federally listed plant species that utilize the maritime hammock community, this community is utilized by other species, including State-listed species (Appendix C).

The **small-flowered lily-thorn** (*Catesbaea parviflora*) is a state endangered shrub that can utilize the maritime hammock community in South Florida. The species has few known occurrences, low abundance at each occurrence, and is subject to overcollection and habitat destruction. In Florida, this species only occurs on Big Pine Key and Bahia Honda Key in Monroe County.

The **west coast prickly-apple** (*Cereus gracilis* var. *simpsonii*) is an endemic cactus that can be found utilizing the maritime hammock community in Collier, Indian River, Monroe, and St. Lucie counties. The species is columnar with 9 to 11 ridged stems, red fruit, and whitish flowers. Other ecological communities where it can be found include: shell mounds, and rockland hammocks.

The maritime hammock community is utilized by the state endangered **aboriginal prickly-apple** (*Cereus gracilis* var. *aboriginum*). While similar to the west coast prickly apple, this species also has whitish flowers but produces a yellow fruit and occurs in Lee, Manatee, and Sarasota counties.

Ecology

In terms of natural disturbances, coastal communities are mainly influenced by intermittent severe storm disturbances and by constant or predictable coastal stresses such as seasonal high tides, winter storms, sand burial and abrasion, and salt spray deposition. Fires occasionally occur in these communities, but it seems likely that natural fires were less frequent on barrier islands than on the

mainland, since there are fewer compass directions from which fire could spread to any given area of barrier island compared to a similar area of mainland by virtue of the island's being surrounded by water. Frost occasionally kills back the tropical species of coastal strand and maritime hammocks in the northern portion of the South Florida coast, with the notable exception of *Myrcianthes fragrans* which survived the December 1989 freeze on the Atlantic coast unscathed.

The zonation of coastal communities at right angles to the shore reflects the decrease in type and intensity of coastal stresses as one moves away from the coast. Plants of the upper beach must be able to rapidly re-colonize this habitat after frequent periodic destruction by seasonal high tides or storm waves. They are all herbaceous and either complete their life cycle in one growing season or colonize vegetatively by sending out low, wide-ranging runners from rooted rosettes in safe sites higher up on the foredune. Most upper beach colonists can withstand inundation by salt water. Beyond the annual reach of the waves, the wind constantly piles sand from the beach around plant stems to create a foredune. This habitat may persist for many years between major storms and favors perennial rhizomatous grasses whose upward growth can keep pace with sand burial and build up the height of the foredune. Aside from sand burial, plants on the foredune must be able to tolerate salt spray blown off the water. Salt from droplets deposited on the foliage may enter the cells through cuts in the cuticle (produced by sand abrasion) and kill the growing buds (Boyce 1954). Plants avoid the entrance of salt into the cells by having a tough cuticle (*e.g., Uniola paniculata*), or by growing low to the ground out of the path of the wind (*e.g.*, *Chamaesyce bombensis*), or they tolerate the entrance of salt by diluting it, producing succulence (*e.g. Iva imbricata*). As the foredune grasses intercept sand, they allow species less tolerant of burial such as the shrubby species of coastal strand, or the less specialized grasses of the coastal grassland, to survive landward of them. The influence of salt spray continues the farthest inland of the coastal stresses, producing the low evenly pruned canopies of coastal strand and maritime hammock communities. Their canopies gradually become taller with increasing distance from the coast as the twigs of the seaward plants comb the salt droplets out of the windstream, allowing the terminal twigs to reach progressively greater heights inland before being killed by salt (Boyce 1954). In order to produce spray-pruning, of course, the wind must blow across water. Low spray-pruned canopies are much more frequently encountered along the Atlantic coast, where the prevailing easterly winds blow across the ocean, rather than on the Gulf coast, where the prevailing easterlies blow across land (Johnson and Barbour 1990).

Waves breaking at other than right angles to the beach tend to move sand along the coast, a process called longshore drift. The prevailing direction of longshore drift in South Florida is southward. If a jetty interrupts this wave conveyor belt, sand will accumulate on the updrift side of the obstruction and be carried away from the downdrift side, producing erosion, especially when storms occur. Coastal erosion has been prevalent in recent years on the Atlantic coast of South Florida (Pilkey *et al*. 1984), where all inlets are "hardened" by jetties, whereas accretion or build-up of new barrier islands from underwater bars has

occurred in the same period in many places on the Gulf coast (Johnson 1994), where many inlets are natural. Although only one hurricane has directly struck South Florida in the last three decades, winter storms called nor'easters have struck the Atlantic coast from Palm Beach County north. Recent erosion has forced relocation of bathhouses and dune overpasses in parks south of Sebastian Inlet in Indian River County and caused overwash of beach sand into mangrove forests along Hutchinson Island south of St. Lucie Inlet. Beach renourishment projects at both these inlets have pumped sand from inside the inlets onto beaches to the south of them. Erosion in this high-density sea turtle nesting area may interfere with nesting by producing a cliff above the beach which blocks the turtles from nesting out of reach of the regular high tides. Accretion on the Gulf coast, on the other hand, has provided new nesting sites for southeastern snowy plovers and least terns (*e.g.* Lido Key, Estero Island, Keewaydin, and Marco Island). The main threat in this case in an area of such high population density is disturbance by boaters, beach strollers, and their dogs.

Status and Trends

Much of the narrow fringe of South Florida's sandy shoreline has been developed into cities and resorts. From Indian River to northern Miami-Dade County only about 56 km of a total 267 km (35 of 160 miles) of coast (22 percent) are not developed; from Sarasota to northern Collier county only 72 km of a total 206 km (45 of 128 miles) of coast (35 percent) remain undeveloped (Johnson *et al.* 1992, Johnson and Muller 1992).

Development is not evenly distributed along the coast. From Sebastian Inlet to Cape Florida, the number and size of sites in natural vegetation on the barrier islands diminishes sharply south of MacArthur Beach State park in northern Palm Beach County. The 121 km (75 miles) of coastline north of MacArthur Beach contains 32 sites in natural vegetation, comprising a total of approximately 1,133 ha (2,800 acres); the 137 km (85 miles) of coastline south of MacArthur Beach contains only 15 sites in natural vegetation totaling approximately 202 ha (500 acres) (Johnson *et al.* 1992). Virtually all of the suitable natural acreage remaining on barrier islands in Palm Beach, Broward, and Miami-Dade counties is already in public ownership, but approximately 65 percent of the remaining natural acreage on barriers in the three northern counties is in private ownership (Johnson *et al*. 1992). About one-fourth of this remaining acreage (all of it in Indian River County) is proposed for state acquisition as part of the Archie Carr NWR in the state (CARL) program. This project would protect the highest-density nesting beaches for sea turtles in Indian River and southern Brevard counties, of which approximately 81 ha (200 acres) in Indian River County has been purchased to date (DEP 1997). Scattered natural hammocks on both the mainland and barrier island shores of Indian River Lagoon are also proposed for state acquisition as part of the Indian River Lagoon Blueway CARL project.

In the 209 km (130 miles) of Gulf coast from Lido Key to Cape Romano, there are 24 sites in natural vegetation comprising a total of approximately 1,214 ha (3,000 acres). Some of these are large sites comprising almost all of certain barrier islands such as Cayo Costa, North Captiva, and Keewaydin Islands. Most of the suitable natural land remaining is in public ownership or

is proposed for public acquisition by the state including Buck Key and portions of Cayo Costa Island as part of the Cayo Costa Island CARL project in Lee County, and Keewaydin, Little Marco, Cannon, and Johnson Islands as part of the Rookery Bay CARL project in Collier County (DEP 1997).

Aside from real estate development, displacement by the exotic Australian pine (*Casuarina equisetifolia*), a coastal tree native to Australia and islands in the Pacific, is the greatest threat to coastal communities in South Florida. It invades bare sand beaches, whether newly deposited or denuded of natural vegetation by storm overwash, as well as spoil deposits produced by dredging the intracoastal waterway. Since *C. equisetifolia* tolerates inundation by seawater and deposition of salt spray on its foliage better than do native woody species, its seedlings can colonize and grow into forests closer to the coast than can native trees, displacing not only native coastal forest, but also coastal grassland and coastal strand along with their associated rare endemic plants, all of which are adapted to a high-light environment (Johnson 1994). Australian pines form tall, shady, monospecific forests with a deep litter layer of "needles" (actually branchlets) that appears to preclude germination of most native understory species, although these will grow in the understory when planted as seedlings or saplings (Fernald and Barnett 1991).

Dense Australian pine forests are found along 44 percent [32/72 km (20/45 miles)] of undeveloped coast from Sarasota to Collier counties and 46 percent [26/56 km (16/35 miles)] of undeveloped coast between Indian River and Miami-Dade counties. Much of the mature Australian pine forests in South Florida are within state parks or preserves including Port Charlotte Beach SRA, Don Pedro Island SRA, Cayo Costa Island SRA (including portions of North Captiva Island), Lovers Key SRA, and Delnor Wiggins SRA along the Gulf coast, and St. Lucie Inlet SRA and John U. Lloyd SRA on the Atlantic. Mature forests of Australian pine also occur on many spoil islands in the intracoastal waterway (FDNR 1990). Mature Australian pine forests formerly occurred on state-managed land at Cape Florida SRA, Miami-Dade County and Keewaydin Island, Collier County. The Cape Florida forest was blown down by Hurricane Andrew in 1992; the trees were chipped and the area re-planted to native hammock.

Management

The chief management concern in coastal communities of South Florida is exotic plant control, primarily of Australian pine, but also of Brazilian pepper (*Schinus terebinthifolius*), beach naupaka (*Scaevola taccada* var. *sericea*), latherleaf (*Colubrina asiatica*) and carrotwood (*Cupaniopsis anacardioides*). One of the most important and effective steps to take with Australian pine is to pull seedlings that are invading new areas. Once a mature forest of *Casuarina* is established, it presents an expensive problem to eradicate all at once and replace with native species. This has been done where funds were made available: at The Nature Conservancy's Blowing Rocks Preserve in Martin County [approximately 5.6 ha (14 acres) cleared and re-planted for about $300,000; Jensen 1994], at Cape Florida SRA in Miami-Dade County after the Australian pine forest was flattened by Hurricane Andrew in 1992 [approximately 121 ha (300 acres) chipped, graded,

and re-planted for about $4 million; P. Schroeder, Cape Florida SRA, personal communication 1994], Palmer Dunes, Sarasota County [3.2 ha (8 acres) cleared and to be re-planted for a proposed $300,000; R. Patten, Coastal Dunes Inc., personal communication 1998] and on Keewaydin Island (part of the Rookery Bay National Estuarine Research Reserve) in 1998 [approximately 182 ha (450 acres) cleared, not re-planted, for unknown amount; D. Addison, The Nature Conservancy Inc., personal communication 1998]. Once the initial money is spent, little is usually allocated for the follow-up jobs of monitoring, re-planting of natives, and pulling of re-invading *Casuarina* seedlings, which tasks have fallen to volunteer labor, at least at the first two sites (Jensen 1994; E. Golden, Cape Florida SRA, personal communication 1998).

While the mature Australian pine forest remains, its shade can skew the gender of loggerhead hatchlings toward males, its root mat can interfere with the female turtle's nest excavation, and it can narrow the zone of bare sand and pioneer sea oats dunes used by beach mice and nesting shorebirds. In addition, beach visitors come to enjoy its shade and will protest a too rapid and complete removal program, even though the tree creates problems for the human population as well. Its wind-dispersed pollen can cause respiratory distress and its shallow root system makes it likely to topple during hurricanes, blocking evacuation routes.

Due to its popularity, as well as financial constraints, the state parks have adopted a program of gradual removal of large Australian pines by girdling and herbiciding the trees and allowing them to die and decay in place (Glisson 1994). Control of seedling invasion in the parks is on a casual basis. Systematic control would require manpower with boat access to monitor newly deposited or eroded beaches annually or semi-annually and pull the invading seedlings, which can grow up to 1.5 to 3m (5 to 10) feet per year (Morton 1980). This could be accomplished by coordination of volunteer efforts and by forming partnerships with interested non-profit groups, such as the Audubon Society. An example of the effectiveness of following up removal of mature pines by pulling seedlings is the experience of Everglades NP which managed to prevent the development of a mature Australian pine forest on Cape Sable by annually pulling up the seedlings that came in after Hurricane Donna in 1960 (Klukas 1969).

Other exotics pose a continuing, if not yet as severe, problem for coastal communities. Beach naupaka naturalizes from landscaped areas into the beach dune community, possibly displacing the native inkberry, *Scaevola plumieri*. *Lantana camara*, the common shrub used in landscaping, naturalizes in disturbed areas and will hybridize with the native endemic varieties of *L. depressa* (Sanders, 1987); Brazilian pepper has seeded into the understory of most maritime hammocks and may become so dense as to exclude seedling regeneration of native species after storms open up the canopy; also common in the understory of maritime hammocks in the Keys and Ten Thousand Islands are the exotics, *Agave sisalana* and *Sansevieria hyacinthoides*. Latherleaf, a woody vine from Asia, occupies the ecotone between the beach and hammock zones and has formed dense populations on some beaches in the Ten Thousand Islands NWR (D. Addison, Nature Conservancy Inc., personal communication

1998). Carrotwood, a common landscape tree, naturalizes on the fringes of maritime hammocks on both coasts (Austin 1994).

Plants may be impacted in several ways. Cutting down of coastal strand and maritime hammock for parking lots or beach structures may allow salt spray to penetrate further inland and kill the canopies of trees in the remaining hammock, since the salt droplets are no longer combed out of the windstream by the seaward twigs in a continuous canopy that slants uniformly upward away from the coast. Raking of seaweed drift off the beach removes a source of fertilizer, as well as the seeds of pioneer species, both of which may be especially needed after storms for rapid recolonization and growth, to help stabilize the sand and restore the elevation of the foredune.

Table 1. Plant species of beach dune, coastal strand, and maritime hammock communities found only on the east or west coast of South Florida (Wunderlin *et al.* 1996).

Species	FLORIDA ENDEMIC	EAST COAST	WEST COAST	Keys
Alternanthera maritima	X	X		
Amyris elemifera		X		X
Argusia gnaphalodes		X		X
Coccothrinax argentata		X		X
Chamaesyce cumulicola	X	X		
Glandularia maritima	X	X		
Guapira discolor		X		X
Harrisia simpsonii	X	X		X
Harrisia aboriginum	X	X	X	
Helianthus debilis ssp. debilis	X			
Helianthus debilis ssp. vestitus	X	X	X	
Jacquinia keyensis			X	X
Krugiodendron ferreum		X		X
Lantana depressa var. sanibelensis	X		X	
Lantana depressa var. floridana	X	X		
Metopium toxiferum		X		X
Okenia hypogaea		X		
Pithecellobium keyense		X		X
Pithecellobium unguis-cati			X	X
Piscidia piscipula			X	X
Remirea maritima		X		
Tephrosia angustissima var. curtissii	X	X		
Zanthoxylum coriaceum		X		

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Restoration of Beach Dune, Coastal Strand and Maritime Hammock

Restoration Objective: Maintain the structure, function, and ecological processes of beach dune, coastal strand and maritime hammocks, and prevent any further loss or degradation of these communities in South Florida.

Restoration Criteria

This restoration objective will be achieved when: (1) beach dune/coastal strand/maritime hammock communities are protected from further destruction and degradation; (2) areas dominated by the exotic Australian pine (*Casuarina equisetifolia*) are replaced with native coastal vegetation; (3) invasion of newly created coastal habitat by this exotic is prevented; (4) endemic, rare, and imperilled species that use these communities have self-sustaining populations in the wild; and (5) natural successional processes following storm destruction or beach accretion are allowed to occur.

Community-Specific Actions

1. **Prevent further destruction or degradation of existing beach dune/coastal strand/ maritime hammock communities**. Acquire remaining natural coastal areas identified on the state (CARL) list. Prevent colonization by Australian pine of newly deposited or storm-denuded coastal areas in public ownership by regularly scheduled pulling of Australian pine seedlings.

2. **Restore existing degraded beach dune/coastal strand/maritime hammock communities.**

   2.1. **Restore native maritime hammock communities** at coastal areas dominated by invasive exotic species, such as Australian pine forests, by introducing seeds or seedlings of native woody species in the understory if they are not already present, and by killing the exotic species with hand-administered herbicide application.

   2.2. **Restore coastal strand communities** in areas dominated by invasive exotic species exposed to salt spray by applying herbicide to kill the canopy of exotics and reduce shading, and then planting seeds or seedlings of native strand species behind the foredune, if plants of the strand community are not already present.

   2.3. **Within their known ranges, introduce rare endemic species**, such as *Jacquemontia reclinata*, into natural openings in the appropriate coastal community which they may be unable to colonize naturally due to fragmentation of the natural linear coastal vegetation by development. Factors to consider in siting such plantings for each species are its tolerance of sand burial, salt spray on its foliage, and saltwater inundation of its root zone.

2.4. **Remove the naturalized landscape ornamentals in the genus *Lantana*** before planting the endemic varieties of *Lantana depressa;* the ornamentals tend to hybridize with the native species.

2.5. **Use a mix of native species in replantings** based on nearest natural coastal communities, bearing in mind that some species are native only to the east or west coast of South Florida (Table 1).

3. Maintain existing natural communities in a natural condition.

3.1. **Permit native coastal species to successfully colonize or re-colonize coastal beach areas** following natural storms or beach accretion by controlling colonization by competing exotics. Introduce native seeds, seedlings, or cuttings to areas that may be too distant from natural seed sources (due to intervening development along the coast) for dispersal to occur.

3.2. **Leave seaweed wrack on the upper beach** to be buried by sand and form a natural fertilizer and seed bed for colonization of the beach.

3.3. **Monitor populations of rare species**, both plant and animal and control overuse by humans of parts of the beach needed for nesting or feeding of turtles and shorebirds.

4. Conduct community-level research.

4.1. **Conduct research on cost-efficient methods of removing Australian pine**, both as mature forest and as colonizing seedlings.

4.2. **Conduct research on best methods of re-establishing native vegetation** of the beach dune, coastal strand, and maritime hammock communities once exotic species have been removed. This would include supporting basic research into the factors influencing the process of natural dune succession in South Florida.

4.3. **Provide a regular forum to encourage sharing of information** on techniques and case histories for dealing with exotic species such as Australian pine removal and subsequent re-vegetation efforts between public agencies at all levels and between private contractors and public agencies.

5. Monitor land management actions.

5.1. **Once cleared of exotic species, monitor coastal areas at least semi-annually** to determine the rate and sequence of natural revegetation and to be sure exotics are not re-invading.

5.2. **Monitor plantings of native species (including rare species) following exotic plant removal** to follow success and to re-plant or modify planting scheme if necessary.

6. Increase public awareness.

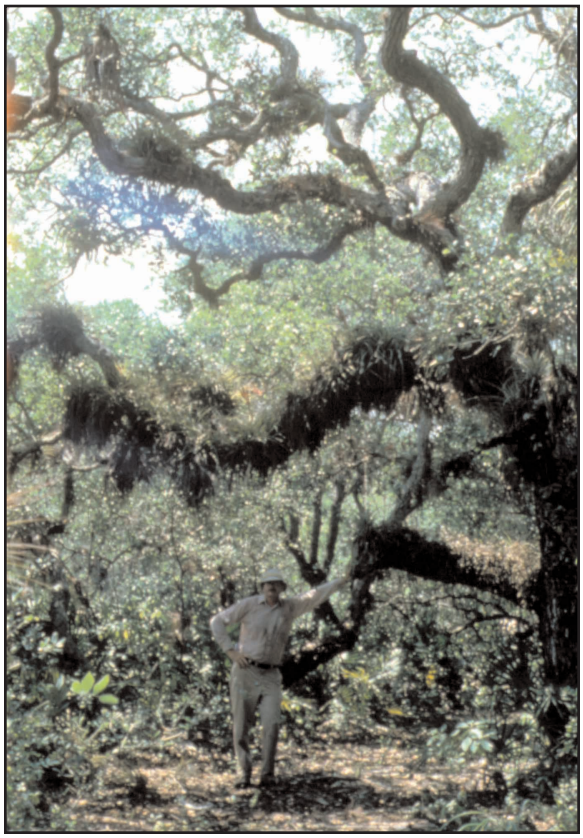
6.1. **Provide pamphlets, information billboards, and guided walks to inform the public** on the effects of invasive exotic vegetation on native plant and animal communities along the coast, as well as the need to avoid disturbing nesting birds during some seasons.

6.2. **Enlist the aid of volunteer groups and nonprofit organizations** to aid in annual or semi-annual pulling of exotic plant seedlings on newly formed or overwashed beaches.

Mesic Temperate Hammock

FNAI Global Rank:	**Undetermined**
FNAI State Rank:	**S3/S4**
Federally Listed Species in S. FL:	**8**
State Listed Species in S. FL:	**22**

Mesic temperate hammock. *Original photograph by Ann Johnson.*



Mesic temperate hammock is a closed canopy forest, dominated by temperate evergreen tree species, primarily live oak and cabbage palm, that is naturally protected from fire by its position on the landscape. Tropical species are common in the shrub layer and become increasingly important in the canopy at the southern end of its range. Soils in mesic temperate hammock are moist due to a dense litter layer and the humid conditions that prevail under the closed canopy, but are rarely inundated. Mesic temperate hammocks are important habitat for wildlife and provide secondary habitat for a number of rare, threatened, and endangered plant and animal species. This community has been heavily impacted by human activity, primarily clearing for agriculture and urbanization. Soils and understory vegetation in mesic hammocks, often the only shaded habitat in a landscape of prairie, pasture, pineland, or marsh, are trampled and compacted by cattle. Mesic temperate hammocks have also been adversely affected by exotic plant and animal species, especially feral hogs, and by fire suppression and hydrological alterations in adjacent and surrounding communities. Protection measures for mesic temperate hammocks include conservation land acquisition; ecosystem management practices, particularly restoration of natural fire and hydrological regimes; control and eradication of exotics; and limits on grazing, development, and recreational uses.

Synonymy

The following terms have been applied in whole or in part to the plant communities of South Florida that are included within this description of mesic temperate hammock: upland hardwood forest, upland mixed forest, prairie hammock, xeric hammock, hydric hammock (FNAI and Florida Department of Natural Resources (FDNR) 1990); I.A.4N.a.050-*Quercus virginiana-Sabal palmetto* forest alliance (Weakley *et al*. 1998); oak hammock, cabbage

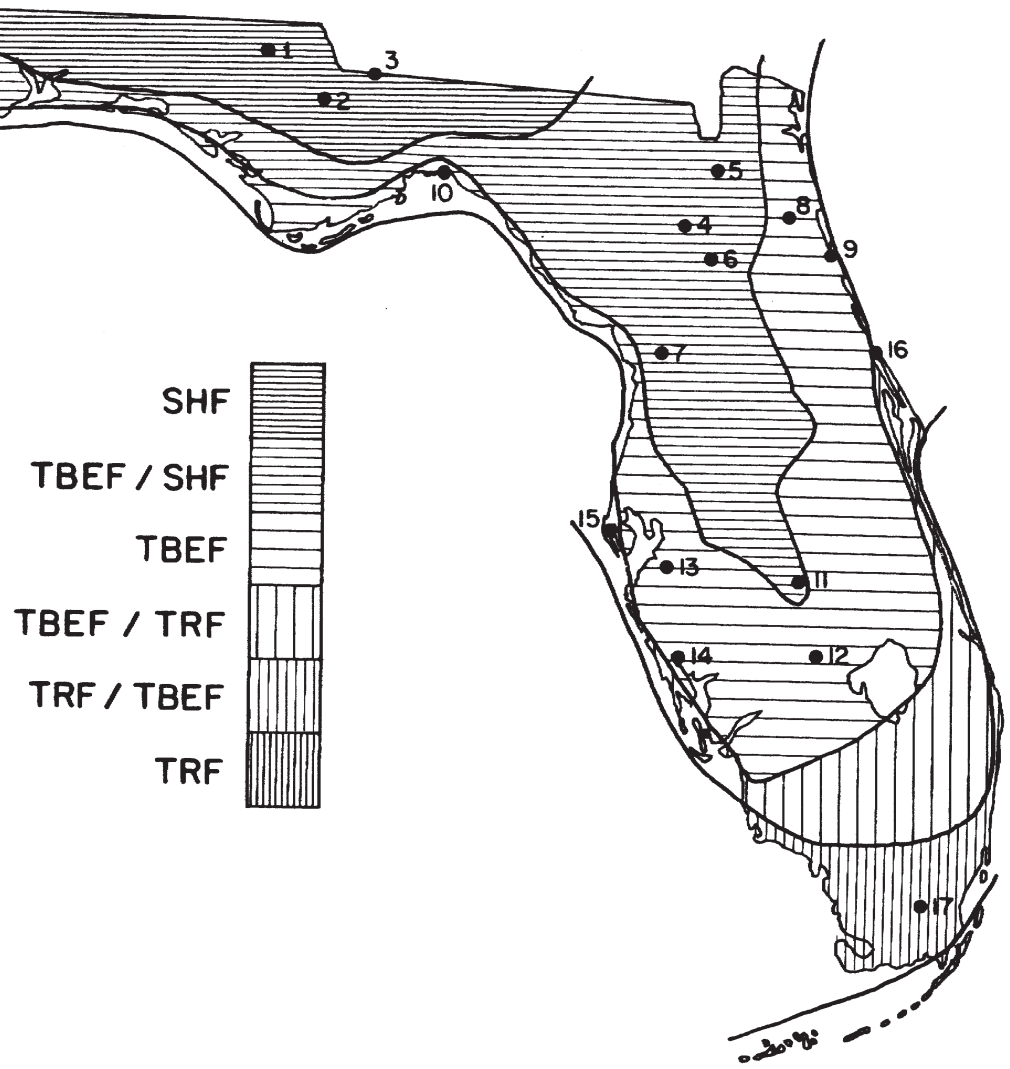
palm hammock, upland hardwood hammock (SWCS 1989); 422-other hardwood forest (DOA 1976); hardwood hammock, live oak-cabbage palm hammock, mesic hammock (Ward 1979); temperate broad-leaved evergreen forest (Greller 1980, Platt and Schwartz 1990); I.A.7a-temperate evergreen seasonal broad-leaved forest (UNESCO 1973); 1.evergreen, b. non-hydric, (2) eastern (b) palmetto-evergreen hardwoods, high hammock (Penfound 1967); upland mixed forest (Duever *et al*. 1979); type 15 (Davis 1967); oak hammock, oak and cabbage palm hammock, cabbage palm hammock (Davis 1943); sandy hammock, calcareous hammock (Harper 1921); low hammock, live-oak hammock, live oak-palmetto hammock (Harshberger 1914); upland hammock (Austin 1998), low hammock (Austin 1998, Richardson 1977, Harper 1927); low temperate hammock (Austin *et al*. 1977, Cox 1988), and high hammock (Alexander 1958). Nomenclature in this report follows Kartesz (1994). The FLUCCS codes for mesic temperate hammock include: 422 (Brazilian pepper), and 414 (pine/mesic oak).

Distribution

Mesic temperate hammock occurs in a broad zone of peninsular Florida, where it is transitional between the southern mixed hardwood forest of north peninsular and panhandle Florida and the tropical forest of southern Florida (Greller 1980) (Figure 1). The southern mixed hardwood forest of north Florida comprises a diverse mix of deciduous hardwoods, such as beech (*Fagus grandifolia*), hickory (*Carya* spp.) and oaks (*Quercus falcata*, *Q. alba*, etc.); broad-leaved evergreens, such as southern magnolia (*Magnolia grandiflora*) and live oak (*Quercus virginiana*); and needle-leaved evergreens, such as spruce pine (*Pinus glabra*) and loblolly pine (*P. taeda*). This north Florida community is typical of the southern mixed hardwood forest found throughout the southeastern coastal plain, and is considered the most species-rich community in North America by some researchers (Platt and Schwartz 1990, Wolfe 1990). North Florida hammocks are classified as upland hardwood or mixed forest by FNAI (FNAI and FDNR 1990) and have been researched and described by a number of authors (Monk 1960, 1965, 1967; Genelle and Fleming 1978, Mohlenbrock 1976, HDR 1987, Wolfe 1990, Daubenmire 1990, Platt and Schwartz 1990).

Tropical forests, or hammocks, of South Florida are also highly diverse, containing a high percentage of species whose centers of distribution lie in tropical latitudes. These forests contain tropical tree species such as tamarind (*Lysiloma latisiliquum*), lancewood (*Ocotea coriacea*), gumbo-limbo (*Bursera simaruba*), poisonwood (*Metopium toxiferum*), wild lime (*Zanthoxylum fagara*), mahogany (*Swietenia mahogoni*), and black ironwood (*Krugiodendron ferreum*). They also have a high component of tropical shrubs, such as wild coffee (*Psychotria nervosa*), marlberry (*Ardisia escallonioides*), myrsine (*Myrsine floridana*), and stoppers (*Eugenia* spp.). Temperate canopy species such as live oak, hackberry (*Celtis laevigata*), and cabbage palm (*Sabal palmetto*) also occur in tropical hardwood hammocks.

Mesic temperate hammock in the South Florida Ecosystem occupies something of a “tension zone” (Schwartz 1988) between these two distinctive



***Vegetation Codes**: SHF=Southern Hardwood Forest; TBEF=Temperate Broad-leaved Evergreen Forest; TRF= Tropical Rain Forest.*
***Sites:** 1. Florida Caverns State Park (Jackson County); 2. Apalachicola River Bluffs (Liberty, Gadsden Counties); 3. Woodyard & Titi Hammocks (Leon County, FL; Thomas County GA); 4. San Felasco Hammock (Alachua County); 5. Goldhead Branch State Park (Clay County); 6. Mud Lake, Ocala National Forest (Marion & Lake Counties); 7. Pineola Grotto (Citrus County); 8. Welaka Reserve (Putnam County); 9. Anastasia Island State Creek Preserve (Polk County); 10. St. Marks Wildlife Refuge (Wakulla County); 11. Tiger Creek Preserve (Polk County); 12. Highlands Hammock State Park (Highlands County); 13. Alafia River Hammocks (Hillsborough County); 14. Little Salt Spring, Northport, Mayakka River State Park (Charlotte & Sarasota Counties); 15. Highlander Hammock (Pinellas County); 16. Turtle Mound (Volusia County); 17. Everglades National Park (Monroe and Miami-Dade counties)*

Figure 1. Hammock vegetation zones of Florida. Modified after Greller (1980) and cited in Myers and Ewel (1990).

forest types. In this "tension zone," lying roughly south of Orlando to just south of Lake Okeechobee, species diversity is significantly lower than in either northern or tropical forests (Schwartz 1988). Although mesic temperate hammocks in the South Florida Ecosystem frequently contain species found in both northern and tropical forests, they are generally less species rich than either of these forests. Species diversity is higher at the northern boundary of the South Florida Ecosystem, where more northern species are present (Bridges and Reese 1996), and at the temperate-tropical boundary, where as much as 70 percent of the species are of tropical affinity (Cox 1988).

Mesic temperate hammock has been distinguished from tropical forests or hammocks on the basis of an overall percentage of tropical species, with tropical forests having more than 70 to 80 percent tropical species (Cox 1988, Austin *et al*. 1977), or on the basis of percent canopy dominants (G. Gann, Institute for Regional conservation, personal communication 1998). Greller (1980) maps the temperate-tropical transition as occurring across a zone south of Lake Okeechobee and extending narrowly up the Atlantic coast to just north of Cape Canaveral; tropical forest predominates from Miami-Dade County south. Mesic temperate hammock is found in every county within the South Florida Ecosystem except perhaps for Monroe (G. Gann, Institute for Regional Conservation, personal communication 1998). Mesic temperate hammocks have been described as far south as Big Cypress National Preserve in Collier County (Duever *et al*. 1979) and as far north in the South Florida Ecosystem as Upper Lakes Basin Watershed in Osceola and Polk counties (Bridges and Reese 1996). Mesic temperate hammocks that occur north of the South Florida Ecosystem are not discussed in this review.

Description

Mesic temperate hammocks are closed canopy forests, dominated by evergreen tree species of temperate affinities, primarily live oak and cabbage palms, that are naturally protected from fire because of their position in the landscape. Soils in mesic temperate hammocks remain moist due to shading and dense leaf litter, but they are rarely inundated. Mesic temperate hammocks are found primarily in four topographic positions in the South Florida Ecosystem: (1) as "islands" in a pine-cypress-or graminoid-dominated community, also known as prairie hammock (FNAI and FDNR 1990); (2) as "islands" on elevated areas within floodplain wetlands, (3) on levees of rivers, and (4) midslope or ecotonal between xeric communities and low-lying wetland communities.

Mesic temperate hammock occurs as prairie hammock "islands" on slight elevations within the relatively flat terrain of central and South Florida (FNAI and FDNR 1990). In Okeechobee and Glades counties, they occur as "islands" in dry prairies composed of saw palmetto and graminoid species (FNAI 1995, Hilsenbeck and Hedges 1994). In Big Cypress National Preserve, at the southern extent of this community in Florida, hammocks develop on limestone outcroppings within graminoid marsh or open cypress forest (Snyder *et al*. 1990, Duever *et al*. 1979). Mesic temperate hammock "islands" also develop on elevated areas within hydric hammocks, as in the Upper Lakes Basin Watershed in Polk and Osceola counties (Bridges and Reese 1996). Mesic

temperate hammock occurs in extensive bands along historical floodplain boundaries in the Kissimmee River Valley and also on elevated ridges and knolls within the floodplain (Milleson *et al*. 1980). It also exists as an ecotonal community, transitional between xeric uplands, such as scrub and high pine, and wetland communities such as hydric hammock, wet flatwoods, floodplain forest, or baygall. Examples of this hammock type occur at Highlands Hammock SP (P. Anderson, DEP, personal communication 1998) and Avon Park AFR (Orzell 1997). In each of these landscape positions, mesic temperate hammock occupies somewhat better drained soils than surrounding or adjacent wetland communities, although dense litter accumulation and a closed canopy maintain relatively high soil moisture conditions at most times.

Vegetative Structure and Composition

Mesic temperate hammock is characterized in South Florida by a closed canopy of hardwood species, primarily live oak and cabbage palm, and by a fairly open shrub layer and a sparse, species-poor herb layer. Herb diversity is frequently higher among epiphytes than among ground layer species. Table 1 contains lists of dominant and characteristic species found in mesic temperate hammocks at 15 sites in the South Florida Ecosystem.

Canopy tree dominants are relatively constant in mesic temperate hammocks throughout the South Florida Ecosystem. Live oak and cabbage palm are consistently present, and are joined by water oak (*Quercus nigra*), laurel oak (*Q. laurifolia*), hackberry (*Celtis laevigata*), red maple (*Acer rubrum*), and other temperate hardwoods at many sites. Hammocks at the northern boundary of the South Florida Ecosystem are more diverse and may contain species such as pignut hickory (*Carya glabra*), sweet gum (*Liquidambar styraciflua*), and southern magnolia (*Magnolia grandiflora*) that do not occur further south (Bridges and Reese 1996). Hammocks at the border of the tropical zone often contain tropical species such as strangler fig (*Ficus aurea*) and trema (*Trema micrantha*) (Austin *et al*. 1977, Cox 1988).

Although canopy composition is relatively constant in mesic temperate hammock throughout its range in Florida, shrub species composition is variable across the range of this community within South Florida. A unifying factor is the presence of at least some shrub species considered tropical in even the most northern locations within the South Florida Ecosystem (Bridges and Reese 1996). Tropical shrub species found in hammocks throughout South Florida include wild coffee (*Psychotria nervosa* and *P. sulzneri*), marlberry (*Ardisia escallonioides*), and myrsine (*Myrsine floridana*). The dense, closed canopy of the hammock protects such tropical species from freezing temperatures. Observers of mesic temperate hammocks in South Florida have commented on the low species diversity of the herb layer, while simultaneously noting the abundance of epiphytes (Harshberger 1914, Harper 1927). Epiphytes include orchids (*Encyclia tampensis, Epidendrum conopseum, E. anceps, Harrisella filiformis*), ferns *(Vittaria lineata, Polypodium polypodioides, Phlebodium aureum, Cheiroglossa palmata*), and bromeliads (*Tillandsia setacea, T. utriculata, T. usneoides, T. fasciculata,* and *T. flexuosa*.)

Table 1. Vegetative Composition of Selected Mesic Temperate Hammocks in South Florida .

Location	Position	Canopy/Subcanopy	Shrubs and Vines	Herbs and Epiphytes
Tiger Creek Preserve, Polk County (FNAI 1982)	floodplain ecotone	*Quercus virginiana, Sabal palmetto, Liquidambar styraciflua, Q. nigra, Q. laurifolia, Morus rubra, Persea sp.*	*Rhododendron viscosum, Callicarpa americana, Asimina parviflora, Psychotria nervosa*	*Cyperus tetragonus, Panicum joori, Thelypteris sp., Habeneria odontopetala, Scleria triglomerata, Mitchella repens*
Upper Lakes Basin Watershed, Polk and Osceola counties (Bridges and Reese 1996)	wetlands ecotone and "islands" in hydric hammocks	*Quercus virginiana, Q. nigra, Q. laurifolia, Sabal palmetto, Pinus elliottii, Acer rubrum, Carya glabra, Liquidambar styraciflua, Magnolia grandiflora, Celtis laevigata, Persea palustris, Zanthoxylum clava-herculis*	*Serenoa repens, Illicium parviflorum, Vitis rotundifolia, Rhododendron viscosum, Vaccinium corymbosum, Lyonia ferruginea, Decumaria barbara, Ilex cassine, Magnolia virginiana, Ardisia escallonioides, Myrica cerifera, Myrsine floridana, Rhapidophyllum hystrix, Callicarpa americana, Citrus aurantium, Toxicodendron radicans, Chiococca alba, Hamelia patens, Rhamnus caroliniana*	*Solidago leavenworthii, Osmunda cinnamomea, Dichanthelium spp., Diodia virginianum, Epidendrum conopseum, Mitchella repens, Polypodium polypodioides, Tillandsia spp., Woodwardia virginica, Bidens bipinnata, Callisia repens, Iresine diffusa, Pharus lappulaceus*
Avon Park Air Force Range, Polk and Highlands counties (Orzell 1997)	transitional to floodplain	*Quercus virginiana, Quercus laurifolia, Sabal palmetto, Acer rubrum*	*Ardisia escallonioides, Psychotria sulzneri, Serenoa repens, Sida acuta, Hypericum hypericoides, Cornus foemina, Myrsine floridana, Gelsemium sempervirens, Parthenocissus quinquefolia, Smilax bona-nox, Ampelopsis arborea, Mikania cordifolia, Toxicodendron radicans*	*Dichanthelium spp., Oplismenus setarius, Carex longii, Rhynchospora caduca, Scleria triglomerata, Mitchella repens, Centella erecta*
Highlands Hammock State Park, Highlands County (Stalter *et al.* 1981)	transitional to floodplain	*Quercus virginiana, Quercus laurifolia, Sabal palmetto, Acer rubrum, Carya glabra, Morus rubra, Celtis laevigata, Liquidambar styraciflua, Persea borbonia*		
Kissimmee Prairie Preserve, Okeechobee County (FNAI 1995 *op.cit.*, Hilsenbeck and Hedges 1994)	"islands" in dry prairie and levee of Kissimmee River	*Quercus virginiana, Sabal palmetto, Persea sp., Pinus elliottii*		*Epidendrum conopseum, Encyclia tampensis, Phlebodium aureum, Polypodium polypodioides, Tillandsia usneoides*
Kissimmee River Valley, Polk, Osceola, Highlands, Okeechobee counties (Milleson *et al.* 1980)	levees, floodplain ridges	*Quercus nigra, Q. virginiana, Sabal palmetto*	*Serenoa repens, Rubus cuneifolia, Smilax sp., Vitis rotundifolia*	*Blechnum serrulatum, grasses, Phlebodium aureum*
Three Lakes WMA, Osceola County (FDNR 1979)	edge of floodplain, "islands" in prairies	*Quercus virginiana, Q, hemisphaerica, Sabal palmetto, Celtis laevigata, Ulmus americana*	*Serenoa repens*	

Table 1. Vegetative Composition of Selected Mesic Temperate Hammocks in South Florida .

Location	Position	Canopy/Subcanopy	Shrubs and Vines	Herbs and Epiphytes
Cypress Creek CARL proposal, St. Lucie County (FNAI 1996a)	elevated areas within hydric hammock	*Sabal palmetto, Quercus laurifolia, Q. virginiana, Morus rubra*	*Serenoa repens, Psychotria nervosa, P. sulzneri, Eugenia axillaris, Ardisia escallonioides, Myrcianthes fragrans, Myrsine floridana*	*Campyloneurum phyllitides*
Myakka River State Park, Sarasota and Manatee counties (Huffman and Judd 1998)	Elevated areas within floodplain, "islands" in flatwoods and dry prairies	*Quercus virginiana, Q. laurifolia, Sabal palmetto, Prunus caroliniana, Morus rubra, Carya glabra*	*Callicarpa americana, Myrsine floridana, Ardisia escallonioides, Campsis radicans, Toxicodendron radicans, Parthenocissus quinquefolia, Cornus foemina, Vitis rotundifolia, Vaccinium arboreum, V. elliottii, Viburnum nudum, Sabal minor*	*Ruellia caroliniensis, Arisaema triphyllum, Carex stipata, Apios americana, Tillandsia setacea, T. usneoides, T. fasciculata, T. recurvata, T. utriculata*
Babcock-Webb WMA/Hall Ranch, Charlotte County (GFC 1997a *op.cit.*, FNAI 1996b)	"islands" in wet flatwoods, edge of stream	*Sabal palmetto, Pinus elliottii, Ulmus floridana, Acer rubrum, Quercus virginiana, Q. nigra*	*Serenoa repens, Callicarpa americana, Psychotria sulzneri, P. nervosa, Sideroxylon sp., Toxicodendron radicans, Smilax sp.*	*Axonopus sp., Vittaria lineata, Phlebodium aureum*
Barley Barber Indian Mound, Martin County (Cox 1988)	Indian mound	*Diospyros virginiana, Ficus aurea, Morus rubra, Persea sp., Quercus virginiana, Q. laurifolia, Sabal palmetto*	*Baccharis sp., Myrsine floridana, Psychotria sulzneri, Erythrina herbacea, Ilex cassine, Schinus terebinthifolius, Serenoa repens*	*Rivina humilis*
J.W. Corbett WMA, Palm Beach County (GFC 1997b, Cox 1988)	knolls within hydric hammock	*Sabal palmetto, Acer rubrum, Quercus laurifolia, Persea sp.*	*Lyonia fruticosa, L. lucida, Baccharis sp., Myrica cerifera, Myrsine floridana, Eugenia spp., Serenoa repens, Zanthoxylum fagara, Psychotria nervosa*	
Hickory Forge-Clavel Ranch, DeSoto County (Peter NeSmith, Water & Air, personal communication 1998)	lee sides of depression marshes	*Quercus virginiana, Sabal palmetto, Pinus elliottii, Celtis laevigata*	*Psychotria nervosa, Rivina humilis, Citrus spp.*	*Vittaria lineata, Phlebodium aureum, Epidendrum conopseum, Encyclia tampensis*
Butts Hammock (low hammock portion), Palm Beach County (Austin *et al*. 1977)	limestone ridge in wetlands	*Chrysophyllum oliviforme, Diospyros virginiana, Ficus aurea, Morus rubra, Pinus elliottii, Quercus virginiana, Sabal palmetto, Trema micrantha*	*Baccharis halimifolia, Lyonia fruticosa, Rhus copallina, Serenoa repens, Ampelopsis arborea, Ipomoea alba, Melothria pendula, Mikania scandens, Parthenocissus quinquefolia, Sarcostemma clausa, Smilax bona-nox, Toxicodendron radicans, Vitis rotundifolia, V. shuttleworthii*	*Phyla nodiflora, Trichostema suffrutescens, Verbesina virginica, Phlebodium aureum, Psilotum nudum, Pteridium aquilinum, Thelypteris kunthii, Tillandsia balbisiana, T. fasciculata, T. recurvata, T. utriculata*

Table 1. Vegetative Composition of Selected Mesic Temperate Hammocks in South Florida .

Location	Position	Canopy/Subcanopy	Shrubs and Vines	Herbs and Epiphytes
Del Ray Oaks, Palm Beach County (Steve Farnsworth, Palm Beach County, Department of Environmental Resources Management; Iverson and Austin 1988)	"island" in wet prairie	*Quercus virginiana, Morus rubra, Celtis laevigata, Ficus aurea, Ocotea coriacea, Sabal palmetto, Persea sp.*	*Psychotria nervosa, Ardisia escallonioides, Ilex cassine, Chiococca alba, Myrica cerifera, Chrysobalanus icaco, Myrsine floridana, Serenoa repens, Vitis rotundifolia, Toxicodendron radicans, Passiflora suberosa, Parthenocissus quinquefolia*	*Blechnum serrulatum, Nephrolepis cordifolia, Psilotum nudum, Euthamnia tenuifolius, Oplismenus hirtellus, Vittaria lineata, Polypodium polypodioides, Tillandsia spp., Phlebodium aureum, Habenaria odontopetala, Galactia elliottii, Campyloneurum phyllitides*
Kendall Indian Hammock, Dade County (G. Gann, Institute for Regional Conservation, personal communication 1998)	Indian mound (sand)	*Quercus virginiana, Q. laurifolia, Ficus aurea, Sabal palmetto, Coccoloba diversifolia, Morus rubra, Diospyros virginiana, Persea palustris, Zanthoxylum fagara*	*Myrsine floridana, Psychotria sulzneri, P. nervosa, Trema micrantha, Vitis rotundifolia*	*Dichanthelium commutatum, Oplismenus hirtellus, Rivina humilis, Phlebodium aureum, Polypodium polypodioides, Tillandsia fasciculata, T. utriculata*

Because mesic temperate hammocks develop naturally in the absence of fire, they share some species with oak hammocks that are the result of anthropogenic fire suppression. Oak hammocks may develop at old home or camp sites that were protected from fire; more frequently, hammocks invade pyric communities such as pine flatwoods or dry prairie that have been fire-suppressed for long periods, eventually fire-proofing the area. Such anthropogenic oak hammocks generally have a depauperate shrub layer or may have a dense, nearly monospecific understory of saw palmetto (*Serenoa repens*).

Wildlife Diversity

Mesic temperate hammocks provide food, cover, roosting, and nesting sites to a wide variety of wildlife species. An abundance of hardwood mast makes mesic hammocks attractive to many birds and mammals. Mature trees and snags provide good roosting and nesting sites. Mesic hammocks that occur as "islands" in wetland communities provide refuge for wildlife during wet conditions. Mesic hammocks provide resting cover and foraging habitat for a large number of passerines during migration. Animal species typically found in mesic temperate hammocks are listed below.

Mammals that utilize mesic temperate hammock include: short-tailed shrew (*Blarina brevicauda*), eastern mole (*Scalopus aquaticus*), eastern gray squirrel (*Sciurus caroliniensis*), eastern wood rat (*Neotoma floridana*), armadillo (*Dasypus novemcinctus*), cotton mouse (*Peromyscus gossypinus*), white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), bobcat (*Lynx rufus*), grey fox (*Urocyon cinereoargenteus*), opossum (*Didelphis marsupialis*), seminole bat (*Lasiurus borealis*), eastern yellow bat (*L. intermedius*), flying squirrel (*Glaucomys volans*), and Florida weasel (*Mustela frenata peninsulae*).

This community also provides habitat to birds. Woodcock (*Scolopax minor*), Coopers hawk (*Accipiter cooperii*), short-tailed hawk (*Buteo brachyurus*), barred owl (*Strix varia*), barn owl (*Tyto alba*), great horned owl (*Bubo virginianus*), screech owl (*Otus asio*), vultures (*Cathartes aura, Coragyps atratus*), red-bellied woodpecker (*Melanerpes carolinus*), pileated woodpecker (*Dryocopus pileatus*), turkey (*Meleagris gallopavo*), blue jay (*Cyanocitta cristata*), flycatchers (Tyrannidae), northern cardinal (*Cardinalis cardinalis*), black-and-white warbler (*Mniotilta varia*), northern parula (*Parula americana*), yellow-throated warbler (*Dendroica dominica*), ovenbird (*Seiurus aurocapillus*), carolina wren (*Thryothorus ludovicianus*), brown thrasher (*Toxostoma rufum*), hermit thrush (*Catharus guttatus*), and ruby-crowned kinglet (*Regulus calendula*).

Reptiles that inhabit mesic temperate hammock include: Florida box turtle (*Terrapene carolina bauri*), southeastern five-lined skink (*Eumeces inexpectatus*), eastern glass lizard (*Ophisaurus ventralis*), fence lizard (*Sceloporus undulatus undulatus*), green anole (*Anolis carolinensis*), ground skink (*Seincella lateralis*), mole skink (*Eumeces egregius onocrepis*), Florida worm lizard (*Rhineura floridana*), barking treefrog (*Hyla gratiosa*), eastern spadefoot toad (*Scelophus holbrooki holbrooki*), southern toad (*Bufo terrestris*), squirrel treefrog (*Hyla squirrella*), green treefrog (*Hyla cinerea*),

Florida kingsnake (*Lampropeltis getulus floridana*), eastern hognose snake (*Heterodon platyrhinos*), ringneck snake (*Diadophis punctatus punctatus*), corn snake (*Elaphe guttata guttata*), Florida red-bellied snake (*Storeria occipitomaculata*), southern black racer *(Coluber constrictor priapus*), yellow rat snake (*Elaphe obsoleta quadrivittata*), rough green snake (*Opheodrys aestivus*), eastern coral snake (*Micrurus fulvius fulvius*), and pygmy rattlesnake (*Sistrurus miliarius barbouri*).

Wildlife Species of Concern

Federally listed species that depend upon or utilize the mesic temperate hammock in South Florida include: Florida panther (*Puma (=Felis) concolor coryi*), Key deer (*Odocoileus virginianus clavium*), eastern indigo snake (*Drymarchon corais couperi*), Kirtland's warbler (*Dendroica kirtlandii*), bald eagle (*Haliaeetus leucocephalus*), Bachman's warbler (*Vermivora bachmanii*), and Audubon's crested caracara (*Polyborus plancus audubonii*). The ivory-billed woodpecker (*Campephilus principalis*) is identified in literature as having occurred in the Highlands Hammock State Park (Robertson and Wolfenden 1992). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. Mesic temperate hammock is also important for State listed species, and other species of concern that require a diversity of forested habitats for cover, food, roosting, or nesting (Appendix C).

Florida panthers have been found in almost all South Florida communities, including mesic temperate hammocks (Humphrey 1992). Primary prey for Florida panther, white-tailed deer and feral pigs, are abundant in mesic hammocks. Panther habitat has been severely decreased by increased urbanization and agricultural expansion into its habitats; however, panthers may persist where forested areas, such as mesic hammocks, exist in a mosaic of agricultural lands. A mix of forested and cleared lands seems to benefit white-tailed deer and feral hogs, the main components of Florida panther diet. The Florida panther is classified as endangered by FCREPA, GFC, and FWS. It is ranked as G5T1 (globally imperiled) by FNAI (1997b).

Florida black bear (*Ursus americanus floridanus*) use a wide variety of forested habitats, including cabbage palm hammocks and mixed hardwood forests, such as mesic temperate hammocks (Humphrey 1992). These habitats are especially important to black bear if contiguous with large tracts of forested wetlands. Forested communities provide cover, nesting habitat, and food. Primary constituents of the black bear diet include berries, hearts of saw palmetto and cabbage palm, and acorns, which are found in abundance in most mesic hammocks. Acorns, in particular, are critical to breeding success of black bear (Humphrey 1992). FNAI (1997b) lists Florida black bear as G5T2 and S2 (both state and globally imperiled). FCREPA and GFC list Florida black bear as threatened. Long-term conservation of this species depends on the preservation of large tracts of forest.

Big Cypress fox squirrel (*Sciurus niger avicennia*) is found south of the Caloosahatchee River and west of the Everglades, a distribution reflected in the recently adopted common name. It uses most forest types within its range, including oak hammocks (Humphrey 1992). Although slash pine and cypress cones are preferred food items, cabbage palm fruits, bromeliad buds, and acorns are included in its diet. This species builds its nests in the tops of cabbage palms and in large clumps of bromeliads, as well as in pines, hardwoods, and cypress. FNAI (1997b) lists Big Cypress fox squirrel as G5T2 and S2 (both state and globally imperiled). FCREPA and GFC list it as threatened. Long-term conservation of this species depends on the preservation of forests from development and clearing.

Florida weasel (*Mustela frenata peninsulae*) is endemic to central peninsular Florida, including areas north and west of Lake Okeechobee, and may be the state's rarest carnivore (Humphrey 1992). Weasels use a wide variety of habitats, including scrub, high pine, pond swamp, pine flatwood, tropical hardwood hammock. It is likely they are found in mesic temperate hammocks. FNAI (1997b) lists Florida weasel as G5T3 and S3? (both state and globally rare or vulnerable). FCREPA classifies Florida weasel as a species of special concern. Little is known about the habitat requirements of this rare species, but habitat loss and fragmentation are assumed to be detrimental (Humphrey 1992)

Sherman's short-tailed shrew (*Blarina carolinensis shermani*) has not been observed since 1955 (Humphrey 1992), but specimens have been taken from mesic hammock (K. NeSmith, FNAI, personal communication 1998). It has one of the most restricted ranges of any Florida mammal, and is considered very rare, possibly extirpated. FNAI (1997b) ranks Sherman's short-tailed shrew as G5T1 and S1 (imperiled globally and statewide). GFC lists it as a species of special concern. FCREPA states that its status is undetermined (Humphrey 1992).

Swallow-tailed kites (*Elanoides forficatus*) require a diverse mix of habitats for foraging including mesic hammocks. They usually nest and roost in tall pine or cypress trees in relatively open stands in a mosaic of woodland-prairie habitats. Habitat for swallow-tailed kite is rapidly disappearing (Rodgers *et al*. 1996). Swallow-tailed kite is not listed by State or Federal agencies, although FCREPA classifies this species as threatened. FNAI (1997) ranks it as G4 (globally secure) and S2/S3 (possibly imperiled or rare, restricted, or vulnerable to extinction in Florida).

Eastern indigo snake is found in a variety of habitats in South Florida ranging from mangrove swamps to xeric uplands, and including mesic temperate hammocks. The eastern indigo snake is listed as threatened by FWS and GFC and is ranked by FNAI as G4T3 and S3 (rare, local, or vulnerable to extinction globally and statewide). The eastern indigo snake requires large tracts of land for its survival and is threatened primarily by the fragmentation and loss of habitat (Moler 1992). It is also exploited for the pet trade.

Plant Species of Concern

Mesic temperate hammocks support relatively few species of rare, threatened, or endangered plants, compared to other South Florida communities.



***Tillandsia flexuosa* (twisted air plant).** *Original photograph by E.D. Hardin.*

Auricled spleenwort (*Asplenium auritum*) is an epiphytic fern, endemic to Florida, found on large trees in mesic hammocks in eight central and South Florida counties (FNAI 1997a, Coile 1998). It is one of the "resurrection ferns" that persist through drought with curled, desiccated leaves that green and expand on exposure to moisture. Auricled spleenwort is listed as endangered by Florida Department of Agriculture and Consumer Services (FDACS) (Coile 1998); it has no Federal status. FNAI (1997b) ranks this species as G5 (globally secure) and S2 (imperiled in Florida). Auricled spleenwort is endangered due to clearing of its habitat for agriculture and development.

Twisted air plant (*Tillandsia flexuosa*) is an epiphytic bromeliad that grows on trees in mesic and xeric hammocks, rockland hammocks, shell mounds, coastal berms, maritime hammock, mangroves, swamps, and scrub (FNAI 1997a, Coile 1998). Twisted air plant is not listed by the FWS, but is listed as endangered by FDACS (Coile 1998). FNAI (1997b) ranks twisted air plant as G4 (apparently globally secure) and S3 (rare, local, or vulnerable to extinction). It is found in 10 South Florida counties, and in the West Indies, Panama, and South America (Coile 1998). Twisted air plant forms a rosette of gray, white-banded, twisted leaves, supporting a twisted, zigzag flowering stem. Twisted air plant is threatened by clearing of its habitat for agriculture and residential development.

Florida Keys (=Green) ladies' tresses (*Spiranthes polyantha*) is an inconspicuous, terrestrial orchid found in six widely scattered central and South Florida counties, where it occurs in mesic and xeric hardwood forests over limestone, and in Mexico and the Caribbean (Luer 1972, Coile 1998). Florida Keys ladies' tresses is listed as endangered by FDACS, but currently has no Federal status. FNAI (1997b) ranked this species G3G5, indicating that there is insufficient data for assigning a definite global rank, and has assigned a State

rank of S1S2, indicating imperilment within the State. Green ladies' tresses is vulnerable to extirpation because of widespread clearing of forests for agriculture and urbanization.

Hand fern (*Cheiroglossa palmata*) is an evergreen, epiphytic fern that inhabits the leaf bases of cabbage palm in mesic, hydric, and maritime hammocks. The fern's rhizome is embedded in the detritus that collects within the persistent petiole bases. Hand fern has no Federal status, but is listed by FDACS as threatened (Coile 1998). The species is ranked by FNAI (1997b) as G5 (globally secure) and S2 (imperiled in Florida). It is known or reported from 18 counties in central and South Florida (FNAI 1997a, Wunderlin *et al*. 1996). Hand fern is threatened by overcollection by fern hobbyists and commercial wholesalers, and by clearing and development of its habitat. Fire is also detrimental to hand fern; although cabbage palm is fire adapted and rarely perishes in fire, the petiole bases can be burned away, destroying the substrate of this species.

Peperomia (*Peperomia humilis*) is a small succulent herb, terrestrial or epiphytic, found throughout central and South Florida and the West Indies (Coile 1998). It is listed as endangered by FDACS; it has no Federal status. FNAI ranks this species as G5 (globally secure) and S2 (imperiled in Florida). Peperomia is endangered due to clearing of its habitat for agriculture and development.

Tropical curly grass (*Schizaea germanii*) is a small terrestrial fern, growing in decaying litter or on stumps in mesic and other hammocks in three central and South Florida counties (including Loxahatchee NWR), the West Indies, and Central and South America (Coile 1998). Tropical curly grass is listed as endangered by FDACS (as *Schizaea germanii*); it has no Federal status. FNAI ranks this species as G4G5 (globally secure) and S1 (critically imperiled in Florida). Tropical curly grass is endangered due to clearing of its habitat for agriculture and development.

Yellow star anise (*Illicium parviflorum*) is an evergreen shrub with small yellow flowers, aromatic leaves, and distinctive anise-like fruits. It is narrowly endemic to central Florida, where it occurs primarily in hammocks along spring-run streams. It also occurs in the two northernmost counties of the South Florida Ecosystem, where it is known from a few mesic hammocks (Bridges and Reese 1996). Yellow star anise currently has no Federal status, but is listed as endangered by FDACS (Coile 1998), and as globally and state-imperiled (G2) by FNAI (FNAI 1998). Yellow star anise is negatively impacted by changes in hydrology, removal of the overstory species through logging or other clearing, and is subject to collection as a landscape species. Yellow star anise is not adapted to frequent fire, but will re-sprout following low-intensity, surface fires. If fire is frequent or hot enough to burn into the top layers of duff, buds buried in the duff will be killed and the plants will not survive.

Yellow hibiscus (*Pavonia spinifex*) is a small, shrubby, summer- and fall-flowering perennial in the Malvaceae family found in seven central Florida counties. Only two occurrences, in Polk and Highlands counties, are documented in the South Florida area; both of these collections were made

prior to 1965. Yellow hibiscus is found in mesic, maritime, and hydric hammock, shell mounds, and in shaded disturbed areas along the coast. This species has neither Federal or State listing status; it is ranked by FNAI as G4G5 (globally secure) and S2S3 (imperiled or rare). Yellow hibiscus had a wide historical range but there are few recent collections. This species is also reported from Bermuda, the West Indies, and continental tropical America. Yellow hibiscus is vulnerable to extirpation by disturbance or competition from exotic species. It is not fire-adapted and is killed by fire.

Ecology

Succession

Although numerous studies have been conducted in the southeastern coastal plain in order to discern patterns of species replacement in mixed hardwood forests, there is considerable doubt regarding the role of succession in these communities. Studies suggest instead that a complex interplay of natural disturbances maintains hammocks in a state of nonequilibrium. The type of disturbance that is most prevalent–wind, fire, flooding–may determine the floristic composition of hardwood hammocks (Platt and Schwartz 1990). However, hammocks have been considered by many researchers to be the climax community of South Florida (Davis 1943, Craighead 1971, Alexander and Crook 1973, Ward 1979). The dominant tree species in mesic temperate hammock, live oak and cabbage palm, are considered to be the pioneer species, which, once established, provide conditions favorable to the establishment of other shade-tolerant mesic hammock species. Occasional hard frosts may topkill tropical species in hammocks, but most are capable of resprouting from root stock or upper limbs. Occasional low-intensity fire favors the perpetuation of live oak and cabbage palm, both relatively fire-resistant species. Catastrophic fire, particularly if it burns into the duff layer, may alter the species composition by killing roots and preventing resprouting. In this event, species dominance in a hammock will shift toward those species with readily available seed sources.

Fire

Mesic hammocks rarely burn although the dominant canopy species–live oak and cabbage palm–are fire-adapted species. Mesic hammocks are protected from fire in several ways. They frequently develop in landscape positions, such as around lakes and sinkholes and in river corridors, that are naturally protected from fire. They may develop on raised positions–limestone outcrops, Indian mounds–within frequently burned marshes and wet prairies where a lack of fuel and moist leaf litter deter fire. In the Big Cypress, mesic hammocks develop on limestone outcrops and are protected from fire by moat-like troughs that develop by solution of the underlying bedrock. They may also develop midslope where upland fires tend to extinguish naturally when they encounter the humid conditions within the hardwood forest. Conditions within the hammocks–dense leaf litter, high moisture levels in the litter layer, and higher

humidity–tend to make the community fire-resistant. Although similar in some respects to anthropogenic, fire-suppressed oak hammocks, mesic hammocks are recognizable on aerial photographs from the 1940s, before the era of extensive fire suppression, on the lee sides of depressional wetlands and along streams (Belinda Perry, DEP, Division of Recreation and Parks, personal communication 1998).

Mesic temperate hammocks burn infrequently as a result of fire entering from adjacent fire-maintained communities. Infrequent, low-intensity fire is not detrimental to mesic hammocks; however, catastrophic fires, burning through in times of drought, may completely destroy some hammocks, which may then be invaded by weedy and exotic species (Alexander and Crook 1973). In the Big Cypress, hammock vegetation may re-establish within 25 years following a catastrophic fire, although it is believed that the natural fire cycle within the Big Cypress hammocks exceeds 50 years (Duever *et al*. 1979).

Tree species composition within mesic hammocks is determined to some extent by the frequency and intensity of fire; more frequent and hotter fires will favor live oak and cabbage palm (Vince *et al*. 1989) over more fire-sensitive species such as hackberry (*Celtis laevigata*) and red maple (*Acer rubrum*). Spatial extent of mesic hammock is also affected by frequency and intensity of fires in surrounding and adjacent natural community types. Most mesic hammocks share at least one boundary with a fire-maintained community, such as marsh, pine flatwoods, or dry prairie. In the prolonged absence of fire in these communities, a species-depauperate version of mesic hammock will expand into the adjacent community, potentially rendering it impervious to fire. Mesic hammocks that develop as the result of fire suppression and invasion into pyric communities usually contain species associated with the invaded community, such as saw palmetto or slash pine (*Pinus elliottii*).

Soils

Soil plays at least as important a role as fire in determining the development of mesic hammocks in the central Florida hammock belt (Wolfe 1990, Harper 1921). Although data are lacking for the relationship between soil and fire in South Florida hammocks, it seems likely that the same interrelationship described by Wolfe (1990) for Gulf coast hammocks prevails in the formation of mesic temperate hammocks in the South Florida Ecosystem: where fire protection is complete, mesic hammock will develop regardless of soil type; where soils are fertile, mesic hammock will persist in the presence of fire. Hammocks have been observed to follow soil types rather than natural firebreaks (Harper 1921) and to show ample evidence of past fires (Vince *et al*. 1989). Mesic temperate hammocks in South Florida frequently develop on soils with limestone, marl, or other alkaline material near the surface or directly beneath the subsoil (Duever *et al*. 1979, Huffman and Judd 1998, SWCS 1989).

Hydrology

Mesic hammocks frequently occur on ridges or knolls in a wetland matrix or adjacent to floodplain wetlands. They are therefore vulnerable to alterations in the natural hydrologic regime of the surrounding or adjacent wetland.

Unnatural fluctuations in streamflow, artificially elevated high-water levels, and prolonged hydroperiods may weaken or kill some mesic hammock tree species as well as destroy adjacent wetland communities. An artificially lowered water table may lead to development of another community type or render a mesic hammock vulnerable to catastrophic fire.

Status and Trends

Mesic temperate hammocks, because they occur on well-drained sites, have long been considered ideal home and recreation sites. They have also been heavily logged. As a result, most of Florida's mesic hammocks have been destroyed or exist only as fragments (Austin *et al*. 1977, The Florida Conservation Foundation, Inc. 1989). Relatively intact hammocks remain in State and federally managed areas, but these are also subject to a number of destructive anthropogenic influences.

Exotic Species

As with many of South Florida's natural communities, the natural species diversity and composition in mesic temperate hammocks is threatened by the encroachment of exotic plant species. Exotic species compete with native plant species, including rare and endangered species, for light and nutrients and may completely overwhelm and eliminate entire vegetative strata within a plant community. Florida's Exotic Pest Plant Council (EPPC 1997) has identified the most invasive plant species in Florida, many of which occur in mesic hammocks. Category I species, those that are currently invading native plant communities, that have been observed in mesic temperate hammocks include air potato (*Dioscorea bulbifera*), coral ardisia (*Ardisia crenata*), Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), rosary pea (*Abrus precatorius*), guava (*Psidium guajava*), Japanese climbing fern (*Lygodium japonicum*), punk tree (*Melaleuca quinquenervia*), and tropical soda apple (*Solanum viarum*). Category II species, which have shown a potential to invade and disrupt native plant communities, have also been observed in mesic hammocks. These include caesar weed (*Urena lobata*), bowstring hemp (*Sanseviera hyacinthoides*), shrubby nightshade (*Solanum diphyllum*), tongue tree (*Albizzia lebbeck*), and wedelia (*Wedelia trilobata*). A complete list of exotic plant species in this community is contained in Appendix E.

Feral hogs are common in mesic hammocks, where they feed on acorns in the fall and winter or on roots and seedlings in other seasons. Feral hogs pose a threat to native species such as turkey, white-tailed deer, and Florida black bear by intensely competing for mast, particularly during a year of mast failure. Their consumption of acorns, roots, and seedlings interferes with natural regeneration of trees and shrubs. Rooting by hogs severely disturbs soil structure and creates conditions that encourage exotic plant invasion.

Many mesic temperate hammocks on private lands and on public lands that are leased for cattle ranching are degraded by cattle grazing and trampling. As

increasing numbers of acres of native grassland and prairie are converted to pasture, patches of mesic hammock within these larger communities are subject to degradation by cows. Grazing and trampling destroys soil structure, promotes erosion, eliminates native shrub and herb species, girdles and kills saplings, and opens up the hammock to invasion by exotic plants. Cattle also compete with native browsers for food.

Loss of Ecological Connectedness to Adjacent and Surrounding Communities

Mesic temperate hammocks have frequently been isolated from the surrounding prairie, grassland, or marsh by the construction of roads or firebreaks in ecotones. Fire suppression in adjacent communities has led to the invasion of some mesic hammock tree species, usually live oak, into surrounding prairie or grassland, thus destroying the natural ecotone between the two communities. Disruption of natural hydrological regimes by draining or ditching or by excessive pumping of ground water has lowered the water table and shifted species composition in some hammocks toward xeric hammock composition. Dewatering of mesic hammocks has also led to destructive fires (Alexander and Crook 1973).

Excessive Recreational Uses

Mesic temperate hammocks have been favored by hunters, campers, and homesteaders for many years because of their cool, shady conditions. Large areas are cleared of understory vegetation to create hunt camps. Prolonged and frequent use of a hammock for a camp site has adverse effects on understory species and leads to the introduction of exotic species. Negative impacts to wildlife species viewed as pests, such as snakes, raccoons, and opossum, also occur (Duever *et al.* 1979). Mesic hammocks have also been degraded by off-road vehicle use which destroys vegetation and promotes rutting and soil displacement.

Management

Because of its transitional landscape position, generally small area, and low numbers of rare species, mesic temperate hammock has seldom been targeted for restoration. However, this community benefits from efforts to restore natural fire regimes in xeric uplands and hydrological regimes in river corridors and wetlands (refer to these specific community accounts, *i.e.*, scrub, high pine, and forested wetlands, for specific management recommendations). In addition, efforts to ameliorate the impacts of grazing on public lands and to eradicate exotic species have also benefitted mesic hammocks. Conservation land acquisition in Florida has focused on preserving ecosystems, such as Kissimmee Prairie or Big Cypress National Preserve, that often encompass mesic hammock as an ecotone or inclusion and has therefore succeeded in preserving some high-quality examples of mesic temperate hammock. Other protected and managed lands containing mesic temperate hammocks are given in Table 1. Because mesic hammock generally occurs in small, included patches or as ecotones, landscape-level approaches to conservation such as land acquisition, landowner agreements, and conservation easements are needed to preserve this community and its relationships with surrounding communities.

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Wunderlin, R.P., B.F. Hansen, E.L. Bridges. 1996. Atlas of Florida Vascular Plants, CD-ROM. Institute for Systematic Botany, University of South Florida; Tampa, Florida. Table 1. Vegetative Composition of Selected Mesic Temperate Hammocks in South Florida.

Restoration of Mesic Temperate Hammock

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

Restoration Criteria

Given that mesic temperate hammocks 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.

Mesic temperate hammock may be considered restored when: (1) intact mesic temperate hammocks are protected from further degradation; (2) the effects of disturbance in degraded hammocks are reversed by active management; (3) ecological linkages to adjacent communities are restored and preserved; (4) management can insure the persistence in the wild of species that use mesic temperate hammocks as habitat; (5) invasive exotic species are reduced to non-threatening levels; and (6) landscape-level habitat diversity is restored.

Community–level Restoration Actions

1. **Protect intact mesic temperate hammocks from further degradation.** Recognizing that mesic temperate hammocks occur on the landscape either as included or ecotonal communities, it is critical to protect intact hammocks from both direct impacts and from indirect effects associated with degradation of the surrounding or adjacent communities. The primary tool for protecting mesic hammocks is therefore landscape-level approaches to conservation such as land acquisition, landowner agreements, and conservation easements. These activities will preserve the interrelationship of mesic hammocks with adjacent natural communities, as well as provide opportunities for better control of direct impacts, such as grazing, exotics invasion, vehicle use, and development. Enforcement of laws and regulations concerning trespassing, over-grazing, and wetlands conversion can also be used to protect mesic temperate hammocks on both public and private lands.

2. **Restore existing degraded mesic temperate hammocks by active management.**

    2.1. **Restore ecosystem function.**

        2.1.1. **Exclude livestock from mesic temperate hammocks.** Grazing and trampling by cattle destroy the herb and shrub layers in mesic hammocks and have long-term consequences for species composition of the canopy. Exclusion of cattle will allow a natural understory to develop.

2.1.2. **Eliminate or control exotic species.** Mesic temperate hammocks, especially if grazed or otherwise heavily disturbed, are highly vulnerable to invasion by exotic plant species, which compete with native species, particularly in the shrub and herb layers. Repeated and frequent hand removal of most exotic plant species will be necessary to completely eliminate these populations from hammocks. Mesic temperate hammocks are also preferred by feral hogs for their abundant mast crops and plant roots and tubers. Hog rooting heavily impacts the soils and vegetation in hammocks and promotes invasion by non-native species. Because of the popularity of hog hunting, it is unlikely that complete eradication of this species will be politically feasible on State or Federal lands open to hunting. A reduction in the numbers of feral hogs is recommended on such lands; complete eradication is recommended on other lands.

2.1.3. **Restore natural hydrological regimes to adjacent and surrounding wetlands.** Altered hydrology in adjacent or surrounding hydric hammocks, wet flatwoods, and floodplain impacts mesic hammocks. Unnaturally elevated high-water levels and prolonged hydroperiods may weaken or kill some mesic hammock tree species as well as destroy adjacent wetland communities. An artificially lowered water table may lead to development of another community type or render a mesic hammock vulnerable to catastrophic fire.

2.1.4. **Restore natural fire regimes in surrounding or adjacent communities, allowing fire to enter hammocks and extinguish naturally.** This effort will result in the restoration of natural ecotones between mesic hammocks and the surrounding communities, and prevent encroachment by hammock species into adjacent prairies and flatwoods. Fire breaks and roads should be placed well away from mesic hammock ecotones. Ecotones that have been degraded by existing roads and fire breaks should be restored. Infrequent, low-intensity fire is appropriate to mesic hammocks; management plans should specifically include allowing both natural and prescribed fires to burn into mesic temperate hammock.

2.1.5. **Control public use.** Some mesic temperate hammocks have been degraded by off-road vehicle use, housing construction, or extended or repeated use as camp sites. Exclusion of these uses on public lands will promote restoration of the understory in mesic hammocks. Signs and fences may be necessary to discourage off-road vehicle use. Concentration of recreational impacts on public lands to a single area of hammock will allow other, off-limit mesic hammocks to recover.

2.1.6. **Eliminate sources of pollution to hammocks.**

2.2. **Restore native species to ground and shrub layers.** The reintroduction of native species, particularly shrub and herb species, is recommended for mesic hammocks that have been heavily grazed or trampled.

3. **Maintain mesic temperate hammocks in a natural condition.**

3.1. **Continue exclusion or eradication of exotic plants and animals, including hogs and cattle.**

3.2. Monitor status of native plant and animal species for negative trends and potential extirpations.

3.3. Maintain natural fire regimes in surrounding and adjacent pyric natural communities.

3.4. Monitor hydrologic conditions in adjacent and surrounding communities and correct unnatural fluctuations in water levels and hydroperiods.

3.5. Maintain limits and controls on human use.

3.6. Monitor and correct for point source and non-point source pollution.

4. **Research ecological role of mesic temperate hammock.** Mesic temperate hammocks have received very little attention from the scientific community. Their contribution to overall landscape diversity is poorly understood. The importance of this community for providing habitat for threatened and endangered species, particularly animals, has not been studied. These and other issues should be examined.

5. **Provide educational materials to public and private land managers on the ecological importance of mesic temperate hammocks and on management needs and issues.**

Tropical Hardwood Hammock

FNAI Global Rank:	**Undetermined**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**9**
State Listed Species in S. FL:	**186**

Tropical hardwood hammock. *Original photograph by Jim Duquesnel.*



Tropical hardwood hammocks are found nearly throughout the southern half of South Florida, with large concentrations in Miami-Dade County on the Miami Rock Ridge, in Miami-Dade and Monroe counties in the Florida Keys and along the northern shores of Florida Bay, and in the Pinecrest region of the Big Cypress Swamp. Tropical hardwood hammocks are closed canopy forests, dominated by a diverse assemblage of evergreen and semi-deciduous tree and shrub species, mostly of West Indian origin. They are not fire maintained communities, although fire may burn into tropical hardwood hammocks under certain conditions. Tropical hardwood hammocks are habitat for a few endemic plants, and are critical habitat for many West Indian plant species when the northernmost portions of their ranges extend into South Florida. Tropical hardwood hammocks also provide important habitat for many species of wildlife, including nine federally listed species. While the majority of the remaining tropical hardwood hammocks outside the Florida Keys have now been acquired, hammocks are still significantly threatened by development in the Keys. Tropical hardwood hammocks have been heavily impacted by outright destruction, conversion to agriculture, exotic plant and animal species, collecting pressure on plants and animals, anthropogenic fires, and alterations in hydrology. Significant work has now been initiated to restore existing disturbed tropical hardwood hammocks and to control exotic plant species. Numerous opportunities also exist to create or maintain tropical hardwood hammocks within the developed landscape.

Synonymy

The following terms have been applied in whole or in part to the plant communities of South Florida that are included in this account of tropical hardwood hammock: coastal berm, coastal rock barren, rockland hammock, sinkhole, shell mound (FNAI and Florida Department of Natural

Resources 1990); 422-other hardwood forest (Florida Department of Administration 1976); tropical hammock (Soil and Water Conservation Service 1989); tropical rockland hammock (Snyder *et al*. 1990); hammock forest (Duever *et al*. 1979); coastal strand forest (Ross *et al*. 1992); coastal berm, coastal rock barren (Kruer 1992); fan palm hammock, madeira hammock, buttonwood hammock (Olmsted *et al.* 1981); tropical hammock (Ward 1979); buttonwood hammock, madeira hammock (Craighead 1971); hammock forest, Everglades tree island (Davis 1943), banana hole, high hammock, low hammock (Harshberger 1914). In the Bahamas, analogous communities include coastal rock communities, coastal coppice, whiteland, and blackland (Correll and Correll 1982). The FLUCCS codes included in the tropical hardwood hammocks are: 422 (Brazilian pepper), 426 (tropical hardwoods), and 433 (western Everglades hardwoods).

Distribution

Tropical hardwood hammocks are found nearly throughout the southern half of South Florida, with large concentrations in Miami-Dade County on the Miami Rock Ridge, in Miami-Dade and Monroe counties in the Florida Keys and along the northern shores of Florida Bay, and in the Pinecrest region of the Big Cypress Swamp (Figure 1). Analogous communities are also found in the Bahamas and the Greater Antilles (Robertson 1955). Most maritime hammocks on barrier islands in South Florida are similar to this community. Large areas of tropical hardwood hammocks are still found in Everglades NP and Biscayne NP in Miami-Dade County, throughout the Florida Keys in Monroe County, and in Big Cypress National Preserve in Collier County. Tropical hardwood hammocks also persist in small preserves along the Atlantic coastal strip from Miami-Dade County north to Martin County.

Description

Tropical hardwood hammock is a closed canopy forest, dominated by a diverse assemblage of evergreen and semi-deciduous tree and shrub species, mostly of West Indian origin. It is also important habitat for ferns and orchids of West Indian origin. Tropical hardwood hammock is not a fire maintained community, although fire may burn into tropical hardwood hammocks under certain conditions. Soils in tropical hardwood hammocks are primarily composed of organic material which has accumulated directly on top of mineral substrate, and are moist, but rarely inundated.

Tropical hardwood hammocks have been described and/or classified by a number of authors (*e.g.* Harshberger 1914, Small 1929, Davis 1943, Craighead 1971, Craighead 1974, Duever *et al.* 1979, Snyder *et al.* 1990, Ross *et al.* 1992). At least five major types of hammocks can be described here: (1) rockland hammock “islands” on limestone substrate in or on the edges of pine rockland or marl prairie communities on the Miami Rock Ridge and in Big Cypress National Preserve; (2) Keys rockland hammock on limestone substrate making up the dominant forest type in the Florida Keys; (3) coastal berm hammock on storm-deposited berms in the Sand Keys (west of Key West), the Florida Keys, and along the northern shores of Florida Bay; (4) tree island

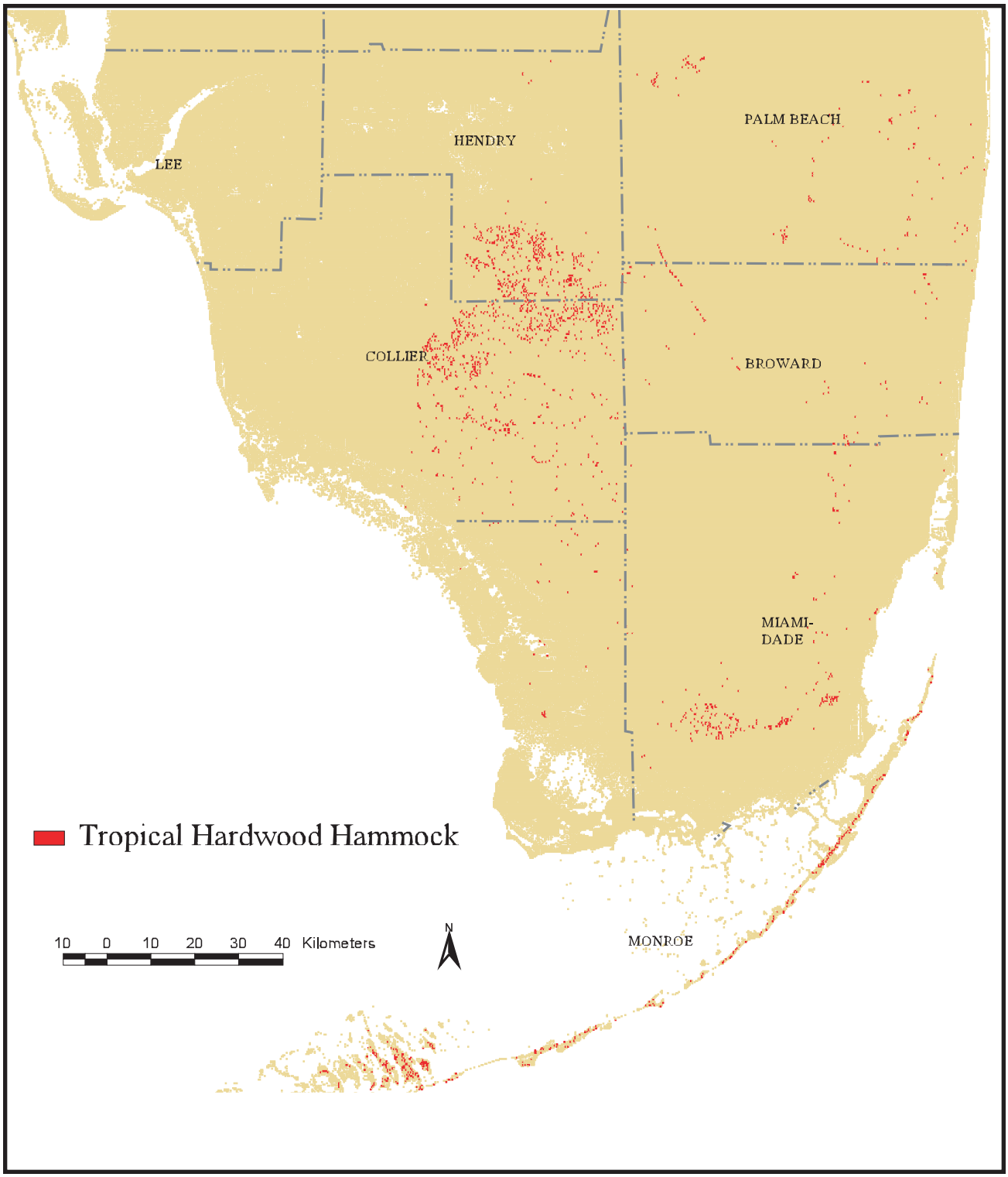


Figure 1. The distribution of tropical hardwood hammocks in South Florida (adapted from USGS-BRD 1996).

hammock in the Everglades marsh and surrounding marl prairie and rocky glades; and, (5) shell mound hammock on aboriginal sites. Tropical hardwood hammocks here also include the more open coastal rock barren and sinkhole communities as classified by the Florida Natural Areas Inventory (FNAI and Florida Department of Natural Resources 1990). Coastal rock barren is a rare community occurring in tiny patches in the Florida Keys (FNAI and Florida Department of Natural Resources 1990). Sinkholes are found in areas of karst limestone, primarily in hammocks on the Miami Rock Ridge.

Vegetative Structure and Composition

Tropical hardwood hammock is characterized by a diverse, closed canopy of hardwood species, primarily of West Indian origin, and by a fairly open shrub layer and a sparse, species-poor herb layer. Hammock composition changes over space, and hammocks in different regions (*e.g.*, the Miami Rock Ridge versus the Florida Keys) are composed of different species. Snyder *et al.* (1990) recorded over 150 species of tree and shrub species that were native to tropical hardwood hammocks in South Florida. Kruer (1992) noted differences in plant community composition and dominant species between lower Keys and upper Keys hammocks.

Tropical hardwood hammocks are habitat for a few endemic vascular plants. South Florida endemics limited in their distribution to tropical hardwood hammocks are Biscayne spleenwort (*Asplenium* x *biscayneanum*) and Ames' halbard fern (*Tectaria* x *amesiana*)--both epipetric hybrid ferns endemic to the Miami Rock Ridge, and Keys indigo (*Indigofera mucronata* var. *keyensis*)--an endemic herb which is found along hammock edges and in coastal rock barrens. South Florida endemics found in tropical hardwood hammocks in addition to other communities include Blodgett's wild-mercury (*Argythamnia bodgettii*)--found in hammock gaps, false leadplant (*Dalea carthagenense* var. *floridana*)--found along hammock edges, and *Chromolaena frustrata*--which is found along hammock edges and in coastal rock barrens.

While few plant species are endemic to tropical hardwood hammocks, hammocks are critical habitat for West Indian species where the northernmost portions of their ranges extend into South Florida. Plants with their entire United States distribution in South Florida, and which are limited to tropical hardwood hammock habitats include Bahama strongback (*Bourreria succulenta*), buccaneer palm (*Pseudophoenix sargentii*), crabwood (*Gymnanthes lucida*), Florida boxwood (*Schaefferia frutescens*), Florida oncidium (*Oncidium floridanum*), ghostplant (*Leiphiamos parasitica*), green thatch palm (*Thrinax radiata*), Key's nutrush (*Scleria lithosperma*), Key's tree cactus (*Pilosocereus robinii*), Krug's holly (*Ilex krugiana*), least halberd fern (*Tectaria fimbriata*), lignum vitae (*Guajacum sanctum*), mahogany mistletoe (*Phoradendron rubrum*), manchineel (*Hippomane mancinella*), milkbark (*Drypetes diversifolia*), pearlberry (*Vallesia antillana*), princewood (*Exostema caribaea*), red stopper (*Eugenia rhombea*), slender spleenwort (*Asplenium dentatum*), spicewood (*Calyptranthes pallens*), West Indian cherry (*Prunus myrtifolia*), West Indian mahagony (*Swietenia mahagoni*), wild cinnamon (*Canella winterana*), wild dilly (*Manilkara jaimiqui* ssp. *emarginata*), and wild-tamarind (*Lysiloma latilisiliquum*).

The canopy height of tropical hardwood hammocks varies according to substrate and climate. On the Miami Rock Ridge, a mature hammock will have a closed canopy at 18 m (59 ft) or less, while those on the Florida Keys have a canopy 9 to 12 m (30 to 39 ft) tall (Snyder *et al.* 1990). Typical canopy species of tropical hardwood hammocks include gumbo-limbo (*Bursera simaruba*), paradise tree (*Simarouba glauca*), pigeon-plum (*Coccoloba diversifolia*), strangler fig (*Ficus aurea*), wild mastic (*Sideroxylon foetidissimum*), and willow-bustic (*Sideroxylon salicifolium*). Although a temperate species, live oak (*Quercus virginiana*) can be found in or on the margins of many tropical hardwood hammocks outside of the Florida Keys. Other canopy trees include short-leaf fig (*Ficus citrifolia*) and wild-tamarind--both mostly associated with rockland hammocks, West Indian mahogany--which naturally occurs in the northern Florida Keys and in hammocks along the northern shores of Florida Bay, and Gulf licaria (*Licaria triandra*)--a tropical species historically known only from a small area near downtown Miami. Some epiphytes also occur in the hammock canopy, including Spanish-moss (*Tillandsia usneoides*) and ball-moss (*T. recurvata*).

Common subcanopy and understory trees and shrubs include black ironwood (*Krugiodendron ferreum*), inkwood (*Exothea paniculata*), lancewood (*Ocotea coriacea*), marlberry (*Ardisia escallonoides*), poisonwood (*Metopium toxiferum*), satinleaf (*Chrysophyllum oliviforme*), and white stopper (*Eugenia axillaris*). Additional rockland hammock species include crabwood and spicewood. Coastal hammocks typically include Jamaica-dogwood (*Piscidia piscipula*), saffron-plum (*Sideroxylon celastrinum*), Spanish stopper (*Eugenia foetida*), and sea-grape (*Coccoloba diversifolia*). Buttonwood (*Conocarpus erecta*) can often be found in hammocks along the interface with mangrove swamps and salt marshes. In the Florida Keys and along the northern shores of Florida Bay, additional subcanopy and understory species include Bahama strongbark (*Bourreria succulenta*), beeftree (*Guapira discolor*), darling-plum (*Reynosia septentrionalis*), Florida boxwood, green thatch palm, Jamaica caper (*Capparis cynophallophora*), Key's tree cactus, lignum-vitae, limber caper (*Capparis flexuosa*), manchineel, mayten (*Maytenus phyllanthoides*), milkbark, pearlberry, princewood, red stopper, torchwood (*Amyris elemifera*), and wild dilly. Species associated with aboriginal activity include red mulberry (*Morus rubra*) and soapberry (*Sapindus saponaria*), and those associated with wet areas in hammocks (such as sinkholes) include coco-plum (*Chrysobalanus icaco*), hackberry (*Celtis laevigata*), and pond-apple (*Annona glabra*). Several species, including Krug's holly, and West Indian cherry are limited in distribution to tropical hardwood hammocks on the Miami Rock Ridge. Subcanopy and understory species with extremely limited distributions include: bitterbush (*Picramnia pentandra*)--occuring only in coastal hammocks on the Miami Rock Ridge; Bahama tree cactus (*Pilosocereus bahamensis*), cinnecord (*Acacia choriophylla*) and soldierwood (*Colubrina elliptica*)--found only in the upper Florida Keys; and cupania (*Cupania glabra*), maidenbush (*Savia bahamensis*), and rough strongback (*Bourreria radula*)--found only in the lower Florida Keys. Vines often associated with the hammock subcanopy include pull-and-hold-back (*Pisonia aculeata*), *Tournefortia hirsutissima*, and *T. volubilis*. Epiphytes found in the sub-canopy and understory include Florida peperomia (*Peperomia obtusifolia*)

and resurrection fern (*Polypodium polypodioides*). In the lower portions of the understory, especially in wetter areas, epiphytes such as strap-leaved guzmania (*Guzmania monostachya*) and soft-leaved tillandsia (*Tillandsia variabilis*), can also be found.

The tropical hardwood hammock shrub and herb layer is sparse, mostly consisting of seedlings and saplings of canopy and subcanopy trees and shrubs. However, shiny-leaf wild-coffee (*Psychotria nervosa*) is not infrequently found in this layer, as well as herbs such as rouge plant (*Rivina humilis*), and false mint (*Dicliptera sexangularis*). Two species of native grasses can also be frequently found in this layer: bamboo grass (*Lasciasis divaricata*), and woods grass (*Oplismenus hirtellus*). Historically on the mainland, a variety of ferns and terrestrial orchids could be found, including Boston fern (*Nephrolepis exaltata*), Florida oncidium, and sword fern (*Nephrolepis biserrata*). Additional species from rockland hammocks include ghostplant, and Key's nutrush. Shrub and herb layer species with very limited distributions include helmet orchid (*Galeandra beyrichii*), and small-flowered orchid (*Prescottia oligantha*)--found only on the Miami Rock Ridge, and seashore ageratum (*Ageratum littorale*), and limestone flatsedge (*Cyperus fuligineus*)--found only in the Florida Keys.

The walls of sinkholes in hammocks are either bare or covered by mosses, liverworts, and ferns.

The vascular flora is dominated by obligate epipetric plants, that is, plants that grow only on the surfaces of rocks. Typical species growing on the walls of sinkholes include brittle maidenhair fern (*Adiantum tenerum*), broad halberd fern (*Tectaria heracleifolia*), creeping fern (*Thelypteris reptans*), least halberd fern, and slender spleenwort. Ferns with limited distributions include delicate spleenwort (*Asplenium verecundum*), fragrant maidenhair fern (*Adiantum melanoleucum*), holly fern (*Lomariopsis kunzeana*), and Kraus' filmy fern (*Trichomanes krausii*)--all with South Florida distributions limited to the Miami Rock Ridge. On the edges of sinkholes, other species such as Costa Rican ladies-tresses (*Spiranthes costaricensis*) can be found. When conditions are appropriate, wetland trees, such as pond-apple and coco-plum, may be found growing out of the bottom or walls of sinkholes.

One of the most important ecotonal communities associated with tropical hardwood hammocks is the hammock edge where it interfaces with pine rockland, buttonwood wetlands, marl prairie, or other communities. The edges of hammocks are floristically very important, and many tropical hardwood hammock species are limited to these ecotones (although they may be found in other communities such as pine rocklands, or in hammock gaps following disturbance). Common trees and shrubs include American beautyberry (*Callicarpa americana*), coco-plum, common snowberry (*Chiococca alba*), coralbean (*Erythrina herbacea*), firebush (*Hamelia patens*), Florida trema (*Trema micrantha*), myrsine (*Rapanea punctata*), rough velvetseed (*Guettarda scabra*), and white indigoberry (*Randia aculeata*). In coastal areas, hammock edge species include blackbead (*Pithecellobium keyense*) and limber caper (*Capparis flexuosa*). Trees and shrubs with limited distributions include Cuban colubrina (*Colubrina cubensis* var. *floridana*), hammock lantana (*Lantana*

canescens), Mexican alvaradoa (*Alvaradoa amorphoides*), shrub eupatorium (*Koanophyllon villosum*), and West Indian lilac (*Tetrazygia bicolor*)--all with South Florida distributions limited to the Miami Rock Ridge, and Keys hopbush (*Dodonaea elaeagnoides*)--which is limited to the Florida Keys. Vines associated with hammock edges include muscadine grape (*Vitis rotundifolia*), and greenbrier (*Smilax auriculata*). Vines with limited distributions include Havana clustervine (*Jacquemontia havanensis*)--which is limited to the Florida Keys. Hammock edges are also extremely important habitat for epiphytes. Typical species include common wild-pine (*Tillandsia fasciculata*), giant wild-pine (*Tillandsia utriculata*), reflexed wild pine (*Tillandsia balbisiana*), and twisted wild pine (*Tillandsia flexuosa*). Herbs commonly associated with hammock edges include woods fern (*Thelypteris kunthii*), and pine fern (*Anemia adiantifolia*).

Hammock gaps, similar to, but substantially different from hammock edges are also important to hammock dynamics. Historically, hammock gaps were typically created by storm events, including hurricanes, which allowed pioneer species to invade openings in the hammock canopy. Pioneer species associated with hammock disturbance include trees, shrubs, and herbs such as common nightshade (*Solanum americanum*), firebush, potatowood (*Solanum erianthum*), rougeplant (*Rivina humilis*), and wood fern (*Dryopteris ludoviciana*), as well as vines such as muscadine grape, and greenbrier. Vines with limited distributions associated with gaps include *Passiflora multiflora*, *Passiflora sexflora*, and *Rhynchosia swartzii*.

Coastal rock barrens are composed of two distinct subcommunities (Kruer 1992). Upland coastal rock barrens are openings on flat rocklands with sparse, mostly low-growing xeric plants and exposed limestone (Kruer 1992). Typical shrubs and herbs of upland coastal rock barren include barbwire cactus (*Acanthocereus tetragonas*), Key's indigo, Key's jumping cactus (*Opuntia triacanthos*), limestone flatsedge, prickly-pear (*Opuntia stricta*), sky-blue morning glory (*Jacquemontia pentanthos*), blue porterweed (*Stachytarpheta jamaicensis*), and yellow hibiscus (*Cienfuegosia yucatanensis*). Wetland coastal rock barrens are influenced by spring high tides and are dominated by common wetland plants, and coastal shrubs such as low-growing buttonwood (*Conocarpus erectus*), bay-cedar (*Suriana maritima*), and less common species such as sea-lavender (*Argusia gnaphalodes*).

Soils, Hydrology, and Climate

Tropical hardwood hammock occurs on limestone, sand, and shell substrates which are moist, and usually do not flood. Hammocks on limestone substrates, however, are dependent on the underlying water table to keep humidity levels high, especially in limestone sinkholes. Mesic conditions are developed by a combination of the hammock's rounded profile and nearly impenetrable edges, which deflect wind and limit the effects of desiccation. The dense canopy minimizes temperature fluctuations by reducing soil warming during the day and heat loss during the night.

Rockland hammocks are found on elevated outcrops of limestone, often in association with limestone sinkholes. Coastal berm hammocks are found on ridges of storm-deposited marine debris, usually within mangrove or salt marsh

communities. In the Keys these hammocks also occur fronting open water areas. Shell mound hammocks are found on elevated mounds of mollusk shells and aboriginal garbage on which a hardwood, closed canopy forest has developed. Coastal rock barrens are found on flat rocky surfaces either immediately adjacent to the coast or within the interior of islands in the Florida Keys. Sinkholes are cylindrical or conical depressions with steep limestone walls, found in karst rockland areas. Soils, when they exist, consist of calcareous marls and organic debris on the surface, within solution depressions, and in crevices in limestone. The organic layer, composed mostly of duff, ranges from between 12 to 15 cm (5 to 6 in) thick on Long Pine Key (Olmsted *et al.* 1983).

Elevations on the Miami Rock Ridge vary from greater than 7 m (23 ft) above sea level in the vicinity of Biscayne Bay to less than 2 m (6.5 ft) above sea level in the Long Pine Key area of Everglades NP, with an average elevation of approximately 3 m (10 ft), and varying in width from 6 to 16 km (4 to 10 miles) (Davis 1943, USDA 1947, DERM 1995). Elevations of the limestone formations in the Keys are significantly lower, from 1 to 2 m (6.5 ft) above sea level. However, high elevations of 4 to 5 m (13 to 16 ft) above sea level are found in Key West and Lignumvitae Key (Snyder *et al.* 1990).

Rainfall in southeastern Florida averages from over 163 cm (64 inches) annually in the northwest portion of Miami-Dade County to between 122 and 142 cm (48 to 56 inches) annually in the rest of the county. Mean rainfall in the upper Florida Keys is 127 cm (50 inches), and in the lower Keys is about 102 cm (40 inches). The majority of this precipitation (75 percent) occurs between June and October. Rainfall generally percolates quickly through the soil, maintaining fresh water or low salinity "lenses" below many hammocks.

Wildlife Diversity

Except for some birds and bats, most vertebrate animal species found in tropical hardwood hammocks are temperate in origin (Snyder *et al.* 1990). While plant species can be transported by birds, waves, or wind from the Caribbean, most animal species have to travel to South Florida by land, and a land bridge has never connected South Florida with the Caribbean. Tropical hardwood hammocks provide food, cover, roosting, and nesting sites to a wide variety of wildlife species. Vertebrate animal species typically found in tropical hardwood hammocks are found in Table 1. Fifteen species of vertebrates are endemic to South Florida rocklands (Snyder *et al.* 1990), and many of these utilize tropical hardwood hammocks as habitat. Ten of these are mammals and five are reptiles. There are no endemic birds found in tropical hardwood hammocks.

It has been noted that rockland habitats, including tropical hardwood hammocks, contain a lower diversity and abundance of wildlife than similar habitats to the north (Robertson and Kushlan 1984). An analysis of habitats in the Big Cypress (Duever *et. al.* 1979) showed hammocks to be "surprisingly unimportant to animals." They point out that while hammocks are refuges for a very diverse flora, the factors which influence this biodiversity may reduce the potential diversity of wildlife. Factors which may limit faunal diversity of

hammocks include their small size and common proximity to deep water areas which reduce frequency of wildfires. Other factors which are believed to contribute to the depauperate fauna of tropical hardwood hammocks include habitat disturbance by humans and the "peninsula effect" (Snyder *et. al.* 1990). Hammocks are, however, noted to be critical habitat to many species during flood conditions (Duever *et. al.* 1979).

Florida Keys and Miami Rock Ridge hammocks are important for a number of West Indian land birds including the mangrove cuckoo (*Cocczyus minor),* the black-whiskered vireo (*Vireo atiloquus),* and the white-crowned pigeon (*Columba leucocephala)* (Snyder *et al.* 1990). Gray kingbirds (*Tyrannus dominicensis)* and smooth billed anis (*Crotophaga ani)* are also present, and the Key West quail dove (*Geotrygon chrysia*) and the Zenaida dove (*Zenaida aurita*) are reportedly historic breeders in the Florida Keys (Robertson and Woolfenden 1992).

Robertson and Kushlan (1984) report breeding bird densities in tropical hardwood hammocks of 5 to 13.5 species, and between 14 and 125.5 breeding birds per hectare. The most common included cardinal (*Cardinalis cardinalis),* red-bellied woodpecker (*Melanerpes carolinus),* pine warbler (*Dendroica pinus),* white-eyed vireo (*Vireo griseus),* great crested flycatcher (*Myiarchus crinitus),* carolina wren (*Thryothorus ludovicianus),* and blue jay (*Cyanocitta cristata)* on the mainland, and black whiskered vireo and great crested flycatcher in the Florida Keys.

Dalrymple (1988) reports 24 species of reptiles and amphibians collected in traps in pine rocklands on Long Pine Key. Among the most common species collected were brown anole (*Anolis sagrei*), eastern narrow mouthed toad (*Gastrophryne carolininsis*), greenhouse frog (*Eleutherodactylus planirostris*), southeastern five-lined skink (*Eumeces inexpectatus*), southern leopard frog (*Rana sphenocephala*), and southern toad (*Bufo terrestris*).

Invertebrate species found in tropical hardwood hammocks include ants, moths, skippers and butterflies, and land snails. These species are both temperate and tropical in origin. Other indigenous invertebrates include banded tree snail (*Orthalicus floridensis*), crablike spiny orb weaver (*Gasteracantha cancriformis*), Florida tree snail (*Liguus fasciatus*), giant orb weaver (*Nephila clavipes*), many-lined drymaeus (*Drymaeus multilineatus*), and Stock Island tree snail (*O. reses reses*). Sinkholes provide habitat for relictual populations of many species that would be unable to survive in otherwise drier areas, including crayfish, isopods, and amphipods (FNAI and Florida Department of Natural Resources 1990).

Wildlife Species of Concern

Federally listed animals that depend upon or utilize tropical hardwood hammocks in South Florida include: Florida panther (*Puma (=Felis) concolor coryi*), Kirtland's warbler (*Dendroica kirtlandii*), eastern indigo snake (*Drymarchon corais couperi*), Key deer (*Odocoileus virginianus clavium*), Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*), Key Largo woodrat (*Neotoma floridana smallii*), Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*), and Stock Island tree snail (*Orthalicus reses*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

Hardwood hammocks in the Big Cypress region provide extremely important habitat for the Florida panther. The eastern indigo snake is found in tropical hardwood hammocks throughout South Florida, as well as other communities such as sandhill and scrub. The Key deer is restricted to pine rocklands and tropical hardwood hammocks on Big Pine Key. Both the Key Largo cotton mouse and the Key Largo woodrat are endemic to tropical hardwood hammocks on Key Largo in the upper Florida Keys. The Stock Island tree snail is historically known only from hammocks on Stock Island and Key West. The Schaus swallowtail butterfly is endemic to tropical hardwood hammocks from South Miami on the mainland to Lower Matecumbe Key in the middle Keys. It is dependent on tropical hardwood hammock trees torchwood (*Amyris elemifera*) and wild-lime (*Zanthoxylum fagara*) to deposit its eggs.

In addition, the following state listed animals are found in tropical hardwood hammocks: red rat snake (*Elaphe guttata guttata*), Florida Keys mole skink (*Eumeces egregius egregius*), Florida brown snake (*Storeria dekayi victa*), rim rock crowned snake (*Tantilla oolitica*), Florida ribbon snake (*Thamnophis sauritus sackeni*), Florida mastiff bat (*Eumops glaucinus floridanus*), Florida tree snail, and numerous species of birds (Appendix C).

The State endangered **Florida mastiff bat** is considered to be the largest bat in Florida (Humphrey 1992). Although the mastiff bat numbers are unknown, the species was once believed to be common on the Florida's east coast (Miami and Coral Gables) but has been reported there only once since 1967 (Humphrey 1992). Other than a single colony of eight individuals, no sightings have been reported on Florida's west coast. Although the Florida mastiff bat's favorite diurnal roosts may be under the shingles of Spanish tiles, they have also been found in the shafts of royal palm (*Roystonea regia*) leaves and in cavities created by red-cockaded woodpeckers (*Picoides borealis*) and enlarged by a pileated woodpecker (*Dryocopus pileatus*) (Humphrey 1992). Most of these animals were found in heavily forested areas. Tree cavities in South Florida are rare and, therefore, competition is fierce. Conservation actions should include preservation and enhancement of old growth tropical hardwood hammock communities that provide suitable nesting and roosting habitat for the Florida mastiff bat.

The **white-crowned pigeon** utilizes tropical hardwood hammocks in the Florida Keys as foraging habitat (Bancroft 1996). This species is important for seed dispersal in South Florida's ecosystem (Bancroft 1996, Bancroft *et al.* in press). It nests on isolated mangrove islands, and primarily feeds on fruits of tropical hardwood hammock trees such as poisonwood and figs (Snyder *et al.* 1990).

The **rim rock crowned snake** is currently listed as threatened by the State of Florida. These snakes can be found in sandy or rocky soils in slash pine (*Pinus elliottii* var. *densa*), deep humus of tropical hammocks, vacant lots, and pastures with shrubby growth and scattered slash pine (Moler 1992). The rim rock crowned snake is a cryptic species and a burrower. Due to the increasing developmental pressures that are occurring its range, it can be expected to decline as its habitat continues to be developed. If the rim rock crowned snake



Rim rock crowned snake. *Original photograph by Barry Mansell.*

is to survive, a natural complex of plants and invertebrates should be retained over a significant portion of its range. These snakes do not appear to tolerate severely modified habitat conditions (Moler 1992). Given this, environmental considerations must be incorporated into open space designs, public parks, and green belts along roadways and throughout low-density residential areas.

The **Florida tree snail** is found on a variety of native hammock trees including *Lysiloma* and *Ficus* (Deisler-Seno 1994). This endemic subspecies can be found from Big Pine Key to the mainland with populations extending north and west into portions of Palm Beach and Collier counties, respectively. The Florida tree snail is listed as a species of special concern with the State primarily due to the loss of its habitat. Some conservation activities have focused on the efforts of a few naturalists to relocate different varieties of the Florida tree snail to Everglades NP. Additional conservation measures can be made to enhance and preserve native habitat to promote the continued existence of the species without the necessity of being relocated.

Some extirpations of animals have occurred in tropical hardwood hammocks. For instance, ten *Liguus* tree snail varieties have been extirpated within their natural range as a result of human development and hurricanes (Jones *et. al.* 1981).

Other rare taxa reported from tropical hardwood hammocks include the Maesites hairstreak (*Chlorostrymon maesites maesites*), a small butterfly known from hammock edges on the Florida mainland where it has almost disappeared, the Keys scaly cricket (*Cycloptilum irregularis*), known only from hammocks on Plantation, Big Pine, and Sugarloaf keys, and the wide-banded forest snail (*Drymaeus multilineatus latizonatus*), known from hammocks on Lower Matecumbe, Long, and Lignumvitae keys (Franz 1982).

Plant Species of Concern

A federally listed plant species that depends upon or utilizes tropical hardwood hammocks in South Florida is the Key tree-cactus (*Pilosocereus (=Cereus) robinii*). A biological account and recovery tasks for this endemic species is included in "The Species" section of this recovery plan. There are over 170 species of tropical hardwood hammock plants that are species of concern (Appendix C). One such example is the endemic Florida filmy fern (*Trichomanes punctatum* ssp. *floridanum*), which is found only on the Miami Rock Ridge and the fern grottos of north-central Florida. Several state listed plants also utilize the tropical hardwood hammock community (Appendix C).

Some imperilled species are found only in hammocks and have more restricted ranges. Species of tropical hardwood hammocks which are found only in the Florida Keys and on the Miami Rock Ridge include trees and shrubs such as red stopper (*Eugenia rhombea*), and spicewood (*Calyptranthes pallens*), vines such as West Indian cock's comb (*Celosia nitida*) and yellow nicker (*Caesalpinia major*), and herbs such as ghost plant (*Leiphaimos parasitica*), and Key's nutrush (*Scleria lithosperma*). Trees and shrubs found only in the Florida Keys and along the northern shores of Florida Bay include: manchineel (*Hippomane mancinella*), mayten (*Maytenus phyllanthoides*), West Indian mahagony (*Swietenia mahogoni*), wild cinnamon (*Canella winteriana*), and wild dilly (*Manilkara jaimiqui*). Other species have limited but geographically diverse ranges. An example is myrtle-of-the-river (*Calyptranthes zuzygium*), found in hammocks in the upper Florida Keys, in a few scattered hammocks in the southern portion of the Miami Rock Ridge, and in a few hammocks near Flamingo in Everglades NP. Other species, such as joewood (*Jacquinia keyensis*) and inkwood (*Hypelate trifoliata*), are found primarily in hammocks in the Florida Keys, but are also found outside of that area in other communities (*e.g.*, pine rockland, maritime hammock, and Keys buttonwood wetlands).

Tropical hardwood hammocks of the Florida Keys include rockland hammocks, coastal berms, shell mounds, and coastal rock barrens. All of these hammocks are dominated by species of tropical origin, many of which are limited in their U.S. distribution to hammocks in the Florida Keys. While some West Indian species are relatively common in South Florida (*e.g.*, gumbo limbo and strangler fig), many of these species are extremely rare, and are listed as threatened or endangered by the State of Florida. Listed trees and shrubs limited in their U.S. distribution to tropical hardwood hammocks in the Florida Keys include Bahama tree cactus (*Pilosocereus bahamensis*), buccaneer palm (*Pseudophoenix sargentii*), cupania (*Cupania glabra*), darling-plum (*Reynosia septentrionalis*), West Indian false-box (*Gyminda latifolia*), Florida boxwood (*Schaefferia frutescens*), lignum vitae (*Guaiacum sanctum*), maidenbush (*Savia bahamensis*), milkbark (*Drypetes diversifolia*), princewood (*Exostema caribaeum*), redberry stopper (*Eugenia confusa*), rough strongback (*Baurreria radula*), soldierwood (*Colubrina elliptica*), yellowheart (*Zanthoxylum flavum*), and wild dilly. Listed hammock vines include Marsh's Dutchman's pipe (*Aristolochia pentandra*), white-flowered passionvine (*Passiflora multiflora)*, and Swartz' snoutbean (*Rhynchosia swartzii)*. Listed hammock herbs include seashore ageratum (*Ageratum littorale*) and limestone flatsedge (*Cyperus fuligineus*). Listed species found primarily in hammock edges include Havana clustervine

(*Jacquemontia havanensis*), and Keys hopbush (*Dodonaea elaeagnoides*). Listed herbs and low shrubs primarily associated with hammock edges and coastal rock barrens include *Chromalaena frustrata*, and yellow hibiscus (*Cienfuegosia yucatanensis*). Species associated with tidally influenced coastal rock barrens include sea-lavender (*Tournefortia gnaphalodes*). One state listed parasite, mahogany mistletoe (*Phoradendron rubrum*), is also known only from tropical hardwood hammocks on Key Largo. Where hammock edges grade into coastal marshes semaphore cactus (*Opuntia corallicola*) can be found.

Several species of plants native to Florida Keys hammocks are probably extirpated in the wild. These include herbs such as Key West heliotrope (*Heliotropium fruticosum*), known from the lower Florida Keys and last collected in 1978, Key West sage (*Salvia micrantha*), historically known from hammocks on Key West (Small 1933 as *S. blodgettii*), and *Tridens eragrostoides*, historically known from hammocks on Key West (Small 1913).

Miami Rock Ridge hammocks are habitat for a number of threatened and endangered plants. While there are no federally listed plant species in this region, a number of state listed endangered plants historically occurred in this area. Listed tree and shrub species limited in their United States distribution to Miami Rock Ridge hammocks include bitterbush (*Picramnia pentrandra*), Gulf licaria (*Licaria triandra*), Krug's holly (*Ilex krugiana*), and West Indian cherry (*Prunus myrtifolia*). Listed herbs include Costa Rican ladies-tresses (*Spiranthes costaricensis*), helmet orchid (*Galeandra beyrichii*), Florida oncidium (*Oncidium floridanum*), and small-flowered orchid (*Prescottia oligantha*). Epipetric plants include fragrant maidenhair fern (*Adiantum melanoleucum*), holly fern (*Lomariopsis kunzeana*), and least halberd fern (*Tectaria fimbriata*). Some rare species of Miami Rock Ridge hammock edges include Cuban colubrina (*Colubrina cubensis*), Mexican alvaradoa (*Alvaradoa amorphoides*), and Cape Sable thoroughwort (*Chromolaena frustrata*). The state listed vine *Passiflora sexflora* is primarily known from hammock gaps. Miami Rock Ridge hammocks are also important habitat for a number of listed epiphytic orchids, bromeliads, ferns, and peperomias found in the Big Cypress and other regions.

A number of extirpations have been recorded for plants native to tropical hardwood hammocks on the Miami Rock Ridge, including trees and shrubs such as balsam torchwood (*Amyris balsamifera*) and hammock groundsel (*Baccharis dioica*); vines such as Dillon's vanilla (*Vanilla dilloniana*) (Luer 1972) and velvety cissampelos (*Cissampelos pareira*); epiphytes such as clasping peperomia (*Peperomia amplexicaulis*), narrow-leaved strap fern (*Campyloneurum angustifolium*), spatulate peperomia (*Peperomia magnoliifolia*), spider orchid (*Brassia caudata*) (Snyder *et al.* 1990), and Trinidad macradenia (*Macradenia lutescens*) (Snyder *et al.* 1990); terrestrial herbs such as Gowen's orchid (*Govenia utriculata*) (C. McCartney, personal communication 1998), moss orchid (*Cranichis muscosa*)(Luer 1972), and young-palm orchid (*Tropidia polystachya*)(Hammer 1997); and, epipetric herbs such as Ames' halberd fern (Nauman 1986), Hattie Bauer halberd fern (*Tectaria coriandrifolia*)(Nauman 1986), and lined filmy fern (*Trichomanes lineolatum*). Of these, only narrow-leaved strap fern is still extant in South Florida.

Ecology

Tropical hardwood hammocks burn infrequently, although the precise role of fire in tropical hardwood hammocks is poorly understood. Recovery of tropical hardwood hammocks following fire is dependent on the nature of the fire, in particular whether the fire consumes a thick layer of the organic matter containing the tree roots (Loope and Urban 1980). When the organic layer is not consumed, recovery of tropical hardwood trees is rapid and canopy closure can be achieved in 40 years or less (Olmsted *et al.* 1983).

The theoretical successional relationship between pine rockland and tropical hardwood hammock has been 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. Fire is a crucial element to the South Florida Ecosystem. With the absence of fire, hammock expansion into pine rocklands would occur only as a result of anthropogenic factors.

Status and Trends

The majority of the remaining tropical hardwood hammocks outside of the Florida Keys have now been acquired and are no longer threatened by development. Large areas of tropical hardwood hammocks are protected in Everglades NP, Big Cypress National Preserve, and Biscayne NP. Other areas with tropical hardwood hammocks 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. Small hammock remnants also exist from Broward to Martin County along the eastern coast of Florida.

In the Florida Keys (Monroe County), significant areas are protected in Key Largo Hammocks State Botanical Site, National Key Deer Refuge, and other Federal, State, local, and privately owned conservation areas. Nevertheless, a significant amount of tropical hardwood hammock remains in private ownership and is still threatened by development in the Keys (C. Kruer, Florida Audubon Society, personal communication 1998). Of the tropical hardwood hammock types addressed here, the upland coastal rock barren is the most threatened by development. The small number and size, four sites totaling 4.5 ha (11 acres) of these unique areas, makes them suceptible to development impacts and invasion by exotic plants (Kruer 1992). A fifth site was just recently discovered. Shell mounds have been damaged and continue to be threatened by damage from artifact-seekers and archeological excavations.

On the negative side, some significant hammock areas have been completely destroyed; most notable is the virtually complete destruction of Brickell Hammock just south of downtown Miami. This once pristine hammock has been reduced to three small fragments totaling less than 20 ha (50 acres). Miami Rock Ridge hammocks have also been fragmented and isolated from surrounding

natural communities due to massive urban and rural development. The surrounding pine rockland community has been decimated, and pine rocklands outside of Everglades NP have been reduced to a small fraction of their former area. Marl prairies in the urban area have been almost completely destroyed. In the upper Florida Keys, virtually all of the tropical hardwood hammock is secondary growth, due to earlier conversions to agriculture (Craighead 1971). Hammocks in Key West have been completely obliterated with the exception of one tiny patch at Little Hamaca Park in the Key West salt ponds. Logging for West Indian mahogany and buttonwood has also occurred in hammocks along the northern shores of Florida Bay (Craighead 1971). In some cases, habitat loss has been the direct cause of plant extirpations (*e.g.* Dillon's vanilla).

Although tropical hardwood hammocks tend to be located in patches across the landscape, they compose part of a complex mosaic of communities including mangroves, coastal marshes and prairies, freshwater swamps, and pinelands. Fragmentation of tropical hardwood hammocks and their artificial separation from other communities has had very serious effects on both the hammocks and the wildlife that utilize them. For instance, the physical separation of Key Largo woodrats caused by hammock fragmentation makes it more difficult for them to locate a mate. Fragmentation may also 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 on tropical hardwood hammocks. The development of roads, among other things, has increased access to natural areas, including hammocks, to collectors of orchids, bromeliads, ferns, butterflies, and *Liguus* tree snails. Collecting pressure has been particularly well documented for orchids by Luer (1972), and several species of orchids have been extirpated from South Florida primarily due to collecting. Collecting pressure is also one of the principal threats to the Stock Island tree snail and the semaphore cactus (*Opuntia corallicola*). Roads also lead to wildlife mortality from automobile traffic, including that of the Florida panther.

Tropical hardwood hammock has been affected by both reductions, and increases in the mean water table. On the Miami Rock Ridge, the average water table has dropped by several feet since the beginning of the century. This has contributed to the extirpation of at least two fern taxa, one an endemic hybrid (Nauman 1986). In contrast, tropical hardwood hammocks in the SFWMD Water Conservation Areas have been flooded out within the last few decades, and on many tree islands tropical hardwood hammock trees have been completely destroyed by high water.

Exotic plant species have also significantly affected tropical hardwood hammocks. At least 162 species of exotic plants are now known to invade tropical hardwood hammocks in South Florida (Appendix E). Impacts of exotic plant species have been particularly severe in hammocks on the Miami Rock Ridge. In some cases, exotic plants now compose 50 percent of the flora of hammock fragments on the Ridge. Vines, such as Gold Coast jasmine (*Jasminum dichotomum*), air-potato (*Dioscorea bulbifera*), and nephthytis (*Syngonium podophyllum*), have decimated many hammocks on the Miami Rock

Ridge. Exotic trees and shrubs such as Brazilian pepper (*Schinus terebinthifolius*) are problematic in hammocks throughout South Florida, including undisturbed areas in Everglades NP. Coastal berm hammocks along the shores of Florida Bay have been heavily impacted by the sprawling vine-like shrub latherleaf (*Colubrina asiatica*). Recent GIS mapping of invasive exotics throughout the Florida Keys shows that approximately 2,833 ha (7,000 acres) of susceptible upland habitat have been invaded by exotic plants, especially Australian pine, Brazilian pepper and latherleaf (Kruer *et al.* 1998). Areas of disturbed substrate within and adjoining Keys hardwood hammocks are often heavily infested with exotic plants that are rapidly spreading into and displacing the natural plant community. Detailed exotics mapping projects (1:2400 scale) have been completed by the Florida Keys Environmental Restoration Trust Fund on North Key Largo and in the National Key Deer Refuge in the lower Keys. The EPPC (1997) has identified the most invasive plants in Florida, many of which occur in tropical hardwood hammocks. Hybrids between native and exotic plant species have also begun to appear (Hammer 1996, Sanders 1987), ultimately threatening native species with extirpation or extinction.

Exotic animals have also impacted tropical hardwood hammocks. 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 ant (*Solenopsis invicta*), and hog (*Sus scrofa*) as well as the domestic cat (*Felis domesticus*), have all been found in South Florida hammocks. Black rats and fire ants both prey on the endangered Stock Island tree snail, and fire ants may increase the mortality of the Key Largo woodrat. Feral and domestic cats prey on both the endangered Key Largo woodrat and 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.

While tropical hardwood hammocks burn naturally under certain conditions, anthropogenic fires have caused severe damage to tropical hardwood hammocks in the past (Small 1929, Craighead 1971, Olmsted *et al.* 1983). Fires set during the dry season can burn into hammocks and destroy the humus layer and tree roots, effectively destroying the hammock (Loope and Urban 1980). Recovery time for such hammocks is "clearly very long" (Loope and Urban 1980).

A variety of contaminants have also affected tropical hardwood hammocks and their constituent fauna. Mosquito spraying has been implicated in a number of problems, including the direct mortality of the Schaus swallowtail butterfly and other butterflies. This in turn, reduces food availability for land birds. Mosquito spraying may also impact food availability of the Key Largo woodrat. Rodent control agents are also known to be problems, specifically for the Key Largo woodrat. Other pesticides are known to cause the mortality of Stock Island tree snails and other invertebrates.

Hurricanes and other disturbance phenomena, which are natural parts of the South Florida Ecosystem can also have negative effects once fragmentation and the spread of exotic plant species have occurred. This was recently exemplified by Hurricane Andrew, which hit southern Miami-Dade County in August of 1992. This hurricane had sustained winds in excess of 233 kmph (145 mph) with

vortices up to 322 kmph (200 mph). Horvitz *et al.* (in press) has shown that invasive exotic species compete with native species for regeneration opportunities. Once species become rare (*e.g.*, the Schaus swallowtail butterfly), extreme climatic events, such as hurricanes, freezes, and droughts, can become serious threats. In September 1998, Hurricane Georges caused major alterations to tropical hardwood hammocks in the lower Keys including damage where roads and other forms of fragmentation opened the hammocks to wind turbulence resulting in downed or broken trees. Aside from wind damage, the storm surge associated with Hurricane Georges overwashed the Cactus Hammock on Big Pine Key resulting in the loss of the hammock's understory.

Management

Most tropical hardwood hammocks outside of the Florida Keys are now protected from development. On the mainland outside of Miami-Dade County, few tropical hardwood hammocks exist that are not already publicly owned. On the Miami Rock Ridge in Miami-Dade County, many tropical hardwood hammock parcels are still privately owned. Development of these tropical hardwood hammocks, however, is regulated and a permit is required from the Miami-Dade DERM before development can commence. In the Keys, tropical hardwood hammocks continue to be developed even though regulations and permit requirements are in place (C. Kruer, Florida Audubon Society, personal communication 1998).

Acquisition of the remaining tropical hardwood hammocks outside of the Florida Keys is now almost complete, although the Miami-Dade County Environmentally Endangered Lands Program still has a few ongoing projects. 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, Florida Audubon Society, personal communication 1998). The CARL program has several active projects in the Florida Keys, and should be encouraged to complete its purchases there as soon as possible. In addition, identification and mapping of remaining hardwood hammock parcels has been performed in the Keys where nearly 500 individual hammock parcels greater than about 1.62 ha (2 acres) in size have been mapped and described (McNeese 1996). These parcels range from the large contiguous hammocks that remain on North Key Largo to small patches of hammock that remain within developed subdivisions. Even the small patches are important in a landscape context as they often contain rare and unique plants and offer refugia to birds and animals within developed areas.

In both Miami-Dade County and the Florida Keys, cooperation with landowners of tropical hardwood hammocks 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 tropical hardwood hammocks and pine rocklands 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 tropical hardwood hammock sites. Unfortunately, no similar system exists in Monroe County, where a significant amount of tropical hardwood hammock is still in private ownership, and much is

subdivided into small parcels. 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 hammocks. 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 tropical hardwood hammocks and pine rocklands with technical assistance including the preparation of management plans, herbicide training, prescribed fire coordination, plant identification workshops, and site-specific consultations (J. Klein, Miami-Dade 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 Miami-Dade DERM Forest Resources Program also has regulatory authority over tropical hardwood hammocks and pine rocklands, and is charged with enforcing regulations which provide partial protection for tropical hardwood hammocks 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 requirements which are administered by Monroe County with oversight by the Florida Department of Community Affairs (DCA) due to the Keys' designation as an Area of Critical State Concern (C.R. Kruer, Florida Audubon Society, personal communication 1998). Property owners now compete for permits through a Rate of Growth Ordinance that assigns positive and negative points for many factors, including presence of natural areas and endangered species (C.R. Kruer, Florida Audubon Society, personal communication, 1998). Neither regulatory program totally precludes development of hammocks.

Until recently, management of tropical hardwood hammock preserves has been minimal, and many tropical hardwood hammock preserves have become degraded due to invasions by exotic plants, invasions by exotic, feral, and domestic animals, anthropogenic fires, unauthorized use (including bicycling), illegal dumping, improper siting of interpretive trails and facilities, poaching of animals, collecting of plants, drainage, flooding and saltwater intrusion, mosquito ditching (Florida Keys) and spraying, and drift of pesticides from agricultural and commercial operations. Shell mounds, because they are constructed from archaeological remains, have been subjected to damage from artifact-seekers and archaeological excavations. Hammock edges must be protected from the effects of fire exclusion. More effort must be made to reduce these and other types of negative impacts on tropical hardwood hammock preserves.

Following public acquisition and the prevention of further disturbance, the most important step in recovery is to restore existing degraded tropical hardwood hammocks through active management, and, with a few exceptions, this process is still in its formative stages. Where possible, connections between tropical hardwood hammocks and surrounding natural communities such as pine rocklands and freshwater wetlands should be re-established. Roads and fire breaks which separate hammock edges from 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 tropical hardwood hammocks should be removed and restored. 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 (which is essential to the survival of many epipetric ferns), and reducing the water level within the Water Management Areas where hammocks are being flooded out by artificially high water levels. Exotic plant species must be controlled with the ultimate goal of extirpating as many invasive exotic taxa as possible, and restoring historic hammock 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 tropical hardwood hammocks. Animal removal must be sensitive to the needs of indigenous wildlife, such as Key Largo woodrats, which might be affected by certain chemical control methods. Efforts should also be made to control unauthorized use, including off-trail hiking which can cause damage to the humus litter in hammocks (which is essential to some organisms such as the Stock Island tree snail which uses it for egg laying). 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.

The most aggressive campaign to restore tropical hardwood hammocks is being conducted by Miami-Dade County Park and Recreation Department, Natural Areas Management Division (NAM). This program has been very active since Hurricane Andrew in 1992, and has completed a substantial amount of management work in hammocks in four parks on the Miami Rock Ridge: The Charles Deering Estate, R. Hardy Matheson Preserve, Castellow Hammock Park, and Matheson Hammock Park (S. Vardaman, Miami-Dade County Park and Recreation Department, Natural Areas Management, personal communication 1998). All four of these parks have management plans which include recommendations for the control of exotic plants (Dade County Park and Recreation Department *et al.* 1991a; Dade County Park and Recreation Department *et al.* 1991b; Dade County Park and Recreation Department 1993, Dade County Park and Recreation Department 1994). Initial work has also been completed in hammocks at several more sites (*e.g.*, Fuchs Hammock, Meisner Hammock, and Kendall Indian Hammock). This work has resulted from a multi-agency collaboration including the Miami-Dade County Park and Recreation Department, Fairchild Tropical Garden, Ecohorizons, Inc., and The Nature Conservancy, and was initiated in 1993 with the ultimate goal of restoring nearly 162 ha (400 acres) of rockland hammock (Wells and Hazelton 1997). Monitoring of this program at three hammocks has been conducted by C. Horvitz of the University of Miami (*e.g.*, Horvitz 1996), and on going technical assistance has been provided by the Institute for Regional Conservation. NAM has also provided technical assistance and training to the City of Miami for the restoration of tropical hardwood hammocks there (Vardaman 1998). This included two of the three Brickell Hammock fragments that remain: Alice Wainwright Park and Simpson Park.

In the Florida Keys, significant work on exotic plant control has now been initiated. Florida Audubon Society and the Florida Keys Invasive Exotic Task

Force have recently completed a Keys-wide exotic species mapping project which clearly demonstrates the problems with exotics in the Keys, including tropical hardwood hammocks (C.R. Kruer, Florida Audubon Society, personal communication 1998). DEP has recently allocated $170,000 to eradicate exotics in uplands in the Keys, and this is primarily being used to control exotics on North Key Largo and other public lands (L. Flynn, The Nature Conservancy, personal communication 1998). Most exotics in this area are on the margins of hammocks and in disturbed areas. Control is being conducted by both the Florida Park Service, FWS, DOT, and Audubon's Florida Keys Environmental Restoration Trust Fund. Exotic species control is also being conducted on CARL lands under the coordination of the GFC. In the future, the Florida Keys Invasive Exotic 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 and restore tropical hardwood hammocks (L. Flynn, The Nature Conservancy, personal communication 1998). Fairchild Tropical Garden and The Nature Conservancy have also been active in reintroducing and augmenting populations of rare plants to tropical hardwood hammocks in the Florida Keys.

Once tropical hardwood hammocks are restored, they must be maintained in perpetuity. In hammocks 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 species, 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 hammock edges. The water table must be monitored to insure that hammocks are not dewatered or flooded. Contaminants, including pesticides, must be continuously monitored. These negative trends must be countered 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 encouraged to continue providing the proper quantity of water; and, preserves must be protected from pesticides and other contaminants.

Tropical hardwood hammocks can also be restored where they have been destroyed. A testament to this is the fact that virtually all of the tropical hardwood hammocks in the Florida Keys are secondary and have recovered following clearing for agriculture and settlements. Craighead (1971) pointed out that hammocks on Elliott and Rhodes keys had recovered well after 35 years of natural regeneration. Tropical hardwood hammocks can also become established in areas of pine rockland that has been cleared and then abandoned. Some of these forests have become so well established that only well-trained botanists can distinguish them from natural forests. Secondary forests can be useful for wildlife, even at a relatively young age. Key Largo woodrats and the Schaus swallowtail butterfly both utilize relatively young secondary forests in the Florida Keys. Unfortunately, the period when tropical hardwood hammocks could become established through natural regeneration and establishment on disturbed lands is probably at

an end due to the invasion of South Florida by exotic plant species. Any site that is abandoned to vegetational succession will almost certainly become dominated by exotic pest plant species, especially if a seed source for exotics is nearby. Opportunities to use natural regeneration to establish or re-establish tropical hardwood hammocks and to establish wildlife habitat, however, should be explored.

On the bright side, a multiplicity of opportunities do exist to create tropical hardwood hammocks within the urban/rural matrix of South Florida, and tropical hardwood hammocks are one of the easiest communities to replicate. 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 tropical hardwood hammocks are one of the first natural communities which people attempted to create from scratch. Efforts to create tropical hardwood hammocks began as early as 1965 (Gann 1979). While most hammocks have been created by homeowners and schools, government agencies and commercial property owners have also created hammocks. One well-known example of a hammock creation is at Kenwoods Elementary School, which began construction of its nationally recognized award-winning outdoor learning center in 1985. For more than 10 years, hammocks have been created on spoil mounds in Biscayne Bay, and as part of the compensatory mitigation and land management process in the Florida Keys. Newly acquired land parcels on North Key Largo are being allowed to succeed to hammock through planting of hardwoods and control of exotics. Tropical hardwood hammocks can be created almost anywhere in the built environment, from residential yards, to small spaces between condominium buildings, to roadside swales. Tropical hardwood hammocks can also be created on abandoned fill pads in the Everglades marsh, in the Big Cypress swamp, and on spoil islands throughout South Florida. If done properly, this type of restoration could make a significant contribution to the recovery of the tropical hardwood hammocks community.

Guidelines for the creation of "hammocks" were first published in the late 1970s (Gann 1979). This article included an extensive table of native trees and shrubs which could be used to create hammocks, including growth patterns, soils, cultural tolerances, uses, special attractions, and drawbacks. Unfortunately, concepts of natural communities, species nativity and natural ranges were not well developed at the time, and this publication has limitations. 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 rockland hammock creation (Jameson and Moyroud 1991). More recently G. Gann (1995) created guidelines for the creation of rockland hammocks in Miami-Dade County, including a list of recommended species, planting techniques, watering requirements, and long-term maintenance. Miami-Dade County has recently published "The Landscape Manual" (Dade County Department of Planning, Development, and Regulation 1996), which includes a brief community description, a list of recommended plants for rockland hammock creation, and a table including cultural requirements and tolerances. These types of guidelines should be expanded to include tropical hardwood hammock creation

in the Florida Keys and Big Cypress regions, and refined to provide specific guidelines for distinct floristic subregions (*e.g.* lower, middle, and upper Keys).

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 pitch-apple (*Clusia rosea*), which is perhaps native to the lower Florida Keys, 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 tropical hardwood hammocks (Gann and Bradley 1996). Other native hammock species naturalizing outside of their historic range include bitterbush (Avery and Loope 1980), butterfly bush (*Cordia globosa*), coffee colubrina (*Colubrina arborescens*), redberry stopper (Avery and Loope 1980), and West Indian mahogany. 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 tropical hardwood hammock recovery, especially applied research that pertains to the recovery of the ecosystem. Although much research on tropical hardwood hammocks and their management had been conducted earlier (*e.g.*, Olmsted *et al.* 1983), a significant amount of research has been conducted following Hurricane Andrew (1992). Recent research on tropical hardwood hammocks has been conducted by C. Horvitz (Horvitz 1994, Horvitz *et al.* 1995, Horvitz *et al.* in press), M. Ross *et al.* (1998), and H.H. Slater *et al*. (1995). This research primarily investigates hammock recovery following hurricane disturbance, and exotic plant species responses and management following Hurricane Andrew. Research has also been completed on the role of the hammock seed bank (L. Flynn, The Nature Conservancy, personal communication 1998).

Current research on tropical hardwood hammocks includes: seedling dynamics relating to light availability in hammocks impacted by Hurricane Andrew versus hammocks undamaged by hurricanes for an extended period of time (M. Ross, Florida International University, personal communication 1998); the effects of Hurricane Andrew on hammocks in Everglades NP (S. Koptur, Florida International University, personal communication 1998); the impact of exotic vines on the post-hurricane recruitment, survival and growth of native species in tropical hardwood hammocks (C. Horvitz, University of Miami, personal communication 1998); and, research on mycorrhizal fungi and its role in tropical hardwood hammock restoration (J. Fisher, Fairchild Tropical Garden, personal communication 1998). More research is needed on wildlife habitat needs in terms of tropical hardwood hammock functions and biodiversity, the long-term role of fire and hurricanes in maintaining hammock structure and composition, and the potential effects of soil oxidation due to the lowering of the water table in southeastern Florida.

Monitoring of tropical hardwood hammocks and their management is also critical. All management actions should be monitored to determine their effectiveness, and changes should be made to management activities as appropriate. This is currently being done in Miami-Dade County hammocks by C. Horvitz of the University of Miami (C. Horvitz, University of Miami,

personal communication 1998). Managers should also have a plan for monitoring relative population levels of selected plant and animal species.

Finally, formal and informal public awareness programs to promote tropical hardwood hammock conservation are very important and should be promoted. The Miami-Dade County Park and Recreation Department has numerous brochures providing information to parks visitors on tropical hardwood hammocks, their importance and conservation. The GFC (1991) has developed an educational brochure and poster on tropical hardwood hammocks. Everglades NP, Biscayne NP, the National Key Deer Refuge and other Federal, State, and local parks have excellent facilities interpreting the importance of tropical hardwood hammocks.

Table 1. Vertebrates of tropical hardwood hammocks

Mammals	
Black bear	Ursus americanus floridanus
Black rat*	Rattus rattus frugivorus
Black rat*	Rattus rattus ssp.
Brazilian free-tailed bat	Tadarida brasiliensis
Bobcat	Lynx rufus floridana
Cotton mouse	Peromyscus gossypinus palmarius
Domestic pig*	Sus scrofa
Eastern cottontail rabbit	Sylvilagus floridanus paulsoni
Eastern gray squirrel	Sciurus carolinensis
Eastern spotted skunk	Spilogale putorius ambarvalis
Evening bat	Nycticeius humeralis
Florida panther	Felis concolor coryi
Florida Red wolf (extinct in Florida)	Canis rufus floridanus
Florida yellow bat	Dasypterus floridanus
Fruit bat	Artibeus jamaicensis
Gray fox	Urocyon cinereoargenteus
Hispid cotton rat	Sigmodon hispidus littoralis
House cat*	Felis domesticus
House mouse*	Mus musculus brevirostris
Key cotton rat	Sigmodon hispidus exsputus
Key deer	Odocoileus virginianus clavium
Key Largo cotton mouse	Peromyscus gossypinus allapaticola
Key Largo woodrat	Neotoma floridana smallii
Lower Keys rabbit	Sylvilagus palustris hefneri
Least shrew	Cryptotis parva floridana
Long-tailed weasel	Mustela frenata
Mangrove fox squirrel	Sciurus niger
Marsh rabbit	Sylvilagus palustris paludicola
Nine-banded armadillo*	Dasypus novemcinctus
Norway rat*	Rattus norvegicus
Opossum	Didelphis marsupialis pigra
Raccoon	Procyon lotor
Red fox	Vulpes fulva
Seminole bat	Lasiurus seminolus

Table 1. Vertebrates of tropical hardwood hammocks *cont.*

Short-tailed shrew	Blarina brevicauda peninsulae
Southern flying squirrel	Glaucomys volans querceti
Southern myotis	Myotis austroriparius
Striped skunk	Mephitis mephitis elongata
Wagner's mastiff bat	Eumops glaucinus
White-tailed deer	Odocoileus virginianus seminolus
Birds	
American kestrel	Falco sparverius
American redstart	Setophaga ruticilla
American robin	Turdus migratorius
American swallow-tailed kite	Elanoides forficatus
Bald eagle	Haliaeetus leucocephalus
Barn owl	Tyto alba
Barn swallow	Hirundo rustica
Barred owl	Strix varia
Black-and-white warbler	Mniotilta varia
Blackburnian warbler	Dendroica fusca
Blackpoll warbler	Dendroica striata
Black-shouldered kite	Elanus caeruleus
Black-throated blue warbler	Dendroica caeruleus
Black-throated green warbler	Dendroica virens
Black vulture	Coragyps atratus
Black-whiskered vireo	Vireo atiloquus
Blue-gray gnatcatcher	Polioptila caerula
Blue grosbeak	Guiraca caerulea
Blue jay	Cyanocitta cristata
Blue-winged warbler	Vermivora pinus
Boat-tailed grackle	Quiscalus major
Broad-winged hawk	Buteo platyperus
Brown-headed cowbird	Molothrus ater
Brown thrasher	Toxostoma rufum
Canary-winged parakeet*	Brotogeris versicolurus
Cape May warbler	Dendroica tigrina
Carolina wren	Thryothorus ludovicianus

Table 1. Vertebrates of tropical hardwood hammocks *cont.*

Cedar waxwing	Bombycilla cedrorum
Chipping sparrow	Spizella passerina
Chuck-will's-widow	Caprimulgus caroliniensis
Common crow	Corvus brachyrhynchos
Common grackle	Quiscalus quiscula
Common nighthawk	Chordeiles minor
Common yellowthroat	Geothlypis trichas
Cooper's hawk	Accipiter cooperii
Cuban yellow warbler	Dendroica petechia
Dickcissel	Spiza americana
Downy woodpecker	Picoides pubescens
Eastern kingbird	Tyrannus tyrannus
Eastern phoebe	Sayornis phoebe
Eastern screech owl	Otus asio
European starling*	Sturnus vulgaris
Fish crow	Corvus ossifragus
Fork-tailed flycatcher	Tyrannus savana
Golden-winged warbler	Vermivora chrysoptera
Gray catbird	Dumetella carolinensis
Gray-cheeked thrush	Catharus minimus
Gray kingbird	Tyrannus dominicensis
Groove-billed ani	Crotophaga sulcirostris
Great crested flycatcher	Myiarchus crinitus
Great horned owl	Bubo virginianus
Ground dove	Columbina passerina
Hairy woodpecker	Picoides villosus
Hermit thrush	Catharus guttatus
Hooded warbler	Wilsonia citrina
House sparrow*	Passer domesticus
House wren	Troglodytes aedon
Indigo bunting	Passerina cyanea
Key West quail-dove	Geotygon chrysia
La Sagra's (Stolid) flycatcher	Myiarchus sagrae
Loggerhead shrike	Lanius ludovicianus
Louisiana waterthrush	Seiurus motacilla

Table 1. Vertebrates of tropical hardwood hammocks *cont.*

Magnolia warbler	Dendroica magnolia
Mangrove cuckoo	Coccyzus minor
Merlin	Falco columbarius
Mourning dove	Zenaida macroura
Northern cardinal	Cardinalis cardinalis
Northern (Yellow-shafted) flicker	Colaptes auratus
Northern (Baltimore) oriole	Icterus galbula
Northern parula	Parula americana
Northern rough-winged swallow	Stelgidopteryx serripennis
Northern waterthrush	Seiurus noveboracensis
Orange-crowned warbler	Vermivora ruficapilla
Orchard oriole	Icterus spurius
Ovenbird	Seiurus aurocapillus
Painted bunting	Passerina ciris
Palm warbler	Dendroica palmarum
Pileated woodpecker	Dryocopus pileatus
Pine warbler	Dendroica pinus
Prairie warbler	Dendroica discolor
Prothonotary warbler	Protonotaria citrea
Purple martin	Progne subis
Red-bellied woodpecker	Melanerpes carolinus
Red-eyed vireo	Vireo olivaceus
Red-shouldered hawk	Buteo lineatus
Red-tailed hawk	Buteo jamicensis
Red-winged blackbird	Agelaius phoeniceus
Rose-breasted grosbeak	Pheucticus melanocephalus
Ruby-crowned kinglet	Regulus calendula
Ruby-throated hummingbird	Archilochus colubris
Rufous-sided towhee	Pipilo erythrophthalmus
Scissor-tailed flycatcher	Tyrannus forficatus
Sharp-shinned hawk	Accipiter striatus
Shiny cowbird	Molothrus bonariensis
Short-tailed hawk	Buteo brachyurus
Smooth-billed ani	Crotophaga ani
Solitary vireo	Vireo solitarius

Table 1. Vertebrates of Tropical Hardwood Hammocks *cont.*

Spot-breasted oriole*	Icterus pectoralis
Summer tanager	Piranga rubra
Swainson's hawk	Buteo swainsoni
Swainson's thrush	Catharus ustulatus
Swainson's warbler	Limnothylpis swainsonii
Tennessee warbler	Vermivora peregrina
Tree swallow	Tachycineta bicolor
Turkey	Meleagris gallopavo
Turkey vulture	Cathartus aura
Veery	Catharus fuscescens
Western kingbird	Tyrannus verticalis
Western tanager	Piranga ludoviciana
Whip-poor-will	Caprimulgus vociferus
White-crowned pigeon	Columba leucocephala
White-eyed vireo	Vireo griseus
White-winged dove	Zenaida asiatica
Wilson's warbler	Wilsonia pusilla
Wood duck	Aix sponsa
Wood thrush	Hylocichla mustelina
Worm-eating warbler	Helmitheros vermivorus
Yellow-bellied sapsucker	Sphyrapicus varius
Yellow-billed cuckoo	Coccyzus americanus
Yellow-breasted chat	Icteria virens
Yellow-rumped warbler	Dendroica coronata
Yellow-throated vireo	Vireo flavifrons
Yellow-throated warbler	Dendroica dominica
Zenaida dove	Zenaida aurita
Reptiles	
Snakes	
Boa constrictor*	Boa constrictor
Braminy blind snake*	Typhlops braminus
Corn snake	Elaphe guttata guttata
Eastern coral snake	Micrurus fulvius fulvius
Eastern diamondback rattlesnake	Crotalus adamanteus

Table 1. Vertebrates of Tropical Hardwood Hammocks *cont.*

Eastern garter snake	Thamnophis sirtalis sirtalis
Florida ribbon snake	Thamnophis sauritus sackenii
Eastern indigo snake	Drymarchon corais couperi
Eastern kingsnake	Lampropeltis getulus getulus
Everglades racer	Coluber constrictor paludicola
Florida brown snake	Storeria dekayi victa
Florida cottonmouth	Agkistrodon piscivorus conanti
Florida kingsnake	Lampropeltis getulus floridana
Florida scarlet snake	Cemophora coccinea coccinea
Key ringneck snake	Diadophis punctatus acricus
Pygmy rattlesnake	Sistrurus miliarius barbouri
Red rat snake / corn snake	Elaphe guttata guttata
Rim rock crowned snake	Tantilla oolitica
Rough green snake	Opheodrys aestivus
Scarlet kingsnake	Lampropeltis triangulum elapsoides
Southern black racer	Coluber constrictor priapus
Southern ringneck snake	Diadophis punctatus punctatus
Yellow rat snake / chicken snake	Elaphe obsoleta quadrivittata
Lizards	
Brown anole*	Anolis sagrei sagrei
Dominican bark anole*	Anolis distichus dominicensis
Eastern glass lizard	Ophisaurus ventralis
Florida bark anole	Anolis distichus floridanus
Florida reef gecko	Sphaerodactylus notatus
Green anole	Anolis carolinensis
Green iguana*	Iguana iguana
Ground skink	Scincella lateralis
Indo-pacific gecko*	Hemidactylus garnoti
Key mole skink	Eumeces egregius egregius
Knight anole*	Anolis equestris
Mediterranean gecko*	Hemidactylus turcicus
Spiny-tailed iguana*	Ctenosaura pectinata
Southeastern five-lined skink	Eumeces inexpectatus
Tokay gecko*	Gekko gecko
West African gecko*	Hemidactylus mabouia

Table 1. Vertebrates of tropical hardwood hammocks *cont.*

Turtles	
Florida box turtle	Terrapene carolina bauri
Amphibians	
Frogs and Toads	
Cuban treefrog	Osteopilus septentrionalis
Giant toad / marine toad*	Bufo marinus
Green treefrog	Hyla cinerea
Greenhouse frog*	Eleutherodactylus planirostris
Oak toad	Bufo quercicus
Narrow mouthed toad	Gastrophryne carolinensis
Southern leopard frog	Rana sphenocephala
Southern toad	Bufo terrestris
Squirrel treefrog	Hyla squirella

* = naturalized exotic (non-native) species

Table Prepared by Roger L. Hammer and Keith Bradley

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Restoration of Tropical Hardwood Hammock

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

Restoration Criteria

Given that tropical hardwood hammocks 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.

This restoration objective will be met when: (1) intact tropical hardwood hammocks are protected through land acquisition or cooperative agreements with landowners; (2) any further destruction and degradation of this community has been prevented; (3) the effects of disturbance in degraded hammocks are reversed by active management; (4) ecological linkages to adjacent communities are restored and preserved; (5) management can insure the persistence in the wild of species that use tropical hardwood hammocks as habitat; (6) invasive exotic species are reduced to non-threatening levels; and (7) landscape-level habitat diversity is restored.

Community-level Restoration Actions

1. Prevent further destruction or degradation of existing tropical hardwood hammocks.

1.1. Acquire tropical hardwood hammocks threatened with development. Complete acquisitions in Miami-Dade County under the Environmentally Endangered Lands Program. Encourage CARL, Preservation 2000, the Monroe County Land Authority, and the Federal government to complete projects such as the North Key Largo Hammocks, the Florida Keys Ecosystem, and other acquisition projects in the Florida Keys.

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

1.3. Enforce regulatory protection of tropical hardwood hammocks. Encourage Miami-Dade and Monroe counties to enforce regulatory protection of tropical hardwood hammocks and require mitigation for unavoidable impacts.

1.4. **Prevent degradation of existing preserves containing tropical hardwood hammocks.** 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), 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. Protect shell mounds from artifact-seekers and archeological excavations. Encourage the use of prescribed fire in pine rocklands to protect hammock edges from effects of fire exclusion.

2. **Restore existing degraded tropical hardwood hammocks through active management.**

2.1. **Restore connections between and among tropical hardwood hammocks and surrounding natural communities.** Roads and fire breaks that separate hammocks edges from surrounding natural communities should be removed. Roads which dissect and fragment tropical hardwood hammocks should be removed and restored.

2.2. **Restore natural fire regimes.** Develop prescribed fire programs that allow fires from surrounding pine rocklands, prairies and other communities to burn freely into 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 hammocks which have been dewatered by drainage in order to provide habitat for rare ferns and other sinkhole species. Reduce water levels in the Water Management Areas to historic levels to restore tropical hardwood hammocks that have been degraded due to unnaturally high water levels. Fill or plug problematic mosquito ditches in lower Keys hammocks without causing negative hydrologic impacts.

2.4. **Eradicate exotic plants and control exotic animals.** Develop control programs that eliminate, to the extent possible, exotic plants and animals from tropical hardwood hammocks, 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.** Tropical hardwood hammocks 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 tropical hardwood hammocks from point and non-point source pollution** including mosquito control spraying, rodenticides, 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. If federally listed species are used for reintroduction purposes, appropriate FWS protocols must be followed.

3. Maintain tropical hardwood hammocks in a natural condition in perpetuity

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

3.2. Continue to use prescribed fire to maintain hammock edges. Develop and budget for prescribed fire programs in adjacent natural communities.

3.3. Continue to monitor the water table to ensure that tropical hardwood hammocks 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, especially outlying populations before they become established.

3.5. Continue to control public use and eliminate improper use, such as illegal dumping, and the collection of rare plants**.**

3.6. Monitor and correct for both point source and non-point source pollution such as mosquito spraying and drift from agricultural and commercial operations.

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

4. Recreate tropical hardwood hammocks 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 tropical hardwood hammocks and other natural communities, as well as to expand the total area of tropical hardwood hammocks.

4.2. Explore opportunities to utilize secondary tropical hardwood hammocks as habitat for wildlife.

5. Create tropical hardwood hammocks where natural communities have been destroyed by human activities.

5.1. Encourage the use of tropical hardwood hammocks as landscape models within the built landscape. Tropical hardwood hammocks are one of the easiest natural communities to create from scratch in South Florida, and it should be promoted as a landscape model for residences, schools, and commercial landscapes. Tropical hardwood hammocks should also be created on abandoned fill pads in the Everglades marsh, in the Big Cypress swamp, and on spoil islands throughout South Florida.

5.2. Refine guidelines and specifications for tropical hardwood hammock creation. Promote the development of refined hammock creation guidelines and the development of specifications for all 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 tropical hardwood hammocks species outside of their historic ranges. Many 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 are now escaping from cultivation and invading natural areas outside of their historic range. The use of native species only within their natural ranges should be encouraged.

6. **Connect existing tropical hardwood hammocks 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 tropical hardwood hammocks need not include tropical hardwood hammocks. Historically, tropical hardwood hammocks existed as "islands" in a matrix of other community types, and this pattern should be maintained as much as possible. 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 tropical hardwood hammock functions and biodiversity, the long-term role of fire and hurricanes in maintaining hammock structure and biodiversity, and the potential effect of oxidation of soil humus due to the lowering of the water table in southeastern Florida. Once exotic plants are initially removed, routine monitoring/inspections need to be performed.

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 Florida's Conservation and Recreational Lands (CARL) program and Preservation-2000. Inform local land owners on the importance and uniqueness of the tropical hardwood hammock ecological community. Environmental education programs in South Florida should be encouraged to distribute materials or develop lesson plans on tropical hardwood hammock habitats, tropical hardwood hammock species and the importance of maintaining natural biodiversity.

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.

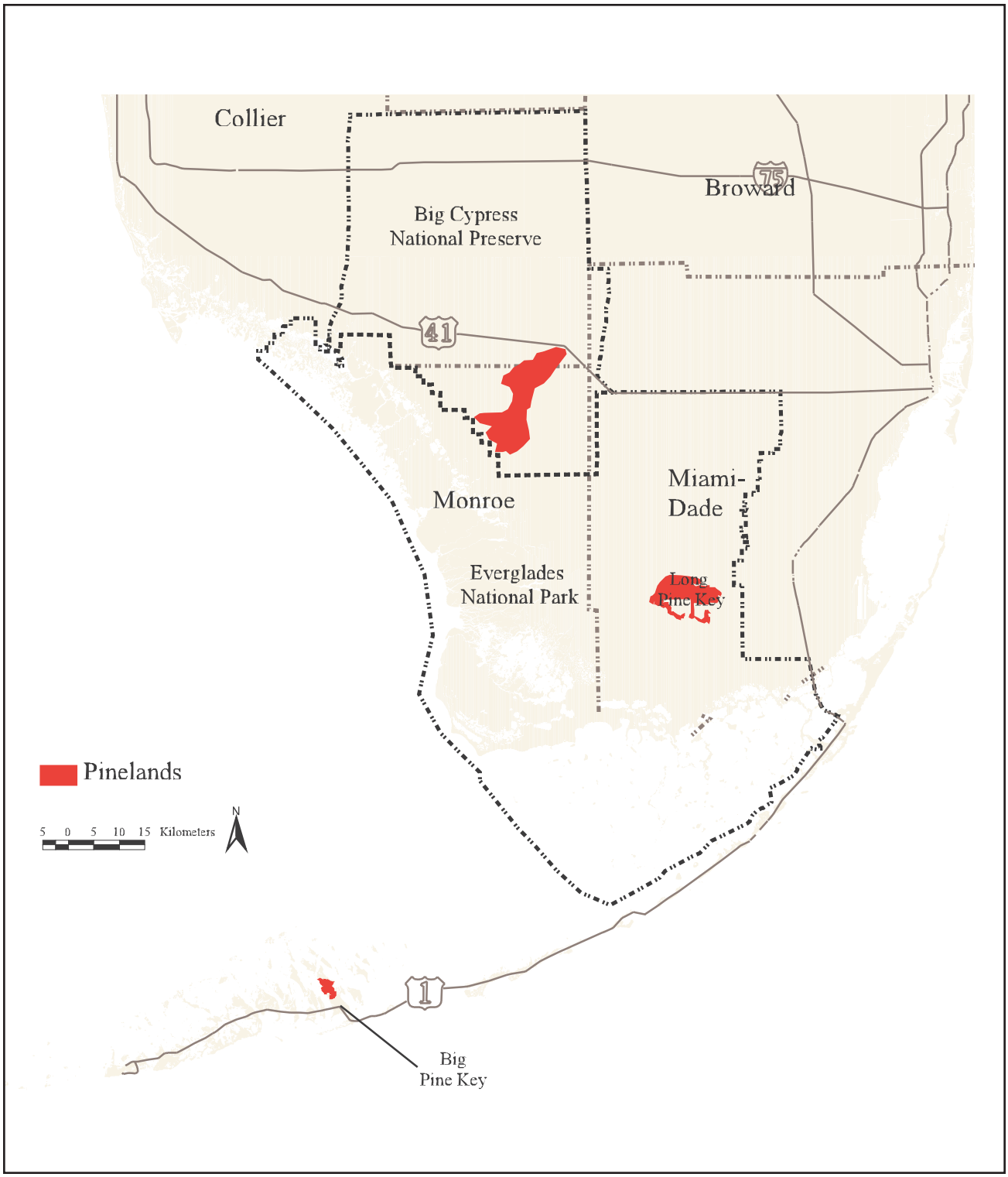


Figure 1. Distribution of the largest remaining contiguous areas of pine rocklands (adapted from Snyder *et al.* 1990.).

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*).

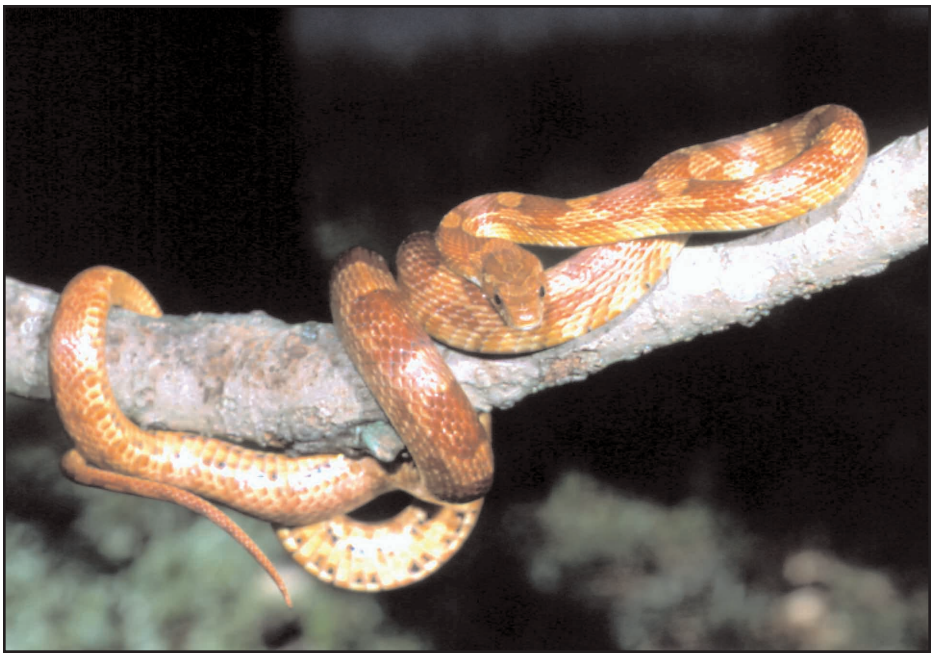
Wildlife Species of Concern

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.

Mesic Pine Flatwoods

FNAI Global Rank:	**Undetermined**
FNAI State Rank:	**S4**
Federally Listed Species in S. FL:	**9**
State Listed Species in S. FL:	**40**

Mesic pine flatwoods. *Original photograph by Deborah Jansen.*



The mesic pine flatwoods of South Florida are of critical, regional importance to the biota of South Florida. They provide essential forested habitat for a variety of wildlife species including: wide-ranging, large carnivores such as the Florida panther *(Puma (=Felis) concolor coryi*) and the Florida black bear (*Ursus americanus floridanus*); mid-sized carnivores; fox squirrels (*Sciurus niger* spp.); and deer (*Odocoileus virginianus).* They provide tree canopy for canopy-dependent species including neotropical migrants, tree-cavity dependent species, and tree-nesting species. Mesic pine flatwoods are also important as the principal dry ground in South Florida, furnishing refuge and cover for ground-nesting vertebrates as well as habitat for non-aquatic plant life (such as upland perennials and annuals). During the summer wet season, the mesic pine flatwoods of South Florida function as the upland ark for non-aquatic animals. Mesic flatwoods serve as ground bird nesting areas; adult tree frog climbing areas; black bear foraging, denning, and travelways; and essential red-cockaded woodpecker (*Picoides borealis*) foraging and nesting habitat. At the current rate of habitat conversion, the mesic pine flatwoods, once the most abundant upland habitat in South Florida, is in danger of becoming one of the rarest habitats in South Florida. The impact of this loss on wide-ranging species, listed species, and biodiversity in South Florida could be irreparable.

Synonymy

The mesic pine flatwoods association of southwest Florida has been variously recognized and alluded to in the plant community literature. Pine flatwoods were first identified as “pine barrens” by Bartram (1791) in his narrative of Florida travels. The term “flatwoods” was coined by English speaking settlers to describe the absence of topographic relief (Ober 1954). The term “pine flatwoods” was first used in the scientific literature by Laessle (1942).

Following Davis' (1967) mapping of South Florida vegetation communities, the term became standard for South Florida pine forests.

Long (1974) was the first to recognize mesic pine flatwoods as a separate vegetation type, "dry pineland," and considered it a successional stage between wet flatwoods and hardwood hammock. Klein *et al.* (1970) and Wharton (1977) separately map mesic pine flatwoods in their hydrogeologic cross-sections of the plant communities of the Big Cypress and South Florida successional stages. Duever *et al.* (1979) formally used the term "mesic pine flatwoods" and distinguished mesic pine flatwoods from hydric pine flatwoods by differences in understory, with the mesic flatwoods having a saw palmetto (*Serenoa repens*) understory. Based upon a conceptual successional model, Duever *et al.* (1976) indicate that upland pinelands occur in a hydroperiod of from 0 to 40 days and a fire frequency of 3-to 10-year intervals. Subsequent descriptions by Duever *et al.* (1986) describe flatwoods on the basis of hydrology and understory components, recognizing mesic flatwoods.

The Florida Natural Areas Inventory (FNAI) (1989) recognizes mesic flatwoods as flatland with sand substrate, mesic, subtropical or temperate; with frequent fire, and vegetation characterized by slash pine (*Pinus elliottii*) and/or longleaf pine (*Pinus palustris*) with saw palmetto, gallberry (*Ilex glabra*) and/or wiregrass (*Aristida beyrichiana*)or cutthroat grass (*panicum abscissum*) understory. FNAI lists the following synonyms for mesic pine flatwoods: mesic flatwoods, pine savanna, cabbage palm savanna, and pine barrens. The Florida Land Use Classification and Cover System (FLUCCS) (DOT 1985) does not have a specific categorization for mesic pine flatwoods. As defined by FNAI (1989), mesic pine flatwoods could be mapped as any of the following FLUCCS codes: 411 pine flatwoods, 415 longleaf-upland oak, 419 other pine, or 428 cabbage palm. The U. S. Soil Conservation Service (1986) combines mesic pine flatwoods with hydric and xeric pine flatwoods in a "South Florida flatwoods" category. Abrahamson and Hartnett (1990) define the mesic flatwoods as occasionally inundated flatlands with sand substrates, canopies of slash pine, longleaf pine, and/or cabbage palm (*Sabal palmetto*), and understories of mixed shrubs, grasses and forbs, which vary in accordance with fire frequency, and are a gradation between hydric and xeric flatwoods.

All Florida State and Federal regulatory agencies recognize mesic pine flatwoods as uplands for wetland regulatory purposes.

Distribution

Mesic pine flatwoods were historically found in all the counties of South Florida. The largest remaining areas are in south and eastern Sarasota County, Charlotte County, north and southeastern Lee County, on Pine Island in Lee County, western and northeastern Collier County, central Hendry County, western Glades County, southwest and northeast Highlands County, the Green Swamp and southeastern Polk County, the Horse Creek basin of DeSoto and Hardee counties, northwest and east Osceola County, within the Everglades NP in Miami-Dade County, North Palm Beach County, and in three ridges paralleling the coast in western, mid-and eastern St. Lucie, Indian River and Martin counties, respectively (Figure 1). There may be no natural mesic pine

flatwoods remaining outside of public ownership in Broward and Miami-Dade counties. Small areas of mesic flatwoods are located in Monroe and Okeechobee counties. Figure 1 illustrates the distribution of all pine flatwoods in the South Florida Ecosystem, as of 1989 (Cox *et al.* 1997).

The South Florida slash pine is the dominant tree of the South Florida mesic pine flatwoods canopy, south of Interstate 4. The longleaf pine and South Florida slash pine are in mixed dominance north of Interstate 4 in Polk and Osceola counties, and in some areas of Highlands County at higher elevations. The longleaf pine is found in clusters as far south as Charlotte County on the west coast.

Major public holdings of mesic pine flatwoods occur throughout South Florida, in Everglades NP (Miami-Dade and Monroe counties); Big Cypress National Preserve (Collier County); the Florida Panther NWR (Collier County); Corkscrew Swamp Sanctuary (Collier County); Charlotte Harbor State Buffer Preserve (Charlotte County); Charlotte Harbor Flatwoods (Charlotte County); Babcock-Webb WMA (Charlotte County); CREW (Lee, Collier counties); The Savannas (Martin, St. Lucie counties)**;** Picayune Strand (South Golden Gate Estates in Collier County); Myakka State Forest, Myakka River State Park and Myakka Prairie (Sarasota County); Oscar Shearer SRA (Sarasota County); Pinelands Preserve (Sarasota County); Platt Branch Mitigation Park (Highlands County); Hickey Creek Mitigation Park (Lee County); Caloosahatchee River SRA (Lee County); Koreshan State Park (Lee County); Jonathan Dickinson State Park (Martin and Palm Beach counties); DuPuis Reserve (Martin and Palm Beach counties); J.W. Corbett WMA (Palm Beach County); Loxahatchee Slough Natural Area; and Sebastian Creek Buffer Preserve (Brevard and Indian River counties).

Description

Structure

Mesic pine flatwoods (*sensu* Stout and Marion 1993) typically exhibit an emergent tree layer of pines with limbless lower trunks and ground layers of low vegetation. However, physiognomy varies markedly with fire regime and moisture. Pine densities in mesic pine flatwoods can range from sparse to dense depending on fire history, seed predation, and seedling predation. Canopy coverage of mature mesic pine flatwoods can range from 10 to 80 percent in unlogged stands. Pine trees are usually abundant enough to dominate the apparent landscape view and canopy, but canopy densities can vary, dependent upon the degree of fire exclusion (Wade *et al.* 1980).

Vegetative Composition

The mesic pine flatwoods habitat is dominated by a slash pine or longleaf pine overstory with an upland understory. Mesic pine flatwoods are distinct from hydric and xeric pine flatwoods in the tendency toward midstory dominance by saw palmetto and scrub species such as fetterbush (*Lyonia lucida*), tarflower (*Befaria racemosa*), rusty lyonia (*Lyonia ferruginea*), cabbage palm (*Sabal palmetto*), and wax myrtle (*Myrica cerifera*). Impacted mesic pine flatwoods

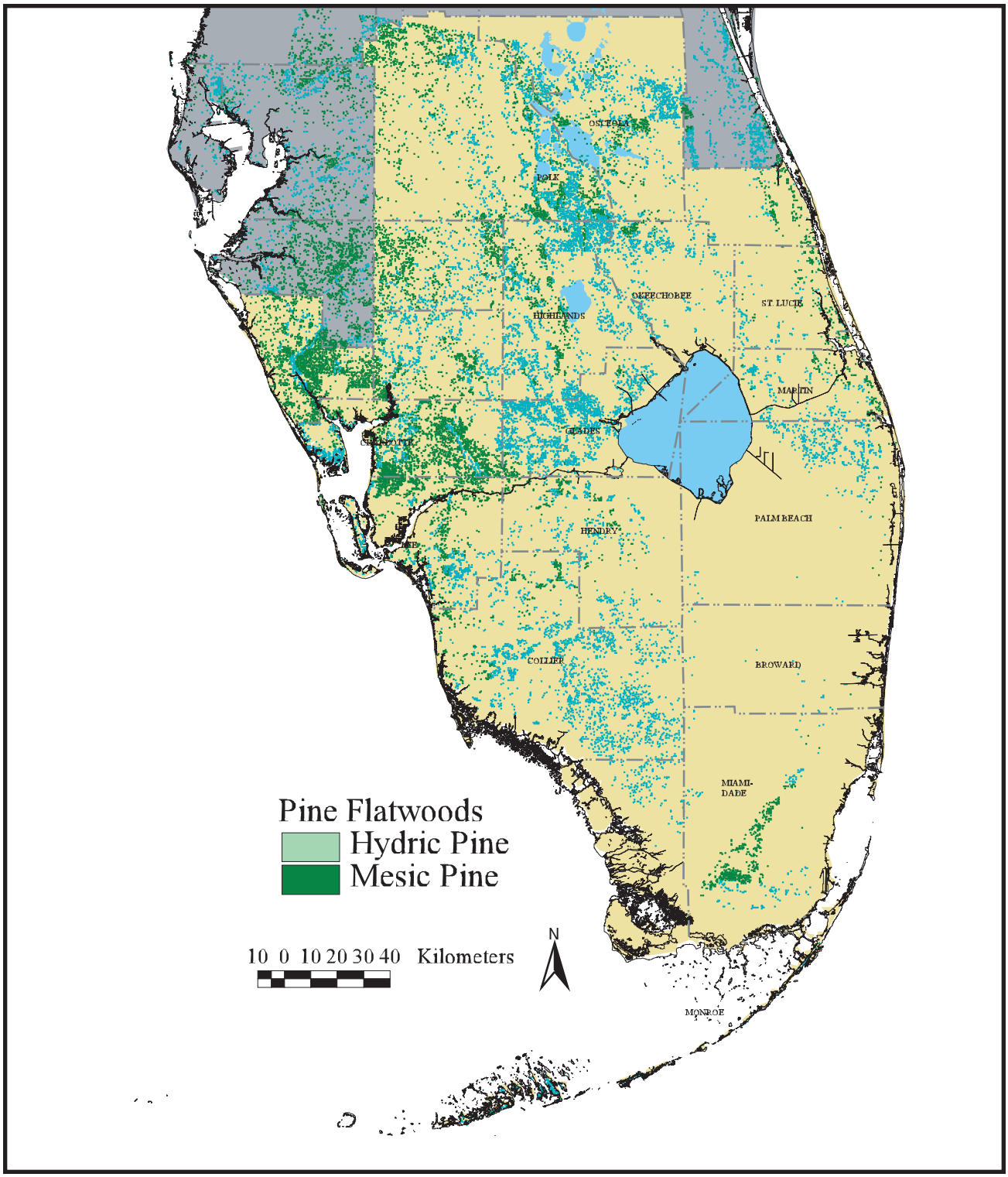


Figure 1. The distribution of hydric and mesic pine flatwoods in South Florida (data from USGS-BRD 1996).

are dominated by the exotic invaders: Brazilian pepper (*Schinus terebinthifolius*), Australian pine (*Casuarina equisetifolia*), downy rosemyrtle (*Rhodomyrtus tomentosus*), ear-leaf acacia (*Acacia auriculiformis*) and melaleuca (*Melaleuca quinquinervia*). Understory includes a wide variety of grasses (*Agrostis*, *Andropogon*, *Aristida*, *Dichanthelium*, *Eragrostis*, and *Panicum* spp., *etc*.), pawpaws (*Asimina* spp.), gopher apple (*Licania michauxii*), legumes (*Cassia*, *Crotalaria*, *Galactia*, *Rhynchosia*, *Tephrosia* spp., *etc*.), milkworts (*Polygala* spp.), blueberries (*Vaccinium* spp.), milkweeds (*Asclepias* spp.), and a wide variety of composites (*Aster, Chrysopsis, Emilia, Eupatorium, Liatris,* and *Solidago* spp., *etc*.).

The taxonomy of the South Florida slash pine has been a matter of significant debate (Small 1913, Little and Dorman 1954, Squillace 1966, Mirov 1967, McMinn and McNab 1971). *Pinus elliottii* var. *densa* is more flood- and drought-tolerant than is var. *elliottii*. Squillace (1966) concluded that the phenotypic plasticity that allows *densa* to accommodate both upland and wetland conditions, fire, and flood is the result of its evolution under the severe environmental factors of South Florida flood and drought that vary from year to year and fluctuate widely over longer time courses.

Mature South Florida slash pine can attain a height of 30 m (110 feet), with a dbh of 40 cm (16 inches) (Duever *et al.* 1976). In an average southwest Florida mesic pine flatwoods, mature trees typically attained 30 to 41 cm (12 to 16 inches) dbh with 23 to 26 m (75 to 85 feet) of height (Beever and Dryden 1998). Growing season is from February to November, with maximum growth rates attained at the spring and autumnal equinoxes (Langdon 1963). The growth rate of South Florida slash pine has been measured in the Corkscrew area of Collier County at an annual diameter at breast height (dbh) increase of 1.15 cm (0.45 inches) per year and an annual height increase of 60 cm (2 feet) per year. The forestry productivity of southwest Florida mesic pine flatwoods for wood products has been recorded at over 27 cords/acre (242 cubic meters/acre) at age 16 (Wade *et al.* 1980). Annual net understory productivity is 140 g/m^2 (1,250 lb/ac) with a litter fall averaging 130 g/m^2/yr (1,160 lb/ac). Decomposition is only 30 percent per year (Duever *et al.* 1976). This results in an annual net accumulation of litter of approximately 90 g/m^2 (800 lb/ac) when fire is excluded. This relatively rapid litter fuel buildup increases the probability of fire ignition and the chance for hot, crowning fires through time.

Longleaf pine and slash pine communities are extremely diverse floristically, and contain several rare and endemic plant taxa, making this one of the most important natural systems in the southeastern United States (Hardin and White 1989). Hardin and White (1989) listed 191 rare plant taxa as occurring in the wiregrass ecosystem; seven of these taxa have been proposed for listing or are currently listed as federally endangered, and 61 are listed as threatened or endangered in three states. The wiregrass ecosystem supports 33 locally endemic plant taxa, all from Florida.

South Florida slash pine and longleaf pine which are growing in normal mesic pine flatwoods conditions and are subjected to fire, typically display: (1) No buttressing of the lower trunk, (2) Fire-darkened or fire-scarred lower trunks, (3) A straight growth form, (4) Little woody debris and needle litter

build-up, and (5) A crowned growth form, with few branches, if any below the top third of the tree.

Long (1974) lists 303 species of plants in the mesic pine forest habitat of South Florida, the third highest plant species diversity of any habitat in South Florida. Presently, 482 plant species (115 monocotyledon, 353 dicotyledon, 3 gymnosperm, and 11 pteridophyte species) have been identified from or are documented as present in the mesic pine flatwoods of southwest Florida. (Beever and Dryden 1998). South Collier County and lower east coast mesic pine flatwoods have more tropical plant species represented in their understory and a different underlying geology, often composed of marl, and oolitic rockland extrusions (Wade *et al.* 1980), when compared to the mesic pine flatwoods of central and western South Florida.

Of the 482 plant species recorded in literature from mesic pine flatwoods of South Florida, 65 species (13 percent) are typically considered to occur in wetland saturated zones. Four hundred and seventeen species (87 percent) are typically considered upland plants. Twenty-five (5 percent) are exotic, introduced species. These 482 plant species comprise 29 percent of the documented terrestrial flora of South Florida (Wunderlin 1986).

Soils

The mesic pine flatwoods of South Florida are all located in the South Florida Basin of the Floridan Plateau (Vaughan 1910, Chen 1965). The soil types in mesic pine flatwoods generally fall into one of two major substrate sediment groups: limestone rock, and sands (marine terraces) (Duever *et al.* 1986, SFWMD 1980). The soils of the mesic pine flatwoods of South Florida are non-hydric soils as defined by the Florida Association of Professional Soil Classifiers (Carlisle 1990).

Sands are the dominant soil type of South Florida, and of the mesic pine flatwoods in particular. Typical mesic pine flatwoods occur on relatively flat, poorly drained terrain. The soils typically consist of 30 to 91 cm (1 to 3 feet) of acidic sands often over an organic hardpan or clay layer. Cabbage palm-dominated mesic flatwoods occur on more neutral sands (pH 6.0-7.5) underlain by marl or shell. This hardpan can substantially reduce the percolation of water below and above its surface (FNAI 1989).

On the east coast of Florida, when exposed limerock substrate is present, these pinelands are identified as Pine Rocklands.

Wildlife Diversity

The mesic pine flatwoods of South Florida are of critical, regional importance to the biota of South Florida. They provide essential forested habitat for a variety of wildlife species including: wide-ranging, large carnivores such as the Florida panther and the Florida black bear; mid-sized carnivores; fox squirrels; and deer. They provide tree canopy for canopy-dependent species including neotropical migrants, tree-cavity dependent species, and tree-nesting species. Mesic pine flatwoods are also important as the principle dry ground in South Florida, furnishing refuge and cover for ground-nesting vertebrates as well as habitat for non-aquatic plant life (such as upland perennials and annuals). During the summer

wet season, the mesic pine flatwoods of South Florida function as the upland ark for non-aquatic animals. Mesic flatwoods serve as ground bird nesting areas; adult tree frog climbing areas; black bear foraging, denning, and travelways; and essential red-cockaded woodpecker foraging and nesting habitat.

The variety and diversity of invertebrate species utilizing the mesic pine flatwoods as foraging, breeding, and nursery habitat has not been well studied. Species that cause economic damage to pine trees, particularly bark beetles, have been the principle focus of entomological literature in pine flatwoods. A total of 7 phyla, at least 12 classes, and at least 40 orders of invertebrates are observed or documented to occur in the mesic pine flatwoods of South Florida. Dominant taxa, in individual numbers and species diversity, include the arthropods, gastropods, nematodes, rotifers, and protozoans. The most conspicuous taxa are the insecta and arachnida. The most common terrestrial crustacean is the isopod pillbug (Beever and Dryden 1998). Representatives of 20 orders of insects are present in the mesic pine flatwoods of South Florida. The abundance and diversity of insect fauna is related to the variable hydrology, host plant diversity, and microhabitat presence (*e.g.*, fungal bracts, dead trees, hosts for parasites, *etc*.) available in the mesic flatwoods ecosystem.

The myriad of invertebrate species in the mesic pine flatwoods support the vertebrate species. This community is important habitat for a number of common pine flatwoods vertebrate species, including the pine woods tree frog (*Hyla femoralis*), oak toad (*Bufo quercicus*), box turtle (*Terrapene carolina*), eastern diamondback rattlesnake (*Crotalus adamanteus*), black racer (*Coluber constrictor*), brown-headed nuthatch (*Sitta pusilla*), Bachman's sparrow (*Aimophila aestivalis*), pine warbler (*Dendroica pinus*), great horned owl (*Bubo virginianus*), least shrew (*Cryptotis parva*), cotton mouse (*Peromyscus gossypinus*), cotton rat (*Sigmodon hispidus*), and gray fox (*Urocyon cinereoargenteus*) (Layne 1974, Layne *et al.* 1977). Although no mammal is endemic only to the mesic pine flatwoods of South Florida, both Sherman's (*Sciurus niger shermani*) and Big Cypress fox squirrels (*Sciurus niger avicennia*) are closely associated with the open understory provided by fire-maintained mesic pine flatwoods. Three large native mammals that regularly use mesic pine flatwoods are the white-tailed deer (*Odocoileus virginianus*), Florida black bear, and Florida panther (Layne 1974).

To date, field studies and the literature (Beever and Dryden 1998, Cunningham 1961, Duever, *et al.* 1986, Ashton and Ashton 1988, Kale and Maehr 1990, Layne 1978, Myers and Ewel 1990, Soil Conservation Service 1986, Florida Department of Natural Resources 1989, Florida Department Natural Resources 1990) have identified 28 mammal, 116 bird, 29 reptile, and 13 amphibian species from the mesic pine flatwoods of South Florida, including 3 endangered species, 6 threatened species, and 6 species of special concern, and 8 Convention on International Trade in Endangered Species (CITES) species.

Twenty-eight of 32 mammal species known from South Florida are found in the mesic pine flatwoods (Layne 1978, Drew and Schomer 1984). The Big Cypress fox squirrel, Florida weasel *(Mustela frenata peninsulae*), and red fox (*Vulpes vulpes*) have only been observed in Lee and Collier counties (Beever and Dryden 1998). One hundred and sixteen (42 percent) of the 274 bird species known from South Florida (Kale and Maehr 1990) are found in the mesic pine flatwoods (Beever and Dryden 1998). Twenty-nine taxa (54 percent) and 27

species (55 percent) of the 54 taxa (49 species) of reptiles not restricted to coastal waters in South Florida (Duever, *et al.* 1986, Ashton and Ashton 1988), utilize the mesic pine flatwoods as habitat. This includes 20 snakes, 1 turtle, 1 tortoise, and 7 lizards. Reptiles utilize mesic pine flatwoods in both wet and dry seasons, although different species may be present seasonally in different hydrologic conditions (Beever and Dryden 1998).

Thirteen (65 percent) of the 20 amphibian species found in South Florida (Ashton and Ashton 1988) utilize the mesic pine flatwoods habitat for feeding and/or breeding. This includes all of the treefrog and toad species of southwest Florida. The most frequently encountered and abundant amphibians are tree frogs, oak and southern toads, and spadefoot toads (Beever and Dryden 1998).

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the mesic pine flatwoods in South Florida include: Florida panther, Key deer (*Odocoileus virginianus clavium*), Audubon's crested caracara (*Polyborus plancus audubonii*), Kirtland's warbler (*Dendroica kirtlandii*), bald eagle (*Haliaeetus leucocephalus*), red-cockaded woodpecker (*Picoides borealis*), and eastern indigo snake (*Drymarchon corais couperi*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

The **Florida panther** utilizes mesic pine flatwoods in combination with other forested upland and seasonal wetland habitats. They provide critical foraging, breeding, and wildlife corridor habitat. The documented foraging and breeding territories of the radio-collared Florida panthers, and documented sightings of Florida panther include the large expanses of undisturbed mesic pine flatwoods in the area (D. Maehr, GFC, personal communication, 1991, L. Campbell, GFC, personal communication, 1991). The panther utilizes hydric, mesic, and xeric pine flatwoods, and savanna, hardwood hammocks, and mixed swamp forest. Prey animals, including white-tailed deer (*Odocoileus virginianus*) and feral hog (*Sus scrofa*), utilize the plant diversity of the mesic pine flatwoods for foraging, and the dry cover for the raising of offspring (Layne and McCauley 1976). The prevalence of mesic pine flatwoods on private ranches is thought to be partly responsible for increased deer numbers and deer health, which supports increased Florida panther presence on private lands. Recently burned mesic pine flatwoods provide more prey for panther, and panthers are documented to move toward fires and stay in areas of recent burns (Belden 1986). Panthers require large territories and abundant prey. The mesic pine flatwoods of southwest Florida can provide both these requirements. Additionally, the mesic pine flatwoods and swamp forests associated with natural drainage patterns provide the travel corridors essential to the panther for traveling between the fragmented foraging areas remaining in southwest Florida.



Florida black bear. *Original photograph by Barry Mansell.*

The **Florida black bear** is a forest habitat generalist with seasonal preference for wherever food is most available. Black bears utilize all the natural forested systems of South Florida, with a decided preference for upland/wetland ecotones. Telemetry information, documented sign and sightings of Florida black bear, and periodic road kills all indicate that large, relatively undisturbed mesic pine flatwoods, in combination with other upland forests and the major wetland systems, provide the principal habitat of the black bear in southwest Florida (Brady and Maehr 1985, Maehr 1984, Maehr *et al.* 1988, Land 1994).

Bears are omnivores that feed on readily available food resources. Preferences for berries, insect larvae, the occasional small animal (frogs, mice, *etc*.), eggs, and wild honey can be satisfied in the mesic pine flatwoods environment. Fruits from cabbage palm, saw palmetto, and berry bushes, are consumed on a seasonal basis. Occasionally, young white-tailed deer and wild hog are taken as prey (Williams 1978a).

The southern limit of the **Sherman's fox squirrel** on the west coast of Florida includes the mesic pine flatwoods and riverine hardwood forests of Sarasota, Charlotte and northern Lee counties. Ehrhart (1978) and Kantola (1991) did not include its range to extend into southwest Florida, perhaps because its principal north and central Florida habitat is longleaf pine-turkey oak sand hills, a habitat not found in South Florida to any large extent. In South Florida, the mesic pine flatwoods and mixed flatwood-hardwood riverine forests are important habitats for this fox squirrel subspecies. Sherman's fox squirrels forage on male pine cones in winter and female pine cones during the summer. Acorns from a variety of oaks (live, laurel, and sand live), cabbage palm fruits, bromeliad buds, and insects are also consumed. All of these food sources are available in the mesic pine flatwoods of South Florida. Oak and hardwood hammocks, xeric sandhill ridges, and riverine forests adjacent to mesic pine flatwoods provide additional forage on a rotating seasonal basis. Nesting occurs in mesic pine flatwoods in pines, oak, and cabbage palms.



Big Cypress fox squirrel. *Original photograph by Grant Webber.*

The **Big Cypress fox squirrel** primarily utilizes flatwoods in South Florida. Mesic pine flatwoods understories that are maintained open by fire can provide a good forage for the fox squirrel. The fox squirrel forages on male pine cones in winter, and female pine cones during the summer. Male and female cones from cypress, cabbage palm fruits, bromeliad buds, and acorns are also consumed (Humphrey and Jodice 1991). Mature mangrove forest, oak and hardwood hammocks, and riverine hardwoods adjacent to mesic pine flatwoods provide additional forage on a rotating seasonal basis. Nesting occurs in upland and wetland habitats in pines, oaks, black mangrove, cypress, and cabbage palms; often in bromeliad clumps. The Big Cypress fox squirrel is not observed in pine flatwoods dominated by a thick saw palmetto understory, monocultural dense melaleuca forest, Brazilian pepper forest, Australian pine stands, and man-made habitats that do not possess a superabundance of food. Maintaining large, unfragmented areas of mesic pine flatwood is important to the long-term survival and recovery of this charismatic mammal.

The **Florida weasel** has been recorded in the mesic pine flatwoods of South Florida (Brown 1978c). The species is naturally rare (Brown 1972) and has been, based on records, for the last 100 years. The species also uses hydric and xeric pine flatwoods, cabbage palm and live oak hammocks, and swamps in its range. Surveys for the Florida weasel (Hovis 1993) continue to confirm its rarity.

The **red-cockaded woodpecker** in South Florida utilizes mesic pine flatwoods as nesting and foraging habitat (Beever and Dryden 1992, Duever *et al.* 1986, D. Jansen, NPS personal communication 1991). The territories of red-cockaded woodpeckers in mesic slash pine flatwoods of South Florida are documented to be larger than reported for northern birds (Nesbitt *et al.* 1983, Patterson and Robertson 1981). Of the 123 known red-cockaded woodpecker colonies in southwest Florida, 24 colonies are located in healthy mesic slash

pine flatwoods (Beever and Dryden 1992). Historically, a greater number may have been present in mesic pine flatwoods but loss of habitat to logging and urban and agricultural development severely constrains the availability of mature forests. Subsequent forest regrowth is typically harvested on 20 to 40 year rotations that do not allow the establishment of a mature forest necessary for the creation of start holes and cavities. Fire exclusion, coupled with fast rotation for pulpwood has rendered significant acreages of mesic pine flatwoods unsuitable for use by the red-cockaded woodpecker.

Bald eagles (*Haliaeetus leucocephalus*) utilize the pines of mesic pine flatwoods of South Florida as nest trees, particularly where this community is located adjacent to an estuarine, riverine, or lacustrine foraging area. Large, mature trees capable of supporting the heavy nests are preferred nesting sites. Bald eagles often remain in mesic pine flatwoods year-round. In some areas of South Florida, large groups of eagles soar on thermals during the fall and spring migrations and gather over large pine flatwoods forests inland from the coast (Beever and Dryden 1998). Without large pine trees, eagle nesting would drop precipitously in South Florida.

Audubon's crested caracara have been observed to utilize open mesic pine flatwoods areas in South Florida in Sarasota, Charlotte, DeSoto, Hardee and Highlands counties during cooler months. Caracaras probably approach the mesic pine flatwoods in a coarse-grained landscape approach. Clusters of mesic cabbage palm seem to be important as a focus for this seasonal foraging by this prairie bird species.

The **Florida sandhill crane** (*Grus canadensis pratensis)* prefers wet prairies, marshy lake margins, low-lying pasture, open marsh, and shallow flooded open areas (Williams 1978b). Sparsely canopied mesic pine flatwoods adjacent to ponds and marshes provide nesting and foraging habitat for sandhill cranes and their young throughout the nesting and fledgling period. In contrast, unburned mesic pine flatwoods are not utilized.

The **southeastern American kestrel** (*Falco sparverius paulus)* is a small falcon that utilizes open habitat for foraging and nests in tree cavities, typically abandoned woodpecker holes in pine trees. The kestrel utilizes tall pine trees, often snags, power and telephone poles and wires, and other tall objects. The kestrel feeds on large insects and, occasionally, on small rodents, reptiles, and birds (Wiley 1978). The mesic pine flatwoods of southwest Florida provide shelter, as well as habitat for reproduction and foraging for the kestrel. The observed foraging areas for these birds often extend to adjacent open habitats, such as pasture, both wet and dry prairies, and mowed roadway edges.

The **eastern indigo snake** utilizes a wide variety of habitats in South Florida, including mesic pine flatwoods, tropical hammocks, and xeric areas (Kochman, 1978). Where available, gopher tortoise (*Gopherus polyphemus*) burrows are utilized as shelter. Eastern indigo snakes occur in mesic pine flatwoods in South Florida throughout the year in the moister areas. The abundant amphibian and reptilian fauna of mesic pine flatwoods are important to the diet of this wide-ranging reptile.

The **gopher tortoise** utilizes dry, well-drained soils with areas of open, herbaceous understory (Auffenberg 1978). In South Florida, gopher tortoise burrows typically are found in xeric and mesic coastal ridges of the Silver Bluff terrace, including coastal scrub, dry tropical hammock, live oak hammock, and pine flatwoods. In most of South Florida, these perennially dry habitats exist as islands surrounded by reticulate hydric habitats. The gopher tortoises that utilize natural mesic pine flatwoods often construct wet season burrows in dry, upland ridge islands. In drained mesic pine flatwoods, gopher tortoises construct dry season burrows in the flatwoods. The gopher tortoise forages in both the upland ridge and the adjacent mesic pine flatwoods when water levels recede and throughout the dry season. The gopher tortoise forages on the grasses, herbs, fruits, and berries provided by the understory of fire-maintained mesic pine flatwoods. Gopher tortoise densities in mesic pine flatwoods are limited by the extent of upland suitable for year-round burrow use and the availability of forage.

The **gopher frog** (*Rana capito*) utilizes gopher tortoise burrows, mouse burrows, stump holes, post holes, and crayfish holes in mesic pine flatwoods. In the breeding season, gopher frogs congregate at night in shallow vegetated ponds to breed (Fogarty 1978b). Mesic pine flatwoods ponds provide such breeding habitat at the appropriate time, adjacent to the xeric scrub habitats where adult gopher frogs are found more frequently.

Plant Species of Concern

Federally listed plant species that are reported to occur in mesic pine flatwoods in South Florida include: beautiful pawpaw (*Deeringothamus pulchellus*), and Carter's mustard (*Warea carteri*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. Many rare plant species, including ferns, orchids, midstory trees, and herbaceous monocots and dicots are found in mesic pine flatwoods with natural hydrology and fire regime.

Carter's large-flowered flax (*Linum carteri* var. *smallii*) is an annual plant that occurs throughout South Florida in Miami-Dade, Collier, Monroe, Hendry, Martin, Palm Beach, Broward, and Charlotte counties. This species is shade-intolerant and prefers moist but not inudated soils. This variety can be distinguished from the related *L. c*. var. *carteri* by its smooth stems, taller habit, and its overall larger flower petals. *Linum carteri* var. s*mallii* has demonstrated a tolerance to human disturbance by persisting along roadsides. This species is under threat by development of its habitat. This variety is known from fewer than 10 occurrences. The State of Florida has listed *Linum carteri* var. *smallii* as an endangered species.

Coastal vervain (*Verbena maritima*) is a perennial herb that utilizes mesic pine flatwoods on the east coast of Florida. The South Florida counties where it is known include: Miami-Dade, Palm Beach, Indian River, Collier, St. Lucie, Hendry, and Martin. Other counties include: Brevard, Volusia, Flagler, and Levy. This shade-intolerant plant prefers sandy clearings that are maintained by fire and wind. This species is being threatened by development and exotic plant invasion such as by Australian pine (*Casuarina equisetifolia*). The State of Florida has listed *Verbena maritima* as an endangered species.

Ecology

Hydrology

The flat topography, sandy soils, and the seasonal precipitation cycle are the principal influences of mesic pine flatwoods hydrology. The flat topography, a result of Pleistocene geology, creates minimal gradients, resulting in sufficient time for percolation, soil saturation and slow runoff that occasionally creates very poorly defined first-order streams and typically results in sheetflow patterns if water becomes high. Where hardpan is present, water moves slowly vertically relative to horizontal movement, through horizons above and below the hardpan layer. Mesic pine flatwoods soils then become waterlogged and poorly aerated during the rainy season. This results in the saturated soils typical of unaltered, undrained mesic pine flatwoods. During the dry season, high evapotranspiration draws most of the water out of the upper soil horizons, drying them out. Soil moisture becomes depleted in the upper soil layers, above the hardpan, and a persistent drought condition frequently prevails through the dry season. As a result, during the dry season, groundwater is inaccessible for plants that cannot penetrate hardpan (FNAI 1989).

Water depths in mesic pine flatwoods vary throughout the seasonal hydrologic cycle. Extreme ranges are from just below the surface to 2.4 m (8 feet) below ground surface. Typical ranges are from 0.15 m to 0.30 m (6 inches to 1 foot) below ground surface at the height of the wet season to 1.8 m (6 feet) below ground surface in the late dry season. For most of the year, undrained mesic pine flatwoods have water within 1.2 m (4 feet) below the ground surface (Abrahamson and Hartnett 1990).

Fire

The mesic pine flatwoods is a fire climax, hydroperiod-mediated community (Wade *et al.* 1980). In pre-Columbian times, fires probably occurred in the mesic pine flatwoods every 3 to 10 years. Nearly all plants and animals of the mesic pine flatwoods are adapted to periodic fires (FNAI 1989). While natural fires were numerous, the areal extent of any given fire was probably small [10 ha (25 acres) or less]. Most fires occurred at the end of the dry season. This pattern of patch fires creates a mosaic of plant and habitat diversity, as opposed to a monopyric, even-aged plant community. Frequent, low-intensity surface fires generally characterize the fire regime. Historical evidence suggests that a fire frequency of 1 to 3 years is necessary to maintain this community (Ware, Frost, and Doerr 1993). The chances that a severe, crown-killing fire will occur increase as the fire frequency decreases (Christensen 1988).

South Florida slash pine seedlings have a grass stage that, like longleaf pine, greatly increases resistance to fire damage. Fire stimulates slash pine seedlings to sprout, promoting their growth as pioneers of burned land. Adult South Florida slash pines are also more resistant to fire than are northern slash pines (Wade *et al.* 1980, Ketcham and Bethune 1963). South Florida slash pine possesses longer tap roots and smaller needle size than do the northern slash pine (McNab 1965, McMinn 1970).

Much of the variation in community structure of mesic pine flatwoods is probably associated with fire frequency. The longer the period since the last fire, the more developed the understory shrub layer. If the understory is allowed to grow too long without fire, the accumulated needle bed and the height of flammable understory shrubs increases the probability of catastrophic canopy fires (FNAI 1989). If fires are very frequent, slash pine seedling regeneration will not occur, and the mesic pine flatwoods will tend to be dominated by a herbaceous understory of wetland species with clusters of cabbage palms forming a mesic cabbage palm prairie (Wade *et al.* 1980).

Less fire tolerant plant community components have refugia in the deeper waters found in pineland ponds and adjacent cypress strands. With overdrainage, fire refugia are lost. This typically results in decreases in the midstory and tropical components of South Florida mesic pine flatwoods with subsequent losses in plant species diversity. If overdrainage is coupled with too-frequent fire, and a melaleuca seed source is nearby, the mesic pine flatwoods can become dominated by the melaleuca monocultures typical of south Lee and northern Collier Counties (Wade *et al.* 1980).

Without regular fires, mesic pine flatwoods are expected to succeed into hardwood dominated forests with a closed canopy, eliminating groundcover herbs and shrubs (Alexander 1967, FNAI 1989). After approximately 6 to 10 years of fire absence, perennial plants that are normally set back by fire attain larger size. An increase in ground cover results from the presence of fewer, but larger, individual plants. These individual plants are subsequently shaded out by other plant species that would normally be killed by fire. This results in an increase in cover, but a decrease in plant species diversity. In general, fire exclusion from mesic pine flatwoods results in species loss, decreased forage quantity and quality for herbivorous species, and subsequently for their predators, increased danger from wildfires, and decreased pine regeneration (Wade *et al.* 1980).

Mesic pine flatwoods systems that have had hydroperiod drainage and/or fire exclusion, such as Golden Gate Estates in Collier County, appear to accumulate litter loads quickly, resulting in plant diversity degradation to disturbed and exotic-invaded conditions, declines in tree recruitment, and subsequent wildfires (Beever and Dryden 1998).

Status and Trends

Land Conversion/Development

An analysis of vegetation types most impacted by human land conversion indicates that statewide only 36 percent of the pine flatwoods remain (64 percent loss). Interestingly, this is the same proportionate loss as for pine rocklands. South Florida pine flatwoods are among the least protected habitats by the current distribution of public land managed areas with only 9 percent protected. This is proportionately less than for longleaf pine-xeric oak sandhills (14 percent) and sand pine scrub (35 percent); habitats typically advocated for protection as under-represented on preserve lands (Cox *et al.* 1997).

The mesic pine flatwoods of southwest Florida were not a rare habitat historically, occupying approximately 3,078,361 ha (7,606,525 acres) of South Florida pine flatwoods (Davis 1967). Using a conservative estimate that one-third

of these flatwoods were mesic, historically there would have been approximately 1,026,120 ha (2,535,508 acres) of mesic pine flatwoods. As a group, xeric, mesic, and hydric pine flatwoods were reduced to approximately 50 percent of their historic extent by 1970 (Birnhak and Crowder 1974) as a result of agricultural activities, speculative real estate clearing, and urban development. Wade *et al.* (1980) reported that in 1980, pine flatwoods occupied more area in South Florida than any other kind of plant community except the Everglades marsh. By 1989, GFC mapping of South Florida (Kautz 1993) indicated that pine flatwoods had dropped to fifth in areal extent (acres) behind grasslands, cypress swamp, dry prairies, and freshwater marsh. This study indicated that, for the first time, urban areas occupied more acreage in South Florida than did pine flatwoods. By 1989, there were only 2,648,850 ha (6,545,219 acres) of pine flatwoods in the entire State of Florida (Cox *et al.* 1994).

Flatwoods dominated by longleaf pine are part of the larger longleaf pine-wiregrass ecosystem that was once dominant throughout the southeastern coastal plain of North America. The distribution of this ecosystem has been reduced by approximately 85 percent (or by 99.9 percent if old growth examples are included). At the time of European settlement, longleaf pine communities covered at least 24 to 38 million ha; today these communities cover less than 4 million ha, and most of this is second growth and degraded (Noss 1988).

As of 1996, 1,077,279 ha (2,661,919 acres) of South Florida pine flatwoods existed, with 269,345 ha (665,542 acres) present in public managed areas (Cox *et al.* 1997). Based on the 1989 distribution of pine flatwoods in coastal southwest Florida (Collier, Charlotte, and Lee counties) approximately 40 percent was mesic pine flatwoods (Beever and Dryden 1998). This would calculate to 430,912 ha (1,064,767 acres) of mesic pine flatwoods in South Florida in 1996.

If mesic pine flatwoods are not protected, they will be converted to urban, suburban, and agricultural development within a relatively short time period. Habitat destruction of mesic pine flatwoods and adjacent habitats is the primary threat to the Big Cypress fox squirrel (Brown 1973, 1978). Large-scale commercial and residential development of mesic pine flatwoods west of the Big Cypress National Preserve (BCNP) in the Naples area, conversion of mesic pine flatwoods to citrus north of the BCNP, and expansion of roadways through mesic pine flatwoods pose serious threats to habitat quality and quantity for the Big Cypress fox squirrel (Humphrey and Jodice 1991).

Many existing Developments of Regional Impact and other large projects in mesic pine flatwoods demonstrate the anticipated fate of the last extensive forested refuges in South Florida, and the endangered, threatened, and species of special concern that depend upon the mesic pine flatwoods for breeding, feeding, and wildlife corridors.

Hydrologic Alteration

The most common form of hydrologic alteration of mesic pine flatwoods is ditching to lower the annual water table for agriculture or construction. Deeper regional canals, such as those in Golden Gate Estates (Collier County), can lower the water table on a regional scale for the purposes of land development. This widespread practice substantially eliminates normal mesic flatwoods hydrology from large areas of South Florida including large platted

subdivisions in the City of North Port, Port Charlotte, City of Cape Coral, Lehigh Acres, South Fort Myers, Golden Gate Estates, Sebastian Highlands and the older parts of Port St. Lucie.

Another commonly encountered form of hydrologic alteration is small levees or berms created as a byproduct of ditching, placed as part of road or other linear construction to elevate the path above wetland grade, and intentional barriers designed as part of surface water management systems to retain all waters on a site as part of a development process. These permit-required water management structures dam sheetflow, redirect sheetflow into rapid discharge channels or stormwater retention and detention areas. The berms can simultaneously drown upstream mesic pine flatwoods (creating a deeper water wetland type), while denying sheetflow to downstream areas (creating a drier type of flatwoods). These blocks to sheetflow, coupled with inadequate culverting, are often the cause of significant flooding to both natural areas and human property. These structures significantly fragment regional hydrology and alter landscape flow into coastal estuaries.

Other types of hydrologic alterations to mesic pine flatwoods include water table drawdown by wellfields and surface mine excavation. Due to the permeable substrates that underlie mesic pine flatwoods, changes in surficial aquifer levels can rapidly translate into a drop in the water table. Mines and borrow pits, particularly those that operate pumps to accommodate excavation, can lower local water levels within a mesic pine flatwood. Wellfield pumping can, at significant levels of withdrawal, dry out mesic pine flatwoods, changing plant community structure and susceptibility to exotic invasion.

Substrate Disturbance, Exotic Plant Invasion, and Exotic Animals

Mesic pine flatwoods soils tend to be sandy with shallow, if any, organic layers. Productivity export and incorporation appear to be extremely efficient in natural mesic pine flatwoods, since bare, sandy soil surfaces are the norm in undisturbed mesic pine flatwoods systems, indicating that natural systems do not accumulate significant bed loads of litter. Simple physical disturbance of the surface by vehicles, plows, unimproved roads, excavations, exotic animals, fill, excavation, explosions, and seismic testing can leave an area with a slightly different elevation, altered soil nutrients, and different soil horizons that when revegetated, can be sites of weedy or exotic plant establishment. The first entry of exotic plants into a mesic pine flatwood area can often be along jeep trails, along plowed fire lanes, at the toe of fill roadways, along cleared utility easements, around borrow pits, where wild hogs have rooted, and along rock mine survey grid lines.

If substrate disturbance is coupled with fire exclusion and drainage, it is almost inevitable that Brazilian pepper or melaleuca will become established in the mesic pine flatwood. Mesic pine flatwood systems that have had hydroperiod alterations and/or fire exclusion coupled with substrate disturbance, such as Golden Gate Estates (Collier County), appear to accumulate litter loads quickly, resulting in plant diversity degradation with invasion by opportunistic species such as cabbage palm and grape vine, accelerated exotic plant invasion, declines in pine tree recruitment, and increases in wildfire.

Mesic pine flatwoods that are cleared of native vegetation but are not otherwise altered in hydrology or fire-frequency may return to mesic pine

flatwoods floristics, but typically will include exotic plant species in areas of substrate disturbance. Activities that increase the susceptibility of pine flatwoods to invasion by exotic species include rooting by hogs, fire suppression, clearings for wildlife food plots, fire plow lines, and revegetation (Martin *et al.* 1996).

Of the 482 plant species documented or recorded from the mesic pine flatwoods of South Florida, 25 (5 percent) are exotic, introduced species. Most of the introduced species are not invasive under natural hydrology and fire frequency. The principle invasive species include Brazilian pepper, melaleuca, and downy rosemyrtle.

There is some debate concerning the relative habitat values of exotic plant dominated landscape. While the presence of a few individual plants does not constitute a major community threat, solid monocultures have demonstrably negative effects on plant and animal community diversity. When exotics replace natives, plant and animal species that depend upon those natives are similarly impacted. Thresholds are not yet well understood and both under- and over-estimation of exotic plant invasion effects is common.

Exotic animals identified in South Florida mesic pine flatwoods include: wild hog (*Sus scrofa),* armadillo (*Dasypus novemcinctus),* feral dogs, feral cats, coyote (*Canis latrans),* Cuban tree frog (*Osteopilus septentrionalis),* the brown anole (*Anolis sagrei),* other exotic amphibians and reptiles, and red-imported fire ants. Wild hogs and to a lesser extent, armadillos, can change understory composition through substrate disturbance. This can negatively affect listed groundcover plant species and provide opportunities for exotic plant invasion. Feral hog activity kills plants directly, increases soil erosion, and facilitates weed and exotic species invasion (Martin *et al.* 1996). Cuban tree frogs are predators on native, smaller tree frog species and have been demonstrated to displace native species in urban and agricultural settings. Feral cats and dogs have been demonstrated to significantly impact small mammal, ground-nesting bird, and songbird populations in Florida and throughout the United States. Fire ants have become a problem for small animals including ground-nesting birds and some tree-nesting bird and mammal species as well. The effect of coyote on South Florida ecosystems and food webs is currently unknown. There have been various reports of benefits (predation on feral cats and dogs, wild hogs and armadillos) and problems (predation on gopher tortoises and ground-nesting birds, competition with native medium-sized predators). So far no organized strategies to address exotic predators in mesic pine flatwoods have been developed. The spread of exotic animals into native mesic pine flatwoods has been assisted by fragmentation of the landscape by roadways, canals, agricultural and suburban development. It is clear that the greater the amount of developed edge areas relative to core areas of mesic pine flatwoods, the greater the potential for exotic animal invasion of the habitat.

Extractive Land Use

Logging of the South Florida mesic pine flatwoods began in the 1920's and continued through World War II. Following logging, the understory components recovered quickly, depending on the level of altered hydroperiod. Pine recovery was slow in upland areas of mesic pine flatwoods (Wade *et al.* 1980). Several

factors contributed to this pattern: (1) upland pine areas were easier to deforest utilizing early twentieth-century techniques; (2) slash pine has less fire protection in mesic pine flatwood hydrologic conditions than in hydric conditions; and (3) in the absence of fire, the thick cover of saw palmetto reduces slash pine seedling growth and survival in fires.

Mesic pine flatwoods display a resilient recovery from overstory damage due to fire or clearcutting, if the natural hydrology and fire regime are allowed to continue. Recovery is poor when hydrology or ground cover is disturbed. While drainage may result in a shift toward more slash pine density, overdrainage can result in conditions too dry for slash pine establishment and survival in areas of previous slash pine dominance. The result has been an increase in the area of palmetto-dominated prairie from historic conditions prior to logging and drainage (Wade *et al.* 1980).

Overdrainage and pasture conversion has changed the South Florida landscape from pine flatwoods to one dominated by rangeland. Cattle ranching in the South Florida mesic pine flatwoods began immediately with the American settlement of South Florida. Calf raising and associated pasture for stock and dairies continues today, particularly in central South Florida. Drainage for range was a common practice and was encouraged by cooperative extension and farm programs from the 1920s until the 1970s. Following light grazing, the understory components of mesic pine flatwoods recover quickly, depending on the level of altered hydroperiod. Mesic pine flatwoods display a resilient recovery from grazing, if the natural hydrology and fire regime are allowed to continue and exotic, improved pasture grass species are not introduced. Recovery is poor when hydrology or ground cover is disturbed by improved pasture management. Drainage of mesic pine flatwoods has resulted in expansion of improved pasture and decreases in plant diversity, and subsequently wildlife diversity in South Florida. Mesic pine flatwoods converted to improved pasture or subject to high grazing pressure are also very susceptible to exotic invasion by range pests such as the exotic tropical soda apple and cogon grass (FNAI 1989). Management for domestic livestock grazing can result in alteration of soil properties and vegetation structure. In areas that have been grazed for long periods of time, soil becomes compacted, reducing water infiltration and percolation (Myers and Ewel 1990).

Saw palmetto berry gathering for pharmaceuticals has recently become a new extractive use of palmetto understory in mesic pine flatwoods. The effect of hand-harvesting tons of palmetto berries from this system is not currently known. Palmetto berries are important food for many wildlife species, including listed mammal species such as Florida black bear. The saw palmetto is also an important understory component for providing cover for prey species. It is not known if a significant number of berries are being removed, if berry-consuming wildlife is finding sufficient forage, or if berries are germinating sufficiently enough to maintain saw palmetto populations.

Waste Disposal and Nutrient Enrichment Issues

Mesic pine flatwoods are subject to a variety of waste disposal uses in South Florida. Landfills in southwest Florida have been uniformly sited in mesic pine flatwoods (Sarasota, Charlotte, Lee, and Collier counties). This invariably involves complex construction, water management, and containment systems

to prevent leachate discharge to adjacent areas. Such sites can become attractors to species found in mesic pine flatwoods, particularly Florida black bear and bald eagles. This in turn results in nuisance situations, mortality from toxins, unnatural population concentrations, and mortality from exposure to human-dominated landscapes (roadkills, power line collisions, and poaching). Fertilization in pine flatwoods may have drastic effects on these communities because they are naturally low in nutrients, and weedy species are likely to invade following nutrient enrichment (Martin *et al.* 1996). Also, Walker and Peet (1983) reported that an increase in productivity resulting from fertilization should lead to a decline in plant species richness, including a decline in rare plant species richness. It is not known whether fertilization will lead to replacement of rare species by more competitive species able to thrive under fertilized conditions. Fertilization can be carried to the aquatic habitat via runoff (Martin *et al.* 1996).

Most mesic pine flatwoods in South Florida that are accessible by vehicles and not patrolled by public or private on-site managers are subject to extensive dumping of yard debris, construction materials, large objects including vehicles and white goods, chemicals, and basic domestic garbage. This results in direct habitat degradation, exotic plant invasion, and water quality pollution. Dispersed rural and semi-suburban development in mesic pine flatwoods areas of South Florida are typically served by septic tank systems that are designed to leach into drain fields in the permeable sands of the mesic pine flatwoods. During annual wet season high water and other flood events, septic systems become saturated and both surface ground water and surface waters display pollution from fecal coliform bacteria, indicative of waste pollution.

Agricultural lands, including high- intensity cattle operations, display surface water fecal coliform bacteria, indicative of waste pollution from cattle waste. The practice of land spreading sludge from sewage treatment plants and septic systems over rangeland to “enhance” the low nutrient levels of mesic pine flatwood sands introduces nutrients and bacterial contamination into highly permeable and easily leached soils. Agricultural lands adjacent to mesic pine flatwoods also may discharge nitrified runoff to mesic pine flatwoods and other wetlands.

Recreational Damage

The activities of off-road vehicles can significantly alter the substrate of mesic pine flatwoods, altering hydrology and encouraging exotic plant invasion on the disturbed soils. Trash and debris from recreational activity is common on unmanaged areas, including food and beverage packaging, items brought in as targets for shooting, and other discarded items including monofilament, rubber, and plastic products.

Significant debate is ongoing concerning the impacts of some hunting activities on the wildlife and landscape of mesic pine flatwoods, including where off-road vehicles are used for access and for certain types of hunting where dogs are used.

Management

Management issues for mesic pine flatwoods include consideration of size and fragmentation, fire ecology, hydrology, substrate disturbance, exotic plant invasion, exotic animals, extractive land use, recreational uses, and effects of resource mitigation policy.

Management of Size and Habitat Fragmentation

Management to maintain and restore the high level of biodiversity found in mesic pine flatwoods is best achieved on large, intact, contiguous tracts of land composed of mesic pine flatwoods and of other native habitats. The habitat reticulation of xeric, mesic, and hydric pine with seasonal marsh, ponds, cypress and mixed hardwood swamp strands, and various hardwood and palm hammocks, maintained by fire and a dendritic sheetflow hydrology provides a self-sustaining community diversity that provides niches for innumerable species. Mesic pine flatwoods are not maintainable nor sustainable in small, "postage stamp" isolates that may be cut off from sheetflow hydrology, excluded from fire, subject to substrate disturbance, suffering significant edge effect, and vulnerable to exotic plant and animal invasion.

Managing mesic pine flatwoods is an issue of landscape ecology. Most existing public and private lands with intact, healthy mesic pine flatwoods and healthy biodiversity are large multi-square mile parcels. Current land acquisition and land protection proposals include protection of other existing large parcels, connection of existing and proposed parcels, and expansion of existing parcels to attain larger landscape size. This is functionally necessary to achieve the long-term persistence of the mesic pine flatwoods habitat type in South Florida and to achieve multi-species recovery in South Florida. Wide-ranging animals such as the Florida panther, Florida black bear, red-cockaded woodpecker, migratory birds, eastern indigo snake, and fox squirrel need a variety of connected habitats over a wide area to complete life-cycle needs and maintain viable population levels in South Florida.

Fire Management

Burning to increase value to livestock and wildlife is a well-established practice in mesic pine flatwoods. It has been documented to increase range values and wildlife habitat (Komarek 1963, Stoddard 1963, Lewis 1964, Moore 1972, Hughs 1975). Different burn regimes favor different wildlife species. For example, quail are favored by 2-year rotational burns (Moore 1972) and turkey are favored by 3- to 4-year cycles (Stoddard 1963).

Little is known about the frequency and timing that is most beneficial to most of the rare species or some plant communities. There have been few studies conducted to assess whether early or late growing-season burns are most beneficial to the community. However, early growing-season burns have been recommended over late growing-season burns because: (1) lightning fires in South Florida are most common in early summer (June), and the largest number of acres are burned naturally during late spring and early summer; (2) studies suggest that early growing-season burns are more favorable to growth

and survival of longleaf pine seedlings and saplings than late growing-season burns; (3) early growing-season fires are more detrimental to hardwoods, which compete with pines for establishment (Robbins and Myers 1992).

Additionally, smoke and fire management considerations in South Florida are increasingly dictated by human population safety concerns. These concerns have promoted some winter burn schedules.

Natural fire breaks created by moisture or the lowest impact method (such as foam) should be used whenever possible to contain the fire. However it is usually necessary to prevent the spread of fires into adjacent plant communities, off-site, or roadways; therefore control lines should be established using existing trails, roads, or plow lines. In flatwoods, plow or control lines should be cut by disc to avoid disruption of hydrology (sheetflow). However, these lines may be subject to weedy or exotic plant invasion. Spot fires can be created by dropping plastic balls of potassium permanganate and antifreeze from a helicopter. The small intermittent fires created by this method will burn together before becoming too hot. However, this method may not be appropriate for rare species management because it can create uniform, even, landscapes. (Natural fire moves differently.) Fire should be allowed to spread into ecotones and adjacent wetlands.

It is important to maintain natural South Florida hydroperiods and a diverse fire management schedule to achieve the highest plant biodiversity for the system. Landscape scale burning performed on large areas has also achieved good results and areas are not forced to micro-manage burns.

Hydrologic Management

A commonly encountered form of hydrologic alteration to mesic pine flatwoods is small levees or berms placed across the landscape. Removal or installing multiple culverts in these man-made flow blocks can substantially restore mesic pine flatwoods hydrology while reducing flooding effects on human property.

Management of Substrate Disturbance, Exotic Plant Invasion, and Exotic Animals

Mesic pine flatwoods soils tend to be sandy with shallow, if any, organic layers. Physical disturbance of the surface can leave an area with a slightly different elevation, altered soil nutrients, and different soil horizons that when revegetated, can be sites of weedy or exotic plant establishment. If substrate disturbance is coupled with fire exclusion and drainage, it is almost inevitable that Brazilian pepper or melaleuca will become established in the mesic pine flatwood.

Mesic pine flatwoods that are cleared of native vegetation but are not otherwise altered in hydrology or fire-frequency may return to mesic pine flatwoods floristics, but typically will include exotic plant species in areas of substrate disturbance. Activities that increase the susceptibility of pine flatwoods to invasion by exotic species include rooting by hogs, fire suppression, clearings for wildlife food plots, fire plow lines, and revegetation (Martin *et al.* 1996)

Of the 482 plant species documented or recorded from the mesic pine flatwoods of South Florida, 25 (5 percent) are exotic, introduced species. Most

of the introduced species are not invasive under natural hydrology and fire frequency. The principal invasive species: Brazilian pepper, melaleuca, and downy rosemyrtle are able to persist and spread if hydrology is altered and fire is suppressed. Removal or control of invasive and non-invasive exotic plant species is achievable in the mesic pine flatwoods of South Florida by direct mechanical and chemical control, and restoration of hydroperiod and natural fire regimes. Successful projects on public and private lands utilize multiple strategies with long-term persistent management staffing and removal effort. The causes of alteration to the mesic pine flatwoods that encourage exotic plant invasion spread must be eliminated to achieve long-term eradication. If the causes are not addressed, then control is achievable only with repetitive persistent management. If management is suspended, gains can be quickly lost and exotic plants attain dominance.

Exotic animals known to occur in South Florida mesic pine flatwoods include: feral hog, armadillo, feral dogs, feral cats, coyote, Cuban tree frog, the brown anole, and fire ants. Feral hogs and armadillos can be managed by direct trapping and hunting. An alternative, concurrent strategy includes management for the natural predators of these species. So far no organized strategies to address exotic predators in mesic pine flatwoods have been developed. The spread of exotic animals into native mesic pine flatwoods has been assisted by fragmentation of the landscape by roadways, canals, agricultural and suburban development. It is clear that the greater the amount of developed edge areas relative to core areas of mesic pine flatwoods, the greater the potential for exotic animal invasion of the habitat.

Management for Extractive Land Use

Mesic pine flatwoods display a resilient recovery from overstory damage due to fire or clear-cutting, if the natural hydrology and fire regime are allowed to continue. Recovery is poor when hydrology or ground cover is disturbed.

Current best management practices for logging in the mesic flatwoods of South Florida utilize seed tree cutting strategies, rather than clear-cutting, but have relatively rapid 20- to 30-year rotations that eliminate all but a few of the mature old-growth trees, essential to red-cockaded woodpeckers. Removal of snags also reduces biodiversity in mesic pine flatwoods, as 53 different animal species depend upon the cavities found in the dead trees of mesic pine flatwoods.

Overdrainage and pasture conversion has changed the South Florida landscape from pine flatwoods to one dominated by rangeland. Following light grazing, the understory components of mesic pine flatwoods recover quickly, depending on the level of altered hydroperiod. Mesic pine flatwoods display a resilient recovery from grazing, if the natural hydrology and fire regime are allowed to continue and exotic, improved pasture grass species are not introduced. Recovery is poor when hydrology or ground cover is disturbed by improved pasture management.

Mitigation Policies

The mitigation policies of Federal, State and local regulatory agencies can significantly affect the management of mesic pine flatwoods of South Florida.

Those entities may encourage conversion of flatwoods into wetlands as mitigation for impacts to wetlands. Lower quality wetland preservation and enhancement is often preferred to the preservation of high quality upland habitats, including mesic flatwoods. This conversion of mesic flatwoods to wetlands typically fails because the necessary hydrology for the mitigation site is not achieved.

Restoration Science

To date, there has been no successful creation of mesic pine flatwoods from other landscapes. Successful restorations in existing mesic pine flatwoods have involved exotic plant and animal removal and control, restoration of hydrology, restoration of fire management, and removal of trash and debris.

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Restoration of Mesic Pine Flatwoods

Restoration Objective: Maintain the structure, function, and biological composition of hydric pine flatwoods, and increase the spatial extent of protected pinelands in South Florida.

Restoration Criteria

South Florida can contribute to the preservation of regionally significant aquifer recharge and fish and wildlife habitat values by preserving mesic flatwoods. The conservation and recovery of listed plant and animal species, wide-ranging species, neotropical birds, and large complexes of isolated and ephemeral wetlands will be accomplished by the preservation and restoration of this community.

The restoration objective will be achieved when: (1) the mesic pine flatwoods habitat is preserved through land acquisition or private landowner cooperative agreements, consistent with the GFC's "Closing the Gaps in Florida's Wildlife Habitat Conservation System," the Florida Panther Habitat Preservation Plan (South Florida Population), the Game and Fresh Water Fish Commission's Preservation 2000 Act Study (Biodiversity Conservation Analysis), current State/Federal land acquisition proposals (including CARL, SOR, *etc*.), other Federal listed species recovery plans, and regional wildlife habitat protection plans; (2) degraded areas are identified and restored to suitable hydric pine flatwoods habitat; (3) hydrology, fire and exotic plant management is regionally applied to restore and maintain regional plant and animal biodiversity; (4) the geographic extent of mesic pine flatwoods in South Florida is identified; and (5) the integrity of the habitat is maintained by proper South Florida management practices.

Community-level Restoration Actions

1. **Identify the extent of remaining mesic pine flatwoods habitat in South Florida.** Although the existing GIS, aerial photograph, and ground-truthed land cover information is available for this community throughout South Florida, a comprehensive regional analysis has not been conducted.

    1.1. **Detail the geographic extent of mesic pine flatwoods in South Florida.** This task should integrate existing GIS and other databases on land cover, soils, and hydrology, to correctly identify and separate mesic pine flatwoods from other pine flatwood and wetland types in South Florida**.** GIS typically cannot differentiate mesic from hydric flatwoods, resulting in an overestimate of the prevalence of mesic pine flatwoods.

1.2. **Update the GIS database for mesic flatwoods to monitor cumulative impacts.** As areas of mesic pine flatwood are converted to other land uses, changes should be mapped to identify cumulative habitat loss.

1.3. **Identify old-growth mesic flatwoods in South Florida.** Old-growth mesic pine flatwoods have the potential to sustain rare plant and animal communities. These areas provide unique habitats that are not replaceable within short time spans.

2. **Preserve remaining areas of mesic pine flatwoods.** Direct loss of habitat resulting from land conversion, habitat degradation, and fragmentation continues unabated in South Florida. However, many of the best remaining areas of intact mesic pine flatwoods have been identified for land acquisition.

2.1. **Complete purchase of the following CARL projects:** Allapattah Flats (Martin County), Atlantic Ridge Ecosystem (Martin County), Belle Meade (Collier County), Cape Haze/ Charlotte Harbor (Charlotte County), Charlotte Harbor Flatwoods (Charlotte County), Corkscrew Regional Ecosystem Watershed (Lee, Collier counties), Fakahatchee Strand (Collier County), Hall Ranch (Charlotte County), Ocaloacoochee Slough (Hendry, Collier Counties) Pal-Mar (Palm Beach, Martin Counties), Save Our Everglades-South Golden Gates Estates (Collier County), Sebastian Creek (Indian River, Brevard counties), South Savannas (Martin, St. Lucie counties), Lykes Brothers/Palmdale (Glades County).

2.2. **Complete purchase of the following Save Our Rivers projects:** Corkscrew Regional Ecosystem Watershed (Lee County), and Loxahatchee Slough (Palm Beach County).

2.3. **Develop additions to existing Federal and State land acquisition proposals in areas identified as GFC strategic habitat conservation areas and in the 1990 statewide charrette, including the following:** Estero Bay Watershed, South of Corkscrew Road, east of I-75 (Lee County); West and East of Burnt Store Road (Charlotte and Lee counties), North of Cape Coral (Lee County): east of the Babcock-Webb WMA (Charlotte County); Picayune Strand in North Golden Gate Estates (Collier County); North of Belle Meade (Collier County), South and East of Myakka Prairie (Sarasota County); Between Oscar Shearer SP and Pinelands Preserve (Sarasota County); East of the Southwest Florida International Airport (Lee County); North of Immokalee Road (Collier County); the Imperial River drainage (Lee County), areas along Horse Creek (Hardee and DeSoto counties), Brushy Creek (Hardee County), the Peace River (Hardee and DeSoto counties), the Green Swamp (Polk and Osceola counties), northern Palm Beach County and western Martin County.

2.4. **Implement cooperative habitat preservation programs with private landowners.** Much of the mesic pine flatwoods habitat is in private ownership and many private landowners may not choose to participate in fee-simple land acquisition projects (Lykes Brothers/Palmdale -Glades County). Protection through alternate methods may conserve important ecosystems by providing landowners with economic incentives and promoting good stewardship by ensuring that landowners view habitat as an asset, not a liability.

2.5. **Support and implement cooperative regional greenways programs with landowners and other agencies.** Greenways planning has successfully developed cooperative, local conservation plans that will maintain, establish, and manage landscape connections between important resource areas.

2.6. Target agency policy or proposed projects under review by COE, Water Management District, and DEP that degrade or eliminate mesic flatwoods habitat. Mesic flatwoods and other pinelands have declined in areal extent and patch size in South Florida because of characterization as non-jurisdictional and suitable wetland creation areas for on-site and off-site mitigation.

2.6.1. Stress avoidance of impacts of this habitat type as a regional permitting concern. Both consultants and permitting entities need to be educated on the importance of this habitat to regional wildlife.

2.6.2. Require type-for-type on- and off-site wetland mitigation when avoidance and minimization criteria have been exhausted. Both consultants and permitting entities often assess credit mitigation on the basis of the wetland depth, not the landscape importance or biodiversity value. This results in conversion of mesic flatwoods to wetland systems and on-site conversion of mesic flatwoods to ponds or pooled wetlands that often kill pine trees.

2.6.3. Examine federal nationwide and State and Federal general permit and permit exemptions to assess impacts on mesic pine flatwoods habitat. Piecemeal development and speculative land clearing in urbanizing areas under agricultural exemptions appears to exacerbate loss of pinelands in the South Florida Ecosystem.

2.7. Protect natural communities from point source and non-point source pollution.

2.8. Use existing regulatory mechanisms to protect mesic pine flatwoods by identifying their contribution to the function of adjacent wetlands and wetland-dependent species.

2.9. Promote protection of mesic flatwoods by encouraging local government resource planning, including identification of the importance, location, and areal extent in local government comprehensive plans.

3. Manage/enhance mesic pine flatwoods on public lands.

3.1. Develop/identify effective habitat management techniques to maximize the biodiversity of the mesic flatwoods community. South Florida mesic pine flatwoods may benefit from alternate management practices that are sensitive to hydrology, climate, and subtropical vegetation. Standard “southeastern” prescribed fire management, employed in the South Florida Ecosystem, may lower biodiversity of plant and animal species. Diversification of management techniques may increase biodiversity.

3.2. Implement or ensure continuance of habitat management on public lands. State and Federal land managers are faced with funding deficits that prevent or reduce management actions. Perpetual funding sources for staff and equipment should be secured.

3.3. Coordinate land management practices between public land managers. Management of mesic flatwoods on a landscape scale will benefit listed species, particularly wide-ranging species, game species, and neotropical migrants.

3.4. Establish management partnerships with private landowners. Successful fire management and hydrological practices can continue to be supported by or expanded to private lands to achieve a higher level of plant and animal diversity in

the South Florida Ecosystem. For some listed species, including the Florida panther and red-cockaded woodpecker, management partnerships may be critical to the regional South Florida recovery.

3.5. Create, maintain, or restore important habitat linkages. Public landowners should coordinate land acquisition and habitat management activities to ensure the protection of large, contiguous tracts of land that include a mosaic of native habitats, including mesic pine flatwoods. The maintenance of regional refugia for wide-ranging species such as the Florida panther or red-cockaded woodpecker may not be sufficient to protect these species in a developing landscape.

3.6. Identify and disallow incompatible public uses that degrade mesic pine flatwoods. Incompatible public uses that disrupt hydrology, prevent fire management, pollute, encourage exotic plant or animal invasion, overharvest resources, harvest resources too frequently, or destroy habitat beyond the ability for effective management should be identified and eliminated.

3.7. Monitor compatible adjacent land uses to protect mesic pine flatwood ecological function. Secondary and cumulative impacts to public lands can result from adjacent development, including loss of habitat, wildlife-endangering litter, chemical discharges, dumping, enhancement of exotic plant and animal invasion, prevention of fire management, alteration of adjacent hydrology, and noise/light pollution.

3.8. Encourage maintenance and recovery of natural ecotones. Ecotones are important elements of any natural landscape but may be overmanaged or eliminated by "restoration" efforts. Fire breaks and roads should be placed well away from ecotones. Ecotones that been degraded by existing roads and fire breaks should be restored.

3.9. Control exotic plants and animals.

3.10. Prevent collecting of rare plant species such as bromeliads on public lands. Discourage collecting of rare plant species on private lands.

4. Restore mesic pine flatwoods habitat where feasible.

4.1. Identify locations of mesic flatwoods habitat that can be restored.

4.2. Restore the natural seasonal hydroperiod and fire regime of mesic flatwoods communities. The natural South Florida pattern of fire occurrence and seasonal hydrology has contributed to the third highest plant species diversity of any community in South Florida and has resulted in this community being the dominant component of the South Florida upland landscape essential to wide-ranging wildlife.

4.3. Restore sheetflow hydrologic conditions by restoring the regional landscape to natural contour. Much of South Florida has been significantly altered by public and private drainage projects that have resulted in both overdrainage and flooding of natural systems. Where possible, off-site, regional hydrological restorations may be necessary to restore mesic flatwoods function. Areas where restoration should occur include the South Golden Gate Estates and Camp Keais Strand in Collier County, the Estero Bay watershed in Lee County, and the Babcock-Webb WMA in Charlotte County, Loxahatchee Slough in Palm Beach County, and the Charlotte Harbor Flatwoods CARL project in Lee and Charlotte counties.

4.4. Re-establish important habitat linkages by constructing wildlife crossings. A wide variety of development and linear infrastructure projects fragment mesic pine flatwoods. Future design and retrofit/rebuild of these projects should include

undercrossings, overpasses and other features that reduce wildlife mortality and preserve hydrology, and increase connectivity with adjacent habitat.

4.5. Enhance and manage pinelands containing beautiful pawpaw. Prevent habitat damage by off-road vehicle use, over-grazing by cattle and hogs, or over-collection.

4.6. Encourage mitigation banks that restore and enhance mesic pine flatwoods.

5. Identify, acquire and manage mesic flatwoods for the conservation of wide-ranging state and federally listed species. The preservation of pinelands, including mesic pinelands, is critical to the recovery of the Florida panther, Florida black bear, red-cockaded woodpecker, bald eagle, eastern indigo snake, Florida sandhill crane, Big Cypress fox squirrel, Sherman's fox squirrel, and southeastern American kestrels, as well as neotropical migrants.

5.1. Complete purchase of and manage mesic flatwoods in the Belle Meade and South Golden Gate Estates CARL projects for regional protection of Florida panther, Florida black bear, eastern indigo snake, Big Cypress fox squirrel, Florida sandhill crane, and other wildlife.

5.2. Complete purchase of and manage mesic flatwoods in the coastal areas to augment neotropical migratory bird migration and bald eagle foraging and nesting activities, including at the Charlotte Harbor Flatwoods and Cape Haze/Charlotte Harbor Buffer CARL projects, and Pine Island.

5.3. Complete purchase of and manage mesic flatwoods within Priority I and II areas identified in the Florida Panther Habitat Preservation Plan.

5.4. Complete purchase of and manage mesic flatwoods on the east coast for a diverse assemblage of non-game species, including at the Pal-Mar, Atlantic Ridge Ecosystem, Loxahatchee Slough, and Allapattah Ranch CARL projects.

5.5. Determine if old-growth mesic pinelands support red-cockaded woodpecker clusters. Red-cockaded woodpeckers nest and roost in cavities that are typically are excavated in old-age living pines if available. Study the utilization of mesic pine flatwoods by red-cockaded woodpeckers, including development of landscape-scale management recommendations for the recovery of this species in South Florida**.**

5.6. Manage pinelands on public lands in southwest Florida to expand occupation by red-cockaded woodpeckers. The large contiguous public preserves that begin in the Picayune State Forest (Belle Meade and South Golden Gate Estates) and extend east and north the Fakahatchee Strand, Florida Panther NWR and Big Cypress National Preserve should be managed as a larger ecological reserve to improve and augment the existing red-cockaded woodpecker population in southwest Florida.

5.7. Exclude fire from identified areas of mesic flatwoods that include understory thickets of tall thick palmetto to provide resting and denning cover for panthers.

5.8. Prioritize the protection of coastal mesic flatwoods as bald eagle nesting habitat, and neotropical migratory bird habitat. Bald eagles prefer nest and perch sites on the largest and tallest trees available near large, open water bodies and are primarily coastal in South Florida. Neotropical birds require available forage as close to the coast as possible to augment migration across the Gulf of Mexico and Caribbean. Coastal pinelands are targeted for urban and agricultural development. Pine Island in Lee County is an example of an area of pinelands that should be protected.

5.9. Identify important habitat linkages. Important connecting areas include: CREW to the Southwest International Airport mitigation lands (Lee County), Rookery Bay National Estuarine Research Reserve to Belle Meade CARL (Collier County), Corkscrew Sanctuary to Lake Trafford (Lee and Collier counties), Babcock-Webb WMA to Charlotte Harbor Flatwoods and Charlotte Harbor State Buffer Preserves (Charlotte County).

6. Complete purchase of and manage mesic flatwoods in contiguous, connected, unfragmented patches for the conservation of South Florida biodiversity, including nongame species, rare and unique species, and keystone species such as the swallow-tailed kite, Florida weasel, and various owl and raptor species.

6.1. Purchase additional mesic flatwoods for the preservation of the beautiful pawpaw. Very few populations of this plant are protected on public lands. The Charlotte Harbor Flatwoods (Charlotte County) area should be prioritized for ongoing and additional public land purchase.

6.2. Determine if old-growth mesic pine flatwoods support rare plant and animal species, or specific species guilds. Examine the habitat value of mesic pine flatwoods for rare and endemic plants. Old-growth pinelands may support rare and unique species of plants and animals or community guilds.

6.3. Inventory and characterize the importance of mesic flatwoods to avian populations, particularly neotropical migrants, owls and raptors.

6.4. Examine wading bird use of the wetland enclosures of mesic pine flatwoods, including prairies and freshwater "isolated" wetlands.

7. Perform additional research on mesic pine flatwoods.

7.1. Survey mesic flatwoods in southwest Florida for the beautiful pawpaw, and conduct research on appropriate fire regimes for this species. Updated surveys for the beautiful pawpaw have not been conducted. The range of this species should be determined in order to better understand how to manage the population.

7.2. Determine what fire regimes are recommended in mesic flatwoods to stabilize or increase beautiful pawpaw populations on public lands in southwest Florida.

7.3. Perform a hydrologic study of the water recharge potential of mesic pine flatwoods under natural hydrologic conditions.

7.4. Examine the correlation between soil type and mesic pine flatwoods habitats.

7.5. Examine the influence of fire regimes in maintaining optimal plant and animal species diversity.

7.6. Examine invertebrate diversity and life-cycles in the mesic pine flatwoods.

7.7. Monitor mesic pine flatwoods to evaluate biodiversity. Monitor community-level processes, community structure, and community composition, including rare and keystone species, and species guilds.

7.8. Improve reference ecosystem information for community composition, biodiversity, and site-to-site variability.

8. **Increase public awareness concerning mesic pine flatwoods**. Identify mesic flatwoods in text, maps, and on resource presentations to raise public awareness of the different types of pine flatwoods. Stress the important ecosystem function of isolated and ephemeral wetlands included in the mesic flatwoods community. Establish the landscape-scale importance of this community to wide-ranging species and the significance of regional losses of this habitat in South Florida.

Hydric Pine Flatwoods

FNAI Global Rank:	**Undetermined**
FNAI State Rank:	**S4?**
Federally Listed Species in S. FL:	**10**
State Listed Species in S. FL:	**75**

Hydric pine flatwoods. *Original photograph by Deborah Jansen.*



Hydric pine flatwoods are unique to South Florida, and provide essential forested habitat for wildlife including Florida black bear (*Ursus americanus floridanus),* Florida panther (*Puma (=Felis) concolor coryi),* wood stork (*Mycteria americana),* red-cockaded woodpecker (*Picoides borealis),* Everglade snail kite (*Rostrhamus sociabilis plumbeus*), bald eagle (*Haliaeetus leucocephalus),* eastern indigo snake (*Drymarchon corais couperi),* gopher tortoise (*Gopherus polyphemus),* Big Cypress fox squirrel (*Sciurus niger avicennia),* Sherman's fox squirrel (*Sciurus niger shermani),* Bachman's sparrow (*Aimophila aestivalis),* bobcat (*Lynx rufus),* swallow-tailed kite (*Elanoides forficatus),* Florida weasel (*Mustela frenata peninsulae),* limpkin (*Aramus guarauna),* northern harrier (*Circus cyaneus),* southeastern kestrel (*Falco sparverius paulus)* eastern American kestrel (*Falco s. sparverius)*, Florida sandhill crane (*Grus canadensis pratensis),* and 900 native plant species including at least 80 rare and endemic plant species. This habitat seasonally functions as both a wetland and an upland. The relatively predictable nature of this hydrologic transformation allows for an abundant diversity of plant life, including both wetland and upland annuals, and supports a diverse invertebrate fauna and, as a result, a diverse vertebrate fauna. The hydric pine flatwoods of South Florida are a distinct habitat in dynamic equilibrium between drought and flood, that is regularly and predictably perturbed by fire and water. The alteration between upland and wetland conditions allows for both upland and wetland plant species to utilize the same habitat through temporal displacement. The latitudinal range of hydric pine flatwoods provides a wide range of microclimates that result in tropical floral components in the south, and temperate-dominated understory in the north and frost-prone interior sites, increasing the overall plant diversity in the understory. As a result the hydric pine flatwoods have the highest plant species diversity of any habitat in South Florida. South Florida pine flatwoods are among the least protected habitats by current distribution of

public lands, with only 9 percent protected. If hydric pine flatwoods are not protected, this unique South Florida habitat will be converted to urban, suburban, and agricultural development within a relatively short time period. Regionally, the loss of hydric pine flatwoods habitats of South Florida will critically affect the biodiversity and endemic flora and fauna of South Florida.

Synonymy

The hydric pine flatwoods association of South Florida has been variously recognized and alluded to in the plant community literature. Long (1974) was the first to recognize hydric pine flatwoods as a separate habitat type, wet pineland, and considered it a successional stage between shallow wet prairie and hardwood hammock. Myers (1976, 1978, 1984) and Ewel *et al.* (1976) characterize this habitat as the ecotonal habitat in which both cypress and pine can grow, but in which neither does especially well. Duever *et al.* (1979) consider this habitat to be too wet for pine, with fire too frequent for cypress. Klein *et al.* (1970) and Wharton (1977) map hydric pine flatwoods in their hydrogeologic cross-sections of plant communities of the Big Cypress and South Florida successional stages. Duever *et al.* (1979) distinguish wet pine flatwoods from dry pine flatwoods by differences in understory, with the wet flatwoods having a wetland understory. Duever *et al.* (1976) indicate that the wet flatwoods association is a rare stage of succession. Based upon their conceptual successional model, Duever *et al.* (1976) indicate that the boundary between dry and wet pinelands occurs in a hydroperiod of from 40 to 60 / 120 to 150 days and a fire frequency of 3- to 10-year intervals. Subsequent descriptions by Duever *et al.* (1986) describe flatwoods on the basis of hydrology and understory components, which accompanies wet flatwoods. The U. S. Soil Conservation Service (1986) characterizes the marl prairie hydric pine flatwoods of southeast Florida and the northern Florida Keys as a separate habitat, but does not recognize the hydric pine flatwoods of Southwest Florida as a separate habitat type. Hydric pine flatwoods are lumped with mesic and xeric pine flatwoods in a “South Florida Flatwoods” category. Abrahamson and Hartnett (1990) define the wet flatwoods as seasonally inundated flatlands with sand substrates, canopies of slash pine, pond pine, and/or cabbage palm, and understories of mixed hydrophytic shrubs, grasses and forbs, which vary in accordance with fire frequency.

The Florida Natural Areas Inventory (FNAI) (1989) identifies hydric pine flatwoods as wet flatwoods, defined as flatland with sand substrate, seasonally inundated, subtropical or temperate, with annual or frequent fire, and vegetation characterized by slash or pond pine and/or cabbage palm with mixed grasses and herbs. FNAI lists the following synonyms for hydric pine flatwoods: hydric flatwoods, pine savanna, cabbage palm savanna, and moist pine barrens. The Florida Land Use Classification and Cover System (FLUCCS) (DOT 1985) does not have a specific categorization for hydric pine flatwoods. However, as defined by FNAI (1989), hydric pine flatwoods could be mapped as any of the following FLUCCS codes: 411 (pine flatwoods), 419 (other pine), 428 (cabbage palm), 622 (pond pine), 624 (cypress-pine-cabbage palm), or 630 (wetland forested mixed).

Distribution

Hydric pine flatwoods were historically found in all the coastal counties of South Florida from Sarasota County to Indian River County. The largest remaining contiguous areas of hydric pine flatwoods are in Charlotte County, northwest and southeastern Lee County, and western, eastern, and northeastern Collier County. Other areas include south and eastern Sarasota County, central Hendry County, western Glades County, North Palm Beach County, and in slough systems paralleling the coast in central Martin, St Lucie, and Indian River counties, respectively (Figure 1). There may be no natural hydric pine flatwoods remaining outside of public ownership in Monroe, Broward and Miami-Dade counties. Figure 1 illustrates the distribution of all pine flatwoods in the South Florida Ecosystem, as of 1989 (Cox *et al.* 1994).

Major public holdings of hydric pine flatwoods occur in the Babcock-Webb WMA (Charlotte County), Charlotte Harbor Flatwoods (Charlotte County), Charlotte Harbor State Buffer Preserve (Charlotte County), Big Cypress National Preserve (Collier County), Collier-Seminole SP (Collier County), CREW (Lee, Collier counties), Fakahatchee Strand State Preserve (Collier County), the Florida Panther NWR (Collier County), Picayune State Forest (South Golden Gate Estates) (Collier County), Jonathan Dickinson SP (Martin County), The Savannas State Preserve (Martin, St. Lucie counties), J.W. Corbett WMA (Palm Beach County), Loxahatchee Slough Natural Area (Palm Beach County), Myakka Prairie and Myakka State Forest (Sarasota County), and the Pinelands Preserve (Sarasota County).

Description

The latitudinal range of hydric pine flatwoods, from Charlotte Harbor to Florida Bay and inland to the Penholoway Terrace, provides a wide range of microclimates that result in tropical floral components in the south, and temperate-dominated understory in the north and frost-prone interior sites, increasing the overall plant diversity in the understory. Long (1974) lists 361 species of plants in the wet pine forest habitat of South Florida. This is the highest plant species diversity of any habitat in South Florida. Beever and Dryden (1998) document or identify in the literature 993 plant species (334 monocotyledon, 602 dicotyledon, 4 gymnosperm, and 53 pteridophyte species) in the hydric pine flatwoods of southwest Florida. Of these 993 species, 677 species (69 percent) are typically considered to occur in wetlands, 244 (25 percent) in submerged zones, and 433 (44 percent) in saturated zones. Three hundred and sixteen species (32 percent) are typically considered upland plants. Ninety-three (10 percent) are exotic or introduced species.

The hydric pine flatwoods habitat is dominated by a slash pine (*Pinus elliottii* var. *densa*) overstory with a wetland plant understory. The wetland understory can be any, or a variety, of wetland plant community types ranging from wet prairie to hatrack cypress. Hydric pine flatwoods are distinct from mesic and xeric pine flatwoods in the absence of understory dominance by saw palmetto (*Serenoa repens*) and more xeric species such as pennyroyal (*Piloblephis rigida*), pawpaw (*Asimina* spp.), and prickly pear (*Opuntia* spp.).

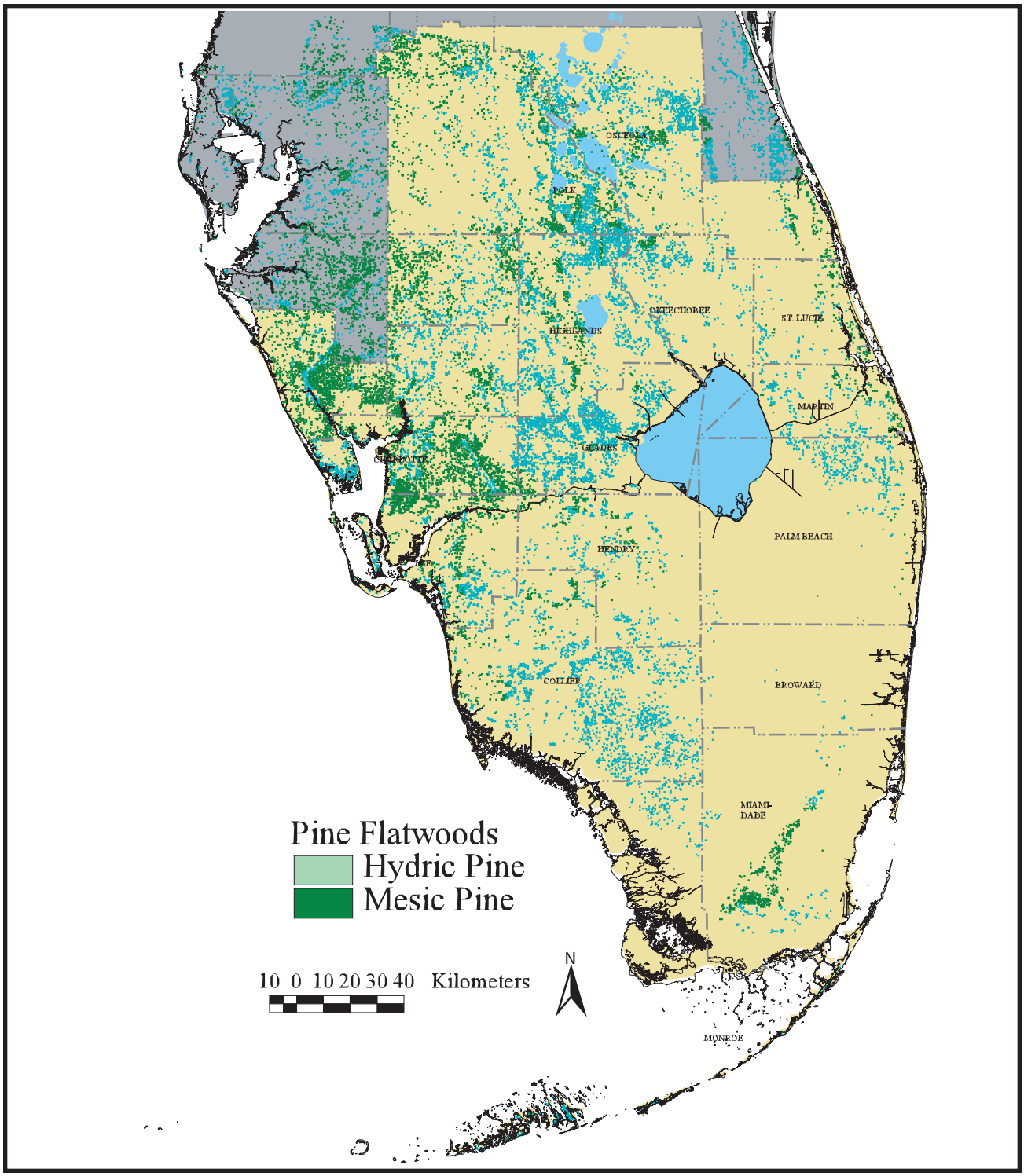


Figure 1. The distribution of hydric and mesic pine flatwoods in South Florida (data from USGS-BRD 1996).

Mid-story plants of hydric pine flatwoods include cypress (*Taxodium* spp.), cabbage palm (*Sabal palmetto*), wax myrtle (*Myrica cerifera*), dahoon holly *(Ilex cassine*), and red bay (*Persea palustris*), as well as species characteristic of mixed hardwood swamp forest and cypress forest of South Florida: red maple (*Acer rubrum)* and buttonbush (*Cephalanthus occidentalis*). Exotic plant invaders primarily include Brazilian pepper (*Schinus terebinthifolius)* and melaleuca (*Melaleuca quinquinervia*). Understory includes ferns (*Nephrolepsis, Osmunda, Thelypteris* spp., *etc*.); arrowhead (*Sagittaria* spp.); a wide variety of grasses (*Agrostis*, *Andropogon*, *Aristida*, *Dichanthelium*, *Eragrostis*, *Muhlenbergia, Panicum, Paspalum, Schizachyrium, and Sporobolus* spp., *etc*.); an amazing diversity of sedges (*Bulbostylis, Carex, Cladium jamaicense, Cyperus, Dichromena, Eleocharis, Fimbrystylis, Rhynchospora, Scirpus, Scleria* spp., *etc*.); yellow-eyed grasses (*Xyris* spp.); pipeworts (*Eriocaulon* spp., *Lachnocaulon* spp., and *Syngonathus flavidulus*); day-flowers (*Commelina* spp.); rushes (*Juncus* spp.); lilies, iris, and amaryllis (*Aletris, Crinum,* and *Hymenocalis* spp., *Iris hexagona, Lillium catesbaei*, etc.); cannas (*Canna* spp.); ground orchids (*Calopogon* spp., *Eulophia alta*, *Spiranthes* spp.); smartweeds (*Polygonella* and *Polygonum* spp. *etc*); sundews (*Drosera* spp.); legumes (*Cassia*, *Crotalaria*, *Galactia*, *Indigofera, Rhynchosia*, *Tephrosia* spp., *etc*.); sorrels (*Oxalis* spp.); flaxes (*Linum* spp.); milkworts (*Polygala* spp.); spurges (*Chaemaescye, Euphobia, Poinsettia, Stillingia* spp.); mallows (*Hibiscus, Kosteletzkya, Sida* spp., *etc*.),;chocolate weeds (*Melochia* spp.); St. John's worts (*Hypericum* spp.); meadow beauties (*Rhexia* spp); evening primroses (*Ludwigia* spp); celeries (*Eryngium, Hydrocotyle,* and *Oxpolis* spp., *etc*.); starflowers (*Sabatia* spp.); milkweeds (*Asclepias* spp.); bladderworts (*Pinguicula* and *Urtricularia* spp.); and a wide variety of composites (*Aster, Carphephorus, Cirsium, Coreopsis, Emilia, Eupatorium, Flaveria, Heterotheca, Liatris,* and *Solidago* spp., *etc*.). Epiphytes are also common, including airplants (*Tillandsia* spp.); ferns (*Ophioglossum, Phlebodium aureum, Polypodium,* and *Vittaria* spp.); and orchids *(Encyclia tampensis, Epidendrum rigidum, etc*.).

Periphyton and Phytoplankton

During the wet season, periphyton is a major component of the understory vegetation of hydric pine flatwoods. It is composed of many different species of green and blue-green algae that grow on bare substrate or the herbaceous vegetation of the inundated understory. At the height of the summer wet season, the blanket of algae can be up to 4 cm thick (1.6 inches) (Van Meter 1965). Ambient water chemistry determines the type and the amount of periphyton that will form in hydric pine flatwoods. Acidic and low-nutrient conditions favor green algae (Gleason and Spackman 1974). Recently burned hydric pine flatwoods favor green algal periphyton (Beever and Dryden 1998).

When periphytic algal mats are thick and abundant, the respiration and photosynthetic processes can produce significant diurnal fluctuations in physical and chemical water quality parameters (Van Meter 1965). In some areas of South Florida, the blue-green algal component precipitates significant amounts of calcium carbonate to form the calcitic mud, or marl, that is a common soil type in southernmost hydric pine flatwoods.

The phytoplankton community of hydric pine flatwoods has not been studied. While a number of studies of phytoplankton communities of South Florida wetlands have been performed (Van Meter 1965, McPherson 1969, EPA 1971, Greenfield 1970, 1972), the ephemeral hydrology, short algal life cycles, and large numbers of species involved have, to date, prevented a synthesis of algal community ecology from being developed (Duever *et al.* 1986). Generally, the phytoplankton community of the hydric pine flatwoods can be expected to consist of recruits from adjacent wetlands of longer hydroperiod and fast-growing species, with resting stages that can tolerate dry season desiccation. The open canopy, warm fresh waters, and diverse substrata (sand, mud, marl, rock, vegetation) of hydric pine flatwoods provide a variety of surfaces for microalgal growth. Due to the relatively shallow depths of inundation, species typical of shallow vegetated ponds would be the expected phytoplankton of the water column in hydric pine flatwoods.

The South Florida slash pine (*Pinus elliottii* var. *densa*) is the dominant tree of the hydric pine flatwoods canopy. The taxonomy of var. *densa* has been a matter of significant debate (Small 1913, Little and Dorman 1954, Squillace 1966, Mirov 1967, McMinn and McNab 1971). *Pinus elliottii* var. *densa* is more flood- and drought-tolerant than var. *elliottii*. Squillace (1966) concluded that the phenotypic plasticity that allows *densa* to accommodate both upland and wetland conditions, fire, and flood, is the result of its evolution under the severe environmental factors of South Florida that vary from year to year and fluctuate widely over time. Pine densities in hydric pine flatwoods are typically sparse. Canopy coverage of mature hydric pine flatwoods is only 10 to 20 percent in unlogged stands. Pine trees are usually abundant enough to dominate the apparent landscape view and canopy, but are not close enough to touch each other. Ground cover receives nearly full sunlight (Wade *et al.* 1980). Mature South Florida slash pine can attain a height of 30 m (110 feet), with a dbh of 40 cm (16 inches) (Duever *et al.* 1975). In average southwest Florida hydric pine flatwoods, mature trees typically attain 25 to 30 cm (10 to 12 inches) dbh with 18 to 23 m (60 to 75 feet) of height (Beever and Dryden 1998). Growing season is from February to November, with maximum growth rates attained at the spring and autumnal equinoxes (Langdon 1963).

South Florida slash pine growing in normal hydric pine flatwoods conditions typically display: (1) some buttressing of the lower trunk, which in mature trees can be extremely obvious; (2) fire-darkened or fire-scarred lower trunks; (3) a sparse and twisted canopy, with twisted axillary branches. This crowned growth form, if viewed from a distance, gives the pine tree the appearance of a tree grown under bonsai; (4) in hydric pine flatwoods that have not burned recently, lichen and algal lines are located on the trunk, indicating wet season water levels; (5) in wetter areas of flow ways and along off-road vehicle trails, formation of root tussocks that stand higher than the adjacent sandy ground level. These tussocks often support less hydrophilic midstory plants such as saw palmetto, a variety of mesic ferns, and tropical hardwood hammock species; and (6) a relatively high frequency of double crowning from the same trunk (Beever and Dryden 1998).

Soils

The hydric pine flatwoods of South Florida are all located in the South Florida Basin of the Floridan Plateau (Vaughan 1910, Chen 1965). During the

Pleistocene era, high sea-level events created terraces by wave, current, and erosional action in belts parallel to the current shoreline. The number of terraces is a subject of debate (Puri and Vernon 1964), with estimates ranging from four to nine. The identified terraces in the hydric pine flatwood areas of South Florida, from coast to inland and from lowest to highest, are: Silver Bluff (0.3 to 3 m or 1 to 10 feet), Pamlico (2.4 to 7.6 m or 8 to 25 feet), and Talbot (7.6 to 12.8 m or 25 to 42 feet) (Klein *et al.* 1964). Hydric pine flatwoods are found only on and within these terraces (Beever and Dryden 1998). In South Florida, the Pleistocene strata are composed of the sands of marine terraces formed during this period of sea level changes. The soils of South Florida have had a relatively short time period (approximately 3,500 to 5,000 years) for formation and often represent only slightly weathered parent material or surficial sediments. The soil types in hydric pine flatwoods generally fall into one of five major substrate sediment groups: limestone rock, calcareous muds (marls), sands (marine terraces), organic materials (peats and mucks), and mixed solids (Duever *et al.* 1986, SFWMD 1980). The soils of the hydric pine flatwoods of South Florida are hydric soils as defined by the Florida Association of Professional Soil Classifiers (Carlisle 1990).

Hydric pine flatwoods occur on relatively flat, poorly drained terrain. The soils typically consist of 0.3 to 0.9 m (1 to 3 feet) of acidic sands often over an organic hardpan or clay layer. Cabbage palm-dominated hydric flatwoods occur on more neutral sands (pH 6.0-7.5) underlain by marl or shell beds. The hardpan can substantially reduce the percolation of water below and above its surface (FNAI 1989). Marls are a muddy deposit of calcium carbonate silts, with occasional shells and shell fragments. Marl is the product of one of three processes in Florida: physicochemical or biochemical precipitation of calcite by freshwater periphyton on sediment and vegetation surfaces, storm deposition of aragonitic marine muds in coastal areas, or weathering of surficial limestone outcrops. In hydric pine flatwoods, the second and third methods may be responsible for initial marl presence in the habitat. Subsequent and concurrent marl production occurs from periphyton each wet season. Major surficial marl deposits are present in the hydric pine flatwoods of the Big Cypress Swamp. Marl soils generally range from 2.4 to 14.2 cm (6 to 36 inches) in depth, have little relief, and have a low permeability to water, rendering a wet habitat in the wet season and a baked desert in the dry season. Marl soils cover 29 percent (approximately 161,943 ha or 400,000 acres) of Collier County (Leighty *et al.* 1954). Exposed limestone rock of the Tamiami Formation, and occasionally Fort Thompson Formation, appears as irregular, undulating surfaces perforated with solution features with a sandy and/or marl soil matrix. The appearance of bare rock on the surface is the result of erosion, dissolution, and reprecipitation. Rock is also exposed by human agency, including vehicle trails, drainage of friable soils, and clearing activities. Exposed limerock substrate is most frequent in Collier County, where approximately 33,603 ha or 83,000 acres (6.4 percent of the county area) is rocklands (Leighty *et al.* 1954). Organic and peat soils formed of partially decomposed plant material and a mixture of inorganic sand, clays, or silts are developed in hydric pine flatwoods areas of longer hydroperiod, where longer-term inundation creates an anaerobic layer at the sediment-water interface.

Typically, hydric pine flatwoods wetlands do not form organic soils due to regular aerobic drying and periodic fires. The large-scale peat soils were formed approximately 4,700 to 5,700 YBP (year before present) in the southwest Florida area (Kropp 1976, Duever *et al.* 1979). Hydric pine flatwoods are found in areas of mixed soils and peats, but cypress, mixed hardwood swamp forest, and marshes vegetate completely peat soils.

Water Quality

No specific data on water chemistry, water flow rates, and water quantities in hydric flatwoods is available. Due to similarities in substrate, water depth, vegetation type, and close physical proximity, the water quality of hydric pine flatwoods in South Florida may be similar to that measured for the sheetflow wetland systems of open wet prairie and scrub cypress prairie in the Big Cypress National Preserve (Beever and Dryden 1998). The major factors that influence water quality parameters in sheetflow systems (Duever *et al.* 1979) include: (1) higher concentrations of dissolved constituents (calcium, chlorine, magnesium, potassium, sodium, hardness, specific conductance, dissolved solids) during dry season evaporation and dry down; (2) higher levels of nutrients (nitrogen, phosphorous, organic carbon) associated with animal and plant concentrations in dry season feeding areas, depressional areas, algal mats, and sloughs; (3) greater diurnal fluctuation in dissolved gases (oxygen, carbon dioxide) and pH associated with higher levels of biologic activity, such as algal growth, in summer and in dry-down pools in winter; (4) higher levels of tannins and lignins associated with the first flush of wet season water level release; (5) lower levels of dissolved oxygen, pH, alkalinity, and hardness associated with peat substrates or contact with bedrock limestone; and (6) higher levels of color, turbidity, aluminum, copper, lead, zinc, other heavy metals, pesticides, and nutrients associated with human impact, including vehicle use, agriculture, construction, herbiciding of upstream canals, and mosquito control.

Wildlife Diversity

The hydric pine flatwoods of South Florida are of critical, regional importance as: (1) one of the principal dominant forest covers of South Florida that provides essential forested habitat for wildlife including wide-ranging species such as the Florida panther, the Florida black bear, mid-sized carnivores, fox squirrels, and deer; (2) the major tree canopy for canopy-dependent species including neotropical migrants, tree-cavity dependent species, and tree-nesting species; (3) a habitat that seasonally functions as both a wetland and an upland. The relatively predictable nature of this hydrologic transformation allows for an abundant diversity of plant life, including both wetland and upland annuals, and supports a diverse invertebrate fauna and, as a result, a diverse vertebrate fauna. The hydric pine flatwoods of South Florida provide essential habitat to the breeding life cycle of aquatic and wetland-dependent animals, and a major forest cover for cover-dependent species. Hydric pine flatwoods provide both aquatic habitat for young and adult amphibians and adult tree frog climbing

areas. Hydric flatwoods serve as wading bird foraging areas, black bear foraging, denning, and travelways, and essential red-cockaded woodpecker foraging and nesting habitat.

Hydric pine flatwoods are an important habitat for a number of common pine flatwoods vertebrate species, including the pine woods tree frog (*Hyla femoralis),* oak toad (*Bufo quercicus),* box turtle (*Terrapene carolina),* eastern diamondback rattlesnake (*Crotalus adamanteus),* black racer (*Coluber constrictor),* brown-headed nuthatch (*Sitta pusilla),* Bachman's sparrow (*Aimophila aestivalis*), pine warbler (*Dendroica pinus),* great horned owl (*Bubo virginianus),* least shrew (*Cryptotis parva),* cotton mouse (*Peromyscus gossypinus),* cotton rat (*Sigmodon hispidus),* and gray fox (*Urocyon cinereoargenteus)* (Layne 1974, Layne *et al.* 1977).

To date field studies and the literature (Beever and Dryden 1998, Cunningham 1961, Duever, *et al.* 1986, Ashton and Ashton 1988, Kale and Maehr 1990, Layne 1978, Myers and Ewel 1990, Soil Conservation Service 1986, Florida Department of Natural Resources (FDNR) 1989, FDNR 1990) identify 31 mammal, 139 bird, 40 reptile, 17 amphibian, and 22 fish species from the hydric pine flatwoods of southwest Florida, including five endangered species, seven threatened species, 10 species of special concern, and four CITES species. Thirty (88 percent) of the 34 mammal species (Drew and Schomer 1984) known from southwest Florida are found in the hydric pine flatwoods. One-hundred thirty-nine (51 percent) of the 274 bird species known from southwest Florida are found in the hydric pine flatwoods. Birds are listed based on direct observation, song identification, and/or documentation in the cited literature (Beever and Dryden 1998).

Although no mammal is endemic only to the hydric pine flatwoods of southwest Florida, both Sherman's and Big Cypress fox squirrels are closely associated with the open understory provided by hydric pine flatwoods. Three large native mammals that regularly utilize hydric pine flatwoods are the white-tailed deer (*Odocoileus virginianus),* black bear, and Florida panther (Layne 1974).

Forty-two taxa (84 percent) and 40 species (83 percent) of the 50 taxa (48 species) of reptiles not restricted to coastal waters in southwest Florida utilize the hydric pine flatwoods as habitat. This includes 25 snakes, 8 turtles, 1 tortoise, 7 lizards, and the American alligator (*Alligator mississippiensis).* Reptiles utilize hydric pine flatwoods in both wet and dry seasons, although different species may be present in different hydric conditions. Resident species include the Florida kingsnake (*Lampropeltis getulus floridana),* eastern coral snake (*Micrurus fulvius),* rough green snake (*Opheodrys aestivus),* dusky pygmy rattlesnake (*Sistrurus miliarius barbouri),* racers (*Coluber constrictor* ssp.), eastern indigo snake, rat snakes (*Elaphe* spp.), ribbon snake (*Thamnophis sauritus sackenii),* eastern garter snake (*Thamnophis s. sirtalis),* green anole (*Anolis carolinensis)* and brown anole (*Anolis sagrei),* and skinks (*Eumeces inexpectatus* and *Scincella lateralis).* Dry season species include the gopher tortoise, racerunner (*Cnemidophorus sexlineatus),* diamondback rattlesnake, glass lizard (*Ophisaurus ventralis),* brown snake (*Storeria dekayi victa),* hognose snake (*Heterodon platyrhinos),* and box turtle. Wet season species

include the water snakes (*Nerodia* spp.), water turtles of various genera and species, the cottonmouth (*Agkistrodon piscivorus),* and the American alligator. It is also not unusual to encounter wet season species in hydric pine flatwoods habitat in the dry season, as they move between isolated wetlands. Similarly, it is not uncommon to observe gopher tortoises foraging at the moist edges of hydric pine flatwoods pools, or crossing inundated hydric pine flatwoods, as they travel between mesic and xeric pine islands in the habitat matrix that includes hydric pine flatwoods.

Seventeen (85 percent) of the 20 amphibian species found in southwest Florida utilize the hydric pine flatwoods habitat for feeding and/or breeding. This includes all of the frog and toad species of southwest Florida. The most frequently encountered and abundant amphibians are tree frogs (*Hyla* spp.), oak toad and southern toad (*Bufo terrestris),* and leopard frogs (*Rana sphenocephala).* The amphibian life-cycle is particularly well-adapted to the hydrologic cycle of hydric pine flatwoods, providing both aquatic habitat for young and adults and upland habitat for more terrestrial species adult forms. Only the amphibians that require year-round, deep standing water do not use this habitat.

Twenty-two (41 percent) of the 54 freshwater fish species found in southwest Florida (Kushlan and Lodge 1974) utilize hydric pine flatwoods during the wet season. The dominant fish species of the hydric pine flatwoods are two cyprinodontids, the golden topminnow (*Fundulus chrysotus)* and the flagfish (*Jordanella floridae);* and three poeciliids, the mosquitofish (*Gambusia affinis),* the least killifish (*Heterandria formosa),* and the sailfin molly (*Mollienesia latipinna).* These five species comprised 90 to 100 percent of field collections (Beever and Dryden 1998). These cyprinodont fish are a fundamental link between the primary producers and higher trophic level fish and wildlife species. The typical cyprinodont diet consists of plant and animal tissue including periphyton, insect larvae, and vascular plant detritus. They subsequently are food for sport fish and wading bird species. The pattern of fish utilization of the hydric pine flatwoods follows the hydrologic cycle. Beginning in June, the standing water levels allow small forage fishes to escape predation and expand into unoccupied feeding and nursery grounds provided by the shallow sheetflow wetlands (Kushlan 1976). The increased habitat space allows for a population boom in species capable of a life cycle in inches of water. As water levels increase, predatory carnivores, such as sunfish, gar, and catfish, follow the forage fishes into the now deeper swamp marsh and feed on the abundant fish, insect, and amphibian prey. As water levels drop in the late autumn and winter, the larger predatory fishes leave the hydric pine flatwoods first, and then the smaller fishes retreat to depressions, ponded areas, alligator holes, sloughs, and solution holes. The concentration of forage fish biomass in shallow isolated areas is exploited by larger fishes, wading birds, turtles, alligators, and piscivorous mammals.

Invertebrates

The variety and diversity of invertebrate species utilizing the hydric pine flatwoods as foraging, breeding, and nursery habitat has not been well studied.

The following is a general summary of the phyla encountered, with specifics on some of the more readily apparent species. A total of 13 phyla, at least 24 classes, at least 41 orders, and at least 274 families of invertebrates are observed or documented to occur in the hydric pine flatwoods of southwest Florida. Dominant taxa, in individual numbers and species diversity, include the arthropods, gastropods, nematodes, rotifers, and protozoans. The most conspicuous taxa are the crustacea, insecta, and arachnida. The crustacean fauna of the hydric pine flatwoods of South Florida includes species typical of the sheetflow wetlands, and in composition does not appear markedly different from the species assemblage of adjacent cypress prairies, cypress sloughs, and pine ponds. Species observed include fairy shrimp, tadpole shrimp, clam shrimp, water fleas, seed shrimp (ostracods), copepods, amphipods, and crayfish. The most common terrestrial crustacean is the isopod pillbug. Representatives of 22 orders of insects are present in the hydric pine flatwoods of southwest Florida. The abundance and diversity of insect fauna is related to the variable hydrology, host plant diversity, and microhabitat presence (*e.g.*, fungal bracts, dead trees, hosts for parasites, *etc*.) available in an ecosystem that functions as both a wetland and an upland. Within the insects, the more obvious and abundant organisms are species that: have a life cycle that combines an aquatic larval stage with an adult flying form that utilizes the prey or plants of hydric pine flatwoods; have a life cycle that combines a larval stage living in live or dead wood of the canopy or midstory of hydric pine flatwoods and an adult form that either lives within live or dead wood and/or utilizes prey or plants of the hydric pine flatwoods; have a larval stage that feeds on the diversity of perennial and annual plant life of hydric pine flatwoods and an adult stage that acts as a pollinator of the flowering plants of hydric pine flatwoods; or have a life cycle linked to conversion of detritus and/or carcasses of the abundant animal and plant life of hydric pine flatwoods.

Dragonflies, damselflies, mayflies, lacewings, butterflies, moths, bees, wasps, flies, and mosquitoes are the commonly encountered flying insects of the hydric pine flatwoods. On plant and leaf surfaces, obvious species include grasshoppers, crickets, katydids, roaches, thrips, true bugs, cicadas, aphids, whiteflies, scales, a wide variety of beetles, caterpillars, galls, maggots, fruit flies and the diverse arthropod predators of herbivorous species. Springtails, silverfish, wood roaches, earwigs, termites, bark lice, bark beetles, boring beetles, wood boring caterpillars, wood boring Hymenoptera, and their associated predators are common in decaying and live wood. During the wet season, nymphs of dragonflies, damselflies, lacewings, mayflies, mosquitoes, aquatic lepidopterans, water bugs, backswimmers, water striders, diving beetles, and whirligig beetles inhabit the sheetflow wetlands, and during the dry season move into drying pools of the hydric pine flatwoods. There are eight families of Odonata, including 21 species of dragonfly and nine species of damselflies, documented by observation and from literature for the hydric pine flatwoods of South Florida (Borror *et al.* 1976, Dunkle 1989, 1990). The easily observed arachnids of the hydric pine flatwoods include web-building spiders, hunting spiders, water spiders, daddy-longlegs, mites, and ticks. Scorpions, pseudoscorpions, whip scorpions, millipedes, centipedes, snails, and slugs also utilize the hydric pine flatwoods.

Without the diverse invertebrate community of the hydric pine flatwoods, most of the vertebrate species found in that habitat could not exist. Vertebrates utilize invertebrates as food directly, as the food of a prey species, as a pollinator of a food plant, as a pollinator of a food plant of a prey item, as a symbiote, or as a parasite that weakens prey items, rendering prey easier to catch. Vertebrate species capable of tracking the changes in food availability as different plant species bloom, seed, and fruit, with subsequent changes in invertebrate and small vertebrate populations, are able to utilize hydric pine flatwoods throughout the year. Other vertebrate species utilize hydric pine flatwoods during the period that best suits their life cycle. It is important to note that the hydric pine flatwoods are a "part-time" wetland (Duever *et al.* 1986) and, by extension, a "part-time" upland. As a result, the same site in this study could serve as a nighthawk nesting area in the dry season and a frog pond in the wet season, while being utilized by black bear and red-cockaded woodpecker throughout year. The same location in hydric pine flatwoods can function as a feeding ground draw-down pool for wood storks and sandhill cranes in February; a browsing area for rabbits and white-tailed deer in March, and subsequently a hunting area for gray fox and Florida panthers in April; a tree frog breeding pool in June; a killifish, water snake, and wading bird feeding area in August; and a foraging area for autumn seed and fruit for quail, turkey, black bear, and fox squirrels in November.

Wildlife Species of Concern

Federally listed species that depend upon or utilize hydric pine flatwoods in South Florida include: Florida panther, Key deer, Audubon's crested caracara, bald eagle, Everglade snail kite, red-cockaded woodpecker, wood stork, Kirtland's warbler (*Dendroica kirtlandii*), and eastern indigo snake. Biological accounts for these species and recovery tasks for these species are included in "The Species" section of this recovery plan.

Hydric pine flatwoods habitats of South Florida are also important for other species such as the State listed Florida black bear, gopher tortoise, Big Cypress fox squirrel, Sherman's fox squirrel, swallow-tailed kite, and Florida weasel. As development continues to impact the remaining hydric pine flatwood habitat these systems will become regionally critical for the limpkin, northern harrier, southeastern and eastern American kestrels, and Florida sandhill crane.

If hydric pine flatwoods are not protected, this unique South Florida habitat will be converted to urban, suburban, and agricultural development within a relatively short time period. Since the contiguous mesic pine flatwood habitat is often dominated by saw palmetto (typically, an upland indicator) and dense pine canopy, the state regulatory wetland agencies may not claim jurisdiction over the mesic or, the similar, long-drained hydric pine flatwoods, hence, regulatory protection by wetland permitting agencies will be minimal.

The **Florida panther** utilizes the hydric pine flatwoods of southwest Florida, in combination with other forested upland and seasonal wetland habitats, which provide essential foraging, breeding, and wildlife corridor habitat. The documented foraging and breeding territories of the radio-collared Florida

panthers in Lee and Collier counties, and documented sightings of Florida panther in Charlotte, Collier, and Lee counties include the large expanses of undisturbed hydric pine flatwoods in the area (D.S. Maehr, GFC, personal communication 1991; L. Campbell personal communication, 1991). The panther utilizes hydric, mesic, and xeric pine flatwoods, and savanna, hardwood hammocks, and mixed swamp forest. Ecotones, such as hydric pine flatwoods, are particularly important to the panther because they support an increased variety and density of species. Prey animals, including white-tailed deer and wild hog, utilize the plant diversity of edge communities such as the hydric pine flatwoods (Layne and McCauley 1976). Recently burned hydric pine flatwoods provide more prey for panther, and panthers are documented to move toward fires and stay in areas of recent burns (Belden 1986).

Panthers require large territories and abundant prey. The hydric pine flatwoods of southwest Florida provide both these requirements. Additionally, the hydric pine flatwoods and swamp forests associated with natural drainage patterns in South Florida provide the habitat essential to the panther for forage between the fragmented foraging areas remaining in southwest Florida.

The **Florida black bear** is a forest habitat generalist with seasonal preference for wherever food is most available. Black bear utilize all the natural forested systems of southwest Florida, with a decided preference for upland/wetland ecotones, such as the hydric pine flatwoods. The documented movements of radio-collared Florida black bear in Lee and Collier counties; documented sign and sightings of Florida black bear in Charlotte, Collier and Lee counties; and periodic roadkills in Charlotte County indicate that the large areas of relatively undisturbed hydric pine flatwoods, in combination with mesic upland forests and the major wetland basins, provide the principal habitat of the black bear in southwest Florida (Brady and Maehr 1985, Maehr 1984, Maehr *et al.* 1988, Land 1994). Bears are omnivores that feed on readily available food resources. Preferences for berries, insect larvae, the occasional small animal (frogs, mice, *etc.*), eggs, and wild honey can be satisfied in the diverse hydric pine flatwoods environment. Seasonal abundances of fruits, from cabbage palm, saw palmetto, and berry bushes, are consumed on a seasonal basis. Occasionally, young white-tailed deer and wild hog are taken as prey (Williams 1978). Movement by individuals can be extensive and may be related to both mating and food availability. The hydric pine flatwoods and swamp forests provide the forested habitat corridors essential to the black bears for forage and movement between the fragmented foraging areas remaining in southwest Florida.

The **Big Cypress fox squirrel** utilizes a wide variety of forested wetland systems including mature mangrove forest, open cypress stands and prairies, and open pine forest. Hydric pine flatwood understories are maintained by fire and hydrology, and provide a high diversity of vegetative and insect forage for the fox squirrel. The hydric pine flatwoods is an extensively documented habitat for the Big Cypress (=mangrove) fox squirrel, including hydric pine flatwoods in Collier and Lee counties, south of the Caloosahatchee River. This habitat is utilized by the Big Cypress fox squirrel in both dry and wet seasons. The fox squirrel forages on slash pine male cones in winter, and female cones

during the summer. Male and female cones from cypress, cabbage palm fruits, bromeliad buds, and acorns are also consumed (Humphrey and Jodice 1991). All of these food resources are available in hydric pine flatwoods of Southwest Florida. Hydric pine flatwoods adjacent to mature mangrove forest, oak and hardwood hammocks, and riverine hardwoods provide additional forage on a rotating seasonal basis. Nesting occurs in pines, hardwoods, including oak and black mangrove, cypress, cabbage palms, and bromeliad clumps.

The Big Cypress fox squirrel does not typically utilize pine flatwoods dominated by a thick saw palmetto understory, a monocultural dense melaleuca forest, Brazilian pepper forest, Australian pine stands, or man-made habitats that do not possess a superabundance of food. Fox squirrel utilization of man-made habitats, such as bird feeders in residential areas and golf courses planted in exotic fruit trees, is dependent upon the availability of food and cover near adjacent natural areas, such as cypress strands and hydric pine flatwoods (Beever and Dryden 1988).

Habitat destruction of hydric pine flatwoods and adjacent upland and wetland habitats is the primary threat to the Big Cypress fox squirrel (Brown 1973, 1978a). Large-scale commercial and residential development of hydric pine flatwoods west of the Big Cypress National Preserve (BCNP) in the Naples area, conversion of hydric pine flatwoods and cypress wetlands to citrus north of the BCNP, and expansion of I-75 through hydric pine flatwoods and cypress wetlands pose serious threats to habitat quality and quantity for the Big Cypress fox squirrel (Humphrey and Jodice 1991).

The southern limit of the **Sherman's fox squirrel** on the west coast of Florida includes the hydric pine flatwoods and riverine hardwood forests of Charlotte and northern Lee counties. Ehrhart (1979) did not include its range to extend into southwest Florida, perhaps because its principal north and central Florida habitat is longleaf pine-turkey oak sand hills, a habitat not found in southwest Florida. It is reported from hydric pine ecotones in north Florida (Ehrhart 1979). In southwest Florida, the hydric pine flatwoods and mixed flatwood-hardwood riverine forests are the principal habitats for this subspecies of fox squirrel. Sherman's fox squirrels may occupy a smaller territory than do Big Cypress fox squirrels, and may be more site constant. This appears to be related to the availability of oak trees for forage and nest sites. Sherman's fox squirrels forage on slash pine male cones in winter and female cones during the summer. Acorns from a variety of oaks (live, laurel, and sand live), cabbage palm fruits, bromeliad buds, and insects are also consumed. All of these food sources are available in hydric pine flatwoods of southwest Florida. Hydric pine flatwoods adjacent to oak and hardwood hammocks, xeric sandhill ridges, small stands of longleaf pine, and riverine forests provide additional forage on a seasonal rotational basis. Nesting occurs in pines; hardwoods, including oak and bay; cypress; cabbage palms; and bromeliad clumps.

The **Everglades mink** (*Mustela vison evergladensis*) is found in the Big Cypress Swamp; the freshwater wetlands, including hydric pine flatwoods, of western Collier County; the western edge of the Everglades; and marshes north to Lake Okeechobee (Allen and Neill 1952). Humphrey and Setzer (1989)

define a more limited range to Miami-Dade, mainland Monroe, Collier, and southern Lee counties. Mink are nocturnal and crepuscular predators of mammals, reptiles, birds, amphibians, fishes, and eggs. The species is not numerous and, given its period of activity, the literature on distribution is based primarily on roadkills. Brown (1978b) indicates a distribution in the hydric pine flatwoods of southeastern Lee County and all of Collier County. The State of Florida has designated this species as threatened.

Sherman's short-tailed shrew (*Blarina brevicauda shermani)* was described in 1955 from a location two miles north of Fort Myers, in drainage ditches with dense grass. This site corresponds with an area in the historic distribution of hydric pine flatwoods in northern Lee County. This subspecies has not been collected since 1955 (Hamilton 1955). Layne (1978) attempted collection in 1956, unsuccessfully. Given development in the Cape Coral and North Fort Myers area that has resulted in direct loss and drainage of hydric pine flatwoods, this apparently restricted subspecies may now be extinct.

The **Florida weasel** has been recorded from the southern extent of the distribution of hydric pine flatwoods in Collier County to areas extending north of Charlotte County (Brown 1978c). The species is naturally rare (Brown 1972) and has been, based on records, for the last 100 years. The species also uses mesic and xeric pine flatwoods, cabbage palm and live oak hammocks, and swamps in its range.

The **red-cockaded woodpecker** in southwest Florida utilizes slash pine hydric flatwoods as nesting and foraging habitat (Beever and Dryden 1992, Duever *et al.* 1986, D. Jansen, NPS, personal communication 1991). This habitat use contrasts with the distribution and habitat preference of the red-cockaded woodpecker for upland mesic and xeric longleaf pine (*Pinus palustris*) forest in north Florida and the remainder of the southeastern United States (Baker 1978, Bradshaw 1990, Crosby 1971, Henry 1989). The territories of red-cockaded woodpeckers in hydric slash pine flatwoods are documented to be larger, on average 144.4 ha (356.7 acres), than reported for northern birds, which ranged from 69.8 to 94.4 ha (172.4 to 233.2 acres) (Nesbitt *et al.* 1983, Patterson and Robertson 1981). The smallest cavity tree diameter we observed in southwest Florida is approximately 15.4 cm (6 inches) dbh, and a common cavity tree size is 20.5 to 30.8 cm (8 to 12 inches) dbh. The largest measured tree to date had a 35.9 cm (14 inch) dbh and was aged, by coring after lightning death, at 153 years (L. Campbell, personal communication 1991).

The hydric slash pine flatwoods provide preferred habitat for red-cockaded woodpeckers of southwest Florida for several reasons. Red-cockaded woodpeckers are documented to avoid areas of dense midstory. Xeric and mesic slash pine flatwoods of southwest Florida typically possess dense midstory vegetation. The dynamics of fire and flood maintain an open understory under the hydric slash pine canopy that is not inhabited by saw palmetto, hardwoods, and associated shrubs. Insect attack on slash pine trees stressed by fire, lightning, and flood provides abundant forage for red-cockaded woodpeckers. Mature trees stressed by the conditions of hydric pine flatwoods may also prove more suitable for the creation of start holes and cavity trees.

Historic forestry, agricultural, and land-clearing practices in southwest Florida concentrated on mesic and xeric pine flatwoods. These practices tended to avoid the hydric pine flatwoods, which were physically difficult to access because of inundation, had a higher percentage of malformed trees, and had a lower tree density. Following logging, southern slash pine recovery is enhanced in wetland areas, around seasonal ponds, and in the topographically depressed hydric slash pine flatwoods (Wade *et al.* 1980). Two factors contribute to this pattern. Slash pine grow more quickly and, during its early life stage, has fire protection in hydric conditions. The absence of a thick cover of saw palmetto also enhances slash pine seedling growth and survival in fires. All these factors resulted in the retention of old-growth pine in hydric slash pine flatwoods, thus enhancing their use by red-cockaded woodpeckers.

Bald eagles utilize the slash pine of hydric pine flatwoods of southwest Florida as nest trees, particularly where this community is located adjacent to an estuarine, riverine, or lacustrine foraging area. Nest trees are located in hydric pine flatwoods of Charlotte, Collier, and Lee counties. One- and two-year-old immature bald eagles have been observed in hydric pine flatwoods in all three counties. Eagles have also been observed utilizing the fish exposed by water level declines in the hydric pine flatwoods in the dry season. In Charlotte and southern Lee counties, large groups of eagles have been observed soaring on thermals during fall and spring migrations. The location of these collective soaring groups of mature and immature eagles were often over large hydric pine forests inland from the coast (Beever and Dryden 1998).

Wood storks utilize the hydric pine flatwoods of southwest Florida for foraging and roosting areas, particularly during the winter and early spring months when the dry-down hydrology concentrates fish for breeding season forage. While rookery areas in southwest Florida are found on mangrove islands and cypress swamps, the principal foraging areas are in depressional wetlands. The hydric pine flatwoods provide critical foraging habitat of 15 to 25 cm (6 to 10 inches) of water, with an abundance of small fishes and other aquatic life, at the critical February to April breeding season (Ogden 1978d). Beever and Dryden (1998) observed wood storks utilizing hydric pine flatwoods for foraging in Charlotte, Lee, and Collier counties in feeding groups from 1 to 53 birds. The longest occupied feeding area was occupied for 11 consecutive days. As the dry season progressed, wood storks would move to deeper depressions as fish became more concentrated. Due to winter rains, the hydric pine flatwoods retained water longer than in three previous years, and wood storks fed in the depressional habitat through April. By May, with the exception of a few pineland ponds, the hydric pine flatwoods were dry and wood stork utilization of this habitat ceased. With the beginning of the wet season, as hydric pine flatwoods depressions filled with water, individual wood storks were observed foraging with groups of little blue herons (*Egretta caerulea),* tricolor herons (*Egretta tricolor),* great blue herons (*Ardea herodias),* snowy egrets (*Egretta thula),* great egrets (*Casmerodius albus),* white ibis (*Eudocimus albus),* glossy ibis (*Plegadis falcinellus),* and a single scarlet ibis (*Guara rubra)* in the returning pools. Wood storks were observed to use slash pines and cypress in the hydric pine flatwoods as short-term roosting sites in all three counties.

The **Everglade snail kite** is documented from eastern and central Collier County (Sykes 1978), and has extended its range westward to nest in Lehigh Acres in eastern Lee County. It feeds only on apple snails (*Pomacea* sp.), which it takes from shallow open freshwater areas. Beever and Dryden (1998) observed snail kites to utilize hydric pine flatwoods areas in northwestern and eastern Lee County and southwestern Charlotte County in January and February of 1991. Each sighting was of individual birds that perched on slash pines and then foraged over open wet hydric pine flatwoods, adjacent deeper marsh areas, pineland ponds, and drainage canals. Specific pine trees were used as perch feeding stations, with accumulations of apple snail shells piled beneath them. Perch trees were located both in wet and seasonally dry hydric pine flatwoods.

The **southeastern American kestrel** is a small falcon that utilizes open habitat for foraging and nests in tree cavities, typically abandoned woodpecker holes in pine trees. Foraging is performed from tall pine trees, often snags, power and telephone poles and wires, and other tall objects. The kestrel feeds on large insects and, occasionally, on small rodents, reptiles, and birds (Wiley 1978). The hydric pine flatwoods of southwest Florida provide for the life history requirements of the kestrel. Southeastern American kestrel and the migratory eastern American kestrel are found in hydric pine flatwoods of Charlotte, Collier, and Lee counties. The observed foraging areas for these birds often extend to adjacent open habitats, such as pasture, both wet and dry prairies, and mowed roadway edges.

Peregrine falcons utilize wintering areas of Florida that provide them bird prey for food (Snyder 1978) and perches on which to roost, sun, and feed. The hydric pine flatwoods in coastal areas provide these prerequisites in combination with an open, sparsely canopied foraging area. Peregrine falcons have been observed in the hydric pine flatwoods of south Charlotte, northwestern Lee, and western Collier counties in winter. When observed, falcons were found in association with migratory passerines or in areas where migratory and resident shorebirds gathered. South Florida slash pine, both dead snags and large solitary trees, were the only observed roosts.

The **Florida sandhill crane** prefers wet prairies, marshy lake margins, low-lying pasture, open marsh, and shallow flooded open areas (Williams 1978b). Sparsely canopied hydric pine flatwoods provide suitable foraging habitat for nesting sandhill cranes, adjacent to ponds and marshes utilized as nesting areas. Adult and adult pairs with young commonly feed in the hydric pine flatwoods in Charlotte and Lee counties especially at the Babcock-Webb WMA. Nesting occurs in adjacent marshy depressional ponds vegetated in pickerelweed, arrowhead, and fire-flag in the hydric pine flatwoods matrix.

Limpkins utilize slow-moving freshwater streams and rivers, marsh, cypress heads, and shoreline habitats in southwest Florida. Diet consists of apple snails, other snails, freshwater mussels, lizards, insects, frogs, worms, and crustaceans. Nesting occurs in a mat of aquatic vegetation (Nesbitt 1978). Limpkins have been observed foraging in hydric pine flatwoods in winter and spring. Nesting in the hydric pine flatwoods of southwest Florida has not been observed. Breeding in adjacent freshwater habitats is not well documented and



Little blue heron. *Original photograph by Betty Wargo.*

can include both wet and dry seasons. Natural hydric pine flatwoods provide large areas of optimal shallow water depths for limpkin foraging. Areas of hydric pine flatwoods and associated ponds that are drained by human activity do not provide optimal foraging at the same depths and temporal sequence.

Little blue herons and tricolored herons utilize a wide variety of freshwater and saltwater habitats in southwest Florida. Their diet consists of crustaceans, insects, small fish, frogs, and lizards. The herons forage throughout the wet and dry season in hydric pine flatwoods and adjacent wetlands. Rodgers (1978) notes that little blue herons appear to prefer to forage in freshwater habitats even when nesting in saltwater wetlands. Nesting colonies are located in cypress, willow, buttonbush, and red maple copses in the center of ponds surrounded by hydric pine flatwoods. Breeding occurs during periods of high water. Areas of hydric pine flatwoods and associated ponds that are drained by human activity cease to function as nesting sites.

Snowy egrets are present as foragers, but perhaps do not nest in this community. They forage throughout the wet and dry season in hydric pine flatwoods and adjacent wetlands of the proper depths to allow for their unique foraging methods.

Roseate spoonbills nest exclusively in mangrove forests and forage wherever concentrations of small fish and crustaceans allow the birds to utilize their unique bills for feeding (Ogden 1978b). Roseate spoonbills have been observed foraging in dry-down pools in the hydric pine flatwoods of Charlotte, Collier, and Lee counties in the late dry season. Foraging groups included wood storks, common egret, white ibis, snowy egret, tricolored heron, and scarlet ibis. Natural hydric pine flatwoods hydroperiods can provide a dependable foraging area during the March dispersal to interior freshwater wetlands (Allen 1942).

The **eastern indigo snake** utilizes a wide variety of habitats in southwest Florida, including pine flatwoods, tropical hammocks, and xeric areas

(Kochman, 1978). Where available, gopher tortoise burrows are utilized as shelter. Kochman (1978) states that eastern indigo snakes are susceptible to desiccation and are more characteristic of mesic than xeric habitats in South Florida. Diet includes small mammals, birds, frogs, lizards, and other snakes that are available in hydric pine flatwoods. We have observed eastern indigo snakes in hydric pine flatwoods in Charlotte, Collier, and Lee counties throughout the year in the moister, but not submerged, areas of hydric pine flatwood. The abundant amphibian and reptilian fauna of hydric pine flatwoods is important to the diet of this wide-ranging reptile.

The **gopher tortoise** forages in both the upland ridge and the adjacent hydric pine flatwoods when water levels recede and throughout the dry season. The gopher tortoise finds excellent forage in the mixed ecotone of upland, wetland, and transitional grasses, herbs, fruits, and berries provided by the understory of hydric pine flatwoods. Gopher tortoises have been observed in hydric pine flatwoods of Pine Island (Lee County), northeastern and northwestern Lee County, and throughout Charlotte County. Collier County populations of gopher tortoises have largely been eliminated from areas of, and adjacent to, the hydric pine flatwoods.

American alligators utilize a wide variety of wetlands in South Florida. During late winter and early spring, as wetland areas dry down, alligators move across hydric pine flatwoods between deeper water wetlands. Large adult alligators construct “gator hole” ponds in the herbaceous wetlands and the depressional pools of hydric pine flatwoods, and these gator holes become centers of wildlife activity in the dry season. Young alligators utilize the hydric pine flatwoods submerged with 3 to 6 m (1 to 2 feet) of water during the wet season. As adults grow larger, they move to swamps, ponds, and lakes. In essence, where present it appears that the hydric pine flatwoods can provide a nursery and escape habitat for young and yearling alligators (Beever and Dryden 1998).

Plant Species of Concern

The federally listed plant that depends upon or utilizes the hydric pine flatwoods in South Florida is the beautiful pawpaw (*Deeringothamnus pulchellus*). The biological account and recovery tasks for this species are included in “The Species” section of this recovery plan. For a listing of other species that utilize the hydric pine flatwoods please see Appendix C.

The State endangered **Edison’s ascryrum** (*Hypericum edisonianum*) is a perennial shrub that flowers all year and is endemic to the Lake Wales Ridge. It can be found in Polk, Highlands, and DeSoto counties of South Florida. This species occurs in sandy soils of low, wet prairies, depressions of pine flatwoods, and pond margins. Periodic fires during dry seasons and droughts maintain the species.

The **pineland jacquemontia** (*Jacquemontia curtissii*) can be found scattered in hydric pine flatwoods throughout Collier and Miami-Dade counties. It was once reported from Monroe and Hendry counties. This somewhat woody perennial may be characterized by fleshy leaves and a white corolla. Periodic fire is required to perpetuate the species. The pineland jacquemontia is being

threatened by development and agricultural activities occurring throughout its range. The State of Florida has classified the pineland jacquemontia as an endangered species.

Ecology

The hydric pine flatwoods of South Florida are a distinct habitat in dynamic equilibrium between drought and flood, that is regularly and predictably perturbed by fire and water. This habitat provides no dependable long-term niche for long-lived specialist plant species, but a plethora of short-term niches for weedy annuals, fire-adapted species, short-lived specialists, and hardy generalists. With natural hydrology and fire frequency, the hydric pine flatwoods are temporally constant, in the absence of human intervention, as a pine prairie habitat of South Florida. Essentially, the hydric pine flatwoods are a dynamically maintained ecotonal habitat of extensive size. This blank slate is cyclically wiped clean by flood and drought, allowing the understory to be vegetated by a variety of species that do not have the temporal opportunity to achieve competitive dominance before being seasonally stressed. The alternation between upland and wetland conditions allows for both upland and wetland plant species to utilize the same habitat through temporal displacement. The dry sands during the dry season are suitable for xeric scrub species, and the same flooded sands during the wet season are suitable for Everglades marsh and wet prairie species.

Hydrology

Hydric pine flatwoods persists as subtropical or tropical savanna (Hela 1952). This results in alternating wet season flooding and severe dry season drought conditions. Mean annual precipitation in the hydric pine flatwoods is approximately 135 cm (53 inches) (Bradley 1972). The dry season is from November to April and the wet season from June to September (Riebsame *et al.* 1974). Between 18 to 23 percent of annual rainfall occurs in the dry season and 60 to 72 percent of the rainfall occurs in the wet season (Drew and Schomer 1984). Typically, the hydric pine flatwood habitat becomes saturated and attains standing water in the middle to late wet season. This pattern corresponds with peak flowering periods for the understory components of the hydric pine flatwood plant community (Beever and Dryden 1998). South Florida is subject to more hurricanes than any other area of equal size in the United States (Gentry 1974). Tropical storms strike once every 3 years in southern Collier County and once every 5 years in the northern extent of the hydric pine flatwoods area, as described by Bamberg (1980). The three primary climatic effects of hurricanes are high wind, storm surge, and heavy rain. The effects on forested ecosystems, including tree fall, substrate disturbance, and seed dispersal, can be considerable. In South Florida, hydric pine systems are particularly vulnerable to windthrow and toppling as a result of high wind events, limited root systems, and shallow soils.

Evapotranspiration estimates for southwest Florida range from 76 to 122 cm (30 to 48 inches) per year (Dohrenwend 1977, Palmer 1978). Evapotranspiration from the saturated soils of wetlands, such as hydric pine flatwoods, is an important control of sea breeze intensity and the formation of

convective thunderstorms. Because evapotranspiration is a cooling phenomenon, land-to-water gradients are reduced, convective processes are reduced, and recently rained-upon areas receive less rainfall. The effect is a natural feedback mechanism that results in a more even spatial distribution of seasonal rainfall (Bamberg 1980). This can also ameliorate the tendency towards formation of tornadoes over hot, convective dry lands.

The hydrology of South Florida flatwoods varies with elevation and topography. Xeric pine flatwoods possess approximately a meter of well-drained dry soil above the typical groundwater level, and the water table only attains the surface during unusual precipitation events such as hurricanes. Mesic pine flatwoods are less well-drained and are infrequently and briefly inundated by water only during extremely high levels of precipitation during the rainy season.

In contrast, water stands on the surface, inundating hydric pine flatwoods for one or more months per year during the rainy season. Typical, undisturbed hydric pine flatwoods in southwest Florida have standing water for at least 60 days (Beever and Dryden 1998). Hydrologically impacted hydric pine flatwoods may have standing water for at least 30 days. Lower hydric pine flatwoods, dominated by a slash pine canopy, sometimes including cypress as a codominant, and often associated with cypress sloughs, swamp forest strands, pineland ponds, and other wetland mosaic systems, have standing water for up to 120 days. Water depths in hydric pine flatwoods vary throughout the seasonal hydrologic cycle. Extreme ranges are from 91 cm (3 feet) above ground surface to 152 cm (5 feet) below ground surface. Typical ranges are from 30 to 61 cm (1 to 2 feet) above ground surface at the height of the wet season to 91 cm (3 feet) below ground surface in the late dry season. For most of the year, hydric pine flatwoods have water within 30 cm (1 foot) above or below the ground surface. The hydric pine flatwoods of southwest Florida have a higher water table and typically experience longer periods of inundation than do east coast rockland pine forests (FNAI 1989).

The flat topography, sandy and/or marly soils, and the seasonal precipitation cycle are the principal influences on hydric pine flatwood hydrology. The flat topography creates minimal gradients, resulting in slow runoff that occasionally creates very poorly defined first-order streams and typically results in sheetflow patterns. Where hardpan is present, water moves slowly vertically relative to the horizontal movement, through horizons above and below the hardpan layer. With standing water, hydric pine flatwood soils become waterlogged and poorly aerated during the rainy season. During the dry season, high evapotranspiration from the surface water and the vegetative component of the community draws most of the water out of the upper soil horizons, drying them out. Soil moisture becomes depleted in the upper soil layers, above the hardpan, and a persistent drought condition frequently prevails through the dry season. As a result, during the dry season, groundwater is inaccessible for plants that cannot penetrate the hardpan (FNAI 1989, Sprecher and Gerami 1990). In southwest Florida, hardpan is rarely complete, resulting in a “leaky” aquaclude that is subject to water table fluctuation (H. Yamataki, personal communication 1991).

Not all hydric pine flatwood soils form a hardpan (Sprecher and Gerami 1990, Sprecher and Cheng 1990, H. Yamataki, personal communication 1991). These altosoils and entiosoils, which display clear wetland soil characteristics, saturate

with water and become waterlogged without the formation of a clear spodic layer. During the wet season, water also moves slowly vertically relative to horizontal movement through these soils, resulting in standing water. During the dry season, soil moisture becomes depleted in the upper soil layers and a water table layer similar to that of a xeric pine flatwoods prevails. As a result, during the dry season, xeric condition-adapted plant species, as opposed to wetland plant species, are at an advantage, particularly if a dry season fire occurs.

With the onset of the wet season, hydric pine flatwoods are quickly saturated. As the rate of precipitation exceeds the rate of runoff, standing water appears in depressions in June. By July, hydric pine flatwoods are uniformly wet. Deep water levels are attained by the late rainy season, in September. As the dry season begins in November, the pattern reverses, with a shift to runoff exceeding precipitation. This results in the formation of isolated pools, as sheetflow recedes below the ground surface. This recession of standing water or drawdown usually extends from November to March, but the magnitude and rate of change can vary by year. By March, only the depressional areas of hydric pine flatwoods retain standing surface water. Measured sheetflow rates in South Florida range from 0 to 430 m (0 to 1,410 feet) per day with an average of 262 m (860 feet) per day. The flow rate is a result of gradient and vegetation density (Leach *et al.* 1972, Parker 1974). Based on measurements of the extremely altered Golden Gate Estates area in Collier County, 43 to 61 cm (17 to 24 inches) of annual runoff (Black, Crow and Eidsness, Inc. 1974, Dohrenwend 1977) can occur from drained hydric pine flatwoods. Undisturbed hydric pine flatwoods may exceed the annual rate of 10 cm (4 inches) per year runoff identified for a mixed swamp forest system like the Fakahatchee Strand in Collier County. Average rates of runoff for southwest Florida are 13 to 25 cm (5 to 10 inches) per year (Duever *et al.* 1986).

Fire

Hydric pine flatwoods are a fire-climax, hydroperiod-mediated community. Nearly all plants and animals of the hydric pine flatwood are adapted to periodic fires (FNAI 1989). In pre-Columbian times, fires probably occurred in the hydric pine flatwoods every 3 to 10 years. While natural fires were numerous, the areal extent of any given fire was probably small, 10 ha (25 acres) or less. Most fires occurred at the end of the dry season. This pattern of patch fires created a mosaic of plant and habitat diversity, as opposed to a monopyric, even-aged plant community.

South Florida slash pine is extremely fire tolerant (Ketcham and Bethune 1963). South Florida slash pine seedlings have a grass stage that, like longleaf pine, greatly increases resistance to fire damage. Fire stimulates slash pine seedlings to sprout, promoting their growth as pioneers of burned land. Adult South Florida slash pines are also more resistant to fire than are northern slash pines (Wade *et al.* 1980). South Florida slash pine has longer tap roots and a smaller needle size than the northern slash pine (McNab 1965, Mc Minn 1970).

Much of the variation in community structure of hydric pine flatwoods is probably associated with fire frequency. The herbaceous plant community of hydric pine flatwoods survives fire by seeding and resprouting from root stock. In hydric pine flatwoods communities, the dried herbaceous growth of several prior growing seasons forms the principal fuel for natural fires. The longer the period since the last fire, the more developed the understory shrub layer. If the understory

is allowed to grow too long without fire, the accumulated needle bed and the height of flammable understory increases the probability of catastrophic canopy fires (FNAI 1989). If fires are very frequent, slash pine seedling regeneration will not occur, and the hydric pine flatwoods will tend to be dominated by a herbaceous understory of wetland species with clusters of cabbage palms, forming a hydric cabbage palm prairie (Wade *et al.* 1980). Less fire-tolerant plant community components are located in deep water refugia found in pineland ponds and adjacent cypress strands. With overdrainage, fire refugia are lost. This typically results in decreases in the midstory and tropical components, with subsequent losses in plant species diversity. If overdrainage is coupled with too-frequent fire, and a melaleuca seed source is nearby, the hydric pine flatwoods can become dominated by the melaleuca monocultures typical of south Lee and northern Collier Counties (Wade *et al.* 1980).

Without regular fire, hydric pine flatwoods are expected to succeed into hardwood dominated forests with a closed canopy, eliminating groundcover herbs and shrubs (Alexander 1967, FNAI 1989). After approximately 6 to 10 years of fire absence, perennial plants that are normally set back by fire attain larger sizes. An increased ground cover results from the presence of fewer, but larger, individual plants. These individual plants are subsequently shaded out by other plant species that would normally be killed by fire. This results in an increase in cover, but a decrease in plant species diversity. In general, fire exclusion from hydric pine flatwoods results in species loss; decreased forage quantity and quality for herbivorous species, and subsequently for their predators; increased danger from wildfires; and decreased pine regeneration (Wade *et al.* 1980).

Status and Trends

The hydric pine flatwoods of South Florida were not a rare habitat historically. Historically there were approximately 3,079,565 ha (7,606,525 acres) of South Florida pine flatwoods (Davis 1967). Using a conservative estimate that one-third of these flatwoods were wet, historically there would have been approximately 1,026,522 ha (2,535,508 acres) of hydric pine flatwoods. As a group, xeric, mesic, and hydric pine flatwoods were reduced to approximately 50 percent of their historic extent by 1970 by agricultural activities, speculative real estate clearing, and urban development (Birnhak and Crowder 1974). Wade *et al.* (1980) reported that in 1980, pine flatwoods occupied more area in South Florida than any other kind of plant community except the Everglades marsh. Kautz (1993) indicated that by 1987, pine flatwoods have dropped to fifth in areal extent behind grasslands, cypress swamp, dry prairies, and freshwater marsh. This study indicated that, for the first time, urban areas occupied more acreage in southwest Florida than did pine flatwoods.

Of the original 3,079,565 ha (7,606,525 acres) of South Florida pine flatwoods estimated by Davis (1967), Cox *et al*. (1996) estimated that 1,077,700 ha (2,661,919 acres) of South Florida pine flatwoods remained, with 269,450 ha (665,542 acres) in public managed areas. Approximately one-half of the pine flatwoods in coastal southwest Florida (Collier, Charlotte, and Lee counties) is estimated to be hydric (Beever and Dryden 1998). Extrapolating from southwest Florida and using Cox *et al* (1996) figures for remaining flatwoods acreage in

South Florida, approximately 53,8821 ha (1,330,888 acres) of hydric pine flatwoods remain in South Florida. In southern Charlotte County alone, at least 12,146 ha (30,000 acres) of hydric pine flatwoods exist. Beever and Dryden (1998) estimate that there were at least 80,972 ha (200,000 acres) of hydrologically intact hydric pine flatwoods existing in southwest Florida in 1989.

An analysis (Cox *et al*. 1996) of vegetation types most impacted by human land conversion indicates that statewide, only 36 percent of the historic pine flatwoods remain (64 percent loss). Interestingly, this is the same proportionate loss as for pine rocklands. South Florida pine flatwoods are among the least protected habitats by current distribution of public lands, with only 9 percent protected. This is proportionately less public land than for longleaf pine-xeric oak sandhills (14 percent) and sand pine scrub (35 percent): habitats typically advocated for protection as underrepresented on preserve lands.

Logging of the South Florida hydric pine flatwoods began in the 1920s and continued through World War II. Following logging, the understory components recovered quickly, depending on the level of altered hydroperiod. Pine recovery was best in wetland areas, around seasonal ponds, and in the topographically depressed hydric pine flatwoods (Wade *et al*. 1980). Several factors probably contributed to this pattern: (1) wetland pine areas were more difficult to deforest utilizing early twentieth-century techniques; (2) slash pines grow more quickly and, during its early life stage, has fire protection in hydric pine flatwood hydrologic conditions; and (3) the absence of a thick cover of saw palmetto enhances slash pine seedling growth and survival in fires (Beever and Dryden 1998, Wade *et al.* 1980).

Hydric pine flatwoods display a resilient recovery from overstory damage due to fire or clearcutting, if the natural hydrology and fire regime are allowed to continue. Recovery is poor when hydrology or ground cover is disturbed. Hydric pine flatwoods are vulnerable to disruptions of fire and hydrologic regimes. Drainage of hydric pine flatwoods has resulted in expansion of pine dominance and decreases in plant diversity, and subsequently wildlife diversity, in southwest Florida. This is evident in Golden Gate Estates (Collier County) (Wade *et al.* 1980). Hydric pine flatwoods are also very susceptible to invasion by melaleuca when they are overdrained (Wade *et al*. 1980). Other exotic plants, including caesarweed (*Urena lobata*), crab's eye (*Abrus precatoris*), natal grass (*Rhynchelytrum repens*), and cogon grass (*Imperata cylindrica*) readily invade the hydric pine flatwoods. While drainage may result in a shift in canopy dominance toward more slash pine, overdrainage can result in conditions too dry for slash pine establishment and survival in areas of previous slash pine dominance. The result has been an increase in the area of palmetto-dominated prairie from historic conditions (Wade *et al*. 1980).

Federal (FWS, COE, NRCS) and some state (GFC) agencies recognize hydric pine flatwoods as a separate wetland habitat type in South Florida. However, the State of Florida wetland jurisdiction rule (ERP) does not consider a hydric pine flatwoods to be a wetland unless the pine canopy and mid-story pine canopy coverage is sufficiently sparse to render jurisdictional determination at the groundcover level and saw palmetto does not dominate the understory. This conflict in jurisdictional claims between the State of Florida and the principal federal wetland regulatory and wildlife management agencies can place hydric pine flatwoods in a regulatory no-man's land, subject to differential regulation with subsequent conflicts in resource protection and management.

Management

Management issues for hydric pine flatwoods include consideration of size and fragmentation, fire ecology, hydrology, substrate disturbance, exotic plant invasion, exotic animals, extractive land use (logging, grazing, saw palmetto berry gathering), waste disposal and nutrient enrichment issues (dumping, enriched run-off, spray-fields, septic systems, and land spreading), recreational uses, and effects of resource mitigation policy.

Management to maintain and restore the high level of biodiversity found in hydric pine flatwoods is best achieved on large, intact, contiguous tracts of land composed of hydric pine flatwoods and a mosaic of other native habitats. The habitat reticulation of xeric, mesic, and hydric pine with seasonal marshes, cypress and mixed hardwood swamp strands, and various hardwood and palm hammocks, maintained by fire and dendritic sheetflow hydrology provides a self-sustaining community diversity that provides niches for innumerable species. Hydric pine flatwoods are not maintainable nor sustainable in small, "postage stamp" isolates that may be cut off from sheetflow hydrology, excluded from fire, subject to substrate disturbance and significant edge effect, and vulnerable to exotic plant and animal invasion.

Managing hydric pine flatwoods is an issue of landscape ecology. Most existing public and private lands with intact, healthy hydric pine flatwoods and healthy biodiversity are large multi-square mile parcels. Current land acquisition and land protection proposals include protection of other existing large parcels, connection of existing and proposed parcels, and expansion of existing parcels to attain larger landscape size. This is functionally necessary to achieve the long-term persistence of the hydric pine flatwoods habitat type in South Florida and achieve multi-species recovery in South Florida. Wide-ranging animals such as Florida panther, Florida black bear, red-cockaded woodpecker, migratory birds, wading birds, wood storks, eastern indigo snakes, and fox squirrels need a variety of connected habitats over a wide area to complete life-cycle needs and maintain viable population levels in South Florida.

Fire Management

Burning to increase value to livestock and wildlife is a well-established practice in hydric pine flatwoods. It has been documented to increase range values and wildlife habitat (Komarek 1963, Stoddard 1963, Lewis 1964, Moore 1972, Hughs 1975). Different burn regimes favor different wildlife species. For example, quail are favored by 2-year rotational burns (Moore 1972) and turkey are favored by 3- to 4-year cycles (Stoddard 1963).

Little is known about the frequency and timing that is most beneficial to most of the rare species or some plant communities. There have been few studies conducted to assess whether early or late growing season burns are most beneficial to the community. However, early growing season burns have been recommended over late growing season burns because: (1) lightning fires in South Florida are most common in early summer (June), and the largest number of acres are burned naturally during late spring and early summer; (2) studies

suggest that early growing season burns are more favorable to growth and survival of longleaf pine seedlings and saplings than late growing season burns; (3) early growing season fires are more detrimental to hardwoods, which compete with pines for establishment (Robbins and Myers 1992). Additionally, smoke and fire management considerations in South Florida are increasingly dictated by human population safety concerns. This concern has promoted some winter burn schedules.

Natural fire breaks created by moisture or the lowest impact method (such as foam) should be used whenever possible to contain the fire . However it is usually necessary to prevent the spread of fires into adjacent plant communities, off-site, or to roadways, therefore control lines should be established using existing trails, roads, or plow lines. In flatwoods, plow or control lines should be cut by disc to avoid disruption of hydrology (sheetflow). However, these lines may be subject to weedy or exotic plant invasion. Spot fires can be created by dropping plastic balls of potassium permanganate and antifreeze from a helicopter. The small intermittent fires created by this method will burn together before becoming too hot. However, this method may not be appropriate for rare species management because it can create uniform, even, landscapes. (Natural fire moves differently.) Fire should be allowed to spread into ecotones and adjacent wetlands.

It is important to maintain natural South Florida hydroperiods and a diverse fire management schedule to achieve the highest plant biodiversity for the system. Based on the observations of the hydric pine flatwood community profile study (Beever and Dryden 1998), a diverse pattern of burning, similar to the natural burn conditions for hydric pine flatwoods, appears to produce the highest species diversity. Landscape scale burning performed on large acreages has also achieved good results when significantly large burn units are used and areas are not forced to burn by micro-management.

It is important to maintain natural South Florida hydroperiods and a diverse fire management schedule to achieve the highest plant biodiversity for the system. Landscape scale burning performed on large areas has also achieved good results when managers are not forced to micro-manage burns.

Hydrology

The most common form of hydrologic alteration of hydric pine flatwoods is ditching to lower the annual water table below the surface throughout the year. Relatively small ditches and canals can achieve this since the redirection of sheetflow into rapid discharge channels can prevent any formation of a surface water layer. Deeply rutted and even small permanent vehicle tracks can transform the sheetflow condition of the hydric pine flatwoods into channelized flows. Deeper regional canals, such as those in Golden Gate Estates (Collier County), can lower water table on a regional scale for the purposes of land development. This widespread practice substantially altered hydric flatwoods hydrology in large areas of South Florida, including the City of North Port, Port Charlotte, City of Cape Coral, Lehigh Acres, South Fort Myers, South Naples, Golden Gate Estates, Sebastian Highlands and the older parts of Port St. Lucie.

Another commonly encountered form of hydrologic alteration of hydric pine flatwoods is small levees or berms created as a byproduct of ditching, placed as

part of road or other linear construction to elevate the path above wetland grade, and intentional barriers designed as part of surface water management systems to retain all waters on a site as part of a development process. These permitted water management features redirect sheetflow into rapid discharge channels or stormwater retention and detention areas. These can have the dual deleterious effects of drowning upstream hydric pine flatwoods, creating a deeper water wetland type, while denying sheetflow to downstream areas, creating a drier type of flatwoods. These blocks to sheetflow, coupled with inadequate culverting, are often the cause of significant flooding to both natural areas and human property. These features significantly fragment regional hydrology and alter landscape connection of flow to the coastal estuaries. Removal or installing multiple culverts of these man-made flow blocks can substantially restore hydric pine flatwoods hydrology while reducing flooding effects on human property.

Other types of hydrologic alteration to hydric pine flatwoods include water table drawdown by wellfield and surface mine excavation. Due to the permeable substrates that underlie hydric pine flatwoods, changes in surficial aquifer levels can be rapidly translated into drops in the water table. Mines and borrow pits, particularly those that operate pumps to accommodate excavation, can lower local water levels within a hydric pine flatwood. Wellfield pumping can, at significant levels of withdrawal, dry out hydric pine flatwoods in the areas of cones of depression, changing plant community structure and susceptibility to exotic plant invasion.

Substrate Disturbance, Exotic Plant Invasion, and Exotic Animals

Hydric pine flatwoods soils tend to be sandy with shallow, if any, organic layers. Productivity export and incorporation appear to be extremely efficient in natural hydric pine flatwoods, since bare, sandy soil surfaces are the norm in undisturbed hydric pine flatwoods systems, indicating that natural systems do not accumulate significant bed loads of litter. Simple physical disturbance of the surface by vehicles, plows, unimproved roads, excavations, exotic animals, fill, excavation, explosions, and seismic testing can leave an area with a slightly different elevation, altered soil nutrients, and different soil horizons that, when revegetated, can be sites of weedy and exotic plant establishment. The first entry of exotic plants into a hydric pine flatwood area can often be along jeep trails, at the toe of fill roadways, along cleared utility easements, around borrow pits, where wild hogs have rooted, and along rock mine survey grid lines.

If substrate disturbance is coupled with fire exclusion and drainage, it is almost inevitable that Brazilian pepper or melaleuca will become established in the hydric pine flatwood. Hydric pine flatwoods systems that have had hydroperiod alterations and/or fire exclusion coupled with substrate disturbance, such as Golden Gate Estates (Collier County), appear to accumulate litter loads quickly, resulting in plant diversity degradation with invasion by opportunistic species such as cabbage palm and grape vine; accelerated exotic plant invasion; declines in pine tree recruitment; and increases in wildfire.

Hydric pine flatwoods that are cleared of native vegetation but are not otherwise altered in hydrology or fire-frequency may return to hydric pine flatwoods flora, but typically will include exotic plant species in areas of substrate

disturbance. Activities that increase the susceptibility to invasion by exotic species include rooting by hogs, fire suppression, clearings for wildlife food plots, fire plow lines, and revegetation (Martin *et al.* 1996).

Of the 993 plant species documented or recorded from the hydric pine flatwoods of South Florida, 93 (9 percent) are exotic, introduced species. Most of the introduced species are not invasive under natural hydrology and fire frequency. The principle invasive species, Brazilian pepper and melaleuca, are able to persist and spread if hydrology is altered and fire is suppressed. Removal or control of invasive and non-invasive exotic plant species is achievable in the hydric pine flatwoods of South Florida by direct mechanical and chemical control, and restoration of hydroperiod and natural fire regimes. Successful projects on public and private lands utilize multiple strategies with long-term persistent management staffing and removal effort. The causes of alteration to the hydric pine flatwoods that encourage exotic plant invasion spread must be eliminated to achieve long-term eradication. If the causes are not addressed, then control is only achievable with repetitive persistent management. If management is suspended, gains can be quickly lost and exotic plants attain dominance.

There is some debate concerning the relative habitat values of exotic plant dominated landscape. While the presence of a few individual plants does not constitute a major community threat, solid monocultures have demonstrably negative effects on plant and animal community diversity. When exotics replace natives, plant and animal species that depend upon those natives are similarly impacted. Thresholds are not yet well understood and both under- and over-estimation of exotic plant invasion effects is common.

Exotic animals identified in South Florida hydric pine flatwoods include: wild hog (*Sus scrofa),* armadillo (*Dasypus novemcinctus),* feral dogs, feral cats, coyote (*Canis latrans),* Cuban tree frog (*Osteopilus septentrionalis),* brown anole (*Anolis sagrei),* walking catfish (*Clarias batrachus*), and other exotic fishes. Wild hogs and to a lesser extent, armadillos, can change understory composition through substrate disturbance. This can harm groundcover plant species and provide opportunities for exotic plant invasion. Both species can be managed by direct trapping and hunting. An alternative, concurrent strategy includes management for the natural predators of these species. Cuban tree frogs are predators on native, smaller tree frog species and have been demonstrated to displace native species in urban and agricultural settings. Feral cats and dogs have been demonstrated to significantly impact small mammal, ground-nesting bird, and songbird populations in Florida and throughout the United States. Walking catfish can be voracious predators in shallow freshwater wetlands with a competitive advantage over native species unable to survive hydrological alteration. Fire ants (*Soleonopsis invicta*) have become a problem for ground- and tree-nesting birds and tree-nesting mammals. The effect of coyotes on South Florida ecosystems and food webs is currently unknown. There have been various reports of benefits (predation on feral cats and dogs, wild hogs and armadillos) and problems (predation on gopher tortoises and ground-nesting birds, competition with native medium-sized predators). So far no organized strategies to address exotic predators in hydric pine flatwoods have been developed. The spread of exotic animals into native hydric pine flatwoods has been assisted by fragmentation of the landscape by roadways, canals, agricultural and suburban development. It is

clear that the greater the amount of developed edge relative to the core areas of hydric pine flatwoods, the greater the potential for exotic animal invasion of the habitat.

Extractive land use

Logging of the South Florida hydric pine flatwoods began in the 1920's and continued through World War II. Following logging, the understory components recovered quickly, depending on the level of altered hydroperiod. Pine recovery was best in wetland areas, around seasonal ponds, and in the topographically depressed hydric pine flatwoods (Wade *et al*. 1980). Several factors contributed to this pattern: (1) wetland pine areas were more difficult to deforest utilizing early twentieth-century techniques; (2) slash pines grow more quickly and, during its early life stage, has fire protection in hydric pine flatwood hydrologic conditions; and (3) the absence of a thick cover of saw palmetto enhances slash pine seedling growth and survival in fires.

Hydric pine flatwoods display a resilient recovery from overstory damage due to fire or clearcutting, if the natural hydrology and fire regime are allowed to continue. Recovery is poor when hydrology or ground cover is disturbed. Drainage of hydric pine flatwoods has resulted in expansion of pine dominance and decreases in plant diversity, and subsequently wildlife diversity, in South Florida. This is evident in Golden Gate Estates (Collier County) (Wade *et al*. 1980). Logged hydric pine flatwoods are also very susceptible to invasion by melaleuca when they are overdrained and the melaleuca is not concurrently logged (Wade *et al*. 1980). Other exotic plants readily invade the drained and logged hydric pine flatwoods (FNAI 1989). While drainage may result in a shift in canopy dominance toward more slash pine, overdrainage can result in conditions too dry for slash pine establishment and survival in areas of previous slash pine dominance. The result has been an increase in the area of palmetto-dominated prairie from historic conditions prior to logging and drainage (Wade *et al*. 1980).

Revised best management guidelines should be developed for logging in hydric pine flatwoods in South Florida. Current best management practices for logging in South Florida utilize seed tree cutting strategies, rather than clear-cutting, but have relatively rapid 20- to 30-year rotations that eliminate all but a few of the mature old-growth trees, essential to such species as the red-cockaded woodpecker. Removal of snags also reduces biodiversity in hydric pine flatwoods, as 53 different animal species depend upon the cavities found in the dead trees of hydric pine flatwoods.

Overdrainage and pasture conversion has changed the South Florida landscape from pine flatwoods to one dominated by rangeland. Revised best management guidelines for cattle grazing should be developed for hydric pine flatwoods in South Florida. Cattle ranching in the South Florida hydric pine flatwoods began immediately with the American settlement of South Florida. Calf raising and associated pasture for stock and dairies continues today, particularly in central South Florida. Drainage for range is common practice, however, and was encouraged by cooperative extension and farm programs from the 1920s until the 1970s. Following light grazing, the understory components of hydric pine flatwoods recover quickly, depending on the level

of altered hydroperiod. Hydric pine flatwoods display a resilient recovery from grazing, if the natural hydrology and fire regime are allowed to continue and exotic, improved pasture grass species are not introduced. Recovery is poor when hydrology or ground cover is disturbed by "improved pasture" management. Drainage of hydric pine flatwoods has resulted in expansion of improved pasture and decreases in plant diversity, and subsequently wildlife diversity, in South Florida. Hydric pine flatwoods converted to improved pasture or subject to high grazing pressure are also very susceptible to other exotic invasion by range pests such as the exotic tropical soda apple.

Saw palmetto berry gathering for pharmaceuticals has recently become a new extractive use of hydric pine flatwoods. The effect of hand-harvesting tons of palmetto berries is not currently known. Palmetto berries are important food for many wildlife species, including listed mammal species such as the Florida black bear. The saw palmetto is also an important understory component for providing cover for prey species. It is not known if a significant number of berries are being removed, if berry-consuming wildlife is finding sufficient forage, or if berries are germinating sufficiently enough to maintain saw palmetto populations.

Waste Disposal and Nutrient Enrichment Issues

Hydric pine flatwoods are subject to a variety of waste disposal uses in South Florida. Landfills in southwest Florida have been sited in hydric pine flatwoods (Charlotte, Lee, and Collier counties). This invariability involves complex construction, water management, and containment systems to prevent leachate discharge to adjacent areas. Such sites can become attractors to listed species found in hydric pine flatwoods, particularly wading birds, Florida black bear, and bald eagles, with concomitant conflicts.

Fertilization in pine flatwoods may have drastic effects on these communities because they are naturally low in nutrients, and weedy species are likely to invade following nutrient enrichment (Martin *et al.* 1996). Also, Walker and Peet (1983) reported that an increase in productivity resulting from fertilization should lead to a decline in plant species richness, including a decline in rare plant species richness. It is not known whether fertilization will lead to replacement of rare species able to thrive under fertilization conditions. Fertilization can be carried to the aquatic habitat via runoff (Martin *et al.* 1996).

Most hydric pine flatwoods in South Florida that are accessible by vehicles and not patrolled by public or private on-site managers are subject to extensive dumping of yard debris, construction materials, large objects including vehicles and white goods, chemicals, and basic domestic garbage. This provides direct habitat degradation, exotic plant degradation, and water quality pollution. Dispersed rural and semi-suburban development in hydric pine flatwoods areas of South Florida are typically served by septic tank systems that are designed to leach into drain fields in the permeable sands of the hydric pine flatwoods. During annual wet season high water and other flood events, septic systems become saturated and both surface ground water and surface waters display pollution from fecal coliform bacteria indicative of waste pollution.

Agricultural lands, including high intensity cattle operations, display surface water fecal coliform bacteria indicative of waste pollution from cattle waste. The practice of land spreading sludge from sewage treatment plants and septic systems over rangeland to "enhance" the low nutrient levels of hydric pine flatwood sands can result in water pollution. Agricultural lands adjacent to hydric pine flatwoods also may discharge, during the wet season, nitrified runoff to hydric pine flatwoods and other wetlands, benefiting nutrient uptake plant species such as cattails and primrose willow.

Recreational Damage

The activities of off-road vehicles can significantly alter the substrates of hydric pine flatwoods altering hydrology, and encouraging exotic plant invasion on disturbed soils. Trash and debris from recreational activity is common on unmanaged areas, including food and beverage packages, items brought in as targets for shooting, and other discarded items including monofilament, rubber, and plastic products.

Significant debate is ongoing concerning the impacts of some types of hunting activities, including where off-road vehicles are used for access and where dogs are used for certain types of hunting. In order to maintain the high biodiversity of South Florida hydric flatwoods, recreational access, activities, and level of resource pressure need to be managed on public and private lands.

Resource and Mitigation Policy

The mitigation policies of Federal, State and local regulatory agencies can significantly affect the management of hydric pine flatwoods of South Florida. Those entities often do not recognize hydric pine flatwoods as valuable wetland systems and may accept or encourage their development before other types of wetlands and conversion into other wetland types as mitigation for impacts to other wetland types.

Other wetland mitigation policies that require on-site mitigation can direct the preservation or creation of wetlands of very small size, located as isolates in a developed landscape, with unnatural hydrology and little to no habitat connection to larger ecosystems. These small isolates cannot function or replace the function of hydric pine flatwoods with sheet flow hydrology. The location of mitigation sites immediately adjacent to highway projects can also cause wildlife mortality.

To date, there has been no successful creation of hydric pine flatwoods wetlands from other landscapes. Successful restoration in existing hydric pine flatwoods includes exotic plant and animal removal and control, restoration of hydrology, restoration of fire management, and removal of trash and debris.

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Restoration of Hydric Pine Flatwoods

Restoration Objective: Maintain the structure, function, and biological composition of hydric pine flatwoods, and increase the spatial extent of protected pinelands in South Florida.

Restoration Criteria

South Florida can contribute to the preservation of regionally significant wetland habitat, hydrology, aquifer recharge, and fish and wildlife habitat values by preserving the geographic extent of hydric pine flatwoods. The conservation and recovery of listed plant and animal species, wide-ranging species, neotropical birds, and large complexes of isolated and ephemeral wetlands will be accomplished by the preservation and restoration of this community.

The restoration objective will be achieved when: (1) the hydric pine flatwoods habitat is preserved through land acquisition or private landowner cooperative agreements, consistent with the Game and Fresh Water Fish Commission's "Closing the Gaps in Florida's Wildlife Habitat Conservation System," the Florida Panther Habitat Preservation Plan (South Florida Population), the Game and Fresh Water Fish Commission's Preservation 2000 Act Study (Biodiversity Conservation Analysis), current State/Federal land acquisition proposals (including CARL, SOR, *etc*.), other federal listed species recovery plans, and regional wildlife habitat protection plans; (2) degraded areas are identified and restored to suitable hydric pine flatwoods habitat; (3) hydrology, fire and exotic plant management is regionally applied to restore and maintain regional plant and animal biodiversity; (4) the geographic extent of hydric pine flatwoods in South Florida is identified; and (5) the habitat is identified as a true forested, wetland community and no longer portrayed as a transitional habitat.

Community-level Restoration Actions

1. **Identify the extent of remaining hydric pine flatwoods habitat in South Florida.** Although the existing GIS, aerial photograph, and ground-truthed land cover information is available for this community throughout South Florida, a comprehensive regional analysis has not been conducted.

    1.1. **Detail the geographic extent of hydric pine flatwoods in South Florida.** This task should integrate existing GIS and other databases on land cover, soils, and hydrology, to correctly identify and separate hydric pine flatwoods from other pine flatwood and wetland types, particularly cypress, in South Florida. GIS and National Wetlands Inventory maps often misinterpret hydric flatwoods as cypress.

1.2. **Update the GIS database for hydric flatwoods to monitor cumulative impacts.** As areas of hydric pine flatwood are converted to other land uses, changes should be mapped to identify cumulative habitat loss.

1.3. **Identify old-growth hydric flatwoods in South Florida.** Old-growth hydric pine flatwoods have the potential to sustain rare plant and animal communities. These areas provide unique habitats that are not replaceable within short time spans.

2. **Preserve remaining areas of hydric pine flatwoods.** Direct loss of habitat resulting from land conversion, habitat degradation, and fragmentation continues unabated in South Florida. However, many of the best remaining areas of intact hydric pine flatwoods have been identified for land acquisition.

2.1. **Complete purchase of the following CARL projects:** Allapattah Flats (Martin County), Atlantic Ridge Ecosystem (Martin County), Belle Meade (Collier County), Cape Haze/ Charlotte Harbor (Charlotte County), Charlotte Harbor Flatwoods (Charlotte County), Corkscrew Regional Ecosystem Watershed (Lee, Collier Counties), Fakahatchee Strand (Collier County), Hall Ranch (Charlotte County), Ocaloacoochee Slough (Hendry and Collier counties) Pal-Mar (Palm Beach and Martin counties), Save Our Everglades-South Golden Gates Estates (Collier County), Sebastian Creek (Indian River and Brevard counties).

2.2. **Complete purchase of the following Save Our Rivers projects:** Corkscrew Regional Ecosystem Watershed (Lee County), and Loxahatchee Slough (Palm Beach County).

2.3. **Develop additions to existing Federal and State land acquisition proposals in areas identified as GFC strategic habitat conservation areas and in the 1990 statewide charrette, including the following:** Estero Bay Watershed, south of Corkscrew Road, east of I-75 (Lee County); west and east of Burnt Store Road (Charlotte and Lee counties), north of Cape Coral (Lee County): east of the Babcock-Webb WMA (Charlotte County); Picayune Strand in North Golden Gate Estates (Collier County); north of Belle Meade (Collier County), south and east of Myakka Prairie (Sarasota County); between Oscar Shearer SP and Pinelands Preserve (Sarasota County); east of the Southwest Florida International Airport (Lee County); north of Immokalee Road (Collier County); Imperial River drainage (Lee County); and areas in northern Palm Beach County that contain hydric pine flatwoods.

2.4. **Implement cooperative habitat preservation programs with private landowners.** Much of the hydric pine flatwoods habitat is in private ownership and many private landowners may not choose to participate in fee-simple land acquisition projects. Protection through alternate methods may conserve important ecosystems by providing landowners with economic incentives and promoting good stewardship by ensuring that landowners view habitat as an asset, not a liability.

2.5. **Support and implement cooperative regional greenways programs with landowners and other agencies.** Greenways planning has successfully developed cooperative, local conservation plans that will maintain, establish, and manage landscape connections between important resource areas.

2.6. **Target wetland agency policy or proposed projects under review by COE, Water Management Districts, and DEP that degrade or eliminate hydric flatwoods habitat.** Hydric flatwoods and other pinelands have significantly declined in areal

extent and patch size in South Florida, primarily because of characterization as uplands or "habitat in transition."

2.6.1. **Stress avoidance of impacts of this habitat type** as a regional wetlands permitting concern. Both consultants and permitting entities need to be educated on the importance of this habitat to regional fish and wildlife.

2.6.2. **Require type-for-type on- and off-site wetland mitigation** when avoidance and minimization criteria have been exhausted. Both consultants and permitting entities often assess credit mitigation on the basis of the wetland depth, not the landscape importance or biodiversity value. This results in off-site mitigation of hydric flatwoods to deeper cypress systems and on-site conversion of hydric flatwoods to pooled wetlands that often kill pine trees.

2.6.3. **Examine Federal nationwide and State and Federal general permit and permit exemptions** to assess impacts on hydric pine flatwoods habitat. Piecemeal development and speculative land clearing in urbanizing areas under agricultural exemptions appears to exacerbate loss of pinelands in the South Florida Ecosystem.

2.7. **Protect natural communities from point source and non-point source pollution.**

2.8. **Use existing regulatory mechanisms to protect hydric pine flatwood wetlands. Identify their contribution to the function of adjacent wetlands and wetland-dependent species.**

2.9. **Promote protection of hydric flatwoods by encouraging local government resource planning, including identification of the importance, location, and areal extent in local government comprehensive plans.**

2.10. **Prioritize hydric pine flatwoods that need protection higher in land acquisition criteria.**

3. **Manage/enhance hydric pine flatwoods on public lands.**

3.1. **Develop/identify effective habitat management techniques to maximize the biodiversity of the hydric flatwoods community.** Hydric pine flatwoods may benefit from alternate management practices that are sensitive to hydrology, climate, and subtropical vegetation. Standard "southeastern" prescribed fire management, employed in the South Florida Ecosystem, may lower biodiversity of plant and animal species. Diversification of management techniques may increase biodiversity.

3.2. **Implement or ensure continuance of habitat management on public lands.** State and Federal land managers are faced with funding deficits that prevent or reduce management actions. Perpetual funding sources for staff and equipment should be secured.

3.3. **Coordinate land management practices between public land managers.** Management of hydric flatwoods on a landscape scale will benefit listed species, particularly wide-ranging species and wading birds, and neotropical migrants.

3.4. **Establish management partnerships with private landowners.** Successful fire management and hydrological practices can continue to be supported by or expanded to private lands to achieve a higher level of plant and animal diversity in

the South Florida Ecosystem. For some listed species, including the Florida panther and red-cockaded woodpecker, management partnerships may be critical to the regional South Florida recovery.

3.5. Create, maintain, or restore important habitat linkages. Public landowners should coordinate land acquisition and habitat management activities to ensure the protection of large, contiguous tracts of land that include a mosaic of native habitats, including hydric pine flatwoods. The maintenance of regional refugia for wide-ranging species such as the Florida panther or wood stork may not be sufficient to protect these species in a developing landscape.

3.6. Identify and disallow incompatible public uses that degrade hydric pine flatwoods. Incompatible public uses that disrupt hydrology, pollute, encourage exotic plant or animal invasion, overharvest resources, or destroy habitat beyond the ability for effective management should be identified and eliminated.

3.7. Monitor compatible adjacent land uses to protect hydric pine flatwood ecological function. Secondary and cumulative impacts to public lands can result from adjacent development, including loss of habitat, wildlife-endangering litter, chemical discharges, dumping, enhancement of exotic plant and animal invasion, prevention of fire management, alteration of adjacent hydrology, and noise/light pollution.

3.8. Protect and manage hydric flatwoods for the beautiful pawpaw (*Deeringothamus pulchellus*) and the other listed plant species.

3.9. Control exotic plants and animals.

3.10. Prevent collecting of rare plant species such as bromeliads on public lands. Discourage collecting of rare plant species on private lands.

4. Restore hydric pine flatwoods habitat where feasible.

4.1. Identify locations of hydric flatwoods habitat that can be restored.

4.2. Restore the natural seasonal hydroperiod and fire regime of hydric flatwoods communities. The natural South Florida pattern of alternating dry season fire and wet season flood has contributed to the highest plant species diversity of any community in South Florida and has resulted in this community being an essential component of the annual wetland drawdown that supports listed wading birds.

4.3. Restore sheetflow hydrologic conditions by restoring the regional landscape to natural contour. Much of South Florida has been significantly altered by public and private drainage projects that have resulted in both overdrainage and flooding of natural systems. Where possible, off-site, regional hydrological restorations may be necessary to restore hydric flatwoods function. Areas where restoration should occur include the South Golden Gate Estates and Camp Keais Strand in Collier County, the Estero Bay watershed in Lee County, and the Babcock-Webb WMA in Charlotte County, the Charlotte Harbor Flatwoods CARL project in Lee and Charlotte counties, and the Loxahatchee Slough in Palm Beach County.

4.4. Re-establish important habitat linkages by constructing wildlife crossings. A wide variety of development and linear infrastructure projects fragment hydric pine flatwoods. Future design and retrofit/rebuild of these projects should include undercrossings, overpasses and other features that reduce wildlife mortality and preserve hydrology, and increase connectivity with adjacent habitat.

4.5. Enhance and manage pinelands with beautiful pawpaw populations for beautiful pawpaw. Prevent habitat damage by off-road vehicle use, over-grazing by cattle and hogs, or overcollection.

4.6. Encourage mitigation banks that restore and enhance hydric pine flatwoods.

5. Identify, acquire and manage hydric flatwoods essential to the conservation of wide-ranging state and federally listed species. The preservation of pinelands, including hydric pinelands, is critical to the recovery of the Florida panther, wood stork, red-cockaded woodpecker, bald eagle, eastern indigo snake, Florida sandhill crane, little blue heron, snowy egret, tri-colored heron, limpkin, white ibis, Big Cypress fox squirrel, Sherman's fox squirrel, and southeastern American kestrels, as well as neotropical migrants.

5.1. Complete purchase of and manage hydric flatwoods in the Belle Meade and South Golden Gate Estates CARL projects for regional protection of Florida panther, Florida black bear, eastern indigo snake, Big Cypress fox squirrel, Florida sandhill crane, and other State listed wading birds. Complete the Loxahatchee Slough purchase, and manage for the regional protection of the sandhill crane.

5.2. Complete purchase of and manage hydric flatwoods in the coastal areas to augment neotropical migratory bird migration, and bald eagle foraging and nesting activities, including the Charlotte Harbor Flatwoods and Cape Haze/Charlotte Harbor Buffer CARL projects, and Pine Island.

5.3. Complete purchase of and manage hydric flatwoods within 15 km of wading bird rookeries and 30 km of wood stork rookeries including Belle Meade, Corkscrew Regional Ecosystem Watershed, the Estero and Imperial River watersheds, and areas east of the Southwest International Airport.

5.4. Complete purchase of and manage hydric flatwoods within Priority I and II areas identified in the Florida Panther Habitat Preservation Plan.

5.5. Determine if old growth hydric pinelands support red-cockaded woodpecker clusters. Red-cockaded woodpeckers nest and roost in cavities that are typically are excavated in old-age living pines if available. Study the utilization of hydric pine flatwoods by red-cockaded woodpeckers, including development of landscape-scale management recommendations for the recovery of this species in South Florida**.**

5.6. Manage pinelands on public lands in southwest Florida to expand occupation by red-cockaded woodpeckers. The large contiguous public preserves that begin in the Picayune State Forest (Belle Meade and South Golden Gate Estates) and extend east and north to the Fakahatchee Strand, Florida Panther NWR, and Big Cypress National Preserve should be managed as a larger ecological reserve to improve and augment the existing red-cockaded woodpecker population in southwest Florida.

5.7. Identify the potential pineland nesting habitat available to the bald eagle in South Florida. Determine regional eagle concentration areas based on nest location data and pineland location. Model potential response of bald eagle populations in South Florida based on potential and existing nest habitat in public holdings.

5.8. Prioritize the protection of coastal hydric flatwoods as bald eagle nesting habitat and neotropical migratory bird habitat. Bald eagles prefer nest and perch sites on the largest and tallest trees available near large, open water bodies and are primarily coastal in South Florida. Neotropical birds require available forage as

close to the coast as possible to augment migration across the Gulf of Mexico and Caribbean. Coastal pinelands are targeted for urban and agricultural development. Pine Island in Lee County is an example of an area of pinelands that should be protected.

5.9. Identify important habitat linkages. Important connecting areas include: the CREW to the Southwest International Airport mitigation lands (Lee County), Rookery Bay National Estuarine Research Reserve to Belle Meade CARL (Collier County), Corkscrew Sanctuary to Lake Trafford (Lee and Collier counties), Babcock-Webb WMA to Charlotte Harbor Flatwoods and Charlotte Harbor State Buffer Preserves (Charlotte County), DuPuis Reserve/J.W. Corbett Water Management Area to the West Palm Beach Water Catchment Area (Palm Beach County).

6. Complete purchase of and manage hydric flatwoods in contiguous, connected, unfragmented patches for the conservation of South Florida biodiversity, including nongame species, rare and unique species, and keystone species such as the swallow-tailed kite, American bittern, various owl and raptor species.

6.1. Purchase additional hydric flatwoods for the preservation of the beautiful pawpaw. Very few populations of this plant are protected on public lands. The Charlotte Harbor Flatwoods (Charlotte County) area should be prioritized for ongoing and additional public land purchase.

6.2. Determine if old-growth hydric pine flatwoods support rare plant and animal species, or specific species guilds. Examine the habitat value of hydric pine flatwoods for rare and endemic plants. Old growth pinelands may support rare and unique species of plants and animals or community guilds.

6.3. Inventory and characterize the importance of hydric flatwoods to avian populations, particularly neotropical migrants, woodpeckers, owls and raptors.

7. Perform additional research on hydric pine flatwoods.

7.1. Examine the habitat value of hydric pine flatwoods in Palm Beach and Martin counties, Florida.

7.2. Continue and update studies in the utilization of hydric pine flatwoods by red-cockaded woodpeckers, including development of landscape-scale management recommendations for the recovery of this species in South Florida.

7.3. Perform a hydrologic study of the water recharge potential of hydric pine flatwoods under natural, sheetflow conditions.

7.4. Examine wading bird use of the hydric pine flatwoods, including prairies and freshwater "isolated" wetlands.

7.5. Inventory and characterize the importance of hydric flatwoods to avian populations, particularly neotropical migrants, owls and raptors.

7.6. Re-examine the fish and wildlife values traditionally attributed to pine flatwoods by Federal, State and local regulatory entities.

7.7. Examine the correlation between soil type and hydric pine flatwoods habitats.

7.8. Examine the influence of fire regimes in maintaining optimal plant and animal species diversity.

7.9. Re-examine the "empty-niche" ecotonal theory of melaleuca invasion in southwest Florida, relative to human-altered and natural hydric pine flatwoods.

7.10. Examine invertebrate diversity and life-cycles in the hydric pine flatwoods.

7.11. Examine plant seasonality and invasion dynamics in the understory of hydric pine flatwoods.

7.12. Examine invertebrate, forage fish, reptile and amphibian populations associated with wet prairie and freshwater ponded wetlands in hydric flatwoods ecosystems.

7.13. Identify and survey hydric flatwoods in southwest Florida for the beautiful pawpaw. Updated surveys for the beautiful pawpaw have not been conducted. The range of this species should be determined in order to manage the population.

7.14. Determine what fire regimes are recommended in hydric flatwoods to stabilize or increase beautiful pawpaw populations on public lands in southwest Florida.

7.15. Monitor hydric pine flatwoods to evaluate biodiversity. Monitor community-level processes, community structure, and community composition, including rare and keystone species, and species guilds.

7.16. Improve reference ecosystem information for community composition, biodiversity, and site-to-site variability.

7.17. Identify historical hydroperiods in hydric pine flatwoods in South Florida. The timing and duration of wetland drawdown in hydric pine flatwoods systems has not been widely documented in South Florida and may differ temporally and in coastal and inland systems.

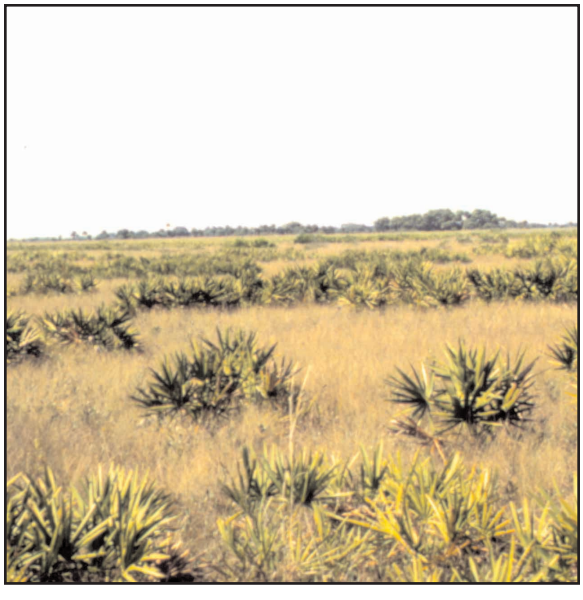
7.18. Investigate wood stork foraging ecology and behavior in the hydric pine flatwoods, particularly in conjunction with rookeries such as the Corkscrew Sanctuary in Collier County.

8. Increase public awareness concerning hydric pine flatwoods. Identify hydric flatwoods in text, maps, and on resource presentations to raise public awareness of the different types of pine flatwoods. Stress the important ecosystem function of isolated and ephemeral wetlands included in the hydric flatwoods community. Establish the landscape-scale importance of this community to wide-ranging species and the significance of regional losses of this habitat in South Florida.

Dry Prairie

FNAI Global Rank:	**G2**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**6**
State Listed Species in S. FL:	**31**

Dry prairie. *Original photograph courtesy of U.S. Fish and Wildlife Service.*



The dry prairie ecosystem consists of a poorly known suite of natural communities endemic to central peninsular Florida. Historically, dry prairie occurred within interior portions of south-central, west-central and central peninsular Florida, mainly on the Okeechobee, Osceola and Desoto plains. Dry prairie is found on nearly level, poorly drained interdrainageway flatlands, on nutrient-poor, sandy to sandy clay Alfisols with a somewhat calcareous clay subsoil and on Spodosols. Dry prairie soils are characteristically saturated during extended wet periods due to the loamy to clayey subsoils, generally low landscape position, and lack of surface drainage features.

Dry prairie is essentially treeless, a pyrogenic landscape with a ground cover diverse in regionally endemic plant taxa and dominated by *Aristida beyrichiana* (wiregrass), scattered, low, stunted *Serenoa repens* (saw palmetto), and low-growing *Quercus minima* (runner oak). The typical dry prairie has a mixture of upland and wetland plants, with the most conspicuous indicator of this mixture being the co-occurrence of *Quercus minima* and *Xyris elliottii*. Five natural community types of dry prairie are tentatively identified [dry (sub-xeric) type, dry-mesic sandy type, mesic type, wet-mesic alfic soil type, and wet-mesic spodic soil type] based upon quantitative vegetation analysis of dry prairies. Each of these community types tends to be correlated with variation in hydrologic regimes (seasonal variation in water table) and edaphic conditions, with ground cover composition similar to that of pine flatwoods and wetland pine savannas in south-central Florida.

In typical, undisturbed, undrained condition, the south-central Florida dry prairie landscape is a mosaic of interdigitating dry prairie and wet prairie, interspersed with ephemeral depression ponds or marshes, mesic hammocks, and slough or swale-like drainages. Dry prairie probably occurred as broad areas with a higher fire return frequency, compared to the mesic pine flatwoods-pine savanna-

depression marsh landscape mosaic. Dry prairie can be thought of as the endpoint along a forested to treeless continuum of flatwoods to savanna landscapes, in response to variation in the natural fire regime. In regions devoid of major natural fire barriers, such as in the historical dry prairie landscape, fire is reported as occurring annually or biennially. The treeless condition, a natural feature of dry prairie, is not simply an artifact of human manipulation. Evidence for extensive naturally treeless areas of dry prairie is supported by the mapping of prairie areas in the pre-settlement public land survey and early historical accounts.

Unlike most other grasslands in the southeastern United States, Florida dry prairie harbors numerous endemic vertebrates. Interior dry prairie is considered to be one of four geographic and/or ecological communities in Florida with a concentration of high-ranked vertebrate taxa. Several of the high-ranked avian taxa are near-endemic to the dry prairie region of south-central Florida. Of these, some are not found exclusively in native prairie habitat, but are capable of persisting in anthropogenic altered landscapes (semi-improved pastures, improved non-native pastures, disturbed rangelands, *etc.*). *Ammodramus savannarum floridanus* (Florida grasshopper sparrow) is a federal and state endangered subspecies which is endemic to the prairie region of south-central peninsular Florida. Frequently burned dry prairie is the preferred natural habitat for this non-migratory subspecies, although it is also documented from degraded prairie and other rangeland sites.

Estimates of the historical and current extent of dry prairie vary substantially. Although dry prairie is declining, there are still considerable opportunities for protection. However, there continues to be fragmentation and a reduction in area of high-quality prairie, and an even greater reduction in the number of sites with a continuous fire history and minimal human disturbance. Perhaps the most reliable method to evaluate the original extent of dry prairie is through examination of the pre-settlement land surveys. These land surveys provide documentation on the overall extent and distribution of pre-settlement dry prairie.

Overall management of dry prairie should strive to mimic natural ecological processes (frequent fire, landscape burns, natural hydrology, *etc.)* and provide adequate protection of dry prairie biodiversity. Critical management issues and challenges include prescribed burning, hydrologic alterations, rangeland and livestock grazing, protection of endangered species, control of exotics, and the impact of mechanical treatments. Recent large-scale protection efforts in south-central Florida are encouraging and will hopefully provide protection of remnant dry prairie landscapes.

Synonymy

Examples of true dry prairie are sometimes referred to as palmetto prairie (Huck 1987, Sullivan 1994, Kuchler 1964 [Kuchler Type K079]), palmetto grasslands (Grossman *et al.* 1994), saw-palmetto prairie (Davis 1943), palm savanna (Harper 1927), pineland three-awn range (Sullivan 1994), Florida dry prairie (Grossman *et al.* 1994, Weakley *et al.* 1996), flat prairies (Harper 1921), wiregrass prairies, or South Florida flatwoods with “few, if any trees” (Soil Conservation Service 1989). In a recent vegetation classification scheme for the

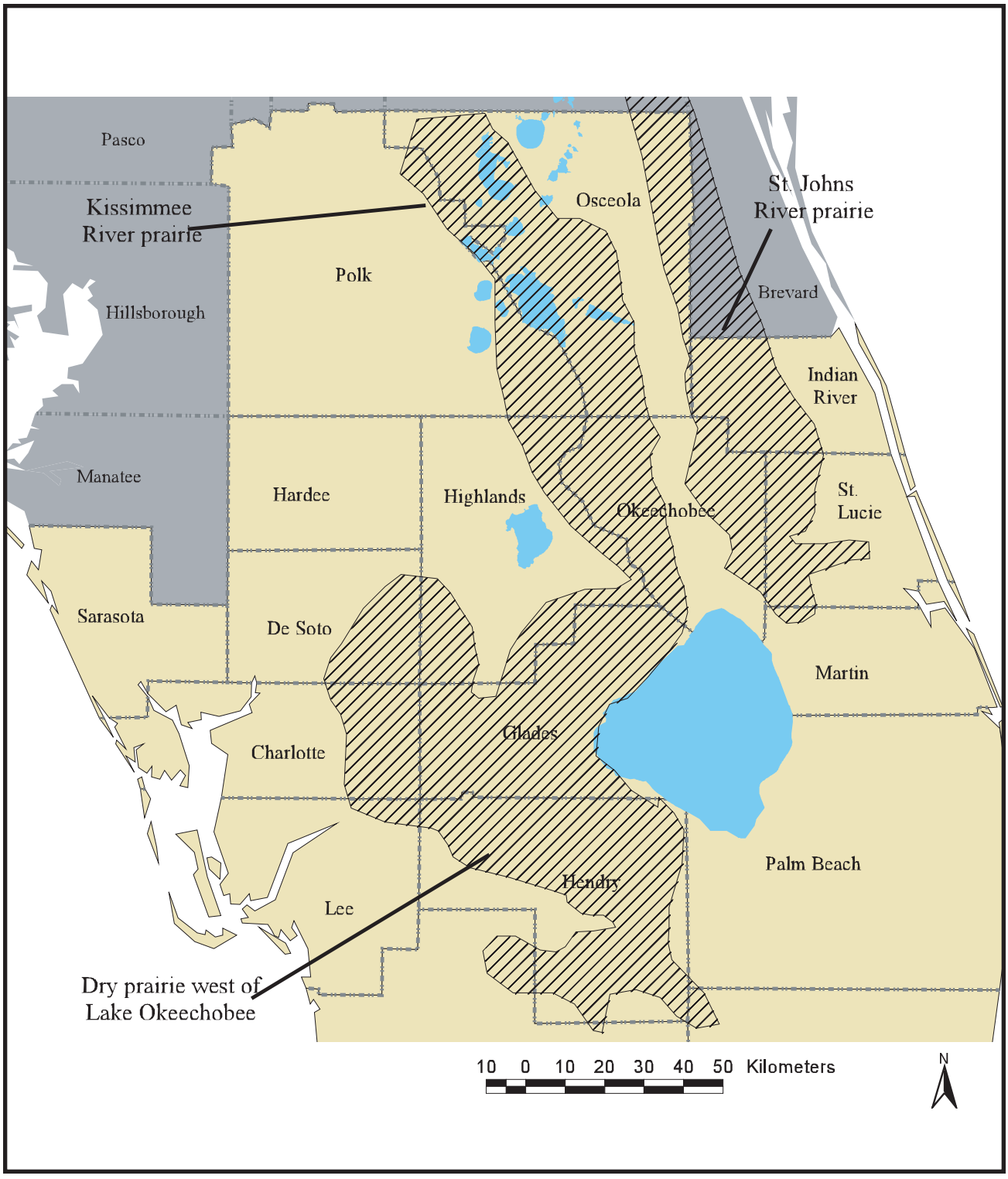


Figure 1. The distribution of dry prairie in South Florida (modified from DeSelm and Murdock 1993).

southeastern United States (Weakley *et al.* 1996), Florida dry prairie is classified as *Serenoa repens/Aristida beyrichiana* upland shrub herbaceous vegetation (saw palmetto/southern wiregrass upland shrub herbaceous vegetation). Clearcut areas of mesic flatwoods are often erroneously referred to as dry prairie, therefore the following names are commonly used interchangeably by resource managers, land stewards, and ranchers for native dry prairies, cut-over flatwoods, treeless mesic flatwoods, and non-forested flatwoods. The FLUCCS code for this account includes: 321 (palmetto prairies), and 310 (herbaceous).

Distribution

General Distribution of Dry Prairie Regions

Historically, the distribution of dry prairie included several disjunct areas of central peninsular Florida (Harshberger 1914, Davis 1943, Harper 1921, 1927, DeSelm and Murdock 1993) (Figure 1). Harshberger (1914) is perhaps the first to provide a map of "prairie vegetation" for south-central and South Florida. He delineates three large areas of prairie: (1) along the Kissimmee River north of Lake Okeechobee, (2) an extensive area west of Lake Okeechobee from south of Fisheating Creek extending northwest to Crewsville and Fort Ogden, and (3) a smaller area north of Charlotte Harbor (in present-day Sarasota and Manatee counties). Davis (1943) also delineates several large areas of "grasslands of prairie type" from parts of nine central Florida counties (DeSelm and Murdock 1993). The Davis (1943) map has been erroneously interpreted as the original distribution of Florida dry prairie, however Davis's map of "grasslands of prairie type," clearly includes other prairie types, many of which are currently referred to as wet prairies and seasonal marshes. Both Davis (1943) and Harper (1921,1927) give some indication of the historical distribution of Florida dry prairie. Harper (1927), depicts two regions of dry prairie. One is centered in Okeechobee County and extends west of the Kissimmee River, and another is centered on Desoto and Glades counties with a southern extension into Hendry and northern Collier counties. Harper (1927) commented that prairies occurred along both sides of the Kissimmee River extending westward with some interruptions nearly to Arcadia and Fort Ogden, forming a region of vast treeless prairie covered with grasses and low bushes. Prairies along the Kissimmee River are somewhat separated from the western prairies by the "Indian Prairie," a palm savanna and marsh region between Lake Istokpoga and Lake Okeechobee (Harper 1927). The Indian Prairie region defined by Harper (1927) in eastern Glades County and southeastern Highlands County had a wetter general landscape dominated by *Cladium jamaicense* (saw grass), and seasonally wet prairies with abundant *Sabal palmetto* (cabbage palm) hammocks and savannas, perhaps with isolated patches of dry prairie on the highest, least wet, soils (Harper 1927). Harper (1927) also notes smaller areas of dry prairie in Manatee and other counties. DeSelm and Murdock (1993) show three general areas of prairie in peninsular Florida-St. Johns River prairie, Kissimmee River prairie, and dry prairies west of Lake Okeechobee; the latter two correspond to areas known for dry prairie.

Kissimmee River Dry Prairie Region

The prairie region centered in Okeechobee County consists of a band of dry prairie, stretching nearly 48 km (30 miles) east to west at some points, adjacent to the Kissimmee River valley from western Osceola County south to Lake Okeechobee, with the greatest extent east of the Kissimmee River in western Okeechobee County. Although the greatest extent of dry prairie in this region lies primarily south of Lake Kissimmee, Davis (1943) maps prairie extending north from the upper Kissimmee River to Lake Tohopekaliga. Harper (1921) commented that the prairies bordering this and other large lakes (see Harper 1921, pg 137 for photo) near the city of Kissimmee are probably different than those further south along the Kissimmee River. However, prior to Harper's (1921) publication he had not been able to access the "Kissimmee River Prairies" on account of their remoteness from railroads. Harshberger (1914) describes extensive prairie north and west of Lake Okeechobee, often extending for 32 to 48 km (20 to 30 miles).

Other Dry Prairie Regions

The dry prairies centered on Desoto and Glades counties occur in the eastern two-thirds of Desoto, northern Charlotte, and Glades counties and were described by Davis (1943) and Harper (1927). This expanse of dry prairie occupied a flat plain that was roughly bounded to the south by the Caloosahatchee River valley, extending northwest nearly to the lower Peace River valley, and east and southeast to south of Fisheating Creek. Harper (1927) notes that before Desoto County was divided into five counties in 1921, it had an area of about 9,713 square km (3,750 sq mi), about 50 percent of which was prairie. During World War I, two aviation fields (Carlstrom and Dorr) were established, perhaps influenced by the suitability of this treeless terrain, at the edge of the prairie a few miles east of Arcadia (Harper 1927). Harshberger (1914) describes the "largest typic prairie" from north of the Caloosahatchee River, along the western shore of Lake Okeechobee, west of Peace Creek, bisected by Fisheating Creek, and centered on Citrus Center. Harshberger (1914) described this area as a prairie grass formation with sod-forming grasses, and some palmetto hammocks. This prairie was described by Harshberger (1914) as grading into sawgrass vegetation where it meets the Everglades at Lake Hicpochee, and merging into pine savanna where it blends into the pine woods. Harshberger (1914) also describes a large semi-circular prairie along the western edge of the Everglades and the Okaloacoochee Slough.

Other dry prairie areas of somewhat lesser extent are mapped by Davis (1943) and mapped, described or photographed in Harper (1927). An outlier region of dry prairie is delineated in Sarasota and southern Manatee counties (Harshberger 1914, Davis 1943, Harper 1927). It occurs in rather close association with the Myakka River valley. Davis (1943) also shows dry prairie in eastern Hendry County and a outlier in northern Collier County. Harper (1927) has a photograph of what is most certainly a dry prairie about five miles north of Immokalee in Collier County.

Other Prairie Regions of Peninsular Florida

Other prairie areas occur in Volusia, Brevard, Palm Beach, and Collier counties, but are not considered in this account since the authors believe these are not a part of the dry prairie landscape, but represent other distinct community types.

A prairie area with north-south orientation, of rather narrow linear strips extending from southeastern Volusia County into western Brevard County through Indian River County and southward into central and western St. Lucie County is mapped by Davis (1943). Harper (1921) mentions prairies scattered through the central portion of Volusia County, and for several miles on either side of the upper St. Johns River. Harper (1921) includes a photograph taken in 1915 of a "nearly treeless prairie in Brevard County about 12.1 km (7.5 miles) west of Melbourne and four miles from the St. Johns River" and notes that "between this point and the St. Johns River there are practically no trees." Harper (1921) describes flat prairies: "going westward from Melbourne one first passes through continuous pine forests for a few miles, and then small prairies begin to appear, gradually becoming larger, and the pines between them smaller and more scattered, until at a distance of about seven miles from the Indian River or four miles from the St. Johns River the trees are all left behind, and the prairie extends beyond the horizon both north and south" (Harper 1921). These areas are not dry prairie, and are best interpreted as shallow seasonal marshes associated with the broad, flat floodplain of the St. Johns River, and are characterized by sand cordgrass (*Spartina bakeri*). Areas mapped as "grasslands of prairie type" by Davis (1943) elsewhere in peninsular Florida *(i.e.* coastal Palm Beach County) are not dry prairies, but probably represent other shallow, seasonally inundated wet prairies or marshes.

The extensive areas of marl prairies (*i.e.* Copeland, Airplane, Windmill, and Buckskin prairies) with their calcareous subsoils, characteristically found in the northern portion of the Big Cypress region, are distinct from the arenaceous, more acidic dry prairies. Marl prairies are discussed in the freshwater marshes and wet prairies account.

Description

Florida dry prairie is a natural landscape that is endemic (Fitzgerald and Tanner 1992, Bridges 1997) to the state, with no similar communities found in adjacent states. It is geographically restricted to the interior of central, south-central and west-central peninsular Florida. Dry prairie is often (but not exclusively) found on the same soil series, topographic positions, and moisture regimes as mesic flatwoods, with dry prairie being the essentially treeless endpoint of a continuum of variation in canopy cover across pine flatwoods landscapes in central Florida.

Physiographic and Topographic Parameters

Extensive areas of dry prairie vegetation once occurred in the Gulf coastal lowlands, Atlantic coastal lowlands, and intermediate coastal lowlands physiographic regions of peninsular Florida, as defined by Schmidt (1997). Within the Gulf coastal lowlands physiographic region, extensive areas of dry

prairie occurred on the Desoto Plain (in most of Desoto, southern Hardee, western Highlands, northeastern Charlotte, southern Manatee, and part of Glades counties) and within the Gulf coastal lowlands (in parts of Sarasota and southern Manatee counties). In the Atlantic coastal lowlands, prairie occurred on the Osceola Plain (in parts of Okeechobee, northern Highlands, southeastern Polk, and Osceola counties), and perhaps in the Eastern Valley (in parts of St. Lucie, Indian River, Brevard, and Volusia counties). Prairie also occurred on the intermediate coastal lowlands on the Okeechobee Plain (in northeastern Glades, southeastern Highlands, and southwestern Okeechobee counties) and the Immokalee Rise (in part of Hendry County and northern Collier County [Harper 1927]).

In each of these Florida physiographic regions, dry prairie occurs on nearly level, poorly to somewhat poorly drained, interdrainage flatlands above major river/stream floodplain valleys. Typically, the flatlands characteristic of the Osceola Plain are dotted with numerous small shallow depressions (with ephemeral ponds and marshes), but have very few surface drainage features. Developed on flat plains, the dry prairies at Avon Park AFR are generally below the 19.6 m (65 ft) contour (Bridges 1998b). It is unclear why the dry prairie landscape at Avon Park AFR is lower in elevation than the other landscape associations on the Osceola Plain at this site, but it seems to be correlated with the proximity of major drainages such as Arbuckle Creek, Arbuckle Marsh, and the Kissimmee River (Bridges 1998b). At Myakka State Park, in Sarasota and Manatee counties, dry prairie occurs from 10.7 to 12.2 m (35 to 40 ft) in elevation (Fitzgerald and Tanner 1992). Dry prairies centered on Desoto and Glades counties on the Desoto Plain are above 12.7 m (42 ft) in elevation (Davis 1943, Harper 1927).

Edaphic and Hydrologic Parameters

Dry prairie is best developed on acidic, nutrient-poor, poorly drained, sandy to sandy clay soils in either Spodosol (Abrahamson and Hartnett 1990) or Alfisol soil orders (Bridges 1997), with a tendency to occupy a greater percentage of the area mapped as Alfisols or soils in alfic subgroups (Bridges 1997, 1998b). Alfisols are similar in hydrology to the typical mesic flatwoods soils (Spodosols) of central Florida, but perhaps holding water slightly longer during wet periods due to their loamy to clayey subsoils, generally lower landscape position, and poorly developed surface drainage features. Table 1 summarizes the taxonomic classification for soil series known to occur on dry prairie sites in the Kissimmee River prairie region of central Florida, all of which are in the poorly drained drainage class. The predominant soil association and secondary soil associations most commonly associated with dry prairie in each county are listed in Table 2.

The soils of at least some dry prairies contain few weatherable minerals and have low levels of clay and nutrients in the surface soil layers (Abrahamson and Hartnett 1990, Weakley *et al.* 1996, Grossman *et al.* 1994). Therefore, nutrient storage and availability can be dependent on the amount and type of dead organic matter present (Abrahamson and Hartnett 1990). The hardpan (a spodic or argillic layer), where present, in dry prairies substantially reduces the movement of water below and above its surface, such that the sites

may become flooded for short periods during heavy summer rains (Bridges 1997, FNAI and DNR 1990, Weakley *et al.* 1996, Grossman *et al.* 1994). However, the normal water table is below the ground surface during most of the year, typically one meter or so below the surface during the dry winter season. During the dry season, high evapotranspiration draws much water from the upper horizons, and persistent droughty conditions result (Abrahamson and Hartnett 1990). Presumably, the depth and degree of development of these subsurface hardpans (spodic and argillic layers) influence hydrology and plant growth. This gives competitive advantages to certain species, resulting in gradients in plant community composition over slight differences in elevation and hydrology. However, the mechanisms and details of this influence is poorly known, and these complex hydrologic/edaphic relationships may be critical in our understanding of the ecosystem dynamics of the dry prairie landscape.

The term "dry" prairie is somewhat of a misnomer. In undrained dry prairies standing water can drain as overland sheet flow in the summer wet season, or even in the winter (the typical dry season) during El Nino years, for periods of a month or more. Dry prairies are "dry" only when considered relative to the other typically treeless communities of Central Florida-wet prairies (with hydroperiods of two months or longer) and freshwater marshes (Bridges 1997). The average percent cover for plant taxa by hydrologic zones in dry prairie are given in Table 3.

Vegetative Structure and Composition

Plant nomenclature essentially follows Wunderlin *et al.* 1996. There are several generalized vegetation descriptions of Florida dry prairie (Abrahamson and Harnett 1990, Bridges 1997, 1998a, Chafin *et al.* 1997, FNAI and FDNR 1990, Grossman *et al.* 1994, Harper 1921, Harper 1927, Hilsenbeck 1994, Huffman and Judd 1998, Weakley *et al.* 1996). However, there have only been a few quantitative vegetation studies of dry prairie (Bridges 1997, Bridges and Reese 1998, Cole *et al.* 1994a, 1994b, Huck 1987). At first glance, dry prairie may appear to be a relatively homogeneous mixture of *Aristida beyrichiana*, *Serenoa repens*, and a few other species. Contrary to this perception, there is substantial local variation in diversity, composition, and dominance of plant species. In such a flat environment, even small changes in elevation can result in different vegetation associations. Similar slight changes in soil type can also produce marked change in vegetation associations.

Dry prairie is an essentially treeless (Harshberger 1914), pyrogenic community with a ground cover diverse in regionally endemic plant taxa. It is most commonly dominated by wiregrass, sparse, scattered, low stunted saw palmetto, and low-growing runner oak (Bridges 1997). Quantitative sampling of vegetation across hydrologic gradients within dry prairie at Avon Park AFR (Polk and Highlands counties), Kissimmee Prairie State Preserve (Okeechobee County), Ordway-Whittell Kissimmee Prairie Sanctuary (Okeechobee County) and Three Lakes WMA (Osceola County) in 1995 and 1997 confirm that these three species share dominance in most frequently burned dry prairies (Bridges and Reese 1998). Other common shrubs of dry prairie include *Lyonia fruticosa, Lyonia lucida, Ilex*

glabra, and *Vaccinium myrsinites* (Bridges 1997, Huffman and Judd 1998). In frequently burned sites, shrub cover is reduced, resulting in a diverse herbaceous ground cover (Bridges 1997, Cole *et al.* 1994a). Other characteristic grasses of dry prairie include *Andropogon ternarius* var. *cabanisii, Andropogon virginicus* var. *decipiens, Schizachyrium stoloniferum,* and *Sorghastrum secundum*. Typical dry prairie has a mixture of wetland and upland plants, the most characteristic of these mixtures being the co-occurrence of *Quercus minima* and *Xyris elliottii* (Bridges 1997). As wetter areas are reached, there tends to be an increase in wet-mesic species such as *Ctenium aromaticum* and *Xyris ambigua* (Bridges 1997). Table 4 includes the vascular plant taxa recorded as occurring in dry prairie from selected central Florida counties, and Table 5 includes those plant taxa recorded from dry prairie in at least three counties of the seven counties with dry prairie floristic data.

Field surveys in central Florida (Bridges 1997) show that the floristic composition of dry prairie is similar to that of mesic and wet-mesic pine flatwoods, and a number of authors have noted that dry prairie differs little from pine flatwoods except for the absence of pine trees (Abrahamson and Hartnett 1990). There has been a prevalent misconception that Florida dry prairie consists of mesic pine flatwoods which unnaturally lack a pine canopy, presumably due to unnaturally frequent fire (Steinberg 1980), past clear-cutting, and/or continuous livestock grazing (Abrahamson and Harnett 1990, Weakley *et al.* 1996, Grossman *et al.* 1994, FNAI and FDNR 1990). Rather, the essentially treeless condition, a natural feature of dry prairie, is not simply an artifact of human manipulation. Strong evidence for naturally treeless areas of dry prairie in central Florida is provided by the mapping of extensive prairie areas on the pre-settlement public land surveys (Bridges 1998a, b; Huffman and Judd 1998) and early historical accounts attesting to the treeless conditions (Harper 1921, 1927; Harshberger 1914).

Dry prairie is an exceptionally species-rich natural community type. A total of 240 vascular plant taxa were present in 590 m^2 (10.8 ft^2) plots sampled to characterize dry prairie vegetation (Bridges 1997, Bridges and Reese 1998). The average number of species per plot for these 590 plots sampled at 17 sites is 22 (Bridges 1997, Bridges and Reese 1998). There is considerable variation in number of species per plot, with a low of 9 species per plot, and a high of 41 species per plot. The largest number of plots contained from 16 to 28 species, and relatively few plots were much lower or higher than this average. Peet and Allard (1993) report that only three natural communities in the Western Hemisphere have had plots recorded with over 40 species per square meter. These are Atlantic longleaf pine savannas (North Carolina), Southern longleaf pine savannas (Mississippi), and fall-line longleaf pine seepage savannas (North Carolina). However, it should be noted that their study included only limited plant community sampling in Florida.

Five natural community types of dry prairie [dry (sub-xeric) type, dry-mesic sandy type, mesic type, wet-mesic alfic soil type, and wet-mesic spodic soil type] are tentatively described, based in part upon quantitative vegetation analysis of south-central Florida dry prairies. These community descriptions and their relationships to environmental gradients within the dry prairie landscape are based upon Bridges (1997, 1998a), and may be subject to revision based on continuing data analysis (Bridges and Reese 1998).

Dry (sub-xeric) Community Type of Dry Prairie

Dominant species: *Aristida beyrichiana*, scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*), *Serenoa repens, Lyonia fruticosa.*

The dry (sub-xeric) community type of dry prairie occurs in scattered roughly circular to elliptic patches, mostly associated with the escarpments above floodplains. These areas are often incorrectly referred to as "scrub". They do not fit the definition of either scrub or scrubby flatwoods, but they have more characteristics in common with scrubby flatwoods than scrub. They differ from scrubby flatwoods only in the absence of a pine canopy, and can be thought of as a treeless variant of this community within a dry prairie landscape mosaic. The dominant species in the community type include *Quercus geminata, Q. myrtifolia, Q. chapmanii, Lyonia fruticosa, L. lucida, Serenoa repens, Befaria racemosa, Aristida beyrichiana*, and *Vaccinium myrsinites*. Although present in other natural community types (*i.e.* scrub and scrubby flatwoods) differential species that distinguish this community type from other dry prairie community types are the semi-evergreen, sclerophyllous xeric oaks. Other characteristic species of this community type are often restricted to herbaceous sandy openings, and include *Balduina angustifolia, Piloblephis rigida, Palafoxia integrifolia, Rhynchospora intermedia*, and *Polygonella polygama*. These herbaceous openings also support large populations of seasonal wetland species, such as *Drosera brevifolia, Syngonanthus flavidulus, Eleocharis baldwinii, Utricularia subulata*, and *Xyris brevifolia.* The presence of these herbaceous species indicative of seasonally saturated soils serves to easily distinguish the dry community type of dry prairie from scrub, and does not support any wetland herbs. Also, this community type lacks any narrow scrub endemic plant or vertebrate species, particularly such widespread and characteristic scrub species as *Garberia heterophylla, Persea borbonia* var. *humilis,* and *Sceloporus woodi* (Florida scrub lizard). However, like scrub, it can support oak-dependent wildlife species *(i.e. Aphelocoma coerulescens*, Florida scrub-jay). Also, in contrast to scrub, there are few to no white sandy openings within the community type except along cleared roadsides. Openings tend to be quickly vegetated by wiregrass and other grasses in this community type of dry prairie.

This community type occurs as patches on very slight rises within the dry prairie matrix, often only a few feet above the surrounding landscape. These dry patches tend to be more concentrated near the drainage escarpments of the major sloughs and along river escarpments at the edge of the dry prairie landscape.

This community type has very consistent soils, all with a deep strong spodic horizon. Examples are found on Pomello fine sand (Typic Haplohumods), although some are also mapped as Immokalee fine sand (Arenic Haplaquods). The Immokalee soil series has spodic layers ranging from 76 cm (30 in) to at least 137 cm (54 in) deep, whereas the Pomello soil series has spodic layers ranging from 140 cm (55 in) to 155 cm (61 in) deep. The proximity of a major drainage feature to these soils serves to more quickly lower the water table after rainfall events, enhancing drainage and thereby reducing the duration of soil saturation.

The fire frequency of this community is naturally less than in typic dry prairie, but parts may burn as often as every 5 years, while other parts of the same patch may escape fire for 10 to 15 years.

Dry-mesic Sandy Community Type of Dry Prairie

Dominant species: *Serenoa repens, Quercus minima, Aristida beyrichiana, Andropogon ternarius* var. *cabanisii, Lyonia fruticosa, Lyonia lucida.*

This community type has several frequent and/or dominant species which serve to distinguish it from all other dry prairie community types, other than the dry, oak-dominated type. Although this type would be considered as poorly drained, and has strong soil spodic layers which result in high perched wet-season water tables, the soils of this type are rarely saturated to the soil surface for extended periods. The species occurring in dry-mesic sandy prairie reflect these drier hydro-edaphic conditions. Common dominants, in addition to those species present in other dry prairie types, include *Andropogon ternarius* var. *cabanisii,* and a greater abundance of shrubs such as *Hypericum reductum, Lyonia fruticosa* and *Lyonia lucida*. These species, although occurring in other dry prairie communities, are comparatively unimportant in the wetter community types. The dry-mesic sandy community type also has a group of species not encountered within the other dry prairie community types (except the dry type). The most important of these include *Lachnocaulon beyrichianum, Cnidoscolus stimulosus, Chapmannia floridana, Carphephorus corymbosus,* and *Euphorbia polyphylla*. Other characteristic species that usually have higher importance values within this community include *Gaylussacia dumosa, Gratiola hispida, Gymnopogon chapmanianus, Licania michauxii, Liatris tenuifolia* var. *quadriflora, Myrica cerifera, Pityopsis graminifolia, Pterocaulon pycnostachyum, Polygala setacea, Schrankia microphylla* var. *floridana, Scleria pauciflora, Sorghastrum secundum,* and *Xyris caroliniana*.

This community type has very consistent soils, all with a deep strong spodic horizon, with the top of the spodic horizon ranging from 67 (26 in) to 122 cm (48 in) below the surface. Most of these soils are clearly of the Immokalee soil series (Arenic Haplaquods), which can have spodic layers beginning at 76 cm (30 in), and ranging to at least 137 cm (54 in) deep. Some examples with shallower spodic layers would fall at the deep end of the Myakka soil series (Aeric Haplaquods). None of the soils have a clay subsurface horizon, and almost all lack a mucky sand surface layer.

Mesic Community Type of Dry Prairie

Dominant species: *Aristida beyrichiana, Serenoa repens, Quercus minima.*

This community type is closest to the dry-mesic community type, but occurs on slightly lower landscape positions or on soils with shallower spodic layers. Common dominants include only those species which are dominant across the prairie/flatwoods landscape: *Aristida beyrichiana, Serenoa repens,* and *Quercus minima*.

Common species with higher frequency within this community type than in wet-mesic and dry-mesic prairie include a diversity of *Andropogon* species. In particular, common species occurring much more frequently within this community type that serve to distinguish it from wetter sites include *A. brachystachyus, A. virginicus* var. *decipiens, Schizachyrium stoloniferum, Eleocharis baldwinii, Xyris brevifolia, Ilex glabra, Myrica cerifera, Pityopsis graminifolia,* and *Vaccinium myrsinites*. Differential species between this community type and the dry-mesic sandy type include *Amphicarpum muhlenbergianum, Andropogon brachystachyus, Andropogon virginicus* var. *virginicus, Aristida spiciformis, Bigelowia nudata* ssp. *australis, Carphephorus odoratissimus, C. paniculatus, Dichanthelium ensifolium* var. *ensifolium, Erigeron vernus, Eupatorium recurvans, Euthamia tenuifolia, Galactia elliottii,* and *Rhexia nuttallii.*

The mesic community type occupies vast expanses of the dry prairie landscape. This community type tends to occupy the broad, very flat, interdrainage sites, and basically forms a matrix within which other communities occur on drier or wetter microsites or ecotones.

Most of the soils of the mesic community type would be classified as in the Myakka soil series (Aeric Haplaquods) but some have shallower spodic layers and would be classified as in the Smyrna soil series (Aeric Haplaquods).

Wet-mesic (Alfic) Community Type of Dry Prairie

Dominant species: *Aristida beyrichiana, Quercus minima, Xyris elliottii.*

The wet-mesic prairie community type develops on soils with argillic horizons (Alfisols or soils in Alfic subgroups) and is one of the most distinctive community types found in the dry prairie landscape. Wet-mesic alfic prairie has several unifying and distinguishing patterns of species composition. It is dominated by two of the landscape dominants, *Aristida beyrichiana* and *Quercus minima.* The third species in dominance, and also a major indicator species within this community, is *Xyris elliottii* (98 percent frequency, 8 percent relative cover). This species attains a maximum relative cover of less than 2 percent in the other defined community types. *Xyris elliottii* has recently been documented as one of the principal nest materials used by Florida grasshopper sparrows on Avon Park AFR (Bridges and Delany, unpublished data).

The low frequency and cover of *Serenoa repens* also seems to differentiate this community from other dry prairie communities. Although present in this type, *S. repens* is not a dominant species. *Serenoa repens* is typically rather widely scattered, and with a low, stunted stature. It often has a rather lengthy decumbent trunk which lies on the ground surface or partially buried in the surface soil. This is in contrast to the generally more robust, somewhat more erect growth form of *Serenoa repens* which is prevalent in most central Florida pine flatwoods. However, relative abundance values for *S. repens* can vary widely between sites due to historical and disturbance events (such as past burn history, roller chopping, *etc.*).

Although they are present in other natural communities (*i.e.*, wet flatwoods, wet prairies, seepage slopes), typical differential species from other dry prairie

types include *Polygala rugelii* and *Sabatia brevifolia.* Other indicator species, such as *Aristida spiciformis, Bigelowia nudata* ssp. *australis, Liatris gracilis* and *Syngonanthus flavidulus,* attain a significantly higher importance in this community type when compared to other similar communities.

Soil characteristics within this community type are relatively uniform, and are characterized by having a deep spodic horizon at 75 to 117 cm (30 to 46 in) and also having an argillic (translocated increase in clay) horizon at 100 to 175 cm (39 to 69 in). This underlying sandy clay layer may have a very significant role in the structure of the community due to its influence on the site hydrologic regime. Based on field observations, a relatively deep argillic layer (over 100 cm [39 in]) seems to result in a much longer hydroperiod than a similarly deep spodic layer. Data presented for the soils of Avon Park AFR by Carter (1995) indicate that the argillic horizon of soils such as Oldsmar (Alfic Arenic Haplaquods) and EauGallie (Alfic Haplaquods) have lower permeability than the spodic layers of these soils series or of typical Spodosols. Consequently, although they can be extremely droughty in the dry season, these areas may have water at or above the surface for a month or more in the wet season. This more extreme hydrological fluctuation may be a primary factor responsible for the species composition of this community type. The juxtaposition of *Quercus minima*, a typically dry-mesic indicator species, and *Xyris elliottii*, a wetland indicator species, may be attributable to this soil situation.

Wet-mesic (Spodic) Community Type of Dry Prairie

Dominant species: *Aristida beyrichiana, Quercus minima, Serenoa repens.*

This community type displays considerable differences in species composition and abundance as well as edaphic conditions. Community dominants are essentially those that tend to dominate the typical central peninsular Florida flatwoods landscape (*Aristida beyrichiana, Quercus minima,* and *Serenoa repens*). This community type may be separated based upon distinctive common species rather than dominants.

Indicator species which are much more important in this community type than any of the other community types include *Ctenium aromaticum, Chaptalia tomentosa, Carphephorus carnosus, Xyris ambigua* and *Burmannia capitata*. These species are nearly absent from other dry prairie community types. Several characteristic species achieve a greater importance value in the wet-mesic spodic type as compared to the other dry prairie community types, but may also be present in other natural communities, including *Rhexia mariana, Bigelowia nudata* ssp*. australis, Rhynchospora fascicularis, Xyris elliottii* and *Lachnocaulon anceps*. These species, especially *Xyris elliottii, Bigelowia nudata* ssp. *australis* and *Rhynchospora fascicularis,* also appear as important species within the wet-mesic alfic community type of dry prairie. Of these, *Xyris elliottii* is much more of a dominant within the wet-mesic alfic community type of dry prairie and the others are slightly more abundant in the wet-mesic spodic type.

Soils within this community type tended to be either Spodosols with the spodic horizon appearing at 13 to 30 cm (5 to 12 in) in depth or alternating areas of Spodosols and Alfisols with bright colored Bw horizons appearing at 10 to 20 cm (4 to 8 in) depth. In addition, these areas mostly display a thin to moderate layer of mucky sand at the surface, mostly from 2 to 10 cm (0.79 to 3.9 in) deep. The typical soil composition consists of Smyrna soils (Aeric Haplaquods) on the higher microsites and Malabar soils (Grossarenic Ochraqualfs) in the intervening flats.

Other Communities of the Dry Prairie Landscape

Harshberger (1914), Abrahamson and Hartnett (1990), Bridges (1997), Hilsenbeck (1994) and others have recognized that the dry prairie landscape includes a complex mosaic with gradations to other communities. Harshberger (1914) described the Florida prairies as flat, treeless, sedge and wire-grass prairies unbroken except by a few scattered areas of pine, merging with open pine savannas or open hammock-dotted savannas. Within the dry prairie landscape are many wet prairies and shallow marshes. The typic, undisturbed, undrained dry prairie landscape of south-central Florida consists of a mosaic of interdigitating dry prairie and wet prairie, with interspersed ephemeral depression ponds/marshes, mesic and hydric hammocks, deep sloughs and shallow drainage swales (Bridges 1998a).

Wet wiregrass prairie is common throughout the dry prairie landscape. The boundary between dry prairie and wet prairie is usually not very discrete, but rather reflects a broad ecotone reflecting strongly increasing hydroperiod with only very slight decreases in elevation. There are actually several plant communities or “micro-habitat zones” which are present across this gradient (Bridges 1997). In some sense, this is not unexpected, since in the flatwoods landscape of central Florida, a distinct natural community (wet flatwoods) is found intermediate in hydrology between mesic flatwoods (hydrologically similar to dry prairie) and wet prairie. The ground cover in the transitional zone between dry prairie and wet prairie is very diverse and reflects the micro-topographic diversity within this ecotonal transition. Refer to the freshwater marshes and wet prairies account for a description of the wet prairie community in South Florida.

The surface water drainage features in dry prairie includes both narrow, long mostly linear swale-like drainageways without a defined channel and with short hydroperiods and deeper water, slough-like drainages. These drainages are distinguished from depression marshes and basin marshes by functioning more as a conduit for surface water than as a water storage depression. There is sometimes a gradual gradation from large linear wet prairies to shallow swale-like drainages, but they can be distinguished by the lesser importance of *Hypericum fasciculatum* and *Aristida beyrichiana* in swales.

The swale-like drainages may have been naturally dominated by *Spartina bakeri*, with zones of *Muhlenbergia capillaris* var. *filipes* mixed with *Aristida beyrichiana* at their shallower edges. Isolated small clumps of *Sabal palmetto* occur within the swales, and perhaps higher small areas protected from fire may have supported small hammocks. Swale-like drainages are defined more

as a hydrologic feature than by vegetative dominance or physiognomy, and as such, are a mosaic of many plant communities.

Slough-like drainages are distinguished from swale-like drainages by their more permanent water, and consequent deeper marsh vegetation. The deep marsh vegetation of the sloughs is often dominated by *Pontederia cordata*, with substantial amounts of *Panicum hemitomon, Cladium jamaicense, Sagittaria lancifolia, Thalia geniculata,* and *Nuphar lutea* ssp. *advena*. There are scattered clumps of woody plants naturally occurring in sloughs, such as *Salix caroliniana, Fraxinus caroliniana,* and *Nyssa sylvatica* var. *biflora*. In the undrained dry prairie landscape, sloughs serve as the major natural drainage system, due to the lack of definite streams in the flat dry prairie landscape.

Hammocks are localized and represent only a small percent of the total dry prairie landscape but are important biodiversity features, and function as islands of forest in the grassland vegetation. "Prairie hammock" is often used to refer to any clump of live oak and/or cabbage palms surrounded by prairie or marsh communities, and is usually found in close association with wetlands, in fire shadows on the dry prairie landscape. These hammocks vary greatly in size, soil type, degree of protection from fire, and hydrology. Some hammocks have a substantial elevation rise from the surrounding marshes or prairies, sufficient to support some upland vegetation in the center of the hammock, with borders of these hammocks saturated or inundated such as to resemble hydric hammocks. These higher hammocks fall into at least three types, one with marl or limestone subsoils and a subtropical understory, the second on high sandy rises with temperate mesic hardwood hammock species, and the third a low-diversity hammock with few woody species other than *Quercus virginiana* and *Sabal palmetto,* and an understory of *Serenoa repens*. Another hammock type, perhaps better referred to as hydric hammock, has high importance of *Quercus laurifolia*, and is shallowly seasonally inundated. More detailed descriptions of these prairie hammock types can be found in Bridges (1998a). Typically, there are five to six species of *Tillandsia* in most hammocks (*T. balbisiana, T. fasciculata* var. *densispica, T. recurvata, T. setacea, T. usneoides,* and *T. utriculata*), three species of epiphytic ferns (*Phlebodium aureum, Polypodium polypodioides,* and *Vittaria lineata*), and sometimes clumps of the epiphytic butterfly orchid, *Encyclia tampensis*.

The prairie hammocks found within the dry prairie landscape are unusual and sensitive habitats. The present-day low biodiversity of many prairie hammocks could be the result of past damage to the ground cover by cattle and feral hogs, both of which preferentially utilize these sites. Alternatively, some hammocks may have lower diversity by being subject to occasional fire, where during dry periods fires from the surrounding prairies and marshes burn through the ground cover of the hammocks.

Wildlife Diversity

There are many common faunal components of dry prairies. Both breeding and seasonal migrants utilize dry prairies extensively. Breeding birds of the dry prairies include the Florida mottled duck, common nighthawk *(Chordeiles minor*),

red-winged blackbird *(Agelaius phoeniceus)*, common yellowthroat *(Geothlypis trichas*), eastern towhee *(Pipilo erythrophthalmus)* and eastern meadowlark *Sturnella magna* (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). Seasonal use by northern avian species during the winter season substantially increases the avifauna diversity of dry prairie (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). Species that migrate into the central Florida area and overwinter within dry prairie include the savannah sparrow (*Passerculus sandwichensis)*, swamp sparrow *(Melospiza georgiana*), Henslow's sparrow *(Ammodramus henslowii),* as well as the northeastern race of grasshopper sparrow *(Ammodramus savannarum pratensis)* (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). Other wintering species include yellow rail *(Coturnicops noveboracensis noveboracensis*), palm warbler *(Dendroics palmarum)*, and a variety of other songbirds. In addition, a variety of avian predators, including northern harrier *(Circus cyaneus)*, American kestrel *(Falco sparverius)*, and *Accipiter* spp. (hawks) migrate into central Florida (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). The effect of this influx on the resident avifauna is uncertain, and the importance of Florida dry prairie as wintering grounds for the seasonal residents is poorly known (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

Herpetofauna of the dry prairies include common species such as Florida box turtle *(Terrapene carolina bauri)*, glass lizards *(Ophisaurus* spp.), ground skink *(Scincella lateralis)*, Florida ribbon snake *(Thamnophis sauritus sackenii)*, Florida banded water snake *(Nerodia fasciata)*, black racer (*Coluber constrictor priapus)*, and rough green snake *(Opheodrys aestivus*) (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). Amphibians including oak toad *(Bufo quercicus)*, southern cricket frog *(Acris gryllus gryllus*), and pine woods tree frog *(Hyla femoralis*) are also abundant in dry prairies (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

Common mammals include eastern cottontail *(Sylvilagus floridanus*), hispid cotton rat *(Sigmodon hispidus*), oldfield mouse *(Peromyscus polionotus*), spotted skunk *(Spilogale putorius*), and bobcat *(Lynx rufus floridanus*), (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

Wildlife Species of Concern

Federally listed species that depend upon or utilize the dry prairie community in South Florida include: Florida panther (*Puma (=Felis) concolor coryi*), bald eagle (*Haliaeetus leucocephalus*), Florida grasshopper sparrow (*Ammodramus savannarum floridanus*), whooping crane (*Grus americana*), eastern indigo snake (*Drymarchon corais couperi*), and Audubon's crested caracara (*Polyborus plancus audubonii*). Biological accounts and recovery tasks for these species are included "The Species" section of this recovery plan. Unlike



Burrowing owls. *Original photograph by Betty Wargo.*

most other grasslands in the southeastern United States, Florida dry prairie harbors numerous endemic vertebrates (DeSelm and Murdock 1993); Appendix C lists the species of concern in this community. Millsap *et al.* (1990) consider interior dry prairies to be one of four geographic and/or ecological communities in Florida with high concentrations of high-ranked GFC avian taxa, and a few other high-ranked vertebrates. In a relative ranking of major Florida ecological communities, these authors list two taxa of reptiles, five taxa of birds, and three taxa of mammals as high-ranked vertebrate species regularly occurring in dry prairie. They noted the importance of the Kissimmee Prairie and associated habitats to species such as the short-tailed hawk *(Buteo brachyurus fuliginosus*), Florida grasshopper sparrow, Audubon's crested caracara, Florida sandhill crane *(Grus canadensis pratensis*), and Florida burrowing owl *(Speotyto cunicularia floridana*); refer to brief discussions of these species below. Several of the high ranking avian taxa are near-endemic to the dry prairie region of south-central Florida. However, others *(i.e., P. planchus audubonii, G. canadensis pratensis, S. cunicularia floridana*) are not found exclusively in native prairie habitat, and are capable of persisting in anthropogenic altered landscapes (semi-improved pastures, improved non-native pastures, disturbed rangelands, *etc.*) within the dry prairie region of south-central Florida. The anthropogenic landscape of the improved pastures should not be considered as essential for survival of these birds, since they evolved within the natural dry prairie landscape. Their current prevalence in anthropogenic landscapes maybe the result of disproportionate loss of the microhabitat and structural conditions preferred by these species in the dry prairie landscape, perhaps due to less frequent fire. It is possible that populations of these taxa may have been naturally limited, or declined after settlement, and the anthropogenic landscape has provided the conditions for population increase of these species by utilizing areas structurally similar to their pre-settlement habitats. Anecdotal evidence of the preferential use of dry



Sandhill crane. *Original photograph by Betty Wargo.*

prairie by these species is provided by Harper (1927), who noted that burrowing owls and Florida sandhill cranes can be seen more often in the prairies than elsewhere in South Florida.

The **Florida burrowing owl** is considered a species of special concern by the State. It is currently an uncommon or poorly known resident of dry prairies and open agricultural lands and ranges from northern peninsular Florida to the Keys (Millsap *et al.* 1996). Historically most burrowing owls were found in the dry prairie region (Harper 1927, Ridgway 1914, Bent 1938, Enge *et al.* 1997), but seem to have expanded their range between the 1940s and 1970s due to land clearing and improved drainage. However, populations on the Osceola Plain are apparently declining, and presently these owls are found in the greatest concentrations in areas of elevated ground features, usually in disturbed habitats (pastures, canal banks, *etc.*) (Enge *et al.* 1997).

Florida sandhill crane, State listed as threatened, is another avian species that is dependent on the open, treeless habitats of the dry prairie region. Sandhill cranes are year-round residents of the prairies and extensive wetland systems. Florida sandhill cranes are well-known foragers in improved pastures, which simulate the low grassy vegetative cover of frequently burned dry prairie, and also occur frequently in savanna-like open flatwoods.

The **short-tailed hawk** reportedly utilizes dry prairie and scrub habitats for foraging and nests in cypress and some other swamps in south-central Florida (Ogden 1971, Millsap *et al.* 1996, Enge *et al.* 1997).

The **Florida grasshopper sparrow** is a federally and state endangered subspecies which is endemic to the prairie region of south-central peninsular Florida (Vickery and Shriver 1994). Frequently burned dry prairie is the preferred natural habitat (Delaney 1993) for this non-migratory subspecies,

although it is also documented from degraded prairie and other rangeland sites (Delaney and Cox 1985).

The **Audubon's crested caracara** is a subspecies of the crested caracara that is listed as a federally and state threatened species, and is endemic to south-central Florida (Morrison 1996). It is largely dependent on the open treeless habitats within the dry prairie landscape. It is also associated with wetlands and rivers within the dry prairie landscape, and uses isolated cabbage palms or palms in hammocks for nesting sites (Morrison 1996). Improved pasture lands that are being actively grazed by livestock are used extensively by this bird (Morrison 1996). Crested caracaras appear to have adapted to cattle ranching in the current Florida landscape; however, conversion of ranchlands to more intensive agricultural uses could potentially pose a threat to this bird (Morrison 1996).

The **whooping crane** (*Grus americana*) is federally listed as an experimental, non-essential population in South Florida. This species was recently extirpated from the State, but was reintroduced in 1993 and 1995 to Three Lakes WMA, as part of the overall recovery strategy for the species. The ultimate goal is to have a self-sustaining population of 25 breeding pair by the year 2020.

In addition to the avian species identified by Millsap *et al.* (1990), Enge *et al.* (1997) address three additional high ranked avian species, Florida mottled duck *(Anas fulvigula fulvigula)*, western kingbird *(Tyrannus verticalis)*, scissor-tailed flycatcher *(Tyrannus forficatus)* and two reptile taxa, South Florida rainbow snake *(Farancia erytrogramma seminola)*, and Florida mole kingsnake *(Lampropeltis calligaster occipitolineata*), that occur within dry prairie, but are not restricted to dry prairie. However the flycatchers are incidental migrants and have not been observed in dry prairie (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). DeSelm and Murdock (1993) noted the black-shouldered or white-tailed kite (*Elanus caeruleus majusculus*), a wide-ranging but rare bird in the southeastern United States, as primarily occupying prairies in central Florida. The prairie/pasture system of central Florida is also the landscape chosen to establish an experimental population of the whooping crane. Like the sandhill cranes, the released whooping cranes are largely dependent on open habitats including native prairies, sparsely forested sites, and the wetlands associated with this landscape.

Bison bison bison, the plains bison, once reported as numerous and widespread in northwest and north-central Florida, was apparently extirpated by 1740 (DeSelm and Murdock (1993), and perhaps ranged into the historical dry prairies.

Other faunal species of concern that are not restricted to the dry prairie region, but are commonly encountered, include the southeastern American kestrel (*Falco sparverius paulus*), gopher tortoise *(Gopherus polyphemus)*, gopher frog *(Rana capito)*, eastern indigo snake *(Drymarchon corais couperi)*, and Florida brown snake *(Storeria dekayi victa*).

Species which are high-ranked by GFC that occasionally are found in dry prairie include Sherman's short-tailed shrew *(Blarina carolinensis shermani*), Florida mastiff bat *(Eumops glaucinus floridanus)*, Florida panther, peregrine falcon *(Falco peregrinus tundrius)*, and bald eagle *(Haliaeetus leucocephalus)*

(Enge *et al.* 1997). Peterson (1997) includes one reptile, 13 birds, and five mammals as elements occurring in dry prairie that are currently being tracked by the Florida Natural Areas Inventory.

Many other species associated with other habitat types also occur in dry prairie (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). The ecological importance of dry prairie habitat to these species remains unknown.

Plant Species of Concern

No federally listed plants are currently known from dry prairie. One state endangered and six state threatened plants occur in dry prairie, based on the 1998 updated list of Florida regulated plants (Coile 1998). *Calopogon multiflorus* (many-flowered grass pink orchid) is the only state endangered plant that occurs in dry prairie. This member of the Orchidaceae family also grows in dry-mesic pine flatwoods within the dry prairie region of south-central Florida. Three rather widespread and locally abundant species of carnivorous plants are listed as state threatened and occur in the dry prairie landscape-*Pinguicula caerulea* (blue butterwort), *Pinguicula lutea* (yellow butterwort), and *Sarracenia minor* (hooded pitcher plant). Two other orchids of dry prairie are also listed as state threatened-*Spiranthes longilabris* (long-lipped ladies-tresses) and *Pteroglossaspis ecristata* (wild coco). *Lilium catesbaei* (southern red lily), a member of the Liliaceae family, despite being widespread and common in Florida, is also listed as a state threatened plant. Peterson (1997) in the FNAI "County distribution and habitats of rare and endangered species in Florida" lists four plant taxa that FNAI tracks in their statewide data base as occurring in dry prairie [*Gymnopogon chapmanianus* (Chapman's skeletongrass), *Linum carteri* var. *carteri* (Carter's small-flowered flax), *Linum carteri* var. *smallii* (Carter's large-flowered flax), and *Vernonia blodgettii* (Blodgett's ironweed)]. Neither of the *Linum* species nor the *Vernonia* occur in dry prairie, but rather grow in marly prairies or seasonally wet pinelands and cypress savannas, usually where calcareous outcrops are near the surface. Other FNAI listed plants known to occur in dry prairies include *Aristida rhizomophora* (Florida three-awn) and *Pteroglossaspis ecristata* (wild coco), but these are not included on the lists of dry prairie species by Peterson (1997). There is a recent unverified report of *Nolina atopocarpa* (Florida beargrass), a globally rare FNAI listed plant, that is also listed as state threatened, from dry prairie at Kissimmee Prairie State Preserve in Okeechobee County (Chafin *et al.* 1997). None of the above listed plant taxa are restricted to dry prairie, with all of them also occurring in other natural communities in Florida.

Ecology

Fire Ecology

Fire is the most common natural disturbance in upland peninsular Florida ecosystems (Menges *et al.* 1993, Robbins and Meyers 1992), with lightning

historically having been the primary ignition source. Peninsular Florida typically has a distinct winter dry season, with the largest burns histoically occurring in late spring and early summer (April through mid-June), at the onset of the May-September lightning season (Abrahamson 1984, Chen and Gerber 1990, Dye 1997). There is no doubt that fires continued to occur throughout the lightning season, but fires later in the season were probably smaller and less intense due to the increasingly wet conditions. Natural fires likely occurred during all seasons to some extent, but the great majority of fires probably occurred during the thunderstorm season. Effects of fire intensity, seasonality, and historical events have been implicated in the dynamics of many Florida plant communities, including dry prairie (*e.g.* Abrahamson 1984, Platt *et al.* 1988, Rebertus *et al.* 1989, Abrahamson and Harnett 1990, Abrahamson 1991).

Frequent lightning strikes just prior to the summer rainy season in dry prairie areas with sufficient fuel, consisting of short shrubs, grasses and herbaceous material, all of which are highly flammable, contributed greatly to natural fire frequency. Deviations in intensity, fire return interval, and seasonality from the natural fire regime are potentially significant anthropogenic factors determining vegetation structure and composition of the dry prairie landscape. Historically, the role of humans before European settlement in shaping the landscape and vegetation with fire is believed by some to have been a significant factor in the maintenance of open pine savannas and prairies. However, the exact fire intensity, fire return interval, and seasonality of fire under which the fire-maintained natural communities and biota evolved in the dry prairie landscape is subject to considerable debate.

In dry prairie communities, dormant season burns tend to favor increased cover of graminoids over forbs, whereas growing season burns tend to favor increased cover of forbs, at least in the year of burning (Orzell and Bridges, personal field observations). Growing season burns also seem to delay flowering of some species, and serve to compress and synchronize flowering peaks of the groundcover species in the year of the burn. Differences between dormant and growing season burns have also been noted by Platt *et al.* (1988) in north Florida, who found that the fire season had little effect on the number of species flowering during the year following the fire. Platt *et al.* (1988) found that fires during the growing season decreased average flowering duration per species and increased synchronization of peak flowering times within species relative to fires between growing seasons. Platt *et al.* (1988) found that fires during the growing season also increased the dominance of fall flowering forbs and delayed peak fall flowering. Field observations by the authors in south-central Florida dry prairies tend to concur with Platt's findings.

The natural fire frequency for dry prairie is unknown but may be every 1 to 4 years, which suggests greater frequency than in any other central Florida community. This statement is based mostly upon historical accounts, journals and surveys (Abrahamson and Hartnett 1990, Frost 1993), although scientific evidence to support or refute this assumption is lacking. A higher fire frequency over a long time period could be the critical factor limiting pine recruitment in this community, but it may not be the sole factor responsible for limiting natural pine establishment. Harper (1921,1927) is perhaps the earliest published source to note that dry prairie was subject to fire practically every year, and like the

flatwoods, practically all the plants have large underground parts enabling them to recover following fire. These observations by Harper (1921, 1927) are testimony to the high fire frequency of the dry prairie landscape during early decades of this century.

Dry prairie probably occurred as broad areas with a higher fire return frequency, compared to the mesic pine flatwoods-pine savanna-depression marsh landscape mosaic. Dry prairie can be thought of as the endpoint along a forested to treeless continuum of flatwoods/savanna landscapes, in response to variation in the natural fire regime. In regions devoid of major natural fire barriers, such as in the historical dry prairie landscape, fire is reported as occurring annually or biennially (Harper 1921, 1927). A 1 to 2 year natural fire frequency would be sufficient to prevent pines from becoming established, except occasionally in fire-shadows and other isolated fire-protected sites. Glitzenstein *et al*. (1995) in north Florida, found that with a 2-year fire return interval, the pine population declined steadily, and suggested that pines might disappear with continued burning at that interval. The fire frequency in dry prairie may differ most significantly from pine flatwoods in the position of dry prairie in a natural landscape that was historically essentially devoid of impediments to the spread of fire. Under these conditions, a single ignition could easily burn thousands of hectares before being naturally extinguished. In the present-day condition, barriers such as roads, ditches, and firebreaks artificially limit the size and extent of landscape-scale fires.

Relationships Between Animals and Plants

There is little published information available on the relationships between dry prairie vegetation and faunal components. Most of the available information is on the habitat preferences of the Florida grasshopper sparrow. Shriver (1996) determined that breeding Florida grasshopper sparrows were associated with certain structural vegetation characteristics of the dry prairie habitat, and did not use available habitat randomly. Vickery and Dean (1997) report that sparrows select areas of habitat with specific structural vegetation characteristics during the non-breeding season, again indicating that the Florida grasshopper sparrow does not randomly utilize dry prairie habitat. The strong association of the Florida grasshopper sparrow with certain structural vegetation characteristics within a structurally varied community suggests that habitat management would affect sparrow populations. Delany and Cox (1986) report that Florida grasshopper sparrows are unlikely to adapt to conditions resulting from intensive pasture improvement, though they may be capable of adapting to some level of modification. Determining the microhabitat preferences of the Florida grasshopper sparrow is difficult due to differing land management histories and current land management strategies between known sites for the species. Clearly, aspects of habitat structure at a small scale, and possibly variation in structure, are required to support the Florida grasshopper sparrow (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

Vegetation density is also a factor that affects the quality of Florida grasshopper sparrow habitat. Frequent burning is required to maintain the vegetation density at a level low enough for the sparrows. Excessive shrub

heights are also reported to deter grasshopper sparrows from settling (Delany *et al.* 1985, Shriver 1996), and fire is an important agent in maintaining low shrub height and cover.

To date, no information is available on the use of habitat relative to landscape features, other than the presence of trees, which the sparrows strongly avoid during the breeding season (Delany *et al.* 1992). The density of ponds, ditches, cypress domes, and other features may affect sparrows' habitat choices. Plotted radiotelemetry locations of Florida grasshopper sparrows suggest that sparrows may be selecting or avoiding particular features of the landscape, but it is currently unclear what these may be (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

Status and Trends

Estimates of the historical and current extent of dry prairie within central Florida vary substantially. Florida dry prairie is ranked as a G2 (globally imperiled) community type (FNAI and FDNR 1990, Grossman *et al.* 1994, Weakley *et al.* 1996). Based upon DeSelm and Murdock (1993), Noss *et al.* (1995) considered ungrazed dry prairie of Florida as an endangered ecosystem (greater than 98 percent habitat loss and continued threat). Although dry prairie area is declining, there are still considerable opportunities to protect dry prairie in south-central Florida (R. Hilsenbeck, The Nature Conservancy, personal communication 1998). Florida harbors the most extensive areas of native grasslands remaining in the southeastern United States (DeSelm and Murdock 1993). Despite declines in dry prairie, there are areas of native pastures of over several thousand acres each, with native range averaging 85 percent of the area on individual ranches as recently as 1968 to 1970 (Mealor 1972, DeSelm and Murdock 1993). However, in central Florida there continues to be a reduction in area and fragmentation of high-quality dry prairie, and an even greater reduction in the number of sites with a continuous fire history and minimal human disturbance (Bridges 1997, Cole *et al.* 1994a).

Crumpacker *et al.* (1988) estimated that approximately 1,127,346 ha (2,784,545 acres) of palmetto prairie were present in 1967, with 73.25 percent (approximately 826,000 ha or 2,040,220 acres) in a natural condition. Cox *et al.* (1994) map 561,114 ha (1,385,952 acres) of dry prairie in central Florida, as part of an attempt to inventory Florida's vegetation types based on 1985 to 1989 Landsat satellite imagery. Of this area, they indicate that 16.6 percent, or 93,145 ha (230,068 acres), is found in conservation areas, being among the lowest percentages of natural Florida plant communities in conservation areas. Subsequent to this publication, acquisition of Kissimmee Prairie State Preserve in Okeechobee County has increased the area of dry prairie in conservation areas. Although the Landsat estimate alone would indicate a fairly large amount of dry prairie in central Florida, Cox *et al.* (1994) state that "the dry prairie land-cover class often includes areas with widely spaced pine trees ...." Unfortunately, much of what is mapped as dry prairie in central Florida by use of Landsat imagery includes substantial areas of cut-over or "understocked" pine flatwoods, as well as wet prairies, some drained wetlands, and coastal grasslands (Bridges 1997). Dry prairie may have historically been of much more limited extent than mapped by Cox *et al.* (1994) using Landsat data.

For example, dry prairie is mapped as the most common natural community at Avon Park AFR by Cox *et al.* (1994), covering all of the base except for the densest areas of pine cover and the deep-water wetlands. Most authorities would agree that the vast majority of this area would best be classified as open pine flatwoods rather than dry prairie, and the Avon Park AFR vegetation classification, perhaps more accurately, considers most of this area as "flatwoods," as opposed to the denser pine stands which are mapped as "flatwoods, forested."

Davis (1967, cited in Cox *et al.* 1997) estimated that 2,048,865 ha (5,060,697 acres) of prairie-type grasslands existed on the historical landscape, but these authors did not distinguish dry prairies from other wetter, palmetto-free prairies in north-central Florida (such as Paynes Prairie). Obtaining consistent estimates of existing areas of dry prairie vegetation is equally difficult. Estimates on the current area of Florida dry prairie are given in studies by the GFC (Kautz 1993, Cox *et al.* 1994, Cox *et al.* 1997) and by Duever *et al.* (1992). Kautz *et al.* (1993), based upon calculations from Davis' 1967 vegetation map of Florida, estimated that 0.83 million ha (2,050,100 acres), or 5.9 percent, of pre-settlement Florida was covered by dry prairie and depression marshes. By 1989, Kautz *et al.* (1993) estimate that 0.56 million ha (1,383,200 acres) of dry prairie remained, but this figure includes areas outside the historic range for dry prairie given in Davis (1967). Cox *et al.* (1997) estimate that 1,385,176 ha (3,421,385 acres) of dry prairie remain in Florida based upon the 1985 to 1989 Landsat imagery, of which 233,069 ha (575,680 acres), 17 percent, is found within managed areas. Duever *et al.* (1992) in a natural area inventory of St. Lucie County estimated that approximately 9,694 ha (23,935 acres) of dry prairie occurred in 1986, whereas 5,438 ha (13,428 acres) remained in 1991, a 43.9 percent loss in a 5-year period based upon GFC Landsat imagery.

Remaining potential dry prairie natural areas have been systematically identified using county black-and-white aerial photography dated 1992 to 1993, as part of a statewide effort to identify significant remaining Florida natural areas for Florida Department of Natural Resources in 1993 to 1994. Shriver (1996) conducted aerial surveys of 138,664 ha (342,500 acres) of these potential dry prairie sites (within 33 potential natural areas) and the adjacent landscape, and identified 64,420 ha (159,117 acres) of this area as high-quality Florida grasshopper sparrow habitat (in native vegetation, with evidence of fire) with an additional 39,933 ha (98,635 acres) of marginal habitat or habitat in need of restoration, and 34,310 ha (84,746 acres) as poor quality or recently converted to agriculture (Shriver 1996). The largest of the dry prairie potential natural areas identified by the senior author, and the highest quality tract verified by the aerial survey (Shriver 1996), later became the Kissimmee Prairie State Preserve.

Losses of dry prairie have been due to several land-use type conversions-conversion of native prairie to improved pasture (Layne *et al.* 1977), conversion to other agricultural uses, such as citrus groves (Davis 1967, Mealor 1972, Callahan *et al.* 1990, DeSelm and Murdock 1993, Layne 1996), conversion to planted pine, and, in the past, conversion to eucalyptus (*Eucalyptus* spp.) plantations. Conversion of dry prairie to citrus groves may

represent the single greatest threat to existing prairie remnants. Current pasture and rangeland are the areas with the highest feasibility for citrus conversion, since these sites, with supplemental drainage, can provide the well-drained soils required to grow citrus (Pearlstine *et al.* 1995). In southwest Florida alone, the extent of citrus groves has doubled to 60,000 ha (148,200 acres) since 1980 and is projected to reach 80,000 ha (197,600 acres) by the year 2000 (Pearlstine *et al.* 1995).

Perhaps the most reliable method to evaluate the original pre-settlement extent of dry prairie is through examination of the original Public Land Surveys compiled from 1855 to 1859. These land surveys not only provide documentation on the overall extent and distribution of pre-settlement dry prairie, they also provide anecdotal evidence on the treeless nature of dry prairie. These surveys show that most of the extensive areas of the dry prairie landscape association were mapped as "prairie" in the original surveys, providing evidence that dry prairie is not simply an artifact of anthropogenic origin. In particular, the dry prairie within the Kissimmee Prairie State Preserve was actually somewhat more extensive in the 1850s than in the present day (Bridges 1998a). Most surveyors drew the boundary between prairie and pinelands on the original land survey plats, and this was confirmed by the presence or absence of witness trees for the section corners and section line midpoints. Surveyors were also careful to note when they transited from pine lands to prairie. Based on these facts, we can assume that the extent of prairie delineated by the original land survey is a fairly accurate picture of the landscape of the1850s. Since there had been no widespread logging in central Florida as of that date, we can assume that this represents the best picture available of the extent of prairie in the pre-settlement landscape. Frequent fires would have been required to maintain the historical extent of open prairie, and with reduction of fire frequency and intensity, much of the remaining dry prairie landscape that has not been converted to pasture has been invaded by pines.

As of 1998, there are five protected, managed areas in Florida with significant areas of native dry prairie vegetation. There are approximately 9,200 ha (23,000 acres) of dry prairie at Kissimmee Prairie State Preserve (Chafin *et al.* 1997), making it the largest and most significant remaining dry prairie area currently within protected status. Other protected managed areas of dry prairie are found at Avon Park AFR, Three Lakes WMA, the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary, and Myakka River SP. Avon Park AFR has the largest and most significant remaining examples of dry prairie in Highlands and Polk counties (Orzell 1997), with an estimated 2,400 ha (6,000 acres) of dry prairie (Vickery and Perkins 1997). Major areas of dry prairie at Avon Park AFR lie both north and south of Kissimmee Road (in O. Q. Range and north of O. Q. Range), and within Echo and Charlie Ranges. The southern management unit at Three Lakes WMA in Osceola County has approximately 4,000 ha (10,000 acres) of dry prairie (Vickery and Perkins 1997). The National Audubon Society's Kissimmee Prairie Sanctuary in Okeechobee County has approximately 1,000 ha (2,500 acres) of dry prairie (Vickery and Perkins 1997), most of which is of outstanding natural quality (Orzell, Bridges and Dean, personal field observations). Myakka River SP in Manatee and Sarasota counties has

approximately 6,800 ha (17,000 acres) of what was once dry prairie (Fitzgerald *et al.* 1995), over half the park's area (Anonymous 1986) prior to CARL land additions to the park.

Recent large-scale protection efforts by The Nature Conservancy in south-central Florida are encouraging, and will hopefully provide for protection of remnant dry prairie landscapes. A 11,508 ha (28,414 acres) conservation easement on the Bright Hour Ranch in Desoto County would provide for protection of at least 5,418 ha (13,387 acres) of dry prairie of varying natural quality (R. Hilsenbeck, The Nature Conservancy, personal communication 1998). A recent CARL proposal submitted by The Nature Conservancy proposes to create a conservation easement on 59,463 ha (146,932 acres) in Glades County and a small section in Highlands County, of which approximately 22,038 ha (54,456 acres) is livestock-grazed rangeland that includes dry prairie of varying natural quality (R. Hilsenbeck, The Nature Conservancy, personal communication 1998). The future of the dry prairie landscape is currently largely dependent upon the management and protection of native rangelands on cattle ranches in south-central Florida.

Management

Overall management of dry prairie should strive to mimic ecological processes (frequent fire, landscape-scale burns, natural hydrologic conditions, *etc*.) in which the dry prairie ecosystem evolved, preferably through an ecosystem management approach. The overall preservation of native biodiversity should be a primary focus, as studies in grasslands support the diversity-stability hypothesis, and show that ecosystem functioning and sustainability may depend upon ecosystem biodiversity (Tilman and Downing 1994, Tilman *et al.* 1996). Rare and endangered species management within dry prairie should not be the sole predicator of overall management goals and strategies. Management and restoration strategies and approaches should vary depending upon the ecological condition or "naturalness" of any given site, for example: (1) high-quality areas with an intact, diverse native ground cover; (2) areas with intact ground cover, but disrupted ecological function due to alteration of ecological processes (fire suppression); or (3) disturbance-altered former prairie sites (through the effects of drainage, partial clearing, pine or *Eucalyptus* plantations). For example, mechanical treatments should not be used on high-quality sites, however, mechanical treatments might be useful in attempts to restore areas of former prairie. Restoration of degraded dry prairies should first emphasize reintroduction of natural ecological processes (reintroduction of fire on fire-suppressed sites, restoration of hydrologic conditions, *etc.*). Critical management issues and challenges include prescribed burning, hydrologic alterations, rangeland and livestock grazing, control of exotics, and impacts associated with mechanical treatments.

Prescribed Burning

Deviation in fire intensity, fire return interval, and seasonality from the natural fire regime of frequent growing-season burns is perhaps the most significant

management factor determining vegetation structure and composition of dry prairie communities (Perry 1997, Dye 1997, Bridges 1997). Loss of ground cover species, changes in pine density and recruitment, invasion of non-constituent oaks, and excessive shrub growth has been documented from dry prairies with long periods (*ca.* 35 years) of fire exclusion (Dye 1997, Perry 1997). When dry prairie is frequently burned, saw palmetto is typically of small stature and sparsely distributed, but it tends to increase in stature and density when fire is absent or infrequent (Cole *et al.* 1994a). Implications of the effects of burning on the native ground cover have been previously discussed in this account. The effects of fire on the faunal component of dry prairie is largely unknown. However, most of the faunal taxa should be well-adapted to the natural fire regime. In particular, those which are endemic to the dry prairie region of south-central Florida have evolved within a high fire frequency ecosystem. In fact, some if not most prairie faunal taxa that are dependent on dry prairie also appear to be dependent on recently burned sites *(i.e.,* Florida grasshopper sparrow, see Walsh *et al.* 1995), or prefer recently burned sites over fire-suppressed dry prairies.

It had been thought that ground-nesting birds might be susceptible to mortality or lower reproductive success due to growing season prescribed burning (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). The Florida grasshopper sparrow, Bachman's sparrow and the eastern meadowlark are all ground-nesting birds of dry prairie. All initiate breeding in mid-March through April (Perkins *et al.* 1998), and have relatively short reproductive cycles (30 to 40 days from egg-laying through fledging). It had been hypothesized that natural frequent late spring and early summer lightning fires, now simulated with prescribed burns during the growing season from late March through early June, would destroy some nests and young birds, and that this would result in significant reduction in reproductive success and population levels.

However, all three of these birds regularly re-nest if nests are destroyed (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). In addition, multiple successful clutches are possible for all three taxa (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). Recent studies have shown that adult Florida grasshopper sparrows and other ground-nesting avian taxa appear to be able to successfully avoid fires, and can occupy recently burned areas within 1 week after fire (Shriver *et al.* 1994, Shriver 1996). Although some nests and young birds could be lost to fire, growing season burning does not preclude successful reproduction in that season for any of these birds. Recent studies have shown that Florida grasshopper sparrows successfully fledge young after June fires (Vickery and Perkins 1997), and increase the length of the breeding season by as much as 8 weeks, extending as late as September, after these fires (Shriver 1996, Vickery *et al.* 1997). However it is still unknown whether reproductive success differs between summer-burned and winter-burned areas (FWS 1997).

There are several factors which suggest that growing season burning may benefit the Florida grasshopper sparrow. Florida grasshopper sparrows preferentially nest in areas less than 1.5 years post-burn (Walsh *et al.* 1995,

Shriver 1996). If such habitat patches are available within a mosaic of areas with differing post-burn times, they would most likely be the areas utilized for nesting. Prescribed burning during the nesting season would most likely be conducted on areas of 2 years or more post-burn, therefore the areas least likely to be currently utilized for nesting. Therefore, as long as a sufficient area less than 1.5 years post-burn is present within the population area, nesting season prescribed burning of adjacent areas should destroy relatively few nests. The extension of the breeding season by prescribed burning during the nesting season may have important consequences for a species which appears to have low reproductive success (Shriver 1996). Lengthening the breeding season by provision of newly burned areas effectively doubles the number of nesting opportunities, may increase the number of pairs that attempt additional clutches, and may provide sub-dominant males the opportunity to establish territories and breed for the first time (Shriver 1996). Further research is needed to test these new hypotheses.

The long-term effects of growing season fires on the overall productivity of these ground-nesting sparrows is largely unknown (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). However, neither is it known how the traditional winter burning of dry prairie by the cattle ranchers and some current land managers may have affected the long-term population levels of such ground-nesting birds.

Larger prairie birds, including sandhill cranes and caracaras, would possibly have greater potential to be affected by growing-season burns, since they require longer periods to produce young, 30 days incubation in cranes (Walkinshaw 1981) and 30 to 33 days for caracaras (Layne 1996, Morrison 1996). However re-nesting is still common in both species (Nesbitt 1988, Morrison 1996), and loss of nests would not preclude nesting in either bird. In addition, the breeding cycles of both species are in the dry season, before the peak time for natural growing season fires. Since caracaras nest in trees and cranes nest in wetlands, nest losses due to fire may be minimal. However, the indirect effects of fire on overall productivity are unknown. The effects of fire on other prairie occupants are also largely unknown. Armadillo and gopher tortoise burrows and the numerous depressional ponds characteristic of the dry prairie landscape likely provide refuge from fires for herpetofauna and small mammals (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

The uncertainty of the effects of growing season burning on the Florida grasshopper sparrow has caused land managers to shift prescribed burns from optimal late spring and early summer burns (especially April and May). The acceptable burning seasons therefore are pre-avian breeding, dormant season *(i.e.* winter) burns (January to early March), or postponement of prescribed burning until post-avian breeding (July through September). Winter or dormant season burns generally result in less overall reduction of aboveground woody biomass, and reduction in flowering of grasses and other native forbs. Prescribed burning conducted during the post-breeding season (July through September), after the onset of summer convective thunderstorms, has the potential to cause significant shifts in species composition in dry prairie. Heavy rainfall events, which are typically more frequent from mid-June through the

summer months, can produce two dramatic effects on vegetation in areas of post-breeding season burns: (1) more patchy burns (resulting in less overall reduction of woody vegetation) and (2) flooding of postburn regrowth, resulting in submersion of regrowth and stress to perennial groundcover grasses. The result is that annual cyperoids, such as *Scleria reticularis* (nut-rush), present in the seed bank are favored over perennial grasses and can locally co-dominate summerburned areas (Orzell and Bridges, personal field observations). Whether this vegetative response is short-term or long-term is unknown, but it needs to be studied.

Hydrologic Alterations

Hydrological restoration of conservation lands has been initiated in recent years, but primarily only in response to clear hydrological problems. Hydrological restoration should become a more important part of management and restoration activities in coming years. Loss of wetland area and reduced wetland quality has been a severe problem nationwide in recent years that has affected many wetland species (Noss *et al.* 1995, Cox *et al.* 1997).

Little data are available on the effects of altering the natural hydroperiod within this ecosystem. Sheet flow was perhaps the most common form of drainage during pre-settlement times. Presently, hydrological alterations have definitely changed the drainage patterns at the smaller prairie sites, but there are still areas with natural sheet flow across dry prairie at Kissimmee Prairie State Preserve. The possibility of additional areas with essentially unaltered sheet flow exists within some of the large rangeland sites. Due to subtle topography, even relatively minor changes in topography and drainage can greatly alter the hydroperiod. Vegetation composition of dry prairie is strongly affected by hydroperiod (Bridges 1997,1998a).

During the last four years, artificial flooding of dry prairie at the Ordway-Whittell Kissimmee Prairie Audubon Sanctuary, due to a dike erected by an adjacent landowner, has reportedly resulted in changes in plant species composition (P. Gray, National Audubon Society, personal communication 1998). Species more commonly associated with wet prairie vegetation (*Eriocaulon decangulare*, *Centella asiatica*, and others) may be replacing dry prairie plants, with individual saw palmetto showing leaf browning, perhaps due to stress from extended periods of inundation (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998). Recent lack of successful reproduction of Florida grasshopper sparrow at this site has been attributed to the changes in hydrology (Vickery 1996).

The effects of decreased hydroperiod in areas of dry prairie are also poorly known. Along ditch banks in dry prairie, growth of woody vegetation is often quite luxuriant. In these areas, trees often become established, and the height of saw palmetto and other shrubs is greater than in surrounding prairies. It is unclear whether this effect results from increased drainage in the immediate area, or from the obstruction of fires by the adjacent ditches. Woody vegetation along fence lines is also frequently taller and more luxuriant that in surrounding prairie areas, and this likely results from historical fire suppression

around fence posts. Comparison of historical and present-day aerial photography confirms recent increases in woody vegetation in proximity to drainage ditches in many dry prairie areas (T. Dean, Department of Forestry and Wildlife, University of Massachusetts, personal communication 1998).

Rangelands and Livestock Grazing

The persistence of dry prairie is closely tied to cattle ranching that has existed in central and South Florida since European settlement, and has continued to the present. The central Florida region was once sparsely populated (in comparison to other regions of Florida) and alternative land use options were scarce, thereby supporting management of native rangeland (DeSelm and Murdock 1993). Livestock have been present in dry prairie, and throughout central and southern peninsular Florida, for several hundred years (Yarlett 1985). Livestock grazing was historically (Harper 1921, Davis 1943) the primary economic benefit from the dry prairie/ flatwoods landscapes of central and south-central Florida (Moore 1974, Sievers 1985, Sullivan 1994). Harper (1927) reported that prior to the division of Desoto County into five counties the U. S. Census of 1900 indicated that Desoto County had 82,183 free-ranging cattle on 9,713 km^2 (3,750 mi^2), about half of which was prairie. In 1920 there were 53,192 cattle in the county (over 95 percent beef cattle) and some 70,459 cattle in 1925 (Harper 1927). Open, unfenced range existed in Florida until 1949 (Yarlett 1985). Between 1940 and 1960, many pastures of bahia grass (*Paspalum notatum*), digit grass (*Digitaria* sp.) and Bermuda grass (*Cynodon dactylon*) were established (Mozley 1985), as a result of land clearing and drainage alterations of native rangeland. By 1985, Florida had 1,215,000 ha (3 million acres) of perennial tame pasture and 405,000 ha (million acres) of annual tame pasture (Mozley 1985), an extensive area of which had formerly been dry prairie and flatwoods. In the early 1970s, production costs caused a shift towards native forage resources, although many ranchers had already recognized the value of native rangeland over improved pasture in the 1960s (Yarlett 1985). In 1984 there was a total cattle and calf inventory of 2.2 million head statewide (Yarlett 1985), with commercial cow-calf operations representing the major livestock production in Florida (Mozley 1985).

One reason Florida attracted such a large cattle industry is a growing season longer than 270 days and ample rainfall, ideal for growing forage and year-round use of native and improved pastures (Mozley 1985, DeSelm and Murdock 1993). Forage production for native rangeland *(i.e*. dry prairie and flatwoods) can range from 1,688 kg/ha (1,500 lbs/acre) on “poor condition ranges” to in excess of 8,438 kg/ha (7,500 lbs/acre) on “excellent condition ranges,” with the average production being from 4,500 to 6,750 kg/ha (4,000 to 6,000 lbs/acre) (Fults 1991, Sievers 1985, Mozley 1985). Hilmon and Hughes (1965) found that native rangelands burned in March or May produced a two-to-fourfold increase in forage, compared to those burned in October or November, with May burns causing *Aristida beyrichiana* to flower. However, native rangeland vegetation is not particularly nutritious for cattle, except

immediately following a burn, with nutritional values rapidly declining thereafter (Hilmon and Hughes 1965).

Native central and South Florida rangelands (*i.e.* dry prairies and flatwoods) are typically burned by ranchers annually or biennially during the winter or early spring months to stimulate forage growth, nutrition and palatability during the lean winter months (Abrahamson and Harnett 1990, Frost *et al.* 1986, Sullivan 1994). Ranchers also burn native pastures to maintain openness, reduce shrub cover, reduce fuel accumulations, and improve wildlife habitat (Abrahamson and Harnett 1990, Frost *et al.* 1986). However, frequent winter burning, when coupled with continuous grazing pressure, can lead to a decline in *Schizachyrium stoloniferum* (creeping bluestem, formerly *Andropogon stolonifera*) (White and Terry 1979), *Sorghastrum secundum* (lopsided Indiangrass), *Amphicarpum muhlenbergianum* (goobergrass), *Andropogon virginicus* var. *glaucus* (little chalky bluestem, formerly *Andropogon capillipes*), all of which are major preferred native forage grasses (Sievers 1985) that occur in dry prairie. Under such a management regime, *Aristida beyrichiana* (previously *Aristida stricta*, in part) (Hilmon and Hughes 1965) and saw palmetto are reported to increase (Sievers 1985), as well as other brush cover (Fults 1991). To lessen the impacts of grazing on rangelands with a previous history of frequent burning, some range managers have recommended burning on a 3-year cycle (Sievers 1985, Penfield 1985), which allows more opportunity for recovery in cover of preferentially grazed grasses.

Although the effects of fire and cattle grazing on the central Florida prairie/flatwoods communities have been examined (Hilmon and Hughes 1965, Sievers 1985, Fults 1991, Mozley 1985), there is a lack of knowledge on the effects of livestock grazing on various components of native prairie biodiversity. This is particularly true of most prairies outside of the Tallgrass Prairie region of the central United States. Herbivores preferentially feed on different plant species, consequently affecting dominance and relative abundance of plant species, thereby altering species composition (Howe 1994), with the potential to increase or decrease plant species diversity (Huntly 1991). Prolonged or severe preferential grazing can lead to colonization by ruderal plant taxa (Weaver 1968). In contrast, moderate grazing can result in greater species diversity relative to ungrazed sites, where a few species may dominate a community (Milchunas *et al.* 1988). Grazing activity may change the structure of the community by disrupting soil properties (Abrahamson and Harnett 1990) or by eliminating some life forms (Howe 1994). Furthermore, grazers may interact with other processes operating at different spatial and temporal scales, such as fire, drought, or other species interactions, resulting in scale-dependent effects (Harnett *et al.* 1996). Differences in livestock grazing management (*i.e.* year-round grazing, high intensity-short duration grazing, *etc.*) contribute to differences in vegetation responses (Harnett *et al.* 1996). Finally, historical ungulate assemblages were not confined, adding stochasticity to grassland development that is less evident in ungrazed prairies, small remnants, and fenced pastures (Howe 1994). All of these factors suggest that domestic livestock grazing, managed in different ways can produce significantly different effects on prairie community structure, species composition and prairie biodiversity (Hartnett *et al.* 1996). The effects of domestic livestock grazing on

components of dry prairie biodiversity therefore have significant implications for management.

Mechanical Treatments

Mechanical treatments (bedding, root-raking, use of a disc, rollerchopping, web plowing *etc.*), by whatever means, typically produce a wide variety of changes in plant community structure and composition in dry prairie. The use of bedding to reduce or remove competing shrubs and other vegetation, to prepare dry prairie for planting with pine or *Eucalyptus* monocultures (Moore and Swindel 1981) produces distinct microsites in the form of beds, flats, and furrows (Abrahamson and Harnett 1990). The native intact ground cover characteristic of dry prairie is significantly affected by these microsite alterations. Practices such as root-raking and use of a disc displace surface organic and litter layers and mineral soil, and may potentially eliminate native species, allow for the establishment of numerous weedy species, and significantly alter the native species composition and vegetation structure of dry prairie.

The most frequently employed mechanical treatment on dry prairie is the use of rollerchopping to control woody shrub height, in particular excessive growth in saw palmetto (Yarlett 1965). The use of rollerchopping on areas of intact, diverse native groundcover vegetation is not recommended and is strongly discouraged. Double chopping has been reported to almost eliminate wiregrass and saw palmetto (Hilmon *et al*. 1963). Although some herbaceous plant frequencies and species richness can increase following some types of roller-chopping, changes in overall species composition and relative abundance occur, with the increase in species richness (= species diversity) being a result of an increase in undesirable ruderal weedy species. Impacts to vegetation from chopping vary widely and are largely dependent upon the method and type of chopping, and the soil and moisture conditions when the chopping is conducted. Studies conducted by Fitzgerald *et al.* (1995) on "former" fire suppressed dry prairie (12 to 15 years of fire suppression) at Myakka River SP found that application of fire regardless of season was not significant in reducing woody cover. However, repeated chopping and follow-up burning aided attempts to restore dry prairie in shrub-dominated "former" dry prairie (Fitzgerald *et al.* 1995, Tanner 1997) at Myakka River State Park. Therefore, rollerchopping on former fire-suppressed or previously disturbed dry prairie may be a useful restoration tool when used in conjunction with frequent burning (Tanner 1997, Fitzgerald and Tanner 1992). Fitzgerald and Tanner's (1992) study on former fire-suppressed (35 years of fire suppression), overgrown dry prairie found shrub control treatments (rollerchopping) had an acute effect on bird abundance and species composition, as they had postulated. They noted that the first birds observed in the chopped plots were prairie bird species (eastern meadowlark, *Melospiza georgiana*; loggerhead shrikes, *Lanius ludovicianus*; and grasshopper sparrow) perhaps an early sign of prairie restoration (Fitzgerald and Tanner 1992). Roller chopping is now accepted by many land managers as an effective means to begin restoration of overgrown former prairies and flatwoods (Tanner *et al*. 1988, Moore 1974). This is particularly true where fire has not been sufficient to control woody shrubs, since

chopping can be effective in reducing the height and dominance of woody shrubs (Tanner 1997, Fitzgerald *et al.* 1995). However, the destructive nature of this technique, even in disturbed prairie, has the potential to cause unforeseen changes in natural processes. If applied during the spring, summer, or early fall, roller chopping may interfere with nesting activities of many prairie bird species. In addition, Bridges (1997) has postulated that roller-chopping may have been the cause of significant long-term vegetation composition changes at some dry prairie sites.

Exotic Species

The greatest effects of exotic species in the dry prairie landscape are from the large-scale conversion of prairies to pastures. Exotic plant species of central Florida that occur in dry prairie include *Axonopus furcatus* (big carpet grass), *Axonopus fissifolius* (little carpet grass), *Paspalum notatum* (bahia grass), *Panicum repens* (torpedo grass), *Cyperus haspan* (sheathed flatsedge), *Fimbristylis cymosa* (hurricane grass), *Cynodon dactylon* (Bermuda grass) and *Solanum viarum* (tropical soda apple). Bahia grass and Bermuda grass were introduced into Florida in the 1920s to improve native range for cattle (DeSelm and Murdock 1993). Carpet grasses are perhaps the most prevalent exotic grasses in central Florida flatwoods and prairies and are very widespread, even occurring sporadically throughout otherwise fairly pristine prairie communities. Seeds of both of these grasses were aerially dispersed across much of the state to aid in stabilization of barren lands. Consequently, they have an abundant and widespread seed source. These species also establish rapidly on disturbed soils and often dominate plowed fire breaks, field edges, areas rutted by feral hogs, and heavily overgrazed sites. Once established, non-native grasses that are often planted (Bahia grass, carpet grasses, Bermuda grass, and others) appear to be quite difficult to remove without intensive effort. However, these species do not actively encroach into native habitats, unless a disturbance causes removal of the native ground cover producing bare soil conditions. Tropical soda apple is a noxious weed that is unpalatable to livestock and is found in disturbed rangelands (Mullahey and Colvin 1993) and also in degraded examples of dry prairie.

The most significant exotic animal in dry prairie is *Sus scrofa*, the feral hog (Herbster and Elfers 1992). Wild or feral hogs are widely viewed as a serious threat to rare plants in Florida (Pace-Aldana and Scott 1997, Weakley and Malatesta 1997, Menges and Yahr 1997) and native plant communities (Herbster and Elfers 1992, Huffman and Judd 1998, Huffman 1990, Longino and Heuberger 1991). Impacts to the native vegetation caused by feral hog rooting habits has been documented for five natural community types at Myakka River SP, including dry prairie (Huffman 1990). Damage to native plant communities by feral hogs is a serious ecological problem in central Florida. Feral hogs not only disturb and consume native plants, but through indiscriminate rooting create unnaturally disturbed areas that serve as sites for establishment of exotic and adventive plant species, often in areas of otherwise native groundcover. Because of their explosive fecundity and the irreversible

damage they can do to native ground cover vegetation, measures need to be employed to attempt to control or eradicate nuisance populations of feral hogs.

Otherwise, among the exotic animals, relatively few threats are present. The exotic shiny cowbird is present in Florida, and is a potential nest parasite for many bird species, including the Florida grasshopper sparrow (Vickery 1996). However, the distribution of this species does not appear to be expanding, and it is not currently a threat to the regional avifauna. The lubber grasshopper is an exotic invertebrate that has become well-established throughout Florida in recent years, and while numbers appear to be low, they are toxic to predators, and are highly resistant to most pesticides.

Table 1. Classification of soil types recorded in dry prairie in the Kissimmee River prairie region (Bridges 1997, Bridges and Reese 1998).*

Soil Series	Soil Order	Soil Subgroup
EauGallie	Spodosols	Alfic Haplaquods
Immokalee	Spodosols	Arenic Haplaquods
Malabar	Alfisols	Grossarenic Ochraqualfs
Myakka	Spodosols	Aeric Haplaquods
Oldsmar	Spodosols	Alfic Arenic Haplaquods
Smyrna	Spodosols	Aeric Haplaquods
Valkaria	Entisols	Spodic Psammaquents* Of

* Of particular note are several soil subgroups which are principally Floridian in range. All soil series of dry prairie are restricted (endemic) to peninsular Florida (due to their hyperthermic temperature regime) (Orzell 1997).

Table 2. Soil associations most commonly associated with dry prairie.*

County	Predominant Soil Association	Secondary Soil Associations
Charlotte	Malabar - Oldsmar - Immokalee	Immokalee - Myakka Oldsmar - Myakka
DeSoto	Farmton - EauGallie - Malabar	Smyrna - Myakka - Immokalee Valkaria - Basinger- Malabar
Glades	Myakka - Immokalee - Smyrna	Pomello - Immokalee
Hardee	Smyrna - Myakka - Ona	
Hendry	Pineda - Oldsmar (s of LaBelle)	
Highlands	Oldsmar - EauGallie - Pomona	Felda - Hicoria - Malabar Myakka - Immokalee - Smyrna
Manatee	EauGallie - Floridana	Myakka - Waveland - Cassia
Okeechobee	Immokalee - Pompano	Myakka - Basinger
Osceola	EauGallie - Smryna - Malabar	Smyrna - Myakka - Immokalee
Polk	Malabar - EauGallie - Valkaria	Smyrna - Myakka - Immokalee
Sarasota	EauGallie - Myakka - Holopaw - Pineda	

* Sources: Charlotte County (Henderson 1984); Desoto County (Cowherd *et al.* 1989); Glades (D. Rutledge, Natural Resources Conservation Service, personal communication 1998); Hardee County (Robbins *et al.* 1984); Hendry County (Belz *et al*. 1990); Highlands County (Carter *et al*. 1989, Carter 1995, Soil Conservation Service 1983); Manatee County (Hyde and Huckle 1983); Okeechobee County (McCullum and Pendleton 1971); Osceola County (Readle 1979); Polk County (Ford *et al.* 1990, Carter 1995, Soil Conservation Service 1983); Sarasota County (Hyde *et al.* 1991).

Not all areas mapped within the soils associations in Table 2 necessarily support dry prairie. In some counties, the dry prairie landscape only occupies a small area within a widespread soil association, whereas in other counties it tends to occupy the major land area of a particular association. In general, the soil associations with Alfisols or soils with argillic (alfic) horizons (associations where either Oldsmar, Malabar, or EauGallie soils are prominent), tend to be more strongly associated with the larger areas of dry prairie. Differences in soil associations between counties in Table 2 is due in part to the ongoing evolution of soil taxonomy, and the differing publication dates of the county soil surveys. In general, a typical soil gradient on the Osceola Plain for dry prairie from dry to wet within the dry prairie landscape is EauGallie - Oldsmar - Malabar - Hicoria - Bradenton - Felda (Bridges 1997).

Table 3. Average percent cover by hydrologic zone in dry prairie, arranged from dry-mesic indicators to wet-mesic indicators (includes only species with an average cover of at least 0.5 % in at least one hydrologic zone) (from Bridges and Reese 1998).

SCIENTIFIC NAME	DRY-MESIC	MESIC	WET-MESIC
Quercus minima	22.0	19.1	10.8
Serenoa repens	9.9	12.6	3.9
Lyonia lucida	2.1	0.1	0.0
Lyonia fruticosa	1.9	1.0	0.0
Vaccinium myrsinites	1.9	0.7	0.1
Gaylussacia dumosa	1.5	0.7	0.0
Eleocharis baldwinii	1.6	1.3	0.2
Hypericum reductum	1.2	0.7	0.1
Liatris tenuifolia var. quadriflora	1.1	0.3	0.0
Andropogon virginicus var. decipiens	1.1	0.4	0.0
Andropogon brachystachyus	1.5	4.5	0.5
Scleria pauciflora	1.1	0.8	0.1
Dichanthelium ensifolium var. unciphyllum	1.2	0.9	0.2
Ilex glabra	1.0	0.6	0.1
Xyris brevifolia	0.9	0.6	0.1
Carphephorus odoratissimus	0.8	0.3	0.0
Galactia regularis	0.7	0.0	0.0
Pityopsis graminifolia	0.8	0.9	0.2
Gymnopogon chapmanianus	0.6	0.1	0.0
Andropogon ternarius var. cabanisii	1.0	1.0	0.4
Paspalum setaceum	0.6	0.4	0.1
Rhynchospora plumosa	0.9	1.3	0.4
Asimina reticulata	0.6	0.3	0.1
Pterocaulon pycnostachyum	0.5	0.2	0.0
Aristida spiciformis	0.5	1.0	0.1
Dichanthelium portoricense	0.6	0.6	0.3
Carphephorus paniculatus	0.5	2.0	0.1
Fimbristylis puberula	0.5	0.5	0.2
Rhynchospora fernaldii	0.3	0.5	0.0
Xyris caroliniana	0.4	0.6	0.2
Sorghastrum secundum	0.8	0.7	0.7
Licania michauxii	0.9	0.2	0.8

Table 3. ***cont.***

SCIENTIFIC NAME	DRY-MESIC	MESIC	WET-MESIC
Polygala rugelii	0.2	0.7	0.2
Drosera brevifolia	0.3	0.6	0.5
Syngonanthus flavidulus	1.1	1.3	1.3
Aristida rhizomophora	0.0	0.9	0.2
Andropogon virginicus var. glaucus	0.2	0.3	0.5
Euthamia tenuifolia	0.1	0.1	0.5
Chaptalia tomentosa	0.0	0.0	0.5
Rhexia nuttallii	0.2	0.7	0.6
Rhexia mariana	0.0	0.1	0.5
Marshallia tenuifolia	0.0	0.0	0.5
Dichanthelium leucothrix	0.0	0.1	0.7
Carphephorus carnosus	0.0	1.8	0.7
Rhexia nashii	0.0	0.1	0.8
Bigelowia nudata ssp. australis	0.0	0.2	0.8
Axonopus furcatus	0.0	0.4	0.8
Dichanthelium strigosum var. glabrescens	0.1	0.5	1.1
Amphicarpum muhlenbergianum	0.1	0.4	1.2
Andropogon virginicus var. virginicus	0.0	0.3	1.1
Lachnocaulon anceps	0.3	0.9	1.4
Erigeron vernus	0.0	1.6	1.3
Xyris ambigua	0.0	0.2	1.3
Helianthus angustifolius	0.0	0.0	1.6
Scleria reticularis	0.3	1.6	2.4
Schizachyrium stoloniferum	0.2	0.8	2.8
Rhynchospora breviseta	0.0	0.0	3.5
Xyris elliottii	0.0	1.0	4.4
Ctenium aromaticum	0.0	0.4	4.8
Aristida beyrichiana	14.3	13.3	26.7

Table 4. Plant species recorded for dry prairie.

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Agalinis linifolia				x		
Agalinis obtusifolia		x		x		
Agalinis purpurea				x		x
Agalinis tenuifolia						x
Aletris lutea		x				x
Amphicarpum muhlenbergianum		x	x	x	x	x
Andropogon brachystachyus		x	x	x	x	x
Andropogon glomeratus var. glaucopsis		x	x	x		x
Andropogon glomeratus var. hirsutior			x	x		
Andropogon glomeratus var. pumilus						x
Andropogon gyrans var. gyrans	x		x			x
Andropogon gyrans var. stenophyllus		x				
Andropogon ternarius var. cabanisii		x	x	x	x	x
Andropogon virginicus var. decipiens		x	x	x		
Andropogon virginicus var. glaucus		x	x	x	x	x
Andropogon virginicus var. virginicus	x	x	x	x		x
Aristida beyrichiana	x	x	x	x	x	x
Aristida gyrans	x					
Aristida patula	x					x
Aristida purpurascens var. purpurascens		x				
Aristida purpurascens var. tenuispica		x	x	x		x
Aristida purpurascens var. virgata						x
Aristida rhizomophora			x			
Aristida spiciformis		x	x	x	x	x
Arnoglossum ovatum	x					x
Asclepias connivens						x
Asclepias feayi						x
Asclepias pedicellata		x	x	x		x
Asclepias tuberosa ssp. rolfsii						x
Asimina reticulata		x	x	x	x	x
Aster adnatus	x					x
Aster dumosus		x	x	x	x	x
Aster reticulatus			x	x		x
Aster simmondsii			x			

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Aster subulatus						x
Aster tortifolius			x			x
Aster walteri	x					
Axonopus compressus	x	x				
Axonopus fissifolius						x
Axonopus furcatus		x	x	x	x	x
Bartonia verna		x				x
Bartonia virginica		x	x			
Befaria racemosa		x	x	x	x	x
Bidens mitis			x			
Bigelowia nudata ssp. australis		x	x	x	x	
Buchnera americana		x	x	x		
Bulbostylis ciliatifolia	x	x				
Burmannia biflora	x					x
Burmannia capitata	x	x			x	
Callicarpa americana			x			x
Calopogon multiflorus	x	x		x		x
Calopogon pallidus		x				x
Carphephorus carnosus		x	x	x	x	
Carphephorus corymbosus		x	x	x	x	x
Carphephorus odoratissimus	x	x	x	x		x
Carphephorus paniculatus	x	x	x	x	x	x
Cassytha filiformis	x					x
Centella asiatica		x	x	x		
Centrosema virginianum	x					x
Chamaecrista fasciculata						x
Chamaecrista nictitans var. aspera	x		x	x		
Chapmannia floridana						
Chaptalia tomentosa	x	x	x	x	x	x
Chrysopsis mariana						x
Cinnamomum camphora						x
Clematis baldwinii						x
Cnidoscolus stimulosus		x	x	x		x
Commelina erecta	x					x

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Coreopsis floridana			x			x
Crotalaria rotundifolia			x	x		x
Ctenium aromaticum	x	x	x	x		
Cuthbertia ornata						x
Cyperus croceus	x					x
Cyperus haspan			x			x
Cyperus polystachyos		x	x			
Cyperus retrorsus		x	x			
Dalea carnea var. carnea	x					x
Desmodium tenuifolium						x
Dichanthelium acuminatum						
Dichanthelium dichotomum	x	x			x	
Dichanthelium ensifolium var. ensifolium		x	x			x
Dichanthelium ensifolium var. unciphyllum		x	x	x		x
Dichanthelium erectifolium	x		x			
Dichanthelium leucothrix		x	x	x		
Dichanthelium portoricense		x	x	x		x
Dichanthelium strigosum var. glabrescens	x	x	x	x	x	x
Dichanthelium strigosum var. strigosum		x				
Diodia virginiana			x	x		x
Diospyros virginiana						x
Drosera brevifolia		x	x	x	x	
Drosera capillaris		x	x	x		x
Dyschoriste oblongifolia	x					x
Eleocharis baldwinii		x	x	x	x	x
Eleocharis flavescens	x	x				
Eleocharis geniculata						x
Eleocharis nigrescens						x
Elephantopus elatus			x	x	x	x
Eragrostis atrovirens	x					x
Eragrostis elliottii		x	x	x	x	x
Eragrostis virginica		x	x	x		x
Erigeron vernus	x	x	x	x	x	x
Eriocaulon decangulare		x	x			

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Eriocaulon ravenelii				x		
Eryngium aromaticum						
Eryngium yuccifolium	x	x	x	x		x
Erythrina herbacea						x
Eucalyptus rudis						x
Eulophia alta						x
Eupatorium recurvans		x	x	x	x	x
Eupatorium rotundifolium		x	x	x	x	x
Eupatorium serotinum						x
Euphorbia inundata		x				
Eustachys glauca						x
Eustachys petraea						
Euthamia tenuifolia	x	x	x	x	x	x
Fimbristylis caroliniana	x		x			x
Fimbristylis dichotoma						
Fimbristylis puberula	x	x	x	x	x	x
Fimbristylis schoenoides						x
Fuirena scirpoidea		x	x	x		
Galactia elliottii		x	x			x
Galactia regularis	x	x	x			x
Galactia volubilis	x					x
Gaura angustifolia						x
Gaylussacia dumosa		x	x	x		x
Gaylussacia nana	x					x
Gelsemium sempervirens						x
Glandularia tampensis						x
Gratiola hispida		x	x	x		x
Gratiola pilosa	x	x		x		x
Gratiola ramosa			x			
Gymnopogon brevifolius			x			
Gymnopogon chapmanianus		x	x	x	x	x
Habenaria floribunda	x					x
Hedyotis corymbosa						x
Hedyotis procumbens			x			x

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Hedyotis uniflora	x	x	x			x
Helianthemum corymbosum						x
Helianthus angustifolius	x	x	x			x
Helianthus floridanus	x					x
Helianthus radula				x		
Heliotropium polyphyllum				x		x
Hieracium megacephalon			x			x
Hymenocallis palmeri	x		x			
Hypericum cistifolium		x		x		x
Hypericum crux-andreae						x
Hypericum fasciculatum			x			
Hypericum gentianoides						x
Hypericum myrtifolium		x	x	x	x	x
Hypericum reductum		x	x	x	x	x
Hypericum tetrapetalum		x	x	x		x
Hypoxis juncea	x	x	x	x	x	x
Hyptis alata	x		x	x		
Ilex glabra		x	x	x	x	x
Imperata brasiliensis	x					x
Indigofera hirsuta						
Juncus marginatus var. biflorus	x	x	x			
Juncus scirpoides		x			x	x
Lachnanthes caroliniana	x	x	x	x		x
Lachnocaulon anceps		x	x	x	x	x
Lachnocaulon beyrichianum	x	x				
Lechea torreyi		x	x	x		x
Leptochloa fascicularis						x
Liatris garberi				x		x
Liatris gracilis		x			x	x
Liatris spicata		x	x	x		
Liatris tenuifolia var. quadriflora		x	x	x	x	x
Licania michauxii		x			x	x
Lilium catesbaei	x	x	x	x	x	x
Lindernia grandiflora	x					

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Linum medium var. texanum	x		x	x	x	x
Listera australis						x
Lobelia glandulosa		x	x	x		
Lobelia paludosa		x	x	x		x
Ludwigia curtissii				x		
Ludwigia erecta						x
Ludwigia lanceolata						x
Ludwigia linifolia			x	x		
Ludwigia maritima		x	x	x	x	x
Ludwigia suffruticosa	x		x	x		x
Lycopodiella alopecuroides		x				
Lycopodiella cernua						x
Lycopodiella prostrata		x				
Lygodesmia aphylla		x	x	x		x
Lyonia fruticosa	x	x	x	x	x	x
Lyonia lucida	x	x	x	x		x
Marshallia tenuifolia		x	x	x		
Melaleuca quinquenervia						x
Melanthera nivea						x
Melochia spicata						x
Mitreola sessilifolia				x		x
Muhlenbergia capillaris var. filpes						x
Myrica cerifera		x	x	x	x	x
Opuntia humifusa	x					
Osmunda cinnamomea	x					x
Oxypolis filiformis		x	x	x		
Panicum abscissum		x				
Panicum anceps			x			
Panicum hemitomon	x		x			
Panicum longifolium		x	x	x		
Panicum rigidulum						x
Panicum tenerum		x		x		
Panicum verrucosum					x	x
Panicum virgatum						x

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Parthenocissus quinquefolia						x
Paspalum floridanum						x
Paspalum laeve		x				x
Paspalum notatum var. saurae						
Paspalum praecox	x	x	x	x		
Paspalum setaceum		x	x	x	x	x
Penstemon multiflorus						x
Phoebanthus grandiflorus		x	x	x	x	
Physostegia purpurea				x		
Piloblephis rigida						x
Pinguicula caerulea						x
Pinguicula lutea		x	x			x
Pinguicula pumila		x	x			x
Pinus elliottii						x
Pinus palustris	x					x
Piptochaetium avenacioides						x
Piriqueta caroliniana				x		x
Pityopsis graminifolia		x	x	x	x	x
Pluchea rosea	x		x	x		
Polygala cruciata				x		x
Polygala grandiflora						x
Polygala incarnata		x		x		x
Polygala lutea		x	x	x	x	x
Polygala nana						x
Polygala ramosa	x	x		x		x
Polygala rugelii		x	x	x	x	x
Polygala setacea		x	x	x	x	x
Pteridium aquilinum var. latiusculum	x		x			x
Pterocaulon pycnostachyum		x	x	x	x	x
Pteroglossaspis ecristata	x	x				x
Quercus geminata	x					
Quercus hemispherica	x					x
Quercus laurifolia					x	
Quercus minima		x	x	x	x	x

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Quercus pumila	x	x	x	x	x	x
Rhexia cubensis		x	x			
Rhexia mariana		x	x	x	x	x
Rhexia nashii	x	x	x	x		
Rhexia nuttallii		x	x	x	x	x
Rhexia petiolata	x					x
Rhus copallina	x					x
Rhynchospora baldwinii	x	x	x			
Rhynchospora breviseta		x	x	x	x	
Rhynchospora cephalantha			x			
Rhynchospora chapmanii						x
Rhynchospora ciliaris		x	x			x
Rhynchospora fascicularis		x	x	x	x	x
Rhynchospora fascicularis var. distans	x	x				
Rhynchospora fernaldii		x	x	x	x	x
Rhynchospora filifolia		x	x	x		
Rhynchospora inundata			x		x	
Rhynchospora microcarpa						x
Rhynchospora microcephala			x			x
Rhynchospora plumosa		x	x	x	x	x
Rhynchospora pusilla	x	x	x	x		
Rhynchospora rariflora		x	x			
Rubus cuneifolius						
Sabal palmetto	x					x
Sabatia brevifolia		x	x	x	x	x
Sabatia grandiflora	x	x		x		
Saccharum giganteum						x
Sacciolepis indica		x	x	x		
Samolus valerandi subsp. parviflorus						x
Sarracenia minor				x		
Schinus terebinthifolius						x
Schizachyrium stoloniferum		x	x	x	x	x
Schrankia microphylla var. floridana	x					
Scleria georgiana	x	x	x	x		

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Scleria hirtella				x		
Scleria pauciflora		x	x	x		x
Scleria reticularis		x	x	x	x	
Scleria triglomerata	x	x				x
Scoparia dulcis			x			
Scutellaria integrifolia	x					x
Serenoa repens		x	x	x	x	x
Setaria geniculata	x	x	x			x
Seymeria pectinata		x		x		
Sisyrinchium angustifolium		x	x	x		
Sisyrinchium atlanticum						x
Smilax auriculata					x	x
Smilax bona-nox	x					x
Solidago fistulosa		x	x	x	x	x
Solidago odora var. chapmanii	x			x		x
Solidago stricta			x		x	x
Solidago tortifolia						x
Sorghastrum nutans						x
Sorghastrum secundum		x	x	x	x	x
Spermacoce assurgens	x					
Spiranthes longilabris	x	x				x
Spiranthes praecox						x
Spiranthes vernalis		x		x		x
Sporobolus indicus						x
Sporobolus junceus			x	x		x
Stenandrium dulce	x					x
Stillingia sylvatica ssp. sylvatica		x	x	x		x
Stillingia sylvatica ssp. tenuis	x			x		x
Stipulicida setacea var. setacea						
Syngonanthus flavidulus	x	x	x	x	x	x
Tephrosia hispidula	x	x	x	x	x	
Tephrosia rugelii						
Tillandsia recurvata	x					x
Tillandsia usneoides						x

Table 4. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Urena lobata			x			
Utricularia simulans	x	x	x		x	
Utricularia subulata		x	x	x	x	x
Vaccinium corymbosum	x					x
Vaccinium darrowii						x
Vaccinium myrsinites		x	x	x	x	x
Vaccinium stamineum	x					x
Vernonia blodgettii						x
Viola lanceolata			x			
Viola primulifolia						x
Viola septemloba						x
Vitis aestivalis						x
Vitis rotundifolia var. rotundifolia						x
Vitis shuttleworthii						x
Xyris ambigua		x	x	x	x	x
Xyris brevifolia		x	x	x	x	x
Xyris caroliniana		x	x	x	x	x
Xyris difformis var. floridana	x	x	x	x	x	x
Xyris elliottii		x	x	x	x	x
Xyris flabelliformis		x	x			x
Xyris jupicai						x
Xyris platylepis		x	x			x
Yucca filamentosa						x
Zigadenus densus	x			x		x

*** Sources for county dry prairie floras:**

Hardee County (Cole et al. 1994a) - seems to include only dry and dry-mesic hydrologic zones, and also includes some disturbed areas; Highlands County - Bridges (1997), Bridges and Reese (1998) - quantitative sampling and compiled floristic lists from dry prairie habitats at Avon Park Air Force Range; Okeechobee County - Bridges (1998a), Bridges and Reese (1998) - quantitative sampling and floristic lists from Audubon Kissimmee Prairie Sanctuary and from Kissimmee Prairie State Preserve; Osceola County - Bridges and Reese (1998), Orzell and Bridges (unpublished data) - quantitative sampling and floristic lists from Three Lakes Wildlife Management Area; Polk County - Bridges (1997) - quantitative sampling and compiled floristic lists from dry prairie habitats at Avon Park Air Force Range; Sarasota and Manatee counties - Huffman and Judd (1998) - species noted as occurring in dry prairie, Myakka River State Park (unpublished data) - species listed for "dry prairie and flatwoods" in the park floristic list (note that this may include some species found only in flatwoods not in dry prairie), Bridges (unpublished data) - floristic lists complied in dry prairie at Myakka River State Park.

Table 5. Species recorded from dry prairie in at least three counties (sources are same as Table 4).

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Amphicarpum muhlenbergianum		x	x	x	x	x
Andropogon brachystachyus		x	x	x	x	x
Andropogon glomeratus var. glaucopsis		x	x	x		x
Andropogon ternarius var. cabanisii		x	x	x	x	x
Andropogon virginicus var. decipiens		x	x	x		
Andropogon virginicus var. glaucus	x	x	x	x	x	x
Andropogon virginicus var. virginicus	x	x	x	x		x
Aristida beyrichiana	x	x	x	x	x	x
Aristida purpurascens var. tenuispica		x	x	x		x
Aristida spiciformis	x	x	x	x	x	x
Asclepias pedicellata		x	x	x		x
Asimina reticulata	x	x	x	x	x	x
Aster dumosus		x	x	x	x	x
Aster reticulatus			x	x		x
Aster tortifolius	x		x			x
Axonopus furcatus		x	x	x	x	x
Befaria racemosa		x	x	x	x	x
Bigelowia nudata ssp. australis		x	x	x	x	
Buchnera americana	x	x	x	x		
Callicarpa americana	x		x			x
Calopogon multiflorus		x	x	x		x
Carphephorus carnosus		x	x	x	x	
Carphephorus corymbosus	x	x	x	x	x	x
Carphephorus odoratissimus	x	x	x	x		x
Carphephorus paniculatus	x	x	x	x	x	x
Centella asiatica	x	x	x	x		
Chaptalia tomentosa		x	x	x	x	x
Cnidoscolus stimulosus	x	x	x	x		x
Crotalaria rotundifolia	x		x	x		x
Ctenium aromaticum		x	x	x		
Cyperus retrorsus	x	x	x			
Dichanthelium ensifolium var. ensifolium		x	x			x

Table 5. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Dichanthelium ensifolium var. unciphyllum	x	x	x	x		x
Dichanthelium leucothrix		x	x	x		
Dichanthelium portoricense	x	x	x	x		x
Dichanthelium strigosum var. glabrescens		x	x	x	x	x
Diodia virginiana			x	x		x
Drosera brevifolia		x	x	x	x	
Drosera capillaris	x	x	x	x		x
Eleocharis baldwinii	x	x	x	x	x	x
Elephantopus elatus	x		x	x	x	x
Eragrostis elliottii		x	x	x	x	x
Eragrostis virginica	x	x	x	x		x
Erigeron vernus		x	x	x	x	x
Eryngium yuccifolium		x	x	x		x
Eupatorium recurvans		x	x	x	x	x
Eupatorium rotundifolium		x	x	x	x	x
Euthamia tenuifolia	x	x	x	x	x	x
Fimbristylis puberula		x	x	x	x	x
Fuirena scirpoidea		x	x	x		
Galactia elliottii	x	x	x			x
Galactia regularis	x	x	x			x
Gaylussacia dumosa	x	x	x	x		x
Gratiola hispida	x	x	x	x		x
Gratiola pilosa		x		x		x
Gymnopogon chapmanianus	x	x	x	x	x	x
Hedyotis procumbens	x		x			x
Hedyotis uniflora		x	x			x
Helianthus angustifolius	x	x	x			x
Hieracium megacephalon	x		x			x
Hypericum cistifolium		x		x		x
Hypericum myrtifolium		x	x	x	x	x
Hypericum reductum		x	x	x	x	x
Hypericum tetrapetalum	x	x	x	x		x
Hypoxis juncea	x	x	x	x	x	x

Table 5. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Ilex glabra	x	x	x	x	x	x
Juncus scirpoides	x	x			x	x
Lachnanthes caroliniana		x	x	x		x
Lachnocaulon anceps	x	x	x	x	x	x
Lechea torreyi		x	x	x		x
Liatris gracilis		x			x	x
Liatris spicata		x	x	x		
Liatris tenuifolia var. quadriflora		x	x	x	x	x
Licania michauxii	x	x			x	x
Lilium catesbaei	x	x	x	x	x	x
Linum medium var. texanum			x	x	x	x
Lobelia glandulosa		x	x	x		
Lobelia paludosa		x	x	x		x
Ludwigia maritima	x	x	x	x	x	x
Ludwigia suffruticosa			x	x		x
Lygodesmia aphylla	x	x	x	x		x
Lyonia fruticosa	x	x	x	x	x	x
Lyonia lucida		x	x	x		x
Marshallia tenuifolia		x	x	x		
Myrica cerifera	x	x	x	x	x	x
Oxypolis filiformis		x	x	x		
Panicum longifolium		x	x	x		
Paspalum praecox		x	x	x		
Paspalum setaceum		x	x	x	x	x
Phoebanthus grandiflorus		x	x	x	x	
Pinguicula lutea		x	x			x
Pinguicula pumila		x	x			x
Pityopsis graminifolia	x	x	x	x	x	x
Polygala incarnata		x		x		x
Polygala lutea		x	x	x	x	x
Polygala ramosa		x		x		x
Polygala rugelii		x	x	x	x	x
Polygala setacea	x	x	x	x	x	x

Table 5. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Pterocaulon pycnostachyum	x	x	x	x	x	x
Pteroglossaspis ecristata	x	x				x
Quercus minima	x	x	x	x	x	x
Quercus pumila		x	x	x	x	x
Rhexia mariana	x	x	x	x	x	x
Rhexia nashii		x	x	x		
Rhexia nuttallii	x	x	x	x	x	x
Rhynchospora breviseta		x	x	x	x	
Rhynchospora ciliaris		x	x			x
Rhynchospora fascicularis	x	x	x	x	x	x
Rhynchospora fernaldii		x	x	x	x	x
Rhynchospora filifolia		x	x	x		
Rhynchospora plumosa	x	x	x	x	x	x
Rhynchospora pusilla		x	x	x		
Sabatia brevifolia	x	x	x	x	x	x
Sacciolepis indica		x	x	x		
Schizachyrium stoloniferum	x	x	x	x	x	x
Scleria georgiana		x	x	x		
Scleria pauciflora		x	x	x		x
Scleria reticularis	x	x	x	x	x	
Serenoa repens	x	x	x	x	x	x
Setaria geniculata		x	x			x
Sisyrinchium angustifolium		x	x	x		
Smilax auriculata	x				x	x
Solidago fistulosa	x	x	x	x	x	x
Solidago stricta			x		x	x
Sorghastrum secundum	x	x	x	x	x	x
Spiranthes vernalis		x		x		x
Sporobolus junceus	x		x	x		x
Stillingia sylvatica ssp. sylvatica	x	x	x	x		x
Syngonanthus flavidulus	x	x	x	x	x	x
Tephrosia hispidula		x	x	x	x	
Utricularia simulans		x	x		x	
Utricularia subulata	x	x	x	x	x	x

Table 5. ***cont.***

Scientific Name	Hardee	Highlands	Okeechobee	Osceola	Polk	Sarasota
Vaccinium myrsinites	x	x	x	x	x	x
Xyris ambigua		x	x	x	x	x
Xyris brevifolia		x	x	x	x	x
Xyris caroliniana	x	x	x	x	x	x
Xyris difformis var. floridana		x	x	x	x	x
Xyris elliottii		x	x	x	x	x
Xyris flabelliformis		x	x			x
Xyris platylepis		x	x			x

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Restoration of Dry Prairie

Restoration Objective: Maintain and enhance the structure, function, and composition of the dry prairie community, protect dry prairie biodiversity to encompass the range of geographic variation, and increase the spatial extent of dry prairie habitat in South Florida.

Restoration Criteria

The restoration objective will be achieved when: (1) dry prairies within the historic range of the community are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression; (2) degraded areas are identified, acquired and restored to suitable dry prairie habitat; (3) appropriate ecosystem management plans (including monitoring and research) have been prepared, funded, and implemented for long-term perpetuation of the dry prairie landscape; (4) dry prairie is appropriately protected and managed to benefit community-dependent species; (5) ecological linkages to adjacent communities are restored; and (6) landscape-level habitat diversity is restored.

Community-level Restoration Actions

1. **Determine the historical and current distribution and status of dry prairie in peninsular Florida.** Published and unpublished data on both the distribution and status of dry prairie is inconsistent and based in part on misinterpretation of Landsat data (see section on Status and Trends in this account). Estimates of the current status of dry prairie vary from virtually none remaining to rather large blocks remaining on privately owned rangeland.

    1.1. **Determine the historical extent and location of dry prairie for all counties in the dry prairie region** as defined by Davis (1943), by utilizing the original land surveys for Florida conducted in the 1850s. These land surveys could be used to produce a historical map of Florida dry prairie and calculate the historical area of dry prairie for each county. See discussion on Status and Trends in this account.

    1.2. **Determine the current distribution and status of dry prairie on both private and public lands in Florida.** This action could be accomplished by using recent aerial photography and Landsat imagery that has been intensively ground-truthed to eliminate errors in interpretation. Digital Orthophoto Quads (DOQ's) could be used to digitize the current distribution of dry prairie as a GIS coverage.

1.3. Identify, map, and conduct ecological (plant and animal) inventories of the remaining dry prairie to determine locations for the highest-quality dry prairie sites. Data from a systematic and comprehensive inventory could be used to develop, rank and prioritize the most ecologically significant dry prairie areas and determine the degree of vulnerability of sites. Plant and animal inventories and *de novo* searches for rare species would uncover previously unknown sites and thereby provide updated documentation on the status and distribution of rare species.

2. Prevent further destruction or degradation of existing dry prairie.

2.1. Secure protection of all the remaining intact, high-quality dry prairie sites. Develop a protection plan for all tracts identified in **1.2** and **1.3.** Continue through land acquisition, landowner agreements, and conservation easements, land trades, or other conservation measures, protection of dry prairie sites. Priority should be placed on preventing the loss of any remaining high-quality dry prairie sites, with emphasis on protection of sites with intact landscapes and an intact, diverse native ground cover. Devise and negotiate interagency agreements (with WMDs, DEP, FWS, *etc.*) to improve mitigation procedures for loss of wetlands in dry prairie landscapes. Sites identified as most threatened with destruction should be targeted and protected to prevent destruction.

2.2. Prevent further degradation of disturbed, but recoverable examples of dry prairie by securing protection of such sites. This may best be accomplished by conservation methods other than land acquisition that prevent development, such as conservation easements, particularly on large cattle ranches where land acquisition is cost-prohibitive.

2.3. Ensure proper protection of existing protected areas. Drainage and other hydrologic alterations on private land adjacent to existing protected areas continues to be an ongoing and unresolved crisis on at least two protected sites-Three Lakes WMA in Osceola County, and the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary in Okeechobee County. Federal and State agencies need to work more efficiently and closely together to solve problems that cross the jurisdictional boundaries of an agency.

2.4. Ensure proper management of existing protected areas. Staffing and budgetary constraints continue to present the greatest threat to proper management of existing protected areas. Other problems faced by land managers that hinder implementation of proper management strategies include lack of technical guidance information, and insufficient equipment and manpower. In the formulation of management plans, avoid uniformity of management treatments which artificially simplify what probably was once a far more varied set of communities that constituted prairie biodiversity (Howe 1994). Varied treatments and experimental management should be encouraged, since so few quantitative studies exist on management effects on prairie biodiversity (Howe 1994). A rethinking of management priorities is needed if such experiments suggest that prairie biodiversity could be managed out of existence by certain practices (Howe 1994).

2.5. Develop private landowner protection incentives for dry prairie (Enge *et al.* 1997). Provide an economic or tax incentive to private landowners to prevent conversion of native pastureland into improved pastureland. Federal, State and

county governments should explore new and innovative ways to provide tax breaks or other economic incentives to private landowners that choose ecological stewardship of their lands. Economic opportunities for private landowners to retain native vegetation should be encouraged, including hunting, eco-tourism, low-intensity grazing of native rangeland, harvesting of native grass seed for mining reclamation and other restoration purposes, and harvesting of saw palmetto fruits for medicinal uses. All of these help provide economic incentives to landowners to retain areas in natural dry prairie vegetation.

2.6. **Connect existing dry prairie preserves 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. Lands acquired as connectors between dry prairie preserves need not be dry prairie. Historically, the dry prairie/flatwoods landscape covered vast areas of south-central Florida, and this pattern should be maintained as much as possible.

2.7. **Conduct vegetation monitoring of dry prairie to determine responses to various management strategies.** Several potential results could come from vegetation monitoring of dry prairie habitat which have implications for the Florida grasshopper sparrow. First, by considering the effects of management on a broader set of ecosystem components (*e.g.* all the plant species present), the possibility of misleading results (in the context of ecosystem management) based on a single species subject to possible non-management related events (*i.e.* predation) is minimized. Secondly, because much more replication is possible in a vegetation study, the chances of uncovering statistically significant differences between treatments is increased. Thirdly, long-term trends in the abundance of conservative versus weedy or opportunistic species can be monitored within vegetation monitoring plots, and can be used as input for management decisions. The long-term population trends of Florida grasshopper sparrows are best addressed by beginning to monitor the health of the ecosystem as a whole, and a better understanding of the microhabitats selected by the species in order to incorporate the perpetuation of these microhabitats into ecosystem management decisions.

2.8. **Encourage and support the efforts of the central and South Florida interagency prescribed fire councils.** Without the ability and flexibility to use prescribed burning, management of dry prairie would be virtually impossible. The role of the prescribed fire councils in safeguarding, promoting and educating the public about the use of prescribed fire is essential to the future of prescribed burning.

3. **Restore existing degraded dry prairies.** Develop techniques for restoring modified or disturbed dry prairie (Enge *et al.* 1997) and criteria for monitoring the success of restoration efforts (Anderson 1997, Zedler 1997).

3.1. **Reintroduce natural fires and/or prescribed controlled burns.** Dry prairies that have been degraded due to fire exclusion can be restored with prescribed burning. Each protected dry prairie site should have a fire management plan. Management plans should specifically include allowing natural, lightning-ignited fires to burn through the dry prairie landscape whenever possible, especially on the larger preserves, such as the Kissimmee Prairie State Preserve and the National Audubon

Society's Ordway-Whittell Kissimmee Prairie Sanctuary. Burn plans for sites should specify fire type, intensity and frequency in order to mimic natural fires and to meet management objectives.

3.2. **Encourage maintenance and recovery of landscape-level ecological processes.** Where possible, management efforts should strive to maintain and enhance ecological processes (natural fire regimes, natural hydrologic perturbations, biological interactions, ecosystem function, *etc.*) characteristic of the natural landscape. In particular, allowing natural lightning fires and other natural disturbances should receive special attention in management plans for areas with intact landscapes. Firebreaks and roads should be placed well away from ecotones. Ecotones that have been degraded by existing roads and fire breaks should be restored.

3.3. **Eliminate or control exotic and off-site species.** The native ground cover of some dry prairies has been altered by past attempts to improve their livestock grazing potential and/or commercial forestry potential. Efforts to eliminate or control exotic plants should be implemented. In addition, total eradication of feral hogs should be a priority on dry prairie preserves.

3.4. **Continue to allow compatible public uses.** Dry prairies acquired for conservation of biotic resources must be protected from inappropriate public use. However, compatible public uses are very valuable in public education about the ecosystem and the need for conservation. Off-road vehicle use and destructive commercial rare plant collecting are not compatible with preservation.

3.5. **Monitor for negative population trends among important dry prairie plant and animal species.** Each dry prairie preserve should have a specific monitoring plan that will alert land managers to extirpation or downward trends in populations of selected dry prairie species, including endemic species, listed species, and keystone species.

3.6. **Monitor and eliminate hydrologic alterations.** Recent hydrologic alterations created by adjacent landowners to control water flows on their properties present a real and current threat on Three Lakes WMA in Osceola County and the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary in Okeechobee County. Vegetation sampling and monitoring of permanent vegetation plots is needed to determine the effects of hydrologic alteration on dry prairie vegetation.

4. **Create dry prairie analogs where dry prairie has been destroyed by human activities such as mining.** In Polk County, Callahan *et al.* (1990) report on preliminary results that suggest the costs of creating "moderate-quality" examples of "palmetto prairie" on a 60 ha parcel of mined land, although higher in initial cost than creating pastures, may not be as high as formerly reported. Callahan *et al.* (1990) report that while improved pastures can be created on mined land by seeding alone, actual restoration of prairies requires topsoiling, intensive planting of herbaceous species, direct seeding, or a combination of these methods, at a higher initial cost. However, Callahan *et al.* (1990) state that prairies might be nearly maintenance-free, while pastures are accompanied by higher land management expenses. Efforts to revegetate former strip mine lands using native species should continue (Callahan and Cates 1991).

5. **Encourage ecosystem/landscape level research projects in dry prairie.** Identify ecosystem processes (vegetation composition and structure, successional patterns, hydrologic regimes, burn regimes, herbivory, *etc*.) in dry prairie and use research findings to aid in development of management guidelines and strategies (Enge *et al.* 1997). Provide useful information on current research needs to IFAS Southwest Florida Research and Education Centers (SWFREC) Agro-Ecology and Natural Resources Advisory Committee (Enge *et al.* 1997).

5.1. **Determine the rangewide geographic variation in the dry prairie ecosystem.** Conduct rangewide studies incorporating floristic surveys (considering species composition, phytogeographic patterns, relative frequency data, and vegetative physiognomy), faunal surveys and correlated environmental parameters (climate, hydrology, edaphic factors and regional landscape context) to recognize and differentiate regional variation in dry prairie. There is considerable regional diversity in peninsular Florida pine flatwoods and savannas (Orzell and Bridges 1997), and preliminary findings by Bridges and Reese (1998) suggest that there is also regional variation in dry prairie. In order to protect the biodiversity of dry prairie there need to be studies to determine the geographic variation within dry prairie.

5.2. **Fund and conduct research on the effects of livestock grazing on dry prairie.** Since much of the economic incentive to private landowners to retain dry prairie is derived from revenues generated from livestock grazing, it is important to fund studies evaluating the effects of livestock grazing on all components of the dry prairie ecosystem, including the effects on specific plants and animals. Funding to evaluate the effects of livestock grazing on dry prairie vegetation through establishment of permanent plots and grazing exclosures to monitor the long-term effects of livestock grazing should be encouraged. Funding should be secured to continue ongoing projects (*i.e.,* Bridges *et al.* 1998), initially funded by Avon Park Air Force Range, to evaluate the effects of grazing on dry prairie vegetation and the Florida grasshopper sparrow.

5.3. **Encourage research on prescribed burning in dry prairie.** As more dry prairie is purchased and/or protected, management knowledge about the effects of fire frequency, intensity and seasonality will become increasingly important to maintenance of the biodiversity of the dry prairie landscape. Recent trends of land managers to burn at times other than early spring and early summer, in order to avoid impacting any potentially listed birds needs to be studied (see section above in this account). In addition, the long-term effects of differing fire frequencies needs study, since recent trends indicate that many land managers of public properties are burning dry prairie typically on a 3-year rotation, rather than the more natural annual or biennial burn cycle. Knowledge about the natural fire season and research on fire intervals would lead to initiation of improved fire management programs (Dye 1997).

5.4. Conduct research to determine the applicability and effectiveness of various mechanical treatments for restoration of severely degraded dry prairies. Former dry prairies that have been degraded due to fire suppression or other disturbances may benefit from controlled burns and some mechanical restoration treatments, such as rollerchopping. Work initiated by Tanner (1997) and Fitzgerald *et al.* (1995) should receive continuing funding to determine long-term effects and trends.

6. Increase awareness and knowledge of the dry prairie ecosystem.

6.1. Provide support for a regional 1-3 day symposium on the Florida dry prairie ecosystem. The Florida Native Plant Society, Florida Department of Environmental Protection Division of State Land Management, Avon Park Air Force Range Natural Resources Flight, Florida Chapter of The Nature Conservancy, Florida Game and Fresh Water Fish Commission Non-game Wildlife Program, Florida Chapter of the National Audubon Society, FWS South Florida Office, and Southeastern Chapter of the Society for Ecological Restoration should sponsor, participate and support a symposium on Florida dry prairie. Ongoing and past research funded by the Department of Defense on rare dry prairies species and vegetation composition, along with research at Myakka River SP, the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary, and inventory efforts at the Kissimmee Prairie State Preserve could be highlighted. In addition, land managers of privately owned rangelands and other public lands should be encouraged to attend and make presentations on their management practices and results.

6.2. Provide technical advisory support to private landowners of dry prairie. Provide technical information on ecosystem management strategies and practices to private landowners willing and interested in protecting biodiversity of dry prairie.

6.3. Increase public awareness and understanding of the dry prairie ecosystem. Public understanding and approval are required for any conservation effort to be successful. Public announcements should highlight land acquisition projects such as Florida's Conservation and Recreational Lands (CARL) program and Preservation-2000. Environmental education programs in South Florida should be encouraged to distribute materials or develop lesson plans on dry prairie habitats, dry prairie species, and the importance of maintaining natural biodiversity. A recent article by Benshoff (1998), "Florida dry prairie, an endangered land," published in Wildlife and Nature, Florida's Outdoor Magazine is an excellent example for educational purposes. Develop a Wildlife Series, like others at GFC, and an education campaign on dry prairie (Enge *et al.* 1997).

Cutthroat Grass Communities

FNAI Global Rank:	**G2**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**1**
State Listed Species in S. FL:	**13**

Cutthroat grass community.
Original photograph by Betty Wargo.



Cutthroat grass (*Panicum abscissum*) is a central peninsular Florida endemic species, found in scattered locations from Orange County south to Palm Beach County. However, it seems to dominate natural communities almost exclusively within Polk and Highlands counties, in association with the sideslopes of the central Florida Ridges. Cutthroat grass communities are mostly associated with areas of slight to strong groundwater seepage; however, not all cutthroat grass communities are well-developed seepage slopes.

Cutthroat grass communities fall into several community types-a cutthroat grass seepage slope complex with 11 microhabitat zones, cutthroat grass mesic flatwoods and dry prairies, cutthroat grass wet flatwoods, cutthroat grass depression marsh margins, cutthroat grass ecotones between flatwoods and drainageways, cutthroat grass wet prairies, and slash pine/cutthroat grass "basin swamp." Each of these can be characterized by differences in landform, topographic position, hydrology, soils, and dominant or characteristic plant species. The cutthroat grass seepage slope complex consists of distinct vegetation zones which vary in hydrology, soils, and species composition, ranging from dry cutthroat grass with only subsurface soil saturation, to mixed herbaceous seepage slopes with a constant year-round water table at the surface of the deep muck soil.

Cutthroat grass communities require frequent fire for maintenance of the open, graminoid-dominated character of these areas. The greatest threats to the integrity of cutthroat grass communities are continued fire-suppression and drainage effects. Even on protected lands, many cutthroat grass communities are not fire-managed aggressively enough to preserve the biodiversity of these community types.

Cutthroat grass communities cover more than 5,800 ha (14,326 acres) at Avon Park AFR, the largest areal extent remaining for these communities. Diverse, fire-maintained cutthroat grass vegetation continuums with intact

species-rich ecotones are now found only in association with the Bombing Range Ridge in Polk and Highlands counties, although they likely historically also occurred in association with the Lake Wales Ridge. These communities support large populations of the endemic *Hartwrightia floridana*, and disjunct populations of species which are more common in seepage slopes of the Florida Panhandle, such as *Myrica heterophylla* and *Rhynchospora oligantha*.

Synonymy

Seepage slope (in part), cut-throat seeps, cutthroat seeps, cutthroat grass seasonal ponds, cutthroat grass flatwoods, swale (Abrahamson *et al*. 1984). The FLUCCS code for the cutthroat grass community includes: 310 (herbaceous), 320 (shrub/brushland), and 411 (pine flatwoods).

Distribution

Cutthroat grass is a central peninsular Florida endemic species, found in scattered locations from Orange County south to Palm Beach County. However, it seems to dominate natural communities almost exclusively in Polk and Highlands counties, in association with the sideslopes of the central Florida Ridges. Most of the available information on cutthroat grass concerns the distribution and ecology of the species, rather than of the communities it dominates. To begin, it is important to contrast the distribution of this narrow endemic species with the distribution of cutthroat grass communities.

History and Distribution of Cutthroat Grass

Cutthroat grass was first described as a new species in 1940, from a 1925 collection made near Sebring, Florida. Most references give the distribution of the species as Polk and Highlands counties *(i.e*., Wunderlin 1982, Soil Conservation Service 1989). There are references to the occurrence of cutthroat grass in Hendry County (Yarlett 1965, 1981), however, Yarlett (1984, 1996) later dropped Hendry County from its range, and research for the *Atlas of Florida Vascular Plants* (Wunderlin *et al.* 1996) did not locate any herbarium specimen to document this report. In 1988, cutthroat grass was first located in Palm Beach County, near the western base of the Atlantic Coastal Ridge. The three known localities for this community in Palm Beach County are still extant, although two locations have suffered partial losses due to development. The third location is the Yamato Scrub Natural Area, a former CARL project managed by the county. Two acres of cutthroat grass are being relocated from one of the development sites to the Yamato Scrub site. In 1992, cutthroat grass was collected on Walt Disney World property in Orange County by David Bickner during a wetland jurisdictional determination, however, only a few small clumps were seen. In 1993, cutthroat grass was first located on the Disney Wilderness Preserve in Osceola County, where there are a few populations. In 1995, cutthroat grass was located at Tosohatchee State Preserve in eastern Orange County, and this occurrence was reported by Taylor (1996).

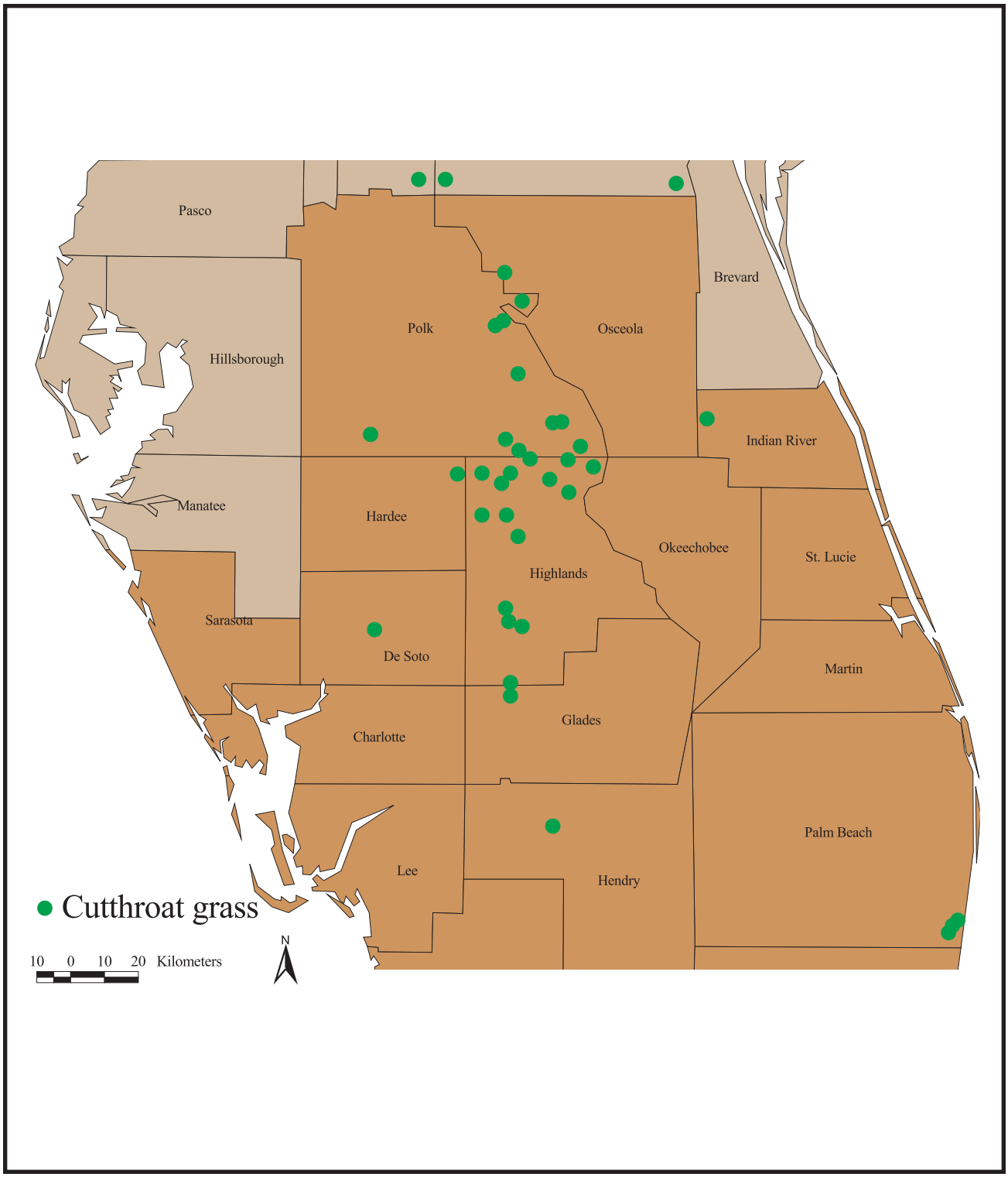


Figure 1. County distribution of cutthroat grass communities in South Florida.

Recent additional focused searches for cutthroat grass locations have been made. One of the methods for locating new sites for this species has been to make contacts with local ranchers and land managers in central Florida familiar with cutthroat grass, and inquire where they had seen cutthroat grass. As a result, new sites for cutthroat grass have been located and documented in Hardee, Lake, Glades, and Indian River counties, in addition to several new sites in counties where the species was previously known. A report from Desoto County has not yet been verified, but the report seems very reliable. This will bring the total range of cutthroat grass to 11 central and south Florida counties (Figure 1).

Physiographically, most historical occurrences of cutthroat grass are in association with the Lake Wales Ridge and the sideslopes and base of this ridge. The largest area of cutthroat grass communities still extant are in association with the Bombing Range Ridge. Cutthroat grass has been found once in association with the southeastern slope of the Lake Henry Ridge, and at three sites on the slope of the Atlantic Coastal Ridge. The remaining sites are in association with slope breaks within the Osceola Plain, and the slope break between the Osceola Plain and the St. Johns River Valley.

Cutthroat grass is listed as an endangered species in Florida (Coile 1998), is ranked as G2/S2 by FNAI (Marois 1997). In reality, cutthroat grass as a species is rather secure, since it is very likely to persist at several protected sites. However, cutthroat grass-dominated communities are less secure, and will be the focus of this account.

Distribution of Cutthroat Grass Communities

One of the first references to the existence of cutthroat grass communities is by Harper (1921), who reports on the occurrence of "cutthroats" in the eastern part of Polk County, about on the line between the lake region (central Florida ridges) and the flatwoods. Harper (1921) notes that the cutthroats are kept perpetually moist by seepage from nearby higher ground, and indicates that they seem to be the only thing in central Florida comparable to the boggy slopes of the West Florida (panhandle) pine hills.

Little information is available on the distribution of cutthroat grass communities, beyond the general statements that they occur in association with the Lake Wales Ridge and its sideslopes in Polk and Highlands counties (Soil Conservation Service 1989). Bacchus (1991) reports that as of 1991 only six locations for cutthroat seeps had been entered in the FNAI database, three in Polk County and three in Highlands County. She attempted to relocate all of these sites and found two to be destroyed, two locations too general to relocate, and two to be extant. However, she also found that many additional locations mapped as species locations for cutthroat grass, and previously undocumented locations, also supported cutthroat grass communities.

The best guide to the specific locations of cutthroat grass communities is the Highlands County soil survey (Carter *et al.* 1989). This is the only county soil survey that specifically recognizes cutthroat grass communities, and it defines a distinct soil association (one of nine soil associations in the county) for cutthroat seeps. There is also a specific soil mapping unit (Basinger-St. Johns-Placid complex) designated to correspond to cutthroat seeps in

Highlands County. By examining the areas mapped as this soil mapping unit in the Highlands County soil survey, it is possible to get an estimation of the original extent of cutthroat grass seeps in the county. This may not include other cutthroat grass communities, such as flatwoods and pond margins, which do not necessarily have this soil combination. No corresponding level of specificity in mapping cutthroat grass community soils is found in the Polk County soil survey, or any other county soil survey in Florida.

More intensive surveys in recent years have located a fairly large number of cutthroat grass communities, mostly in association with the Lake Wales Ridge in east-central and southeastern Polk County and in a north-south band through the west-central part of Highlands County, just overlapping into Glades County at the southern limit. It seems that the greatest extent of cutthroat grass communities associated with the Lake Wales Ridge is on the eastern slope of the ridge, but there are also cutthroat grass communities in flats and depressions on the ridgetop, in the intra-ridge valley, and on the western slope of the ridge. Extensive cutthroat grass communities also occur on the flat ridgetop, sideslopes, and slope base of the Bombing Range Ridge in southeastern Polk and northeastern Highlands counties. Scattered cutthroat grass communities are found along the slope break from the Osceola Plain to Arbuckle Creek in Highlands County, and a few isolated communities are found elsewhere on the Osceola Plain portion of Avon Park AFR.

Cutthroat grass communities are found in relatively few preserved or managed areas. Only three locations for significant areas of cutthroat grass communities seem to be preserved without a "multiple use" focus, these are in Highlands Hammock SP, Archbold Biological Station, and the Nature Conservancy's Tiger Creek Preserve (Bacchus 1991). The cutthroat grass occurrences at Disney Wilderness Preserve (Osceola County), and Tosohatchee State Preserve (Orange County) are fairly limited in extent. However, there are more significant areas of cutthroat grass communities on three areas managed as "multiple-use" natural areas-Lake Wales Ridge SF, Avon Park AFR and the Platt Branch Mitigation Park (GFC-managed) in southern Highlands County.

The extent of cutthroat grass communities at Lake Wales Ridge SF has not been quantified, but certainly totals over several hundred hectares. The GIS plant community classification scheme developed and produced by the natural resources staff of Avon Park AFR recognizes 23 cover types, of which four are cutthroat grass cover types. These total greater than 5,800 ha (14,326 acres) of cutthroat grass communities, divided as follows: "cutthroat" (3,337 ha or 8,242 acres), "cutthroat-forested" (431 ha or 1,065 acres), "cutthroat flatwoods" (1,504 ha or 3,715 acres), and "cutthroat flatwoods-forested" (532 ha or 1,314 acres). Cutthroat grass-dominated communities at Avon Park AFR represent the largest areal extent remaining for these natural communities.

Description

Cutthroat grass dominated communities fall within four distinct natural community classes. Since the landscape position, hydrology, soil types, and community composition differ significantly between each of these types, they are best discussed as distinct sets of natural communities. Plant nomenclature essentially follows Wunderlin *et al.* (1996).

The most distinct set of cutthroat grass communities can be described as falling within the category of "seepage slopes." These will be the primary focus of this account. However, cutthroat grass communities also occur within the community classes of flatwoods, wet prairies, and depression marshes. It is important to recognize and discuss these communities to make it clear that not every occurrence of cutthroat grass, or even of cutthroat grass dominance of a plant community, is by definition a "cutthroat seep slope."

The structure of most fire-maintained cutthroat grass seepage slopes is a densely vegetated, single-layer grassland community. Only rarely are trees and shrubs present, and these tend to be correlated with particular zones, mostly at the ecotones of cutthroat seep slopes with other communities. Cutthroat grass is a stiff, strongly rhizomatous, turf-forming grass, which results in a large amount of both above-and below-ground biomass production of this species in a relatively short time period after fire. This tends to result in overwhelming dominance of cutthroat grass in the ground cover of almost all cutthroat grass communities. This is in distinct contrast to the ground cover dominance relationships of most central Florida flatwoods, wet prairies, and sandhills, in which several grass, forb, and low shrub species share dominance in the most natural, fire-maintained, stands. The cutthroat flatwoods community types differ in structure primarily in having an open canopy of widely spaced pines, mostly slash pine (*Pinus elliottii* var. *densa)*, but with some longleaf pine (*Pinus palustris*) on the mesic flatwoods sites.

Cutthroat Grass Seepage Slopes

Cutthroat grass seepage slopes can best be thought of as a seepage slope complex, within which subtle variations in slope, relative elevation, and hydrology result in high turnover in community composition over short distances. These plant communities or microhabitat zones of cutthroat seepage slopes are often clearly defined and highly predictable. The general occurrence of cutthroat seep slopes is correlated with slope breaks from deep sand ridges, at the point where groundwater reaches the surface of the slope and begins to diffusely flow at or near the surface downslope. This often occurs at an upper or mid-slope position, particularly where the area and sand depth of the upslope ridge is relatively large, but can occur at lower slope or even on flats at the base of the adjacent sand ridges. The upslope limit of cutthroat grass is highly correlated with the rise of the wet season water table to levels near the surface, however, at this upslope extreme there is rarely evident surface seepage. At the peak of seepage influence in the center of the cutthroat seepage slope complex, water may be present at the surface year-round. Gradually, at the downslope edge of cutthroat seep slopes the seepage influence becomes more diffuse, and there is a gradual transition from seep slope to a more typical flatwoods community. With variation in local microtopography, this transition can be to a mesic flatwoods, wet flatwoods, or wet prairie.

There has been very little scientific study of cutthroat seep slopes. The only quantitative vegetation sampling of cutthroat seep slopes has been a study by Bridges and Orzell (1995a), and there have been only a few detailed floristic studies of cutthroat seep slopes (Bridges and Orzell 1995a, 1995b; Orzell and

Bridges 1995). The results of these studies provided most of the information concerning vegetative composition and environmental factors included in the cutthroat seepage slopes of this account.

For these studies, the locations of herbaceous-dominated seepage slopes within Avon Park AFR were determined by close examination of true color aerial photographs flown in 1992 and printed at a scale of 1:400 (1 in = 400 ft). Floristic surveys of these sites were conducted at several dates from 1993 to 1995, with attempts to visit each site at various seasons. The floristic surveys emphasized sites which had been prescribed-burned within the previous 12 months, although some sites had not been burned recently. At each site, floristic lists were compiled by zones. These zones were easily delineated by a combination of vegetative physiognomy and dominance, slope position, surface soil characteristics, and hydrology. In October of 1993, quantitative sampling of several seepage slopes was conducted. The sampling design consisted of 268-0.25 m^2 (2.7 ft^2) plots, located along five transects within four seepage slopes, and for comparison, one transect in a mesic flatwoods to wet prairie transition. The transects began at the upslope end of the continuous herbaceous-dominated zones and extended perpendicular to the slope, following the hydrological/slope gradient, terminating at the end of the herbaceous-dominated zone or within a community not influenced by seepage. Within each plot, all species were enumerated and an estimate of percentage cover by each species was determined.

All floristic lists were computerized by date and zone, and summarized to produce 230 lists of species presence by site and zone. These were used to produce total floristic lists for each zone and for the entire seepage slope complex, and relative frequency of each species within each zone. Relative frequencies for each zone were compiled to determine preliminary lists of characteristic and differential species of each zone based on floristic data. The quantitative plot data was plotted along transects and utilized for cluster analysis. Results of the cluster analysis were used to determine the average cover of each species in each of 11 clusters, and this was compiled to produce tables of characteristic and differential species of each cluster.

In these studies a total flora of 234 taxa was compiled from the 230 seepage slope zone floristic lists collected at Avon Park AFR from June 1993 through July 1995. Although a few more species of low frequency are likely, this flora is quite complete for the more frequent vascular plants. A total of 53 families are represented 5 fern and fern ally, 1 gymnosperm, 15 monocot, and 32 dicot families. The largest plant families are Poaceae (43 taxa), Cyperaceae (34), Asteraceae (28), Xyridaceae (10), Orchidaceae (8), Ericaceae (7), Clusiaceae (incl. Hypericaceae) (7), Eriocaulaceae (6), Lentibulariaceae (6), Melastomataceae (5), and Polygalaceae (5). Monocots account for 116 total taxa, dicots for 106 taxa, ferns and fern allies for 9 taxa, and gymnosperms for 2 taxa. The largest genera in the flora are *Rhynchospora* (17 taxa), *Xyris* (10), *Andropogon* (9), *Panicum* (7), *Dichanthelium* (6), and *Hypericum* (6).

Analysis of the compiled floristic data supported the *a prioiri* assumptions of the distinction of floristic zones within the seepage slopes. This was expected since there is rather high species turnover in a short distance along the

sharp edaphic gradients within these communities. Between each pair of adjacent zones along the gradient, differential species could be determined based on the constancy of occurrence in each of the two zones. Between communities farther apart on the topoedaphic gradient, the number of differential species is obviously even higher. An exception is the comparison of the dry *Panicum abscissum* communities (Zone 1) to the mesic flatwoods downslope from the seepage slopes. Analysis of quantitative plot data revealed very similar patterns to the floristic list data. Cluster analysis of plot data produced clusters with an almost perfect correlation to the zones within which each plot was located.

Table 1 lists the microhabitat zones defined for Cutthroat Grass. (See page Slope Complex at Avon Park AFR). This is based on the quantitative analysis of floristic data, and comparison with environmental features of each zone. It should be noted that not all microhabitat zones are known to occur at each cutthroat grass seepage slope complex. Table 2 gives the percentage frequency of occurrence of each species in each zone, based on compilation of floristic lists.

The driest, most upslope, zone of the cutthroat seep slope complex is here termed the "dry cutthroat grass" zone (Zone 1). This zone represents the transition from the scrubby flatwoods which are usually found immediately upslope of the cutthroat grass seepage slope complex, to communities dominated by cutthroat grass. The dominant species of this zone include cutthroat grass, gallberry holly (*Ilex glabra*), wiregrass (*Aristida beyrichiana*), and saw palmetto *(Serenoa repens*). Additional differential species of this zone from other cutthroat grass seepage slope zones include *Asimina reticulata, Hypericum reductum, Pterocaulon pycnostachyum, Befaria racemosa, Vaccinium myrsinites, Schrankia microphylla* var. *floridana, Polygala setacea, Xyris caroliniana, Euthamia tenuifolia, Galactia elliottii,* and *Gratiola hispida.* In this zone, there is not a mucky textured soil surface, and the water table stays below the surface throughout the year. The presence of cutthroat grass in this relatively dry habitat indicates the presence of subsurface seepage, which emerges downslope in the wetter zones.

The second seepage slope zone is termed the "cutthroat grass lawn," due to its even, low appearance in the natural, fire-maintained condition, much like a well-maintained turfgrass lawn. These tend to occur on midslope flats, and are roughly linear features oriented perpendicular to the overall slope of the ridge. Similar communities are also found in shallow linear depressions within the sand ridges, and the "swale" community described for Archbold Biological Station (Abrahamson *et al.* 1984) may represent a variant of this zone which occurs in the absence of wetter, stronger seepage zones. The average relative cover of cutthroat grass in this zone is 74 percent, and in some plots it has almost 100 percent relative cover. The only other species with more than 2 percent average relative cover in this zone are *Eleocharis baldwinii, Lyonia lucida,* and *Rhexia nuttallii*. These species, along with *Xyris platylepis, Rhynchospora ciliaris,* and *Polygala rugelii*, differentiate this zone from the "dry cutthroat grass" zone. This zone can be distinguished from wetter zones by the low frequency of *Xyris ambigua, Marshallia tenuifolia, Sabatia*

difformis, and *Eriocaulon decangulare*, among others. This zone is saturated to the surface for most of the growing season, but rarely has surface water except for a few hours after rainfall events. The soils tend to have a surface of a few centimeters of pure muck and/or several centimeters of mucky fine sand.

Often present at a landscape position slightly downslope from the cutthroat grass lawns is a shrubby zone, sometimes forming linear shrub bands separating cutthroat grass-dominated communities. Cutthroat grass is still quite frequent in this zone, but does not form the continuous cover of the previous zone due to shading. Frequent shrubs in this zone include *Serenoa repens, Lyonia lucida, Ilex glabra, Lyonia fruticosa,* and *Vaccinium myrsinites.* The most differential herbaceous species in this zone is *Osmunda cinnamomea*, with other frequent herbs including *Aster reticulatus, Hypericum cistifolium,* and *Hartwrightia floridana*. It is unclear why these shrubby bands occur regularly in a fire-maintained seepage slope, but it is perhaps due to slightly better local soil drainage because of subtle increases in microtopographic relief. Although these areas tend to have deeper surface soil muck layers, partially due to the increased organic matter from the denser vegetation and reduction of oxidation by shading, they rarely have standing water at the soil surface.

Wet cutthroat grass lawns are found in the areas transitional between cutthroat grass lawns and seepage slopes proper. In this microhabitat zone, there is less dominance by cutthroat grass (mean relative cover of 48 percent), and associated species have greater cover, including *Ilex glabra, Dichanthelium ensifolium* var. *ensifolium*, *Scleria reticularis, Xyris ambigua, Hartwrightia floridana, Myrica heterophylla,* and *Sarracenia minor*. This microhabitat zone has the most seepage of the cutthroat communities observed at most sites on the Lake Wales Ridge; however, on the Bombing Range Ridge it is transitional to zones with greater seepage. The soils of this zone have a muck surface layer of usually 10 to 20 cm (3.9 to 7.9 in.), and are saturated to near the surface year-round, with standing water at the soil surface for much of the growing season.

Cutthroat grass seepage slopes, *sensu stricto*, are at most sites the most strongly seepage-influenced communities found within the cutthroat grass seepage slope complex. The dominant species of this zone are cutthroat grass with a distinct ground cover layer of *Sphagnum* spp. Other species with significantly higher cover values in this zone include *Myrica heterophylla, Xyris elliottii, Eriocaulon decangulare, Rhynchospora cephalantha*, and *Andropogon glomeratus* var. *hirsutior.* Cutthroat grass seepage slopes are saturated to the surface year-round, and with standing water at or above the soil surface for most of the year. These communities are relatively common along the sideslopes of the Bombing Range Ridge, but have only rarely been seen in recent surveys of the Lake Wales Ridge, at a few locations in Lake Wales Ridge SF. Vascular plant diversity is very high in this seepage slope zone, with as many as 23 species per 0.25 square meter (2.7 sq. ft.).

At some sites, there is a seepage slope microhabitat zone which is transitional between cutthroat grass seepage slopes, *sensu stricto*, and mixed herbaceous seepage slopes. In this zone, there is a decline in the relative cover of cutthroat grass, and an increase in the cover of wiregrass. Associated species

are indicative of the very wet nature of this transition zone, and include *Myrica heterophylla, Hartwrightia floridana, Lycopodiella alopecuroides, Sarracenia minor,* and *Dichanthelium ensifolium* var. *ensifolium*. At some seepage slope sites, a community reflecting this transitional zone is present as the most seepy zone, without an adjacent mixed herbaceous seepage slope zone. The characteristic indication of this zone is the presence of both cutthroat grass and wiregrass on deep mucky soils.

The best developed seepage community in the cutthroat grass seepage slope complex, the mixed herbaceous seepage slope, often lacks cutthroat grass entirely. The dominant species in this zone are *Hartwrightia floridana, Dichanthelium ensifolium* var. *ensifolium*, *Scleria reticularis,* and *Rhynchospora oligantha*. The locations of this community represent the only locations of *Rhynchospora oligantha*, a common species of seepage slopes in the Florida Panhandle, in peninsular Florida. Other species which tend to differentiate mixed herbaceous seepage slopes from all other seepage slope zones include *Rhynchospora rariflora, Polygala cruciata, Hypericum fasciculatum, Calopogon tuberosus, Xyris smalliana, Xyris fimbriata*, and *Andropogon glomeratus* var. *glomeratus*. The species of this zone tend to be a mixture of species of very mucky seepage slopes and species more characteristic of wet prairies. However, the water source of this community is totally from copious groundwater seepage. The soil has a muck surface often 60 cm (23.6 in.) or more deep, and there is standing water on the soil surface throughout the year. These seepage-influenced communities differ strongly from other deep-muck herbaceous wetlands in not being subject to flooding, therefore having an almost constant water table. Many of the species of this community are very rare in peninsular Florida.

On the lower slope below either the cutthroat grass seepage slope, *sensu stricto*, or the mixed herbaceous seepage slope, there is often a zone resembling the cutthroat grass lawn (Zone 2), but more irregular in shape and mixed in composition. This is referred to as the cutthroat grass lawn below seepage slope (Zone 8). This zone seems to occur when the slope flattens slightly below Zone 5, 6, or 7, and seepage influence distinctly lessens. The vegetation is a mixture of seepage slope and lawn species, in an irregular pattern. This zone is present mostly on the larger, best developed examples of the seepage slope complex.

Gradually, at the lower slope end of the seepage slope complex, there is a transitional zone to the natural communities of the surrounding flatwoods landscape. This is referred to as transitions from seepage slope to flatwoods (Zone 9). With variation in the microtopography and hydrology of the surrounding landscape, this transition can be to either mesic or wet flatwoods. In this zone, cutthroat grass loses dominance to wiregrass, and there is a mixture of seepage slope complex and flatwoods species. This transition zone is often rather broad, with some seepage influence extending locally to the base of the slope or beyond.

A distinct variant of the transitions of the seepage slope complex to other communities is the boggy sphagnous meadow (Zone 10). This seems to occur where the seepage slope complex extends to the broad, flat base of a slope or into a broad, shallow drainageway. This zone combines the characteristics of

cutthroat grass seepage slopes, *sensu stricto*, and wet prairies. There is often standing water in this community, and a thick mat of *Sphagnum* mosses, much as in a fringing peaty wet prairie. However, seepage slope species are also quite common, even very abundant. This zone seems to support more *Hartwrightia floridana* and *Platanthera blephariglottis* var. *conspicua* than any other community in Florida. Wet prairie species such as *Hypericum myrtifolium, Ctenium aromaticum, Paspalum praecox,* and *Chaptalia tomentosa* are more common in this zone than in other zones.

The last zone of the seepage slope complex consists of the natural drainageways through seepage slopes (Zone 11). These small natural drainageways form where seepage water becomes channeled through microtopographic lows in the slope, and are narrow, shallow intermittent stream channels, generally less than one meter deep and wide. Seepage slope species are often present within the channel, along with *Hypericum fasciculatum* and *Osmunda cinnamomea.* The composition of these channels is quite variable, due to differences in depth and permanence of surface water and diffuse seepage within the channels.

Other Cutthroat Grass Communities

In addition to the 11 microhabitat zones of the cutthroat seep slope complex, the following cutthroat grass-dominated natural communities are known to occur at Avon Park AFR:

Cutthroat grass dry prairie
Cutthroat grass mesic flatwoods
Cutthroat grass wet flatwoods
Cutthroat grass wet prairie
Cutthroat grass deep wet prairie/slough
Cutthroat grass outer rim of depression marsh
Cutthroat grass ecotone between mesic flatwoods and drainageways
Slash pine/Cutthroat grass “basin swamp”

For convenience in description, these will be combined into six categories-mesic flatwoods, wet flatwoods, depression marsh margins, ecotones to drainageways, wet prairies, and seepage-fed basin swamps. Each of these is markedly different from communities of the cutthroat grass seepage slope complex in vegetation, soils, hydrology, landform, and relationship to the surrounding landscape. The presence of cutthroat grass as a dominant or subdominant species in so many different community classes attests to the ecological breadth of cutthroat grass in the center of its range.

Although almost all of the data used to describe these communities is from examples at Avon Park AFR, some of these communities are similar to those described by Abrahamson *et al.* (1984) for Archbold Biological Station. At Archbold Biological Station, cutthroat grass occurs in three community types. The first is a “cutthroat grass flatwoods” type, which differs from typical wiregrass flatwoods in the greater robustness of saw palmetto, lower frequency of *Quercus minima, Hypericum reductum*, and *Myrica cerifera* var. *pusilla,* and greater frequency of *Lyonia lucida* and *Pinus elliottii*, in addition to the

dominance of the ground cover by cutthroat grass. This would correspond to the "cutthroat grass wet flatwoods" type described for Avon Park AFR. The second cutthroat type is termed as "Swale" by Abrahmson *et al.* (1984). In this community, cutthroat grass cover is nearly 100 percent, associated with such species as *Andropogon brachystachyus, A. virginicus* var. *glaucus*, *Polygala rugelii, Drosera capillaris, Burmannia biflora, B. capitata, Carphephorus paniculatus*, and *Syngonanthus flavidulus*. This community is said to occupy "low-lying stretches of land," and seems to correspond to the "cutthroat lawn" zone of cutthroat seepage slopes, but without the corresponding areas of stronger seepage-influenced community types. It is possible that the "Swale" community at Archbold Biological Station has just enough seepage influence from the surrounding sand ridges to support the formation of a "cutthroat lawn (Zone 2)" seepage slope, but without enough topographic relief downslope of this zone to support other seepage slope zones.

The third cutthroat grass type at Archbold Biological Station is the cutthroat grass seasonal pond, or pond margin. Depending on the depth of the depression pond, cutthroat grass can either be restricted to the outer margin of the pond, or for shallower ponds can dominate the entire pond. Species with more than 1 percent average cover in cutthroat grass-dominated pond zones at Archbold Biological Station include *Hypericum edisonianum, Schizachyrium stoloniferum, Woodwardia virginica, Syngonanthus flavidulus, Rhynchospora cephalantha,* and *Spartina bakeri* (Abrahamson *et al.* 1984).

At Avon Park AFR, a total of 217 plant species are associated with cutthroat grass communities other than cutthroat grass seepage slopes (Table 3). Some of these community types are very limited in occurrence, whereas others are quite extensive. The driest of these cutthroat grass communities are cutthroat grass dry prairies and cutthroat grass mesic flatwoods. These occur in close proximity to the base of the slope of the Bombing Range Ridge, and represent an extension of cutthroat grass dominance into the flatwoods landscape off of the ridge. They occur on poorly drained flats, mostly on Myakka soils, and can be distinguished from other cutthroat grass communities by the higher frequency of *Pterocaulon pycnostachyum,Vaccinium myrsinites, Serenoa repens, Pinus palustris, Xyris caroliniana, Hypericum reductum,* and *Asimina reticulata*. The composition of this community is much like the dry cutthroat grass zone (Zone 1) of the seepage slope complex, but it differs in landscape position.

Cutthroat grass wet flatwoods are much more common, and are fairly extensive at Avon Park AFR and Highlands Hammock SP. Only 7.63 ha (18.8 acres) of cutthroat grass flatwoods are mapped for Archbold Biological Station. These are found at Avon Park AFR on extensive poorly drained flats at the base of the Bombing Range Ridge. Similar communities are located at the western base of the Lake Wales Ridge in the southern addition to Highlands Hammock SP. Cutthroat grass wet flatwoods combine characteristics and species of seepage slopes and flatwoods landscapes. They can be distinguished from cutthroat grass mesic flatwoods by dominance of slash pine (*Pinus elliottii* var. *densa*) rather than *Pinus palustris,* and by an increased frequency of *Sarracenia minor, Xyris platylepis, Eriocaulon decangulare, Scleria reticularis, Centella asiatica, Rhynchospora cephalantha,* and *Paspalum*

praecox. Cutthroat grass wet flatwoods can be distinguished from typical wet flatwoods by increased frequency of *Hartwrightia floridana, Eleocharis baldwinii*, and *Sphagnum* spp., in addition to the increase in cutthroat grass and slash pine.

Cutthroat grass depression marsh margins are fairly common even a few miles away from the base of the Bombing Range Ridge at Avon Park AFR, and seem to be fairly common on the southern Lake Wales Ridge. In this community, cutthroat grass forms a concentric ring around deeper depression marsh zones. In most cases, the cutthroat grass zone is immediately waterward of the saw palmetto margin at the boundary between the depression marsh and the surrounding flatwoods. Waterward of the cutthroat grass zone is typically a zone of intermediate hydroperiod which is dominated by *Hypericum*. At Avon Park AFR, this zone is dominated by St. Johns wort (*Hypericum fasciculatum)*, but at Archbold Biological Station and other areas on the southern Lake Wales Ridge, Edison's hypericum *(Hypericum edisonianum*) is dominant in this intermediate hydroperiod depression marsh zone. Cutthroat grass depression marsh margins have many species in common with cutthroat grass wet flatwoods. Species with higher frequency in depression marsh margins include *Eupatorium recurvans, Rhexia cubensis, Hypericum fasciculatum, Sabatia grandiflora, Pluchea rosea,* and *Hypericum cistifolium*. In general, the cutthroat grass depression margin is much like the wiregrass-dominated margin of many other depression ponds in Florida, except for the dominance of cutthroat grass and a higher percentage of species adapted to mucky soil surface conditions.

Cutthroat grass ecotones between mesic flatwoods and drainageways are found in scattered locations on the Osceola Plain at Avon Park AFR. These differ from the cutthroat grass seepage slope complex in not being associated with sand ridges. Rather, they occur where there is a drop in elevation of a few feet between broad expanses of mesic flatwoods and deep, flowing-water herbaceous marsh-dominated drainageways. These are occurring in response to an increase in groundwater seepage, but without sufficient seepage flow to produce a seepage slope with surface water. Similar slight seepage ecotones occur in other areas of central Florida, in association with slope breaks to drainageways or to dome swamps, but outside of the range of cutthroat grass are most often dominated by wiregrass or by big chalky bluestem (*Andropogon glomeratus* var. *glaucopsis*). Common indicator species of these seepage ecotones, with or without cutthroat grass dominance, include *Rhynchospora ciliaris, Pinguicula caerulea, Sarracenia minor,* and *Ilex glabra* (particularly in absence of fire). These zones are usually less than 3 to 6 m (9.8 to 19.7 ft) in width, but can extend for a hundred meters or more along such an ecotone. In aspect, they are similar to the wet cutthroat grass lawn (Zone 4) of the cutthroat grass seepage slope complex, but differ in topographic position and the surrounding landscape.

Cutthroat grass wet prairies have been found only on Avon Park AFR, where they tend to be associated with the margins of bay-dominated depression swamps at the slope base of the Bombing Range Ridge. In this cutthroat grass community, trees and shrubs are essentially absent from frequently burned

examples. The water table is at or above the surface for most of the year, and most of the area of this community is inundated for up to 30 cm (11.8 in.) above the surface for most of the growing season. In aspect, these are analogous to wet wiregrass prairies, but perhaps with more of a mixture of mucky soil indicators (such as *Xyris fimbriata* and *Andropogon glomeratus* var. *glaucopsis*). The composition of this community is a mixture of seepage slope and wet prairie species, but it differs from wiregrass-dominated wet prairies in the abundance of cutthroat grass and of *Hartwrightia floridana.*

To our knowledge, there is only one example known of a Slash pine/ cutthroat grass "basin swamp." This area is known as "The Deadens," and is found at the base of the western slope of the northern part of the Bombing Range Ridge on Avon Park AFR. This community has a canopy of slash pine, mixed with sweet bay (*Magnolia virginiana*) and loblolly bay (*Gordonia lasianthus*), a shrub layer with moderate to dense cover, including *Lyonia lucida, L. ligustrina, Ilex cassine, I. glabra, Myrica cerifera, M. heterophylla,* and *Hypericum fasciculatum*, and a ground cover dominated by cutthroat grass, with mucky wet prairie and seepage slope indicator species present in the ground cover. At first impression, one would suspect that this area is a fire suppressed example of a cutthroat grass wet flatwoods or wet prairie, or even perhaps a fire-AFR "boggy sphagnous meadow" (Zone 10), of the seepage slope complex. However, this area is indicated, in essentially its current configuration, as a "Bay & Pine Swamp" on the 1859 public land survey plat map and notes. We surmise that because of the close proximity of sand pine scrub to the east and a deep stream channel to the west, that this area was naturally protected from almost all landscape-level fires. In the absence of frequent fire, this area passed the threshold needed to become a naturally "fire-retardant" community, reaching the point where fires would naturally extinguish at the border of the swamp. It is possible that other such situations existed at the base of the Lake Wales Ridge, but each example must be examined critically to determine whether woody dominance of these areas is a natural state or the result of post-settlement fire suppression.

Species Diversity and Species of Concern

Several species of conservation concern are associated with cutthroat grass communities. Although little information is available at this time on faunal species associated with this cutthroat communities, it is likely that the eastern indigo snake (*Drymarchon corais couperi*) occurs here.

Endangered State-listed plant species that occur in the cutthroat grass community include: cutthroat grass, many flowered grass-pink (*Calopogon multiflorus),* and Edison's ascyrum (*Hypericum edisonianum).* A large number of plant species that are State-listed as threatened occur in the cutthroat grass community (Coile 1998). Among these are *Hartwrightia floridana, Lilium catesbaei, Pinguicula caerulea, Pinguicula lutea, Platanthera blephariglottis* var. *conspicua, Platanthera integra, Platanthera ciliaris, Platanthera cristata, Pogonia ophioglossoides,* and *Sarracenia minor*. Most of these species were relatively common in the fire-maintained, undrained natural landscape of peninsular Florida, and most are still quite common in the cutthroat grass communities of Avon Park AFR.

The flora of these cutthroat grass communities consists of at least 279 plant taxa, including many Florida endemics and near-endemics, as well as many other species that are widespread in the southeastern coastal plain, but reach their southern limit in these communities in Highlands County. The nearest known locations to the cutthroat grass community region for other herbaceous-dominated seepage slopes are in Clay County, just southwest of the Jacksonville area in northeastern Florida. Therefore, many species of seepage habitats are dependent on cutthroat grass communities for maintenance of viable populations in peninsular Florida.

Panicum abscissum (Poaceae) is an endemic perennial grass that grows on mositure-receiving seepy slopes on the sandy eastern and western slopes of the Lake Wales Ridge. It may also occur on small isolated slopes which receive moisture from a scrub site at higher elevation, around small seasonal ponds in scrubby flatwoods, and around depression marshes and ponds in wet pinelands. It can be frequently found in pure stands with an open slash pine overstory. The species occurs in Highlands, Orange, Osceola, Palm Beach, and Polk counties.

Calopogon multiflorus (Orchidaceae) is a diminutive and poorly known species which is more common in dry prairie and dry-mesic sandy longleaf pine savanna than in cutthroat communities. It has recently been found in frequently burned examples of the dry cutthroat grass zone of the cutthroat grass seepage slope complex. This orchid is State-listed as endangered and dependent on frequent winter or early growing season fire for flowering, which tends to occur only three to four weeks after fire.

Hypericum edisonianum (Hypericaceae): is a distinctive semi-woody shrub that has the most restricted geographic range of any member in the genus *Hypericum*. This species is State-listed as endangered and is known from four contiguous counties in south-central Florida (Highlands, Glades, Desoto, and Polk). The type specimen was originally cited in error from Desoto County, since it is actually from Highlands County (before it was split from Desoto County). In 1995, Bridges and Orzell reinstated Desoto County into the overall range of this species, having collected specimens from eastern Desoto County. The only Polk County record is that discovered by Orzell in 1994 from Avon Park AFR, and it represents the first record from the Osceola Plain (Orzell 1997). *Hypericum edisonianum* can be locally abundant, forming thick stands an acre or more in extent in sandy depressional ponds, open prairies, and pine flatwoods. It seems to be most commonly associated with cutthroat grass depression marsh margins on the southern portion of the Lake Wales Ridge.

Hartwrightia floridana (Asteraceae) is a distinctive monotypic genus which is strongly associated with seepage slopes throughout its range, extending from extreme southeastern Georgia south to Highlands County, Florida. It was probably historically widespread within this region, occurring both in well-developed seepage slopes and in the fire-maintained herbaceous slight seepage ecotones between flatwoods and wetlands. Although historically it has been found in 11 Florida counties and 3 Georgia counties, it is currently known to be extant only in two small regions within this range. One of these comprises the seepage slopes and roadside seepage ecotones of northeast Florida and

Charlton County, Georgia, in a total of four counties (Clay, Putnam, Nassau, Charlton). The only other extant locations for this species are in the cutthroat grass communities of Polk and Highlands counties. All of the intervening localities seem to have been extirpated due to fire-suppression and/or drainage. Field surveys have revealed that Avon Park AFR contains the largest known number of reproducing, viable populations occurring within intact habitat (based on FNAI database records and field visits to all known populations as of 1994). It is found at Avon Park AFR in most zones of the cutthroat grass seepage slope complex, cutthroat grass wet flatwoods, cutthroat grass wet prairie, cutthroat grass depression marsh margins, and cutthroat grass ecotones to drainageways. There are also a very few locations of *Hartwrightia floridana* at Avon Park AFR which are not in association with cutthroat grass. These are found in a few ecotonal seepage slopes which lack cutthroat grass. There are well over 100 populations with over 1,000 plants each on Avon Park AFR, easily over 90 percent of the entire worldwide abundance of this species.

Hartwrightia floridana is one of the few rare species of cutthroat grass communities that has been recently confirmed in cutthroat grass areas other than Avon Park AFR. It occurs in cutthroat grass seepage slopes at Lake Wales Ridge SF, and in association with a degraded cutthroat grass seepage slope at the southeast end of the Lake Henry Ridge. *Hartwrightia floridana* seems to have persisted in other former seepage slopes on the Lake Wales Ridge, particularly where roadsides provide the open seepy habitat necessary for this species. This species is dependent on prescribed growing-season burns, to maintain groundcover diversity in communities and prevent or inhibit woody encroachment, and lack of alteration of natural hydrology. Long-term monitoring studies should be conducted to determine the life history and aid in developing management strategies for this plant. The State of Florida has listed *Hartwrightia floridana* as a threatened species.

Lilium catesbaei (Liliaceae) is a perennial lily that ranges from southeastern Virginia to Florida and west to Louisiana on the coastal plain. Southern red lily is a rather common species in wet prairies, wet flatwoods, and seepage slopes throughout nearly all of Florida. It is most frequently encountered at Avon Park AFR in undisturbed frequently burned flatwoods and sometimes in seepage slopes. Florida has designated this species as threatened.

Pinguicula caerulea and ***Pinguicula lutea*** (Lentibulariaceae) are rather common in a wide variety of seepage slope, mesic to wet flatwoods and pine savannas, and wet prairies throughout most of Florida. The State of Florida has listed these plants as threatened species.

Platanthera blephariglottis* var. *conspicua (Orchidaceae) reaches its southern limit in Highlands County. In the Florida panhandle, this orchid is uncommon but not particularly rare. However, in peninsular Florida it is currently quite rare, despite having been historically recorded from numerous central Florida counties. This State-listed species may have suffered a similar fate as described for *Hartwrightia floridana*. Within central peninsular Florida, it seems to be currently extant only from cutthroat grass seepage slopes at Avon Park AFR in Polk and Highlands counties. A Polk County population north of Smith Road



***Lilium catesbaei* (southern red lily).** *Original photograph by Betty Wargo.*

near the old Bravo target area, growing in a seepage slope and downslope wet prairie, had an estimated population exceeding 500 flowering plants (and countless vegetative plants) in September 1994, making this the largest extant population currently known in central Florida. For management of this orchid, it is important to conduct prescribed burning during the growing season and prevent alteration of the hydrology. Plants should also be protected from feral hogs. The fact that the largest population of this orchid occurs in the Bravo Range at Avon Park AFR, which has been subject to very little or no grazing pressure, indicates that the sensitivity of this species to livestock grazing needs to be investigated (Orzell 1997). This plant is listed by the State of Florida as a threatened species.

Platanthera integra (Orchidaceae) is a rather widespread species, occurring sporadically in the southeastern United States. However, it is not common except in frequently burned wet pine savannas and pitcher plant bogs on the southeastern United States coastal plain. In Florida, it is listed as an endangered species and very rarely occurs outside of the panhandle region, where it occurs in fire-maintained pine savannas, wet prairies, seepage slopes and hillside seepage bogs. It is exceedingly rare in peninsular Florida (historical from Orange and Osceola counties and extant in Highlands County) and northeast Florida (Nassau and Duval counties) and highly habitat-restricted. The only known extant population in central Florida is the population at Avon Park AFR in Highlands County, which represents the southernmost record. In September 1994, a total of some 171 plants (most in peak flowering condition) were observed in a wet wiregrass prairie and adjacent seepage-influenced roadside ditches through the wet prairie habitat. This population is just downslope and adjacent to a cutthroat grass seepage slope community, and may be influenced by

seepage from that area. This is undoubtedly one of the largest extant populations of this orchid in Florida and certainly the largest population currently documented in all of north and peninsular Florida (Orzell 1997).

Prescribed growing season burns should be conducted to maintain groundcover diversity and prevent woody invasion. Care should be taken to protect the only known population on Avon Park AFR, particularly following prescribed burning, from feral hog damage. There has been some recent feral hog damage to the groundcover adjacent to the known population; however it is not known whether this damage caused localized extirpation of the population. The absence of orchids from the feral hog-rutted portion of the site makes it highly suspect that the hogs have already impacted the population. This population should be monitored to determine population dynamics and aid in developing management strategies.

Platanthera ciliaris and ***Platanthera cristata*** (Orchidaceae) are rather common and widespread orchids in the southeastern United States, but become increasingly rare and restricted in peninsular Florida. *Platanthera ciliaris* is the slightly more common of the two, being known historically from most central peninsular Florida counties south to Highlands County. *Platanthera cristata* was only known to occur south to Orange and Hillsborough counties until its discovery in 1981, from Polk County at Avon Park AFR (Wunderlin *et al.* 1982). *Platanthera ciliaris* is known from one cutthroat grass seepage slope complex at Avon Park AFR, and could possibly occur in other cutthroat grass seepage slopes. These orchids are subject to declining populations for the same reasons as *Hartwrightia floridana*. Both species are State-listed as threatened.

Pogonia ophioglossoides (Orchidaceae) is a threatened species listed by the State. It is a spring-flowering orchid that is rather common in cutthroat grass seepage slopes, and occasionally occurs in other cutthroat grass communities. It ranges south to Highlands and Martin counties in Florida. The habitat conditions and requirements of this species are rather similar to the *Pinguicula* species.

Sarracenia minor (Sarraceniaceae) is the only pitcher plant species in central peninsular Florida, ranging south to Highlands and (rarely) to Okeechobee counties. It is present in almost every example of the cutthroat grass seepage slope complex, being quite common in Zones 4 through 10 of the complex. This species is also quite common in fire-maintained wet flatwoods, wet prairies, and seepage ecotones throughout the Osceola Plain. There are at least several hundred populations of *Sarracenia minor* at Avon Park AFR with hundreds or more clumps each. *Sarracenia minor* is also found in most other cutthroat grass communities, and is particularly rather common in cutthroat grass wet flatwoods and wet prairies. It is known from cutthroat grass wet flatwoods as far south as near Highlands Hammock SP.

Several additional species of cutthroat grass seepage slopes are regionally rare, in most cases much rarer and more endangered in peninsular Florida than the State listed species of these communities. These are not listed as rare plants for Florida due to their relative abundance and secure populations in the

Florida Panhandle. Disjunct populations of plant species are very important to regional biodiversity. They are usually very habitat-specific where they occur in peninsular Florida and indicative of the unique seepage slope conditions of cutthroat grass communities. These include *Rhynchospora oligantha, Myrica heterophylla,* and *Eleocharis tuberculosa*. *Sarracenia minor* is listed as a threatened species by the State of Florida.

Ecology

Hydrologic Regimes and Soil Conditions

Cutthroat grass seems to occupy a fairly wide hydrologic range, from subsurface seasonal soil saturation to nearly year-round shallow inundation. The hydrologic key to the occurrence and dominance of cutthroat grass seems to be at least some diffuse groundwater seepage. However, out of the relatively narrow range of cutthroat grass, other grasses (particularly *Aristida beyrichiana)* seem to flourish under these same hydrologic conditions. It has been speculated that cutthroat grass displaces wiregrass in certain natural communities within a narrow geographical range, but is less favored with only slight changes in geography and edaphic conditions.

Cutthroat grass communities, at least the cutthroat grass seepage slopes, are habitats in which groundwater flows downslope at or near the soil surface for at least part of the year. These habitats are hydric (although the hydroperiod may be variable) and nutrient levels are related to soil organic matter and chemistry, and the chemistry of the geologic materials in the upslope, unconsolidated aquifer.

No specific hydrologic or soil research has been conducted on cutthroat grass communities. The Highlands County soil survey maps cutthroat seeps as having Basinger, St. Johns, and Placid soils (Spodic Psammaquents, Typic Haplaquods, and Typic Humaquepts). These soils are poorly drained to very poorly drained, with a water table within 30.5 cm (12 inches) of the surface for most of the year (Carter *et al.* 1989). All of these soils have a thick dark gray to black sand upper horizon, sometimes with a thin layer of pure muck at the soil surface. There is a moderately developed subsurface spodic layer in St. Johns soils, a weak indication of a developing spodic layer in Basinger soils, and no diagnostic subsurface horizon in Placid soils. Included within this soil mapping unit are smaller areas of Myakka, Samsula (Terric Medisaprists), Sanibel (Histic Humaquepts), and Smyrna soils. The Myakka and Smyrna soils (both Aeric Haplaquods) have a well-developed spodic layer, and indicate conditions transitional to mesic or wet flatwoods. The Sanibel and Smyrna soils have a deep organic surface horizon, and correspond to the muckier areas within the seepage slope complex. Deeper histisol soils, perhaps representing undescribed soil series, are present in seepage slopes at Avon Park AFR, but are too limited in extent to merit description on a county soil survey level (L. Carter, retired from Soil Conservation Service, personal communication 1997).

In the Polk County soil survey (Ford *et al.* 1990), no specific soil mapping unit is used for cutthroat grass communities. However, the soil types mapped for cutthroat communities can be determined from examination of the mapped

soil types for known cutthroat grass communities. The most common soil mapped for cutthroat communities in Polk County seems to be Basinger fine sand. Not all areas mapped as Basinger soils are cutthroat communities; however, since this mapping unit is also used for wet flatwoods and wet prairie communities. Some areas of cutthroat grass in Polk County are mapped as St. Johns sand. This seems to be utilized as the soil mapping unit for some of the wetter zones of the cutthroat grass seepage slope complex. St. Johns sand is mapped for only 818 ha (2,022 acres) in Polk County, and an examination of the Polk County soil survey indicated that all of this area may be current or former cutthroat grass communities. Some areas mapped as Placid and Myakka sand, depressional in the Polk County soil survey, support cutthroat grass communities, and limited areas mapped as Immokalee (Arenic Haplaquods), Myakka, or Sanibel series also have some cutthroat grass communities.

Hydrologic and soil parameters of cutthroat grass seepage slopes can be estimated from research conducted on seepage slopes in other areas of the Coastal Plain. The hydrologic and soil conditions of seepage slopes have best been summarized by Platt *et al.* (1990), which forms the basis for this section.

The soil and water chemistry of seepage slopes is relatively complex. They are typically poor in certain nutrients, such as calcium and magnesium, since some ions are leached from the soil by water. In east Texas and western Louisiana, potassium and sodium levels in seepage slope soils may be comparable to other forest soils in the region, and seepage slope soils may contain 5 to 10 parts per million (ppm) nitrate and ammonium nitrogen (Platt *et al.* 1990). Organic matter content of seepage slope soils is regularly 3 percent or more by weight, and is often greater than 5 percent at depths less than 15 cm (5.9 in.).

Seepage areas are integrated hydrologically with surrounding habitats. Water seeping out at the surface originates from rainfall in the upslope watershed that percolates through the soil and moves along a sloping gradient. The emergence of the seepage water on the sideslope can be the result either of reaching a shallow, less permeable layer (such as a subsurface spodic horizon), or the saturation of the surficial aquifer such that hydrostatic pressure alone results in emergence of seepage flow. The flow of water is directed by hydraulic conductivity and soil porosity until it reaches the surface.

It is characteristic of seepage slope complexes throughout the Coastal Plain to have different kinds of seeps, ranging from seasonally moist areas along slopes with relatively few seep-associated species, to bogs that have standing water (due to a “terraced slope” effect) throughout the year and support a large array of bog-associated herbaceous species. The degree of seepage is primarily dependent on five major characteristics that influence water flow: (1) surface and subsurface soil characteristics which govern soil infiltration and saturated flow rates,(2) size of the recharge area, (3) vegetation present in both recharge and seepage areas, (4) local topography, and (5) depth, gradient, and extent of the underlying impermeable layer (Bridges and Orzell 1989, Platt *et al.* 1990).

Surface soil characteristics determine the degree to which water percolates through the soil. Water infiltration into a soil generally increases as the percentage of sand and soil depth increases. Under saturated conditions, water

flow in coarse-textured soil will be faster than in fine-textured soils; however, total storage capacity will be greater in fine-textured soils. The mineral soil surface texture of all cutthroat grass communities is fine sand, and it is likely that few, if any, cutthroat grass communities have soil textures other than sand or fine sand throughout the soil profile.

The size of the recharge area or watershed is also important. Most of the geologic strata of these watersheds are of relatively recent marine origin. Since there may have been subtle variations in the deposition of sediments over time, drainages and divides may be present but covered by more recent deposits. The general slope and drainage pattern of subsurface layers may or may not correspond to the present topography. One of the few generalizations that can be stated with certainty is that water feeding a seepage slope must come from positions topographically higher than the seep itself.

The degree to which a seepage slope remains wet throughout the year will depend on the size of the watershed, the soil infiltration rate, the rate of saturated flow in the soil, the topographic position of the seepage slope, its water storage ability, and the rate of water leaving the seepage slope from evapotranspiration and surface and subsurface flow. In general, the greater the infiltration rate of the watershed soils and the water-holding capacity of the seepage slope soils, the smaller the recharge area needed to maintain seepage throughout dry periods of the year.

Vegetation will have a different effect on the hydrologic regime of the watershed recharge area than on the seepage area. Vegetation on the recharge area intercepts a portion of the rainfall and in large rainfall events may redistribute rainfall. The infiltration of rainfall reaching the ground surface on some deep sandy soils is nearly 100 percent, even with a sparse vegetative cover. Again, infiltration is dependent upon rainfall intensity and duration. Vegetation in the seepage area has a much greater impact on water relations. Woody vegetation in seeps removes water in excess of actual needs and acts as a phreatophyte but woody vegetation also has the effect of "stabilizing" the soil immediately around it.

Seepage slope hydrology can, within the limits set by the physical properties of the soil, underlying impermeable layer, and by the size of the recharge area, be influenced via management of the vegetation in the recharge area and in the seepage slope itself. Normally, the volume of water entering subsurface soils will decrease as the biomass of woody vegetation increases; so, a reduction in the amount of vegetation should increase water flow and facilitate the seepage character. Likewise, shifting the dominant vegetation from hardwoods to pines and herbaceous ground cover should increase the water entering subsurface soils. It is important to accomplish such changes in the vegetation with a minimum of soil disruption to avoid erosion and a possible alteration of sheet flow across the ground surface (Platt *et al.* 1990).

Fire Regimes

Cutthroat grass communities are strongly dependent on frequent fire. Without fire, cutthroat grass seepage slopes become invaded by shrubs such as *Lyonia lucida, Myrica heterophylla*, and *Ilex glabra.* Within a short period, perhaps only

a decade without fire, trees begin to become established within cutthroat grass seepage slopes. The most characteristic tree which invades, and eventually dominates, unburned seepage slopes is loblolly bay (*Gordonia lasianthus*). These can be mixed with swamp red bay (*Persea palustris*), sweet bay (*Magnolia virginiana*), and swamp black gum (*Nyssa sylvatica* var. *biflora*) in some areas.

Cutthroat grass is very flammable, even during the growing season. This is likely due to its high productivity, with biomass production of as much as 10,105 kg/ha (9,000 pounds/acre).

Although the character of cutthroat grass communities is dependent on the hydrology of the landscape in which they occur, fire regimes are critical in determining the type of vegetation present. Fire regimes that involve frequent, early growing-season fires (generally April to mid-June in south central Florida) favor cutthroat grass and other herbaceous species. These fires are critical for flowering and seed production by most species of grasses and many forbs, especially fall-flowering composites. Early growing-season fires can also depress woody shrubs and trees since they introduce a second stress at the time of year that these species are already under stress and have low carbohydrate reserves after green-up (Platt *et al.* 1990). Consistent application of annual or biennial growing-season fires, in other southeastern United States seepage communities can lead to a decline of shrub recruitment and also a decrease in shrub abundance (Drewa and Platt 1997, Olson and Platt 1995).

In contrast, fires that occur late in the growing season, or between growing seasons, stimulate clonal growth of woody shrubs and many trees, such as scrub oaks. In addition, fires at this time depress flowering of most species in the ground cover. While this does not result in immediate changes in the ground cover, continued use of such fires over long time intervals would result in a reduction in the number of herbaceous species present in the ground layer and an overall displacement of herbaceous plants by clonal woody species in the ground cover. Such changes are magnified by soil disruption and/or removal of the ground cover during clear-cutting and site preparation activities.

Cutthroat grass very rarely flowers in the absence of prescribed burning (Myers and Boettcher 1987) or some type of mechanical soil disturbance in the near vicinity of the clumps. The seasonality of prescribed burning was found to have a dramatic effect on the flowering phenology of cutthroat grass (Myers and Boettcher 1987, Robbins and Myers 1992). Fall and winter burns resulted in the production of very few inflorescences in cutthroat grass, whereas it flowered abundantly when burned between mid-April and mid-August. This is consistent with the general trend for increased flowering of native forbs with growing-season burning (Robbins and Myers 1992).

Status and Trends

Long-term fire suppression has resulted in a decline in the extent and natural integrity of cutthroat grass communities more than any other factor. Over much of the original extent of cutthroat grass communities along the Lake Wales Ridge, the open grassland nature of these areas has been replaced by shrub thicket and baygall communities. At this date, it is impossible to even determine the pre-settlement extent of cutthroat grass communities. Our best

estimate is from the Highlands County soil survey, which maps 11,850 ha (29,281 acres) of the Basinger-St. Johns-Placid soil complex in the county, amounting to 4.4 percent of the county. Examination of the areas mapped as this soil complex in Highlands County indicates that the vast majority of the area mapped as this soil association once supported cutthroat grass communities. There are also areas of cutthroat grass communities on other soil mapping units in Highlands County; however, these seem to be much more limited in extent, and we can assume that the 11,850 ha figure is a reasonable approximation of the pre-settlement extent of cutthroat grass communities in Highlands County. Unfortunately, since a specific soil mapping unit was not used for cutthroat grass community soils in the Polk County soil survey, it is not possible to arrive at a similar estimate for Polk County.

Currently, the extent of cutthroat grass communities is much more limited than the soil survey would indicate. There is a very good correlation between the extent of cutthroat grass soil types and extant cutthroat grass communities at Avon Park AFR. However, in most of the remainder of Highlands County, most of the area mapped as cutthroat grass soils is now dominated by woody vegetation, particularly broadleaf evergreen wetland shrubs and trees. This is likely due to the effects of long-term fire suppression. Typical trees which have invaded cutthroat grass communities include loblolly bay, sweet bay, swamp red bay, and slash pine. Many former cutthroat grass communities have also developed a dense shrub layer, typically including fetterbush (*Lyonia lucida*), gallberry holly, and wax myrtle *(Myrica cerifera*), all tied together with puncture vine (*Smilax laurifolia*). This is also true of most of the cutthroat grass communities in Polk County.

The only study which attempts to determine a percentage loss of cutthroat grass communities is Yahr *et al.* (1995) which looks at changes in cutthroat-dominated communities at Archbold Biological Station in relation to fire suppression and drainage history. They found in comparing the extent of cutthroat grass communities at Archbold between 1940 and 1994, that 39 percent of the sites which were cutthroat-dominated in 1940 were no longer cutthroat grass dominated. Over half of these were in areas which were fire-suppressed or both fire-suppressed and drained. Given that Archbold Biological Station has been more subject to good ecosystem management practices than almost anywhere else in the range of cutthroat grass communities, we can anticipate that the percentage loss would overall be much higher in the surrounding landscape.

Intact cutthroat grass community landscapes with the full range of cutthroat community types are now found only within Avon Park AFR. Even at Avon Park AFR, there has been a decrease in cutthroat grass communities since the 1940s (based on examination of aerial photography from 1941, 1943, 1958, 1973, and 1993). These losses have been due to past limited ditching, conversion to pine plantations, and less frequent and intense fire in most areas. Despite these losses, the over 5,800 ha (14,326 acres) of cutthroat grass communities remaining at Avon Park AFR represent the largest areal extent remaining for these natural communities. Avon Park AFR is the only area remaining where it is possible to see cutthroat grass communities with intact,

fire-maintained ecotones extending from near the top of a central Florida sand ridge to the base of the ridge and grading into fire-maintained open pine savannas.

Cutthroat grass communities are secure at Avon Park AFB. However, there are some cutthroat community types which may not be represented at Avon Park AFR, and there are important biodiversity linkages which cutthroat communities on the Lake Wales Ridge could have which would not be duplicated on the Bombing Range Ridge. Archbold Biological Station provides protection for some of these other communities. It will be necessary to begin intensive fire management, and probably remove many mature pine trees, to begin restoration of cutthroat grass communities at Highlands Hammock SP, Lake Wales Ridge SF, and other protected areas.

Management

Most cutthroat grass communities have been subjected to alterations in hydrology and fire regimes that have resulted in deterioration of these sensitive habitats. The goal of proposed restoration and management efforts thus is to delineate the general nature of the changes that have occurred in these natural communities and to suggest restoration and management actions that will reverse these changes. The goal of this management should be to reinstitute environmental conditions present in the original habitats.

Management of cutthroat grass seepage slopes must also consider the environmental conditions present within the recharge areas of the upslope watershed. A low density of arboreal vegetation and moderate density of herbaceous ground cover will best approximate pre-settlement conditions that characterized the recharge areas. Changing these characteristics of recharge areas should increase the seepage character, both in terms of the amount of water flow and the length of hydroperiod. Such alterations of the hydrological regimes can be accomplished via prescribed burning in recharge areas, preferably via frequent, randomly timed, early growing-season fires. Such management direction should enhance the dominance of the hillside seeps by herbaceous species of plants, and should suppress trees and shrubs. Study of the extent to which such alterations in the vegetation of recharge areas will affect the seepage slopes needs to be conducted.

Removal of overgrown shrubs and promotion of herbaceous vegetation will favor species indigenous to cutthroat grass communities. Growing-season fires provide an essential environmental cue for flowering by herbaceous species. Early growing-season fires provide an effective management tool to remove woody species and prevent their re-invasion.

There are likely to be a number of changes that will result from changes in management. The environment of cutthroat grass communities will be modified following the institution of forces similar to those that historically controlled these habitats. Populations of endemic or disjunct seepage slope herbaceous species likely will be enhanced, including populations of rare or sensitive plant species. The increased water flow, coupled with the removal of shrub cover and herbaceous litter by fire, will cause a natural sheet flow across the soil surface in certain areas of the seepage slopes. This is a natural

characteristic of these habitats, and is, in fact, part of the reason that some plant species are found only in these seepage slopes. Care must be taken to protect the seepage slope environment from accentuation of erosion via regulation of vehicular and foot traffic in the seepage slopes to the extent practicable, especially during wet periods.

Buffer zones for cutthroat grass seepage slopes should be designated to contain the recharge areas upslope from the seepage slope, if readily identifiable, and extend to the drainageways below the seepage slope. In areas with an obvious slope gradient, the recharge zone may be considered to extend to the top of the slope above the seepage slope. However, in areas with little topographic relief, it may not be possible to accurately delimit the total recharge zone for cutthroat grass communities. This is due primarily to an almost complete lack of information on the details of groundwater hydrology in this region. On broad, shallow slopes, the recharge zone is more difficult to delineate, and is probably quite extensive. Therefore, in these cases the outer buffer boundary should be established at least a minimum of 61 m (200 ft.) beyond the edge of cutthroat grass communities.

In some situations, some very selective timber removal activities should be conducted in the zone upslope from the seepage slope. Methods of timber management in this critical zone should incorporate sensitive, non-invasive practices, such as those used in streamside management zones (*e.g.*, directional tree falling near seepage slopes). Further, timber removal should be conducted in a manner that favors maintenance of indigenous ground cover vegetation and minimizes soil disruption: use only skidders with large, soft tires, log only in driest weather to prevent rutting and compaction, do not drag log butts or ends on the ground, do not damage trees to remain on site, designate log-haul routes if this will minimize overall soil/vegetation disruption, leave no logging slash piles, locate log landing areas outside of sensitive habitats. Mechanical site preparation activities, such as drum-chopping or discing, should never be conducted in these areas. In no case should machinery enter the seepage slope itself.

Other mechanical disturbances of soil and vegetation should be prevented to the greatest extent practicable, including off-the-road vehicle use and plowed firelines. If new firelines are plowed in improper positions, they must be repaired immediately. Existing plowed firelines through or immediately upslope of seepage slopes should be restored, where possible, to eliminate ditching effects and alteration of local hydrology. Attempts should be made to determine desirable methods of restoring these old firelines. New firelines or roadways should never be created upslope from seepage slopes, as these can serve to alter or divert seepage flow.

Initial removal of trees in cutthroat grass communities, both pine and hardwood, may be necessary to restore areas where these trees have shaded out herbaceous vegetation. Removal may be accomplished by hand cutting or careful use of stem-selective herbicides. Note that scattered longleaf and/or slash pines are characteristic of some cutthroat grass communities, especially cutthroat grass flatwoods, and so a few should be left, particularly older trees.

Continuation of timber management in the buffer zone is contingent upon the activity not causing significant soil disturbance and damage to the

herbaceous layer. The effects of logging on ground cover must be assessed after each logging event. If it is determined that there has been significant disruption of the soil and herb layer, as judged by the presence of key indicator weed species, and by the critical reduction or elimination of certain disturbance-intolerant perennial grass species, timber management in the buffer zone must be appropriately modified.

Most cutthroat grass communities should be prescribed-burned in the growing season, during the period generally from April through mid June. If a site has been fire-suppressed for several years, an initial fuel reduction burn may be necessary in the dormant season prior to implementation of growing-season burns. These sites may require yearly growing-season burns thereafter for the first few years to bring woody encroachment under control. After woody encroachment is controlled, burn every 1 to 3 years on a random cycle, not burning at the same time of year each time. Vary the prescribed burning to the extent possible within the April through mid-June period. If manpower or legal restrictions (such as fire danger and smoke management issues) result in limited spring burning opportunities, then it is better to burn some cutthroat grass communities in the dormant season, rather than risk not being able to burn the site at all that year. To facilitate longleaf pine recruitment into the stands surrounding the cutthroat grass communities, burn late in the spring of a mast year (before fall seed-drop), and do not burn the spring after a mast year (Platt *et al.* 1990).

Broadscale application of herbicides in or near seepage slopes, and in areas that drain into seepage slopes, should not be allowed. However, some stem-selective herbicide treatment may prove a safe and efficient method of controlling undesirable woody vegetation within seepage slopes or buffer zones in some instances. This possibility should be investigated.

Historically, there has been an emphasis on grazing of much of the intact area of cutthroat grass communities. With grazing, creeping bluestem (*Schizachyrium stoloniferum)* and chalky bluestem (*Andropogon virginicus* var. *glaucus*) have been considered as decreasers, but cutthroat grass is considered an increaser (Sievers 1985). Various estimates have been given for the biomass production of cutthroat grass, up to 10,105 kg/ha (9,000 lb/acre), where slash pine overstory remains open (Sievers 1985). This productivity is higher than the maximum estimated for flatwoods, 8,420, kg/ha (7,500 lbs/acre), and only slightly less than that for freshwater marshes, 11,227 kg/ha (10,000 lbs/acre) (Sievers 1985).

An important factor making cutthroat grass communities highly suitable for grazing is the sod-forming nature of cutthroat grass (Penfield 1985). With careful management of the grazing timing and intensity, Avon Park AFB has successfully grazed cutthroat grass communities through leases for over 20 years with no seeming detrimental effect on biodiversity.

Where cattle grazing or trampling is shown to be an intolerable problem in a seepage slope, steps should be taken to attract cattle away from the seepage slope. Fencing may be necessary if livestock trampling becomes problematic.

In summary, cutthroat grass communities are highly diverse natural communities which are primarily found in Polk and Highlands counties in south-central Florida. They are threatened by fire-suppression and drainage, and have been lost from most of the landscape in which they once existed. An active fire management program with high fire-return intervals is needed in order to protect the biodiversity of these communities.

Table 1: Microhabitat zones of the cutthroat grass seepage slope complex:

ZONE	DESCRIPTION
1	Dry cutthroat grass
2	Cutthroat grass lawn
3	Shrubby cutthroat grass lawn
4	Wet cutthroat grass lawn, transitional to seepage slope
5	Cutthroat grass seepage slope
6	Transition from cutthroat grass to mixed herbaceous seepage slope
7	Mixed herbaceous seepage slope
8	Cutthroat grass lawn below seepage slope
9	Transition from seepage slope to flatwoods
10	Boggy sphagnous meadow
11	Natural drainageway through seepage slope

Table 2. Frequency of plant species in cutthroat grass seepage slope complex microhabitat zones at Avon Park Air Force Range.

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Agalinis linifolia	0	0	0	0	0	0	0	11	0	0	0
Aletris lutea	0	10	0	28	15	17	30	33	67	50	9
Amphicarpum muhlenbergianum	4	0	0	22	27	33	30	22	83	50	45
Andropogon brachystachyus	17	0	0	6	19	17	10	11	17	33	0
Andropogon glomeratus var. glaucopsis	4	55	6	33	50	33	20	56	50	33	18
Andropogon glomeratus var. glomeratus	0	3	0	0	19	0	10	11	33	17	9
Andropogon glomeratus var. hirsutior	0	13	13	11	31	33	20	0	33	17	0
Andropogon glomeratus var. pumilus	4	0	0	6	0	0	40	0	17	17	0
Andropogon gyrans var. stenophyllus	0	0	0	0	12	17	10	0	50	17	0
Andropogon ternarius var. cabanisii	4	0	0	0	0	0	0	0	0	0	0
Andropogon virginicus var. glaucus	8	13	0	0	8	0	0	0	17	0	0
Andropogon virginicus var. virginicus	8	3	0	6	31	0	10	0	0	0	0
Aristida beyrichiana	79	13	13	28	12	17	30	33	83	67	0
Aristida palustris	0	0	0	6	8	0	10	0	33	17	0
Aristida spiciformis	46	23	0	11	8	0	0	33	17	0	0
Asclepias connivens	0	3	0	0	12	0	0	11	0	33	0
Asclepias pedicellata	21	16	6	0	12	0	0	0	33	17	0
Asimina reticulata	71	16	13	11	8	0	0	33	50	17	0
Aster dumosus	0	3	0	0	8	0	0	0	0	0	0
Aster reticulatus	25	42	63	61	58	67	40	78	67	0	18
Axonopus compressus	0	0	0	6	0	0	0	0	0	0	0
Axonopus fissifolius	0	0	0	0	4	0	0	0	17	0	0
Axonopus furcatus	0	10	0	28	12	0	0	22	33	17	18
Bacopa caroliniana	0	0	0	0	0	0	0	0	0	0	9
Bartonia verna	0	0	0	0	0	0	20	0	33	0	9
Bartonia virginica	0	0	0	11	15	33	40	33	33	17	18
Befaria racemosa	54	0	19	0	0	0	0	0	17	0	0
Bigelowia nudata subsp. australis	0	3	0	22	19	0	40	11	67	17	9
Boltonia diffusa	0	0	0	0	0	0	0	11	0	0	0
Buchnera americana	4	0	0	0	0	0	0	0	0	0	0
Bulbostylis ciliatifolia	4	0	0	0	0	0	0	0	0	0	0
Burmannia biflora	0	0	0	11	0	0	20	0	17	0	9
Burmannia capitata	0	3	0	0	12	17	10	0	17	0	27
Calopogon barbatus	4	10	6	22	27	0	50	22	17	17	18

Table 2. *Cont.*

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Calopogon pallidus	0	10	0	17	23	17	20	22	0	33	0
Calopogon tuberosus	0	6	6	11	35	33	70	0	33	0	36
Carphephorus carnosus	0	6	0	11	4	0	0	22	50	33	0
Carphephorus corymbosus	4	0	0	0	0	0	0	0	0	0	0
Carphephorus paniculatus	29	52	0	28	27	0	0	44	33	17	0
Carphephorus odoratissimus	4	0	0	0	0	0	0	0	17	0	0
Centella asiatica	4	29	13	39	42	33	50	33	50	67	45
Chaptalia tomentosa	0	3	0	17	12	17	30	11	33	50	0
Cirsium nuttallii	0	0	0	0	4	0	0	0	0	0	0
Cnidoscolus stimulosus	4	0	0	0	0	0	0	0	0	0	0
Coreopsis floridana	0	6	0	0	15	17	20	0	33	17	18
Ctenium aromaticum	0	3	0	17	31	33	50	11	67	83	0
Cuphea carthagenensis	0	0	0	0	4	0	0	0	0	0	0
Cyperus haspan	0	0	0	6	4	17	0	0	0	33	27
Cyperus lanceolatus	0	0	0	0	4	0	0	0	0	0	0
Cyperus polystachyos	0	10	0	6	4	0	0	0	0	0	9
Cyperus retrorsus	8	6	0	0	0	0	0	0	0	0	0
Dichanthelium dichotomum	0	0	0	0	8	0	0	11	0	0	9
Dichanthelium ensifolium var. ensifolium	0	10	19	28	62	83	70	33	83	33	18
Dichanthelium ensifolium var. unciphyllum	21	3	0	0	0	0	0	11	17	0	0
Dichanthelium leucothrix	0	0	0	0	0	0	0	0	0	17	0
Dichanthelium portoricense	25	39	0	17	4	0	0	33	17	17	0
Dichanthelium scabriusculum	0	0	6	0	8	0	0	0	0	17	9
Dichanthelium strigosum var. glabrescens	0	0	0	0	0	0	0	0	17	0	0
Dichanthelium strigosum var. strigosum	0	0	0	6	8	0	0	11	17	17	0
Drosera capillaris	0	26	0	22	35	50	50	11	67	17	55
Eleocharis baldwinii	29	94	25	44	35	0	0	78	33	17	9
Eleocharis vivipara	0	0	0	0	0	17	0	0	0	0	18
Elephantopus elatus	17	0	19	0	0	0	0	0	17	0	0
Eragrostis elliottii	0	3	0	0	8	17	0	0	33	0	0
Eragrostis virginica	4	0	0	0	0	0	0	0	0	0	0
Erigeron vernus	8	13	6	28	38	17	20	33	67	33	27
Eriocaulon compressum	0	0	0	0	0	0	0	0	0	0	9

Table 2. *Cont.*

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Eriocaulon decangulare	0	16	13	61	77	83	70	33	83	83	64
Eryngium yuccifolium	0	0	0	6	0	17	0	0	0	17	0
Eupatorium leptophyllum	0	0	0	0	0	17	0	0	0	0	0
Eupatorium pilosum	0	6	0	6	8	0	0	0	17	17	0
Eupatorium recurvans	25	45	0	56	31	0	10	67	33	50	9
Eupatorium rotundifolium	8	10	13	0	4	0	0	33	0	17	18
Euphorbia inundata	0	0	0	6	0	0	0	11	33	33	0
Euthamia tenuifolia	38	16	6	44	19	0	10	44	33	33	9
Fimbristylis autumnalis	0	0	0	0	4	0	0	0	0	0	9
Fimbristylis dichotoma	0	0	0	0	4	0	0	0	0	0	0
Fimbristylis puberula	13	3	6	0	0	0	0	11	17	0	0
Fimbristylis schoenoides	0	0	0	0	4	0	0	0	0	0	0
Fuirena breviseta	0	0	0	0	0	33	0	0	0	17	9
Fuirena scirpoidea	8	13	6	28	42	17	60	22	50	67	55
Galactia elliottii	38	0	44	0	8	0	0	0	17	0	0
Galactia regularis	4	0	0	0	0	0	0	0	0	0	0
Gaylussacia dumosa	50	32	6	33	8	17	20	0	0	0	9
Gaylussacia nana	13	13	13	6	12	0	0	22	0	0	0
Gordonia lasianthus	0	3	31	0	15	0	0	0	0	0	9
Gratiola hispida	25	0	0	0	0	0	0	0	17	0	0
Gratiola pilosa	0	0	0	17	15	0	0	0	0	67	18
Gymnopogon chapmanianus	17	0	0	0	0	0	0	0	0	0	0
Habenaria repens	0	0	0	0	0	0	0	0	0	0	9
Hartwrightia floridana	4	48	50	72	88	100	80	67	83	100	55
Hedyotis uniflora	4	0	0	17	4	0	0	11	0	17	9
Helianthus angustifolius	0	0	0	0	4	0	0	0	0	0	0
Hydrocotyle umbellata	0	0	0	0	0	0	0	0	0	17	9
Hypericum cistifolium	0	32	50	50	54	33	20	56	67	33	73
Hypericum fasciculatum	0	3	13	28	27	17	50	0	50	50	64
Hypericum mutilum	0	0	0	0	0	0	0	0	0	0	9
Hypericum myrtifolium	0	0	0	28	15	0	20	22	50	67	9
Hypericum reductum	83	10	0	0	0	0	0	33	17	0	0
Hypericum tetrapetalum	42	23	6	17	8	0	0	33	17	17	0

Table 2. *Cont.*

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Hypoxis juncea	54	32	19	6	23	0	10	44	33	17	0
Ilex cassine	0	3	6	0	0	17	0	0	0	0	0
Ilex glabra	58	61	75	72	77	83	60	89	100	67	55
Juncus marginatus var. biflorus	4	0	0	11	4	17	0	0	0	17	0
Juncus scirpoides	8	6	0	28	8	0	0	0	17	0	36
Lachnanthes caroliniana	0	10	0	0	23	50	40	0	0	33	9
Lachnocaulon anceps	13	16	0	22	19	0	0	22	50	50	9
Lachnocaulon beyrichianum	4	0	0	0	0	0	0	0	0	0	0
Lachnocaulon engleri	0	0	0	0	8	0	0	0	0	0	9
Lachnocaulon minus	0	0	0	0	0	0	0	0	0	0	18
Lechea torreyi	4	3	6	0	0	0	0	11	0	0	0
Liatris spicata	0	6	0	6	19	17	40	22	50	33	18
Liatris tenuifolia var. quadriflora	21	0	0	0	0	0	0	0	0	0	0
Lilium catesbaei	0	0	0	6	27	17	20	22	33	33	9
Linum medium var. texanum	0	0	0	6	0	0	0	11	17	0	0
Lobelia glandulosa	0	6	0	6	12	17	0	0	50	17	9
Lobelia paludosa	4	6	0	11	15	17	0	11	0	33	0
Ludwigia alata	0	0	0	6	8	0	0	0	0	17	0
Ludwigia maritima	21	6	0	22	4	0	0	0	0	17	0
Lycopodiella alopecuroides	0	29	13	44	65	83	80	33	83	67	27
Lycopodiella appressa	0	0	0	0	8	0	0	0	17	0	18
Lycopodiella caroliniana	4	3	0	11	19	17	30	0	33	0	36
Lycopodiella prostrata	0	0	0	0	0	0	10	0	0	0	0
Lygodesmia aphylla	17	0	6	0	0	0	0	0	33	0	0
Lyonia fruticosa	67	61	44	33	8	0	0	78	33	0	9
Lyonia ligustrina var. foliosiflora	0	13	44	6	31	17	10	22	17	0	9
Lyonia lucida	79	77	50	67	54	0	20	67	33	0	18
Magnolia virginiana	0	0	0	0	0	0	0	0	17	0	0
Marshallia tenuifolia	0	10	0	56	38	67	50	33	67	67	27
Myrica cerifera	75	61	63	50	50	0	20	56	83	50	27
Myrica heterophylla	0	0	25	28	54	100	60	0	50	0	27
Osmunda cinnamomea	4	10	69	17	23	50	20	22	17	0	45
Osmunda regalis var. spectabilis	0	0	6	6	4	17	0	0	0	0	18

Table 2. ***Cont.***

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Oxypolis filiformis	4	6	0	0	27	17	20	33	50	33	27
Panicum abscissum	96	94	63	83	96	67	30	100	83	67	55
Panicum hemitomon	0	0	0	0	4	0	0	0	0	17	0
Panicum hians	0	0	0	0	0	17	0	0	0	0	0
Panicum longifolium	0	0	0	0	0	0	0	0	33	0	0
Panicum repens	0	0	0	0	0	0	0	0	0	0	18
Panicum rigidulum	0	0	0	6	0	0	0	0	0	17	0
Panicum tenerum	0	0	0	0	0	0	0	0	33	0	9
Panicum verrucosum	0	3	0	0	4	17	10	11	17	0	0
Paspalum laeve	0	0	0	11	12	17	0	0	33	17	9
Paspalum notatum var. saurae	0	0	0	6	4	0	0	0	0	0	0
Paspalum praecox	0	10	0	17	23	0	30	11	33	50	18
Paspalum setaceum	42	19	0	6	4	0	0	0	0	0	0
Paspalum urvillei	0	0	0	0	4	0	0	0	0	0	0
Persea palustris	0	6	44	0	8	17	10	0	17	0	18
Physostegia purpurea	0	0	0	6	4	0	0	0	17	33	0
Piloblephis rigida	8	0	0	0	0	0	0	0	0	0	0
Pinguicula caerulea	0	16	6	11	19	0	30	33	17	17	0
Pinguicula lutea	25	71	19	33	23	33	0	56	33	0	0
Pinguicula pumila	4	3	0	6	0	17	0	11	0	0	0
Pinus elliottii var. densa	13	19	31	6	19	17	50	22	33	0	9
Pinus palustris	25	32	25	22	31	50	40	44	83	0	27
Pityopsis graminifolia	12	0	0	0	0	0	0	0	17	0	0
Platanthera blephariglottis var. conspicua	0	6	6	6	8	17	20	11	33	17	18
Platanthera ciliaris	0	0	0	6	4	0	0	11	0	0	9
Platanthera integra	0	0	0	0	4	0	0	0	0	0	9
Pluchea foetida	0	0	0	6	0	17	0	0	0	33	9
Pluchea rosea	0	3	0	0	0	0	0	0	0	0	0
Pogonia ophioglossoides	0	0	6	11	31	67	60	11	0	17	27
Polygala cruciata	0	0	0	11	19	17	60	11	33	17	18
Polygala incarnata	0	3	0	0	0	0	0	11	0	0	0
Polygala lutea	0	3	0	6	8	0	0	11	33	33	9
Polygala ramosa	0	0	0	0	0	0	10	11	0	17	9

Table 2. *Cont.*

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Polygala rugelii	38	81	13	67	73	83	50	100	100	50	27
Polygala setacea	58	13	0	0	4	0	0	33	33	17	0
Polypremum procumbens	4	0	0	0	0	0	0	0	0	0	9
Pontederia cordata	4	0	0	0	0	0	0	0	0	0	0
Proserpinaca pectinata	0	0	0	6	0	0	0	0	0	33	18
Pteridium aquilinum var. latiusculum	17	3	38	0	4	0	0	11	17	0	9
Pterocaulon pycnostachyum	71	23	19	17	8	0	10	44	33	17	0
Pyrus arbutifolia	0	0	13	0	0	0	0	0	0	0	0
Quercus geminata	13	3	0	0	0	0	0	0	0	0	0
Quercus laurifolia	0	3	0	0	0	0	0	0	0	0	0
Quercus minima	25	3	6	0	0	0	0	22	17	17	0
Rhexia cubensis	0	6	19	17	46	17	20	11	33	17	27
Rhexia mariana	8	29	0	50	50	33	60	44	67	67	45
Rhexia nashii	0	0	0	0	15	0	0	0	17	17	9
Rhexia nuttallii	54	68	13	67	73	83	50	78	67	33	36
Rhexia petiolata	0	3	6	11	12	33	30	0	0	0	36
Rhynchospora baldwinii	0	6	0	6	0	0	10	11	0	0	0
Rhynchospora breviseta	0	3	0	6	35	67	40	22	83	33	18
Rhynchospora cephalantha	0	3	6	39	62	67	80	11	67	50	36
Rhynchospora chapmanii	0	0	0	11	19	17	10	11	17	17	9
Rhynchospora ciliaris	8	84	25	67	77	83	70	89	83	50	36
Rhynchospora colorata	0	0	0	0	4	0	0	0	0	0	0
Rhynchospora decurrens	0	0	0	6	4	0	0	11	0	17	0
Rhynchospora fascicularis	42	55	13	33	46	50	50	78	67	50	9
Rhynchospora fascicularis var. distans	0	0	0	0	0	0	0	0	17	0	0
Rhynchospora fernaldii	13	3	0	0	0	0	0	0	0	0	0
Rhynchospora inundata	0	0	0	0	0	0	0	0	33	17	0
Rhynchospora latifolia	0	0	0	0	0	17	20	0	17	17	0
Rhynchospora microcarpa	0	0	0	0	8	0	0	0	0	0	9
Rhynchospora microcephala	0	0	0	0	0	0	0	0	0	0	9
Rhynchospora oligantha	0	0	0	0	15	50	50	0	0	0	0
Rhynchospora plumosa	4	3	0	0	8	0	0	0	0	0	0
Rhynchospora rariflora	0	3	0	17	31	83	70	33	0	67	18

Table 2. *Cont.*

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Rhynchospora wrightiana	0	19	0	17	19	17	20	0	17	17	0
Sabatia difformis	0	26	19	39	58	83	60	22	67	17	36
Sabatia grandiflora	4	16	6	33	46	50	60	56	67	50	18
Saccharum giganteum	0	0	0	0	0	17	10	0	0	0	0
Sacciolepis indica	0	0	0	0	0	0	0	0	0	17	27
Sagittaria graminea var. chapmanii	0	0	0	0	0	0	0	0	0	17	36
Sagittaria isoetiformis	0	0	0	6	0	0	0	0	0	0	0
Sagittaria lancifolia	0	0	0	0	0	0	10	0	0	0	0
Sarracenia minor	4	45	31	50	73	83	70	67	50	100	64
Schizachyrium stoloniferum	29	16	6	17	27	17	20	33	33	17	0
Schrankia microphylla var. floridana	67	19	13	6	8	0	0	11	33	17	0
Scleria georgiana	0	0	0	0	4	0	10	0	0	0	0
Scleria pauciflora	8	6	6	0	0	0	0	0	0	0	9
Scleria reticularis	13	26	6	56	62	50	20	44	50	67	36
Scleria triglomerata	13	6	19	11	15	17	20	22	0	0	0
Serenoa repens	83	48	81	28	15	33	0	33	67	33	9
Setaria geniculata	0	6	0	0	4	0	0	0	0	0	0
Sisyrinchium angustifolium	0	0	0	0	0	0	10	0	0	17	9
Smilax auriculata	4	3	0	0	0	0	0	0	0	0	0
Smilax laurifolia	0	0	19	0	4	0	0	0	0	0	9
Solidago fistulosa	4	6	13	11	15	0	0	0	0	33	18
Solidago odora var. chapmanii	4	0	0	0	0	0	0	0	0	0	0
Sorghastrum secundum	8	6	0	0	4	0	0	11	17	0	0
Sphagnum spp.	0	13	31	33	65	100	70	11	33	50	91
Spiranthes vernalis	0	3	0	0	8	0	10	11	0	17	0
Stillingia sylvatica var. sylvatica	8	3	6	0	0	0	0	0	17	0	0
Stillingia sylvatica var. tenuis	0	0	0	0	0	0	0	0	0	17	0
Syngonanthus flavidulus	92	81	25	56	38	0	40	78	100	50	36
Triadenum virginicum	0	0	0	0	4	0	0	0	0	0	0
Utricularia fibrosa	0	0	0	0	0	0	0	0	0	0	9
Utricularia juncea	0	0	0	6	8	0	10	11	17	0	27
Utricularia purpurea	0	0	0	0	0	0	0	0	0	0	9
Utricularia subulata	13	19	6	17	23	17	30	22	50	33	36

Table 2. ***Cont.***

SCIENTIFIC NAME	1	2	3	4	5	6	7	8	9	10	11
	n=24	n=31	n=16	n=18	n=26	n=6	n=10	n=9	n=6	n=6	n=11
Vaccinium myrsinites	92	48	44	17	12	0	0	44	33	0	0
Viola lanceolata	0	3	6	6	4	0	10	0	0	17	9
Viola primulifolia	0	0	0	0	0	0	0	11	0	0	0
Vitis rotundifolia var. rotundifolia	0	0	19	0	0	0	0	0	0	0	0
Woodwardia areolata	0	0	0	0	0	0	0	0	0	0	18
Woodwardia virginica	0	0	31	22	35	50	30	0	33	33	27
Xyris ambigua	0	23	0	50	65	50	60	67	83	67	18
Xyris brevifolia	38	39	6	6	0	0	10	33	33	0	9
Xyris caroliniana	50	10	6	0	0	0	0	11	17	0	0
Xyris difformis var. floridana	4	3	0	11	4	33	0	11	33	0	0
Xyris elliottii	17	42	19	50	54	67	60	67	100	67	36
Xyris fimbriata	0	3	13	11	35	33	60	0	17	17	36
Xyris jupicai	0	6	0	6	4	17	0	0	0	0	27
Xyris platylepis	4	77	19	61	85	33	30	100	50	33	27
Xyris serotina	0	0	0	0	0	0	0	0	0	0	9
Xyris smalliana	0	0	0	6	0	0	30	0	0	17	0
Zigadenus densus	0	3	6	0	12	0	20	0	0	0	0

Table 3. Percent frequency of species in other cutthroat grass community types at Avon Park Air Force Range.

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Pterocaulon pycnostachyum	100	10	7	20	0
Vaccinium myrsinites	100	20	14	60	9
Serenoa repens	100	40	14	80	18
Pinus palustris	75	20	7	20	0
Xyris caroliniana	75	20	0	20	0
Hypericum reductum	75	30	0	20	0
Asimina reticulata	75	30	0	20	9
Gratiola hispida	50	0	0	0	0
Befaria racemosa	50	10	0	0	0
Aristida spiciformis	50	30	7	20	0
Galactia elliottii	50	10	0	0	0
Quercus minima	50	20	0	20	0
Schrankia microphylla var. floridana	50	10	0	20	0
Eleocharis baldwinii	50	60	36	40	9
Dichanthelium ensifolium var. unciphyllum	50	10	0	0	9
Lyonia fruticosa	50	20	14	0	9
Carphephorus paniculatus	50	60	7	40	9
Lyonia lucida	75	60	57	80	36
Euthamia tenuifolia	50	40	7	20	18
Aristida beyrichiana	50	50	7	40	18
Tephrosia hispidula	25	0	0	0	0
Carphephorus odoratissimus	25	0	0	0	0
Carphephorus corymbosus	25	0	0	0	0
Pityopsis graminifolia	25	0	0	0	0
Lechea torreyi	25	0	0	0	0
Eragrostis virginica	25	0	0	0	0
Bulbostylis ciliatifolia	25	0	0	0	0
Liatris tenuifolia var. quadriflora	25	10	0	0	0
Aster dumosus	25	0	0	0	0
Gymnopogon brevifolius	25	0	0	20	0
Rhynchospora plumosa	25	10	7	0	0
Seymeria pectinata	25	0	0	0	0

Table 3. ***cont.***

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Agalinis obtusifolia	25	0	0	0	0
Elephantopus elatus	25	0	0	0	0
Pinguicula pumila	25	0	0	0	0
Hypericum tetrapetalum	25	10	0	0	0
Lygodesmia aphylla	25	10	0	0	0
Rhynchospora fernaldii	25	10	0	0	0
Gaylussacia dumosa	25	10	0	20	0
Scleria pauciflora	25	10	0	0	0
Blechnum serrulatum	25	0	0	0	0
Gaylussacia nana	25	0	0	0	0
Andropogon virginicus var. decipiens	25	10	0	0	0
Gaylussacia tomentosa	25	0	0	0	0
Pinguicula lutea	25	40	14	0	0
Pityopsis graminifolia var. tracyi	25	10	0	0	0
Schizachyrium stoloniferum	50	20	0	40	27
Rhexia nuttallii	50	50	64	40	27
Andropogon brachystachyus	50	20	7	20	27
Andropogon ternarius var. cabanisii	25	0	0	0	9
Solidago fistulosa	25	10	14	20	9
Paspalum setaceum	25	20	0	60	9
Sorghastrum secundum	25	10	0	0	9
Xyris brevifolia	25	10	7	0	9
Hypoxis juncea	25	20	7	20	9
Polygala setacea	25	30	0	20	9
Dichanthelium dichotomum	25	0	0	20	9
Aster reticulatus	25	20	21	0	9
Pinus elliottii var. densa	25	70	0	0	9
Stillingia sylvatica var. sylvatica	25	0	0	0	9
Dichanthelium portoricense	25	30	0	20	9
Lachnocaulon anceps	50	40	7	80	36
Rhynchospora fascicularis	50	70	14	40	36
Myrica cerifera	75	90	36	80	64

Table 3. ***cont.***

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Utricularia subulata	25	0	7	40	18
Ludwigia maritima	25	40	0	20	18
Xyris difformis var. floridana	25	10	7	40	18
Syngonanthus flavidulus	50	70	21	60	45
Eupatorium recurvans	50	20	50	40	45
Polygala lutea	0	20	7	40	0
Vaccinium corymbosum	0	0	0	20	0
Pteridium aquilinum var. latiusculum	0	10	0	0	0
Hydrocotyle umbellata	0	10	0	0	0
Polygonum hydropiperoides	0	0	7	0	0
Eriocaulon compressum	0	0	7	0	0
Juncus repens	0	0	7	0	0
Bartonia virginica	0	0	7	0	0
Scleria baldwinii	0	0	7	0	0
Gratiola pilosa	0	20	7	20	0
Diodia virginiana	0	10	0	0	0
Burmannia capitata	0	0	7	0	0
Nyssa sylvatica var. biflora	0	0	7	0	0
Sagittaria lancifolia	0	0	7	0	0
Juncus scirpoides	0	20	0	20	0
Ludwigia suffruticosa	0	0	7	0	0
Scleria triglomerata	0	10	7	20	0
Myrica heterophylla	0	30	7	0	0
Ludwigia lanceolata	0	0	7	0	0
Gratiola ramosa	0	0	7	0	0
Rhynchospora chapmanii	0	0	14	20	0
Sacciolepis striata	0	0	7	0	0
Polygala ramosa	0	0	0	20	0
Sagittaria isoetiformis	0	0	7	0	0
Sisyrinchium angustifolium	0	10	0	0	0
Ilex cassine	0	10	0	0	0
Chaptalia tomentosa	0	30	0	0	0

Table 3. ***cont.***

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Viola lanceolata	0	10	0	20	0
Persea palustris	0	30	0	0	0
Panicum tenerum	0	10	0	20	0
Xyris jupicai	0	10	0	20	0
Pluchea rosea	0	0	29	0	0
Rhexia petiolata	0	20	0	0	0
Ludwigia linifolia	0	0	7	20	0
Rhynchospora filifolia	0	0	7	20	0
Calopogon tuberosus	0	0	7	20	0
Polygala cruciata	0	20	7	0	0
Dichanthelium scabriusculum	0	10	0	0	0
Asclepias connivens	0	10	0	0	0
Dichanthelium strigosum var. glabrescens	0	10	0	0	0
Spiranthes longilabris	0	0	0	20	0
Lyonia ligustrina var. foliosiflora	0	10	7	0	0
Rhynchospora baldwinii	0	0	0	20	0
Sacciolepis indica	0	20	0	0	0
Bartonia verna	0	0	0	20	0
Gordonia lasianthus	0	20	0	0	0
Lycopodiella caroliniana	0	0	14	0	0
Setaria geniculata	0	20	0	0	0
Panicum verrucosum	0	10	0	0	0
Juncus marginatus var. biflorus	0	10	0	0	0
Osmunda cinnamomea	0	10	7	0	0
Cyperus polystachyos	0	10	0	0	0
Smilax walteri	0	10	7	0	0
Paspalum notatum var. saurae	0	10	0	0	0
Polygala cymosa	0	0	14	0	0
Hedyotis uniflora	0	0	14	0	0
Vitis rotundifolia var. rotundifolia	0	10	0	0	0
Viola primulifolia	0	10	0	0	0
Cyperus retrorsus	0	10	0	0	0

Table 3. ***cont.***

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Calopogon pallidus	0	10	0	0	0
Andropogon virginicus var. virginicus	25	10	7	20	27
Andropogon virginicus var. glaucus	25	10	0	40	27
Axonopus furcatus	25	30	0	40	27
Rhynchospora ciliaris	25	40	43	100	27
Ilex glabra	50	70	7	100	55
Cyperus haspan	0	0	7	0	9
Ludwigia alata	0	0	7	0	9
Helianthus angustifolius	0	0	0	0	9
Asclepias pedicellata	0	10	7	20	9
Andropogon glomeratus var. hirsutior	0	0	0	0	9
Utricularia purpurea	0	0	0	0	9
Spartina bakeri	0	0	0	0	9
Lycopodiella appressa	0	0	0	0	9
Rhynchospora rariflora	0	30	0	0	9
Saccharum giganteum	0	0	0	0	9
Dichanthelium erectifolium	0	0	7	20	9
Rhynchospora fascicularis var. distans	0	0	7	20	9
Rhynchospora wrightiana	0	10	0	20	9
Woodwardia virginica	0	40	14	0	9
Panicum repens	0	0	0	0	9
Dichanthelium ensifolium var. ensifolium	0	10	21	20	9
Fimbristylis puberula	0	10	7	0	9
Eupatorium rotundifolium	0	20	0	0	9
Rhynchospora microcarpa	0	0	0	0	9
Drosera capillaris	0	10	29	20	9
Dichanthelium strigosum var. strigosum	0	0	0	20	9
Physostegia purpurea	0	0	0	20	9
Scleria georgiana	0	10	14	0	9
Utricularia juncea	0	0	7	0	9
Pogonia ophioglossoides	0	10	7	0	9
Sarracenia minor	25	90	43	80	36

Table 3. ***cont.***

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Polygala rugelii	50	60	79	80	64
Proserpinaca pectinata	0	30	14	0	18
Pinguicula caerulea	0	0	7	0	18
Sabatia difformis	0	30	14	0	18
Sagittaria graminea var. chapmanii	0	0	7	0	18
Coreopsis floridana	0	0	0	0	18
Aletris lutea	0	30	14	20	18
Aristida palustris	0	0	14	20	18
Hypericum cistifolium	0	0	21	40	18
Pluchea foetida	0	10	21	0	18
Liatris spicata	0	10	0	0	18
Taxodium ascendens	0	0	0	0	18
Eragrostis elliottii	0	0	0	0	18
Coelorachis rugosa	0	0	0	0	18
Paspalum laeve	0	0	0	20	18
Agalinis linifolia	0	0	0	0	18
Xyris elliottii	25	50	36	60	45
Panicum abscissum	75	100	93	100	100
Andropogon glomeratus var. glomeratus	0	0	0	0	27
Xyris smalliana	0	0	7	0	27
Fuirena scirpoidea	0	20	14	60	27
Panicum longifolium	0	0	7	0	27
Lobelia glandulosa	0	10	0	40	27
Bidens mitis	0	0	0	0	27
Sphagnum spp.	0	50	36	0	27
Rhynchospora inundata	0	0	0	0	27
Rhynchospora decurrens	0	0	14	0	27
Oxypolis filiformis	0	20	7	20	27
Andropogon gyrans var. stenophyllus	0	0	0	0	27
Rhexia nashii	0	0	0	20	27
Xyris ambigua	25	50	57	40	55
Rhexia mariana	25	60	50	40	55

Table 3. ***cont.***

SCIENTIFIC NAME	Mesic flatwoods	Wet flatwoods	Depression marsh margin	Drainage ecotone	Wet prairie
	n=4	n=10	n=14	n=5	n=11
Rhynchospora breviseta	0	20	7	20	36
Bigelowia nudata subsp. australis	0	20	7	40	36
Erigeron vernus	0	40	14	60	36
Lobelia paludosa	0	10	0	40	36
Carphephorus carnosus	0	40	7	60	36
Panicum hemitomon	0	0	7	0	36
Marshallia tenuifolia	25	40	36	20	64
Paspalum praecox	0	50	7	0	54
Lachnanthes caroliniana	0	40	29	0	45
Xyris fimbriata	0	10	29	0	45
Rhexia cubensis	0	20	43	20	55
Ctenium aromaticum	0	20	0	60	55
Hypericum fasciculatum	0	20	43	0	55
Xyris platylepis	0	80	43	60	55
Lycopodiella alopecuroides	0	40	43	20	55
Scleria reticularis	25	80	29	60	82
Sabatia grandiflora	0	10	36	40	64
Andropogon glomeratus var. glaucopsis	0	30	36	60	64
Hypericum myrtifolium	0	30	21	40	73
Amphicarpum muhlenbergianum	0	30	21	40	73
Centella asiatica	0	60	50	60	73
Hartwrightia floridana	0	60	43	20	82
Rhynchospora cephalantha	0	50	50	0	82
Eriocaulon decangulare	0	80	71	40	91

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Restoration of Cutthroat Grass Communities

Restoration Objective: Maintain and enhance the structure, function, and composition of cutthroat grass communities, protect cutthroat grass biodiversity to encompass the range of geographic variation, and increase the spatial extent of cutthroat grass habitat in South Florida.

Restoration Criteria

The restoration objective will be achieved when: (1) cutthroat grass communities are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression; (2) degraded areas are identified, acquired, and restored to suitable habitat; (3) appropriate ecosystem management plans (including monitoring and research) have been prepared, funded, and implemented for long-term perpetuation of the cutthroat grass landscape; (4) cutthroat grass is appropriately protected and managed to benefit community-dependent species; (5) ecological linkages to adjacent communities are restored; and (6) landscape-level habitat diversity is restored.

Community-level Restoration Actions

1. **Determine the historical and current distribution and status of cutthroat grass communities in peninsular Florida.** There is very little specific published or unpublished data on the rangewide distribution and status of cutthroat grass and cutthroat grass communities. Estimates of the current extent of cutthroat grass communities are known only for Archbold Biological Station and Avon Park AFB.

    1.1. **Estimate the historical extent and location of cutthroat grass communities for all counties within the range of cutthroat grass.** This would require interpretation of soil surveys, geomorphologic features, and historical aerial photography, in conjunction with mapping of known occurrences, to derive an estimate of potential range and extent of cutthroat grass and cutthroat grass communities.

    1.2. **Determine the current distribution and status of cutthroat grass communities on both private and public lands in Florida.** Some cutthroat grass communities could be located by interpretation of recent aerial photography. However, fire-suppressed examples and cutthroat grass flatwoods communities would be difficult to accurately locate on aerial photographs, and would require intensive ground-truthing to eliminate errors in interpretation.

1.3. Identify, map and conduct ecological (plant and animal) inventories of remaining cutthroat grass communities to determine locations for the highest quality cutthroat grass community sites. Data from a systematic and comprehensive inventory would be used to develop, rank and prioritize a listing of the most ecologically significant cutthroat grass communities and to determine the degree of vulnerability of sites. Plant and animal inventories and *de novo* searches for rare taxa would uncover previously unknown sites and thereby provide updated documentation on the status and distribution of rare taxa. To date, these surveys have been conducted at few sites other than within Avon Park AFB.

2. Prevent further destruction or degradation of existing cutthroat grass communities.

2.1. Secure protection for all of the remaining intact, high-quality cutthroat grass community sites. Develop a protection plan for all tracts identified in **1.2** and **1.3**. Continue through land acquisition, landowner agreements, and conservation easements, land trades, or other conservation measures protection of cutthroat grass sites. Priority should be placed on preventing the loss of any remaining high-quality cutthroat grass community sites, with emphasis on protection of sites with intact landscapes and an intact, diverse native ground cover. Devise and negotiate interagency agreements (with Water Management Districts, Department of Environmental Protection, U. S. Fish & Wildlife Service, *etc*.) to improve mitigation procedures for loss of wetlands in cutthroat grass community landscapes. Sites identified as most threatened with destruction should be targeted and protected to prevent destruction. Once cutthroat grass communities have been converted to agricultural, commercial, or residential uses, there is no known way to restore cutthroat grass or associated species. The highest priority should be placed on preventing development of remaining cutthroat grass communities.

2.2. Prevent further degradation of disturbed, but recoverable examples of cutthroat grass communities by securing protection of such sites. This could be accomplished by conservation methods that prevent development, other than land acquisition, such as conservation easements, particularly on large cattle ranches where land acquisition is prohibitively expensive.

2.3. Ensure proper protection of existing protected areas. Fire-suppression and lack of sufficiently frequent or intense prescribed burning continues to be a problem in management of cutthroat grass communities even in protected areas. Drainage and other hydrologic alterations on private land adjacent to existing protected areas, and alterations in the source of seepage hydrology within the uplands adjacent to cutthroat grass communities could be a major long-term problem in maintaining protected sites. Federal and State agencies need to work more efficiently and closely together to solve problems that cross the jurisdictional boundaries of an agency.

2.4. Ensure proper management of existing protected areas. Staffing and budgetary constraints continue to present the greatest threat to proper management of existing protected areas. Other problems faced by land managers that hinder implementation of proper management strategies include lack of technical guidance information, insufficient equipment and manpower, and restrictions on the timing, size, and intensity of prescribed burning.

2.5. Develop private landowner protection incentives for cutthroat grass communities. Provide an economic or tax incentive to private landowners to prevent drainage and alteration of the watersheds supporting cutthroat grass communities.

Federal, State and county governments should explore new and innovative ways to provide tax breaks or other economic incentives to private landowners that choose ecological stewardship of their lands. Economic opportunities for private landowners to retain native vegetation should be encouraged, including hunting, eco-tourism, low-intensity grazing of native rangeland, and harvesting of native grass seed for reclamation and restoration purposes. All of these help provide economic incentives to landowners to retain areas in natural cutthroat grass vegetation. Eliminate any tax incentives for silvicultural operations on cutthroat grass communities.

2.6. **Connect existing cutthroat grass community preserves 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. Lands acquired as connectors between cutthroat grass community preserves need not be cutthroat grass communities. Much of this interconnection can be provided by designing preserves and connectors which encompass scrub and other xeric upland communities in association with the adjacent cutthroat grass communities.

2.7. **Conduct vegetation monitoring of cutthroat grass communities to determine responses to various management strategies.** Several potential results could come from vegetation monitoring of cutthroat grass communities which have implications for long-term management strategies. First, by considering the effects of management on a broader set of ecosystem components (*e.g.* all the plant species present) the possibility of misleading results (in the context of ecosystem management) based on a single species subject to possibly non-management related events is minimized. Secondly, because much more replication is possible in a vegetation study, the chances of uncovering statistically significant differences between treatments is increased. Thirdly, long-term trends in the abundance of conservative versus weedy or opportunistic species can be monitored within the plots, and can be used as input for management decisions.

2.8. **Encourage and support the efforts of the central and South Florida interagency prescribed fire councils.** Without the ability and flexibility to use prescribed burning, management of cutthroat grass communities would be virtually impossible. The role of the prescribed fire councils in safeguarding, promoting and educating the public about the use of prescribed fire is essential to the future of prescribed burning.

3. **Restore existing degraded cutthroat grass communities.** Develop techniques for restoring modified or disturbed cutthroat grass communities.

3.1. **Reintroduce natural fires and/or prescribe controlled burns.** Cutthroat grass communities that have been degraded because of fire exclusion may be restorable with prescribed fires. Each protected cutthroat grass community site should have a fire management plan. Management plans should specifically include allowing natural, lightning-ignited fires to burn through the cutthroat grass community landscape whenever possible, especially on the larger preserves. Burn plans for sites should specify fire type, intensity and frequency in order to mimic natural fires to meet management objectives.

3.2. **Encourage maintenance and recovery of landscape-level ecological processes.** Where possible, management efforts should strive to maintain and enhance ecological processes (natural fire regimes, natural hydrologic perturbations,

biological interactions, ecosystem function, *etc.)* characteristic of the natural landscape. In particular, allowing natural lightning fires and other natural disturbances should receive special attention in management plans for areas with intact landscapes. Firebreaks and roads should be placed well away from ecotones. Firebreaks at ecotones can greatly disrupt the hydrology of cutthroat grass communities. Ecotones that have been degraded by existing roads and fire breaks should be restored.

3.3. Eliminate or control exotic and off-site species. The native ground cover of some cutthroat grass communities has been altered by past attempts to improve the livestock grazing potential and /or commercial forestry potential. Effort to eliminate or control exotic plants should be implemented. In addition, eradication of feral hogs should be a priority on cutthroat grass community preserves.

3.4. Continue to allow appropriate public uses. Cutthroat grass communities acquired for conservation of biotic resources must be protected from inappropriate public use. However, public access is very important for educational purposes and to build public support for conservation efforts. Off-road vehicle use and commercial rare plant collecting are not compatible with conservation.

3.5. Monitor for negative population trends among important cutthroat grass community plant and animal taxa. Each cutthroat grass community preserve should have a specific monitoring plan that will alert land managers to extirpations or downward trends in populations of selected cutthroat grass community species, including endemic species, listed species, and imperilled species.

3.6. Monitor and eliminate hydrologic alterations. Artificial drainage from cutthroat grass communities should be minimized by plugging of ditches, and filling ruts associated with old firebreaks, fire plow furrows, and woods roads, particularly those which run downslope and serve to drain the community. Vegetation sampling and monitoring of permanent vegetation plots is needed to determine the effects of hydrologic alteration on cutthroat grass communities.

4. Encourage ecosystem/landscape-level research projects in cutthroat grass communities. Identify ecosystem processes (vegetation composition and structure, successional patterns, hydrologic regimes, burn regimes, herbivory, *etc*.) in cutthroat grass communities and use research findings to aid in development of management guidelines and strategies.

4.1. Determine the rangewide geographic and local edaphic variation in the cutthroat grass community ecosystem. Conduct rangewide studies incorporating floristic surveys (considering species composition, phytogeographic patterns, relative frequency data and vegetation physiognomy), faunal surveys and correlated environmental parameters (climate, hydrology, edaphic factors and regional landscape context) to recognize and differentiate regional variation and local edaphic variation. This is of particular importance to determine if the cutthroat grass communities described for Avon Park AFR (mostly on the Bombing Range Ridge) are similar or dissimilar to communities on the Lake Wales Ridge, and if additional,

as yet undescribed, cutthroat grass community types are present on the Lake Wales Ridge. Understanding local and regional variation is necessary in order to protect the biodiversity of cutthroat grass communities.

4.2. Fund and conduct research on the effect of livestock grazing on cutthroat grass communities. Since much of the economic benefit to private landowners of cutthroat grass communities is derived from revenues generated from livestock grazing, it is important to fund studies evaluating the effects of livestock grazing on not only the cutthroat grass community, but also on its flora and fauna. Funding to evaluate the effects of livestock grazing on cutthroat grass vegetation through establishment of permanent plots and exclosures to monitor the long-term effects of livestock grazing should be encouraged.

4.3. Encourage research on prescribed burning in cutthroat grass communities. As more land with cutthroat grass communities is purchased and/or protected, management knowledge about the effects of fire frequency, intensity and seasonality will become increasingly important if we are to maintain the biodiversity of the cutthroat grass community and landscape. In addition, the long-term effect of differing fire frequency needs study, since recent trends indicate that many land managers of public properties are burning cutthroat grass communities typically on a 3-year rotation, rather than the potentially more natural annual or biennial burn cycle. Knowledge about the natural fire season and research on fire intervals would lead to initiation of improved fire management programs.

4.4. Conduct research to determine the applicability and effectiveness of various mechanical treatments for restoration of severely degraded cutthroat grass communities. Former cutthroat grass communities that have been degraded because of fire suppression or other disturbances should benefit from controlled burns.

5. Increase awareness and knowledge of the cutthroat grass ecosystem.

5.1. Provide technical advisory support to private landowners of cutthroat grass communities. Provide technical information on ecosystem management strategies and practices to private landowners willing and interested in protecting biodiversity of cutthroat grass communities.

5.2. Increase public awareness and understanding of the cutthroat grass ecosystem. Public understanding and approval are required for any conservation effort to be successful. Public announcements should highlight land acquisition projects such as Florida's Conservation and Recreational Lands (CARL) program and Preservation-2000. Environmental education programs in South Florida should be encouraged to distribute materials or develop lesson plans on cutthroat grass community habitats, cutthroat grass community species and the importance of maintaining natural biodiversity. Develop a Wildlife Series, like others at GFC, and an education campaign on cutthroat grass communities.

Freshwater Marshes and Wet Prairies

FNAI Global Rank:	**G3/G4**
FNAI State Rank:	**S4**
Federally Listed Species in S. FL:	**12**
State Listed Species in S. FL:	**82**

Freshwater marsh. *Original photograph by Rob Bennetts.*



Wet prairie. *Original photograph by Deborah Jansen.*



"Stability seems deadly to marsh systems..." Weller (1982).

For this account, higher elevation areas that tend to have shorter durations and lower depths of flooding are classified as short-hydropattern prairies, while areas of lower elevation are called long-hydropattern marshes. Within both general categories, there are natural mosaics of subtypes related to depressions, elevations, bedrock surface exposure, soil types, and fire regimes. Therefore, South Florida's freshwater marshes and wet prairies are best thought of as a complex mosaic that varies over time through natural succession and human-made influences (Weller 1994).

In South Florida, some marshes and wet prairies are found as isolated features in the landscape, or as zones (*e.g.* littoral zones) along significant gradients in topography and elevation around the many lakes and river systems in the northern portions of the study area (Gilbert *et al.* 1995). Other freshwater marshes and wet prairies are found along minimal gradients of topography, hydrology and soil, like those found in the Everglades and Big Cypress ecosystems. Some physiographic features, such as creeks, sloughs and seeps have, themselves, been included as marsh types (Davis 1943). The single largest, and best known freshwater marsh and wet prairie complex within South Florida is the Everglades. Isolated small freshwater marshes and wet prairies found throughout South Florida serve local and regional functions, and as Hartman (1992) has said: "Ephemeral, isolated, smaller marshes are more vulnerable to both agricultural and urban development and drainage or use as stormwater holding basin." Unique types of isolated freshwater marsh and wet prairie conditions in the Florida Keys are of critical importance to the preservation of a significant number of unique species and races found only in this chain of small islands (Moler 1992).

Synonymy

Freshwater Marsh - long-hydroperiod marshes; intermediate hydroperiod marshes; saw grass marsh; cattail marsh; flag marsh (dominated by one or more species of *Sagittaria* spp. and *Pontederia lanceolata*); mixed emergent grass/sedge marshes that include combinations of saw grass, cattails, bulrushes (*Scirpus* sp.), maidencane (*Panicum hemitomon)*, beakrush (*Rhynchospora spp*) and spikerush (*Eleocharis* sp.); sloughs, including open water marsh, submerged vegetation marsh bladderwort (*Utricularia* spp.); and floating vegetation marshes, including white water lily (*Nymphaea odorata*), floating hearts (*Nymphoides aquatica*), and/or yellow cow lily (spatterdock, *Nuphar luteum*). Other terms that have been commonly used for marshes include: water lily marsh, submerged marsh, wet prairie on peat, and open water marsh. The FLUCCS code for the freshwater marsh community includes: 641 (freshwater marshes).

Wet Prairie - short-hydroperiod prairies; marl prairies dominated or co-dominated by sparse short saw grass (*Cladium jamaicense*); muhly grass (*Muhlenbergia capillaris);* beak rush; black sedge (*Schoenus nigricans*); sandy prairies or wire grass (*Aristida stricta*) prairies; savannahs (usually dominated by short mixed prairie or saw grass prairie with isolated dwarf cypress (*Taxodium* spp.) or small isolated tree islands. Other terms that have been commonly used for wet prairie types include: short-hydroperiod prairie, wet prairie on marl, rocky glade, transverse glade, finger glade, dwarf cypress savannah, wet prairie on sand.

Olmsted and Armentano (1997) summarized the various terms used by a number of earlier authors to describe the various marsh and wet prairie associations found in the Shark Slough region in Everglades NP. The FLUCCS code for the wet prairie community includes: 643 (wet prairies).

Terminology

In preparation of this account, it became clear that there is no consensus on the terminology applied to the vegetative communities called freshwater marshes and wet prairies. Specialists in vegetative community analysis are all o aware of the wide range of plant community types found at regional scales of landscape and physiography, and as smaller localized micro-habitats, to expect an easy resolution of the terminology problems of the past (Mitsch and Gosselink 1986). In general, this account follows the classification system derived from Kushlan (1990) and Olmsted and Loope (1984), which are in strong overlap with that of Hartman (1992) used by the Florida Committee on Rare and Endangered Plants and Animals (FCREPA). In their review of plant communities in Everglades NP, Olmsted and Loope (1984) state: "We use the term "prairie" in reference to extensive short-saturated grass/sedge dominated vegetation in southern Florida which has an annual period of inundation of no more than a few months." Kushlan (1990) stated that "Wet prairie is the least frequently flooded of any Florida marsh type. Their short hydroperiod (50-150 days per year) preclude peat development." Finally, Olmsted and Armentano (1997) state "...that Davis [1943] intended 'wet

prairie' to refer to marl areas dominated by mixtures of forb and graminoid species but with dominance by sparse saw grass and spikerush and increasing admixtures of many other species associated with slightly higher elevations and sometimes rock outcrops."

Due to variability in the usage of the term wet prairie, a review and clarification of the terminology for the non-forested wetland communities, especially with regard to depth and duration of flooding, is necessary before they can be discussed in detail. Kushlan (1990) effectively summarized the range of hydroperiods typical of freshwater marshes and wet prairies: (1) short-hydroperiod areas, flooded less than 6 months per year--wet prairies, (2) intermediate-hydroperiod areas, flooded 6 to 9 months per year--cattail, saw grass, flag, maidencane, beakrush, spikerush freshwater marshes, (3) long-hydroperiod areas, flooded more than 9 months per year--submerged, water lily, open water marshes and slough.

Short and moderate hydroperiod prairies and freshwater marshes are seasonally dry enough to burn and they are maintained by a combination of hydropattern and fire. Frequent fires restrict the expansion of woody vegetation. Because they are seasonally flooded, the majority of wet prairie and freshwater marsh plants are tolerant of anaerobic soil conditions for varying periods of soil saturation and/or inundation. Also, depending upon their hydroperiod, the plants of a given marsh type may depend more or less on seed germination in contrast to vegetative growth.

Marshes are flooded for longer periods annually, and some types are continuously flooded. The depth and duration of flooding is greater than in wet prairies, and the plants are better adapted to continuous anaerobic soil conditions. Woody vegetation tends to be more restricted to higher elevations in the form of tree islands, or in depressions such as cypress strands or domes. Because of the longer hydropatterns, fire is a more rare event in development of marsh structure. Because they are frequently dry and contain many non-wetland species (species not listed as Facultative Wetland (FACW) or Obligate Wetland (OBL) by State and, or Federal wetland delineation lists (*e.g.* Gilbert *et al.*1995, Reed 1988), wet prairies are often difficult to delineate, and designation is often based on soil and indirect evidence of average high water levels.

No matter what else we have learned about marshes and wet prairies, it is that they are dynamic in nature and in a natural setting undergo periodic droughts, floods, and fires. In a managed state, this dynamic pattern of change must be simulated or these systems will follow successional trends toward filling in of their basins and eventual transition to forested community types ,with a dramatic loss of habitats necessary for species diversity. Much of the current problem in the Everglades is a function of holding two-thirds of the system in rigidly managed states for agriculture or water control with little or no ability for variation in the conditions needed to sustain natural biological functions.

Implications of Terminology for Management Planning

In general, the term wet prairie has been used in such a wide range of contexts as to lead to confusion by non-experts, and in planning analyses. One good example of the resulting confusion is the current wetland status of the

Pennsuco Everglades region of Miami-Dade County. This wetland is characterized by a peat soil with saw grass stands up to 3 m (9.8 ft) as the dominant vegetation with a long hydroperiod and deep water (O'Hare and Dalrymple 1997). Unfortunately, the area was and remains commonly referred to as "prairie," leading many to presume it has a shorter hydroperiod and shallower water level than actually exists. Planning options for such areas can often be dramatically misleading. Another common confusion regarding the term wet prairie has led to a great deal of misunderstanding regarding habitat preservation for Cape Sable seaside sparrows *(Ammodramus maritimus mirabilis)* and Everglade snail kites *(Rostrhamus sociabilis plumbeus)*. Both of these species have been described as using wet prairie habitat. But the Cape Sable seaside sparrow uses wet prairies on marl soils with short hydroperiods, shallow water levels, and sparse muhly grass and saw grass (Curnutt 1996), while the Everglade snail kite uses emergent grass or sedge marshes with long hydroperiods, deep water levels (required by their main prey the apple snail (*Pomaceae paludosa*), and emergent vegetation including flag marsh, white water lily marsh and open slough with submerged vegetation. When confronted with demands for preservation of wet prairie habitat for each of these species, it would be easy to presume that hydroperiod and hydropattern restoration needs of both species are similar, when in fact they could not be more different.

The simplest solution is to follow the definition of wet prairie used by Olmsted and Loope (1984) and recognize that wetlands with longer hydroperiods (typically 9 to 12 months) and greater maximum depths of flooding (30 cm [11.8 in] to a meter or more) are all easily categorized as marshes, and wetlands with short hydroperiods (typically 1 to 3 months) and shallower maximum levels of flooding (saturated soils up to about 30 cm [11.8 in]) are wet prairies. It is important to note that the clarification of the terms used herein has not included a soil designation. This is purposefully done because there are conditions in which peat, marl, or sandy soil substrates may be the current dominant soil substrate for a plant association due to geographic location along the Florida peninsula or due to short-and long-term modifications in soil formation (including soil erosion, and "oxidation" of peat) related to hydrology and fire frequency in the southern portion of the peninsula (Robertson 1954, Wade *et al.* 1980).

Distribution

The distribution of dominant plant species in freshwater marsh and wet prairie systems is considered to be a function of soil type, depth, and hydrological conditions (Kushlan 1990). Kushlan's recent review of the freshwater marshes and wet prairies of Florida identified and mapped the remaining stands of marsh habitat throughout the state. While recognizing a great many small, often isolated marshes or marsh remnants, he identified five predominant marsh systems in Florida: highlands marshes, flatwoods marshes, St. Johns marshes, Kissimmee marshes, and Everglades. (Figure 1). Davis *et al*. (1994), Light and Dineen (1994), and Olmsted *et al.* (1980) make it very clear that a variety of the freshwater marsh and prairie types are currently found in areas

with hydroperiods that are much shorter than under more natural conditions. The current problems involved in accurately distinguishing the natural historical hydropatterns and soil associations of the various non-forested wetlands are difficult, because there are significant lag-times between vegetational community change and short-term water management practices (Davis *et al.* 1994, Gunderson 1994, Light and Dineen 1984, White 1994).

Description

The majority of the plant associations of freshwater marshes and wet prairie are found throughout South Florida, including the Big Cypress Swamp region, St. Johns Marsh system, Kissimmee River floodplain, Lake Okeechobee perimeter marshes, and as far southward as isolated marshes in the Florida Keys.

Besides the enormous expanse of marshes found in the Everglades region of South Florida, marsh and wet prairie communities are associated with natural depressions, the edges of natural lakes, ponds, creeks, rivers, and human-made impoundments such as borrow pits and canals. When these communities are found within the study area from Lake Okeechobee northward, they are frequently associated with lakes, creeks, and rivers, and are often described as littoral zones. Natural lakes and rivers are absent from South Florida below Lake Okeechobee (with the exception of Lake Trafford, near Immokalee, in Collier County). However, numerous artificial impoundments and lakes are common in the southern portion of the study area, in the form of canals, borrow pits, and human-made lakes.

The soils associated with marshes are histosols, composed of thick organic peat underlain by marl and/or limestone. The soils associated with wet prairies in the southeastern portion of the study area are entisols, dominated by either poorly drained marls or mixtures of marl and sand underlain by limestone. The wet prairies of the southwestern and more northern portions of the study area are either entisols, or spodosols, which are poorly drained sandy soils with loamy subsoils (Brown *et al.* 1990). However, frequent shifts in water management practices have created a recent history of changes in many of these soils, with layers of marl and peat reflecting variations in hydrology and decomposition rates of vegetation.

Long-and Intermediate-Hydropattern Freshwater Marshes

Saw grass Marsh

The saw grass marshes tend to be dominated by tall, dense to sparse stands of *Cladium jamaicense*. Saw grass once covered more than 800,000 ha (1,920,000 acres) of the Everglades, and Loveless (1959a) estimated that it covered 70 percent of the remaining Everglades at the time of his study. These freshwater marshes also may have significant invasions of *Melaleuca quinquenervia*, or native trees (*e.g*. *Myrica cerifera*, *Persea borbonia* and *P. palustris, Salix carolina,* and *Ilex cassine)*. Some sparse saw grass marshes are more savannah-like, and have widely scattered individual dwarf cypress trees and isolated cypress domes.

Saw grass marsh is defined here as any wetland in which the dominant plant species is *Cladium jamaicense*. This plant species is found in a wide

range of ecological settings including estuarine and coastal grasslands; mangrove forests; wet prairies; short-hydropattern prairies; lakes, ponds, and other depressional features; cypress savannahs, cypress domes and swamps; and hardwood forests (Craighead 1971, Kushlan 1990, Olmsted *et al*. 1980, Wade *et al*. 1980). It is clear that the species is tolerant of a wide range of physiological stressors (Steward 1984). Marshes that are dominated by saw grass are generally subdivided into dense saw grass and sparse saw grass marsh types (Kushlan 1990). In dense saw grass marshes, the species reaches heights of 3 meters (9.8 ft), is extremely dense, and forms a near monoculture. In sparse saw grass marshes, the species is usually much shorter, only about a meter (3.28 ft) in height, and the space between individual stems is occupied by a diversity of other marsh plant species (Craighead 1971, Olmsted and Armentano 1997, Wade *et al.*1980, Werner 1975). Olmsted and Armentano (1997) recognized that an "intermediate" category of saw grass (between tall dense and short sparse saw grass) could be identified, but they felt that it was unnecessary, since the density and height of saw grass appears to respond rapidly to changes in hydropattern and fire.

Cattail Marsh

Cattail marshes are dominated by dense stands of *Typha* spp. with *Scirpus* spp. In many areas, the marsh complex is in dynamic transition from saw grass marsh to monotypic stands of *Typha* spp. These changes have been related to changes in water quality and/or quantity (Craft *et al.* 1995, Davis *et al.* 1994). In the southern portion of the study area, it is natural to find small dense stands of *Typha dominguensis*, while *Typha latifolia* is more common farther north.

Lodge (1994) and Newman *et al.* (1996) considered *Typha dominguensis* to be an indicator of eutrophication, especially of high phosphorus levels. Newman *et al.* (1996) noted that *Typha dominguensis*, in experimental treatments, responded positively in terms of growth to both increased water levels and increased phosphorus loadings. Net accumulation of phosphorus was 2 to 3 times greater than in *Cladium jamaicense* or *Eleocharis interstincta.* They noted that *Typha* showed an increase in biomass in response to elevated phosphorus by as much as 45 percent, and an increase in biomass to higher water levels by as much as 60 percent (Dalrymple, Everglades Research Group, personal communication 1998). *Typha dominguensis* often occurs naturally in the most isolated, oligotrophic, and pristine waters of the southern marl prairies in Everglades NP. In the marl prairies, the cattail stands tend to be in depressions with longer hydropatterns and where more peat and less marl is found. Small dense stands of cattails are also a normal part of the mosaic in both freshwater marshes and wet prairies, and are valuable habitat for many animals (including least bitterns (*Ixobrychus exilis*), common snipe (*Capella galinago),* limpkin (*Aramus guarauma),* red-winged blackbird (*Agelaius phoeniceus),* and round-tailed muskrat (*Neofiber alleni*). The rapid expansion of cattail marsh in the long-hydropattern marsh system is probably a long-term response to altered hydropatterns as well as increased phosphorus levels and the exclusion of fire.

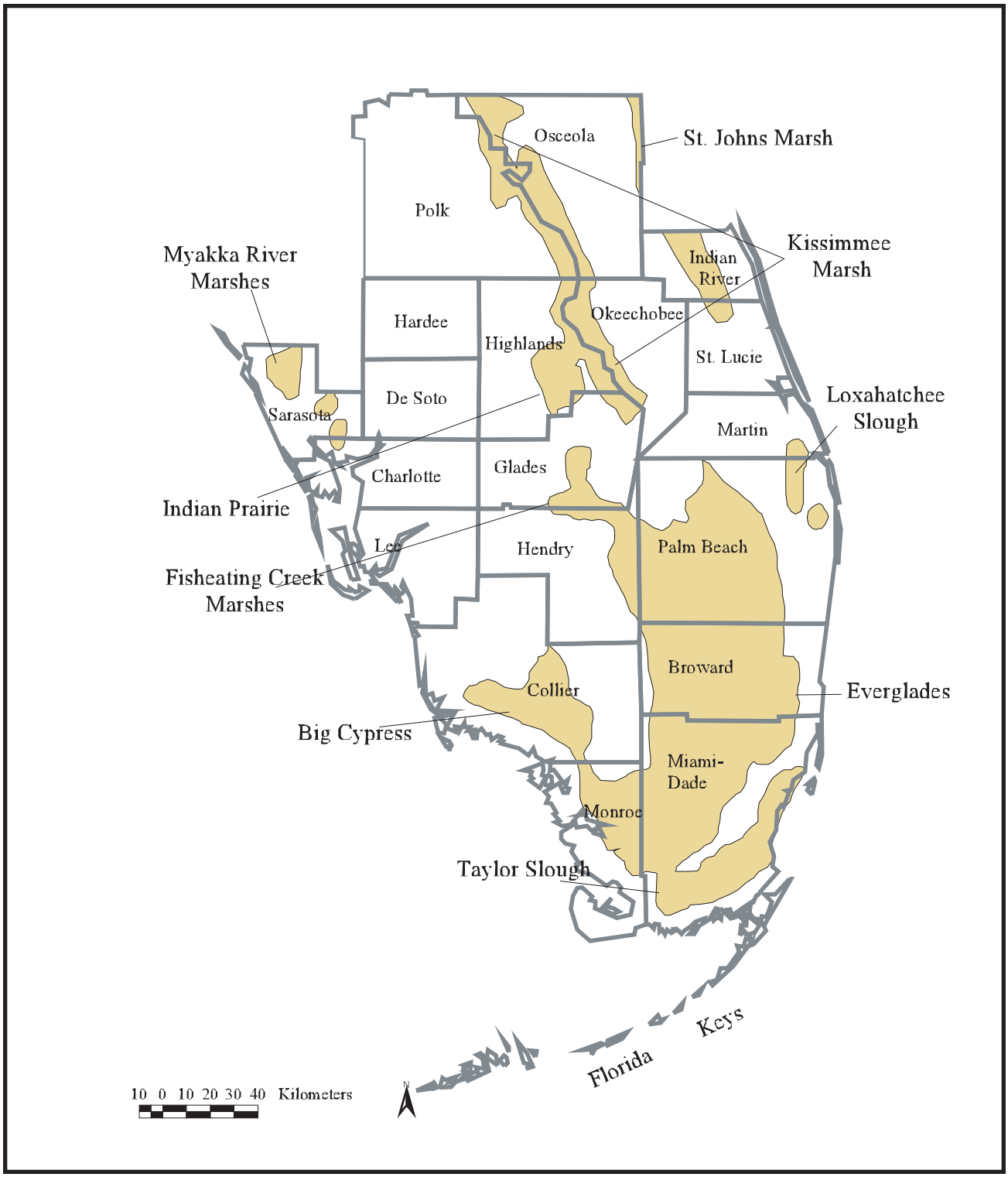


Figure 1. The distribution of major freshwater marshes and wet prairies in South Florida.

Maidencane Marsh

This is typically dominated by *Panicum hemitomon*, but often has rice cut grass (*Leersia hexandra*), *Sagittaria lancifolia*, *S. latifolia*, *Xyris difformis* and *Pontederia lanceolata*. In Paynes Prairie, Birkenholz (1963) considered this marsh type to be typical of water 15 to 46 cm (6 to 18 inches) deep. In the northern portions of the study area, maidencane marshes may grow on pure sand substrates (Birkenholtz 1963), and show a marked seasonality in growth and coverage, due to varying hydropattern and cold winter temperatures. Loveless (1959a) considered maidencane marshes to be rather recent in their dominant role in the marsh system. He considered this species to be better adapted to drier conditions, where it showed higher density, but noted that it can withstand long periods (up to 9months) of flooding up to one meter (3.28 ft) by growing rapidly. Propagation by rhizomes is common in flooded conditions, but seeds commonly germinate during dry periods. The species is well adapted to fire, showing rapid growth of new sprouts. According to Kushlan (1990), maidencane marshes cannot tolerate continuous flooding and require an annual period of drying down. However, Gilbert *et al.* (1995) found maidencane marsh occupying the deepest portions of the marshes that they evaluated in Jonathan Dickinson SP in southern Martin County. In the Martin County marshes, the substrate was described as Waveland soil. In the Everglades, maidencane marshes are usually found on peat, show little seasonal variation due to the more subtropical growing conditions, and are in a range of hydropatterns.

Beakrush Marsh and Spike Rush Marsh

These marshes are typically dominated by *Rhynchospora tracyii* or *Eleocharis* spp., respectively, but often have a mix of other rushes. These areas are often called *Rhynchorpora* or *Eleocharis* flat. In general, they occur in intermediate water depths with hydroperiods that show more variation, with continuous surface flooding being more variable, and periods when the surface peat is merely saturated are not uncommon under natural conditions. This marsh type is often found in deeper areas within wet prairie mosaics.

Flag Marsh

Flag marshes are dominated by *Sagittaria lancifolia*, *S. latifolia*, or *Pontederia lanceolata.* They are generally found in deeper areas and depressions surrounded by other marsh types, such as saw grass or maidencane. This marsh type is frequently found as isolated small areas within the wet prairies as small marshes in solution holes and depressions, frequently with a higher peat soil layer. When this marsh type is found in a mosaic of short-hydropattern wet prairies, it becomes an especially important refugia and breeding area for apple snails, crayfish, and a host of other invertebrates as well as fishes and amphibians (Dalrymple, Everglades Research Group, personal communication 1998). As isolated marshes in a wet prairie matrix, there may be significant amounts of *Bacopa* spp., *Proserpinaca* spp., *Utricularia* spp., *Chara* spp., *Crinum americanum*, and *Oxpolis filiformis* in these solution hole flag marshes.

Floating Vegetation Marsh

White water lily (*Nymphaea odorata*), floating hearts (*N. aquatica*), and/or yellow cow lily (spatterdock, *Nuphar luteum*) form expansive regions in deeper

water with longer hydroperiods. Associated submerged and floating plants include heavy mats of periphyton and *Utricularia* spp. *Nymphaea* spp. is commonly associated with Loxahatchee peat, which is considered to form only under almost continuous inundation (Cohen and Spackman 1984).

Slough

The freshwater marshes with the longest hydroperiods and deepest water levels include open water marsh and submerged vegetation marsh. *Utricularia* spp. and periphyton are the most common plant associations in these areas.

Davis *et al.* (1994) defined slough as: "A composite of two plant associations growing in deeper areas of peat and characterized by *Eleocharis cellulosa*, *E. elongata*, *Rhynchospora tracyii*, *R. inundata*, *Panicum hemitomon*, *Nymphaea odorata*, *Nymphoides aquatica*, *Nuphar luteum*, *Utricularia foliosa*, and periphyton." Common plant species in these marshes include *Nymphaea odorata*, *Orontium aquaticum*, *Nelumbo lutea*, *Najas guadalupensis*, *Utricularia* spp., *Potamogeton* spp., *Pontederia lanceolata*, *Sagittaria latifolia*, *Eleocharis* spp., *Panicum hemitomon*, *Thalia geniculata*, *Rhynchospora colorata, R. tracyii*, *Spartina bakeri*, and *Hypericum* spp. (Davis 1994, Egler 1952, Gunderson 1994, Kushlan 1990, Lodge 1994, Olmsted *et al*, 1980, Robertson 1955, Wade *et al.* 1980).

Short-Hydropattern Wet Prairies

This category includes wet prairies found on marl soils, sandy soils (farther northward), and exposed limestone bedrock in the rocky glades region of the southeastern Everglades, as well as in dwarf cypress savannahs. These wet prairies typically have a high frequency of limestone exposures above the marl soil, resulting in what is locally called a micro-karst topography. However, in some areas such as the rocky glades region of the east Everglades and in peripheral wet prairies to Taylor and Shark sloughs, there may be numerous solution holes in bare limestone. Some of the solution holes retain organic matter, and over long periods of time, develop a soil locally known as "Gandy peat" within them. One early describer of the wet prairies said they had more holes than solid ground (Dade County 1979). These numerous solution holes are in direct contact with the underlying aquifer and serve as vital refugia for aquatic and semi-aquatic species during seasonal drying down of water levels. These refugia become concentrated with fishes, amphibians, reptiles, and invertebrates, and are preferred foraging areas for a wide range of wading birds as water levels are dropping.

Marl Prairies, Short Saw grass Prairie, Muhly Prairie, Mixed Grass/Sedge Prairie, and Rocky Glades Prairie

Olmsted *et al.* (1980) and Kushlan (1990) described wet prairies as the driest of the marsh categories. Olmsted *et al.* (1980) found that "*Muhlenbergia* appears to thrive best where hydroperiods of 2 to 4 months occur." Wet prairies on marl soils and exposed limestone have a mixture of *Muhlenbergia capillaris*, short *Cladium jamaicense*, *Schoenus nigricans*, *Rhynchospora* spp., *Hypericum* spp., *Baccharis* spp., *Panicum* spp., *Aristida purpurascens*, *Schizachyrium rhizomatum, Eragrostis ellioti,* and *Spartina bakeri*. Overall,

this wetland type is found on the widest range of environmental conditions with regard to substrate, soil, and salinity. Most of the species in the wet prairies tend to be herbaceous, not graminoids, but the short *Cladium* or *Muhlenbergia* is the dominant plant by coverage.

Early descriptions of the marl prairies did not mention muhly grass, leading many to believe it is a recent community type, related to reduced hydroperiods and/or more frequent fires in prairies previously dominated by saw grass. Much attention has been recently given to muhly prairie as the preferred habitat for the endangered Cape Sable seaside sparrow. Olmsted *et al*. (1980) evaluated this issue at length: "Although *Muhlenbergia* prairie is presently one of the most extensive communities of Everglades National Park and occupies large areas in Big Cypress National Preserve, this may be the result of recent vegetation changes." Werner (1975) states that "some of the older South Florida naturalists claim that *Muhlenbergia* was somewhat rare in the past and that it is only the recent destruction by drought fires of the shallow organic soil which formerly overlaid the marl and the general drying of South Florida which has propagated the vast *Muhlenbergia* prairies of today." Two other factors should be noted: In the vegetative state, *Muhlenbergia fillipes* [*capillaris*] and *Schoenus nigricans* look very much alike and are not distinguishable from afar. It is very possible that *Muhlenbergia* was mistaken for *Schoenus* in earlier days. The beakrush, *Rhynchospora tracyii*, also looks very much similar to *Muhlenbergia*.

When wet prairies are found as elongated strips of lower-lying land intersecting sections of the large stands of *Pinus ellioti* and tropical hardwood hammocks in the southern portions of the elevated Atlantic Coastal Ridge, they are locally called transverse or finger glades. These finger glades are narrow and abundant in the remaining large pinelands of Long Pine Key in Everglades NP and in parts of the Big Cypress National Preserve, and are seasonally available to a wide range of animals and plants. As ecotones, they have a higher overall annual diversity of plants and animals than the upland habitats they intersect (Dalrymple 1988, Olmsted *et al.* 1980).

Wet Prairies on Sandy Substrates

These wet prairies are often difficult to delineate due to their short hydropatterns and high frequency of non-wetland herbaceous species including wiregrass (*Aristida stricta)*, *A. spiciformis*, *Andropogon virginicus*, *Asimina* spp., *Befaria racemosa*, *Drosera* spp., *Eragrostis* spp., *Euthamia* spp., *Hypericum reductum*, *H. tetrapetalum*, *Ilex glabra*, *Lyonia fruticosa*, *L. lucida*, *Penstemon australis*, *Rhexia* spp., *Schizachyrium* spp., *Serenoa repens*, *Sabal palmetto*, *Vaccinium myrsinites*, as well as *Quercus pumila*. They are often delineated on the basis of the geographic distribution of the dominant wetland species and evidence of algal mats of periphyton, and hydric soils. Dominant wetland plants include: *Aster* spp., *Baccharis halimifolia*, *Drosera* spp., *Eustachys* spp., *Hypericum cistifolium*, *H. fasiculatum*, *Myrica cerifera*, *Panicum scabrisculum*, *Scleria* spp., and *Xyris brevifolia*. Further northward in the South Florida study area, sandy soils become more common, especially along the Lake Wales Ridge and the Kissimmee chain of lakes, and the species composition is significantly different than in the southern Everglades region (Gilbert *et al.* 1995, Wunderlin 1982).

The Everglades

The Everglades is the largest single basin of diverse wetlands in the study area, originally covering over 6,440 square km (4,000 sq. miles). The basin is bordered on the east by the Atlantic Coastal Ridge and on the west by the Big Cypress Swamp. The basin is approximately 160 km (100 miles) long, and 65 km (40 miles) wide, with an average slope of only 3.16 to 4.73 cm per km (about one ft in 10 miles) (Izuno and Bottcher 1994, Light and Dineen 1994). Depth in the Everglades historically varied seasonally, but was never much more than 1.3 m (about 4 ft) in its deepest marshes. The southern portion of the Everglades, the western edge of the Shark Slough has a more abrupt change from higher to lower elevations, but both edges of the basin are bordered by distinct edges that show a transition from longer hydroperiods with peat soils, to shorter hydroperiods with marl soils and extensive limestone bedrock exposures (Olmsted and Armentano 1997).

Historically, when waters in Lake Okeechobee rose over 1.4 m (4.5 ft) above mean sea level, a sheet of water up to 51 km (32 mi) wide overflowed the southern rim of the lake into the Everglades (Parker, 1984). The Lake Okeechobee basin historically covered approximately 193,333 ha (464,000 acres) (Izuno and Bottcher 1994) with a mean depth of only 3 meters. This extremely large basin of shallow water made the historical Kissimmee-Lake Okeechobee-Everglades basin attractive habitat for a wide range of semi-aquatic and aquatic plant communities, and diverse food webs dominated by hundreds of thousands of water birds, wading birds, and alligators.

The single most important element in adding habitat interspersion and a higher diversity of organisms in the Everglades is the presence and distribution of tree islands. Loveless' (1959b) review of the Everglades' white-tailed deer herd recognized the importance of these dry islands of hardwoods for a variety of wildlife, and he estimated that approximately 12 percent of WCA 2 was tree island habitat during the time of his studies. Tree islands play the most significant role in determining overall marsh and wet prairie diversity in the Everglades, and excessive flooding due to management practices has a slow but dramatic effect on the health of tree islands (Guerra 1998).

Plant Density and Composition

The identification of flag marshes, water lily marshes, and others. are all based on the fact that a single species dominates a local area (Gunderson, 1994, Turner 1996). In his study of marsh types in relation to apple snail oviposition preferences, in Blue Cypress Water Management Area (Indian River County), Turner (1996) chose a variety of marsh types in which he measured stem density per square meter. In saw grass marshes, stem density averaged 151 per square meter. In maidencane (*Panicum hemitomon*) marshes, stem density averaged 255 stems per square meter; in deep marshes, stem densities were only 18 per square meter; and in mixed shallow marshes (*Eleocharis elongata*, *Sagittaria lancifolia*, *Panicum hemitomon*, and *Pontederia cordata*) density averaged 286 stems per meter square.

In wet (marl) prairies in the southern Everglades, "*Cladium* generally provides 80 to 90 percent of the cover in *Cladium* prairie. *Muhlenbergia* typically provides 70 to 90 percent of the cover in the community with a

shorter hydroperiod" (Olmsted *et al*. 1980). Other important species include *Schizachyrium rhizomatum*, and *Schoenus nigricans*. In the dwarf cypress savannahs, *Taxodium distichum* forms an open canopy of up to 20 percent (see below). More than 100 species can be found in the muhly prairies, with 4 to 13 species per square meter, and 10 to 22 species per five square meters (Armentano *et al.* 1998b, Dalrymple *et al.* 1993, Dalrymple and Doren 1998, and Olmsted *et al*. 1980) Freshwater marshes of the Lower Keys are typified by saw grass, buttonwood (*Conocarpus erectus*) , red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), wax myrtle (*Myrica cerifera*), saffron plum (*Sideroxylon celastrinum*), *Fimbrystylis* spp., and. *Eleocharis cullulosa*.

Olmsted and Armentano (1997) reviewed the distributions, soil depths, soil types, percent coverage and species per square meter in a series of transects in Shark Slough in Everglades NP and summarized their results by saying: "The Shark Slough marsh communities are distinguished by their low plant species diversity (3 to 6 species/m^2), and single species dominance and low vascular plant cover (2 to 16 percent) except for tall saw grass stands where cover reaches 96 percent." The researchers find "The available evidence, however, suggests the conclusion that saw grass communities have expanded in Shark Slough as a response to reduction in hydroperiods."

Species Diversity

Weller (1982) recognized the importance of the wide diversity of semi-aquatic and upland species that seasonally use and contribute to the productivity and diversity of wetland settings. Weller noted that: "Commonly, marshes are viewed as basins that can be changed to a unit more productive of a single species or complex of species other than those found there at a given time." And he considered it important in both natural and artificial wetlands to maintain species diversity for overall system health.

Weller (1982, 1994) reviewed the literature on nesting by wetland birds and noted the following:

(1) There was a positive correlation between the number of bird nests with the number of plant communities in marshes.

(2) Many marsh birds nest near water/cover interfaces or the meeting of two cover types.

(3) Most species favor marshes with a ratio of 1:1 cover-water interspersion.

(4) The greatest species richness and greatest density of nests occurred where there was high interspersion of open water within the vegetated portions of marshes (ranging from 1:1 to 1:2 cover-water interspersion).

(5) Marshes with a complete plant zonation also have several layers of vegetation.

(6) To preserve a typical marsh avifauna, it is best to have several wetland types, as well as upland areas present.

Weller (1982) also reviewed the importance of aquatic invertebrates and mammals in overall wetland function and concluded that a healthy marsh is part of a wetland-upland complex that includes fully aquatic, semi-aquatic and

upland species (*e.g*. herbivores such as nutria, deer, muskrat). He stated that "Stability seems deadly to marsh systems, at least where terrestrial or semiaquatic faunas are preferred to open marsh or lake faunas."

Mammals

The mammal fauna of saw grass marshes includes species that are well adapted to the community, including: rice rat (*Oryzomys palustris natator),* round-tailed muskrat, river otter (*Lutra canadensis),* and highly mobile species that regularly or seasonally move through the marshes, including the white-tailed deer (*Odocoileus virginianus),* Florida panther (*Puma concolor coryi),* bobcat (*Lynx rufus),* and raccoon (*Procyon lotor).* The Lower Keys marshes are very important to Key deer and Lower Keys rabbits.

Birds

In marshes, passerine birds show low species richness and abundance (Robertson 1955, Robertson and Kushlan 1984), especially in dense pure stands of saw grass and cattail marshes. Two to six species of passerine birds are typical in open country habitats (Cody 1985). Most wading birds and water birds find the dense stands of tall emergent plants difficult to forage in (Hoffman *et al*. 1994, Kushlan 1976). The absence of true grass species and small trees in pure saw grass marsh limits the value of this marsh type for nesting habitat for birds. There are some species that do regularly use these denser tall emergent marshes including: common snipe (*Gallinago gallinago*), limpkins (*Aramus guarauna*), bitterns (*Botaurus lentiginosus*), and red-winged blackbirds (*Agelaius phoeniceus*). Wading birds and water birds, including: cormorant (*Phalacocorax auritus),* anhingas, (*Anhinga anhinga),* moorhens (*Gallinula chloropus*) and purple gallinule (*Porphyrula martinica),* use the more open marsh types more commonly, especially flag marshes, where lower stem densities and dropping water levels during the dry season make them particularly attractive foraging areas (Bancroft *et al.* 1994, Hoffman *et al.* 1994, Kushlan 1976, Ogden, 1994). Wading birds normally exploit forage fishes during periods of dry-down, when the fishes are trapped in small puddles and pools of water at extremely high densities (Frederick and Collopy 1988, Kushlan 1976). Such drying down currently does not exist for many portions of the WCAs and Everglades NP, which have long periods of near-constant high water levels artificially maintained for water management purposes. Great concentrations of ducks can be found in the most open water marshes including submerged marsh, water lily marsh, slough, and along the littoral zone edges of lakes and rivers.

The wet prairies also have low densities and low richness of breeding species including the common yellowthroat (*Geothlypis trichas*), eastern meadowlark (*Sturnella magna*), and Cape Sable seaside sparrow; and neotropical migratory birds (*e.g.* bobolink (*Dolichonyx oryzivorus*), yellow-rumped warbler (*Dendroica coronata*), but they usually focus on trees found as small tree islands within these prairies and in savannah settings (O'Hare and Dalrymple 1997). The sparser vegetative cover of wet prairies makes them particularly attractive to wading birds as foraging sites, especially as water

levels are falling and prey are being concentrated in depressions (Hoffman *et al*. 1994).

Herpetofauna

In comparison to the bird fauna, the herpetofauna of saw grass marsh is diverse and abundant. While many vertebrate groups show a significant decline in species diversity proceeding down the peninsula of Florida (Robertson and Kushlan 1984, Robertson and Frederick 1994), salamanders are the only group of amphibians or reptiles that shows an appreciable decline in diversity in the southern portion of the state (Dalrymple 1988). Only four species, *Amphiuma means*, *Siren lacertina*, *Pseudobranchus striatus*, and *Notopthalmus viridescens,* are recorded from the Everglades region (Dalrymple 1988, Duellman and Schwartz 1958). The other major herptile groups are well represented (Dalrymple 1988, Dalrymple *et al.* 1991a, b). As in the case of freshwater fishes, what the herpetofauna may lack in diversity is compensated for by the high standing crops of the existing species. Without these high standing crops, the forage base for higher trophic levels, including wading birds, many raptors, carnivorous mammals, and the American alligator (*Alligator mississippiensis)* would not be as abundant as it once was, and still is.

Snakes, turtles, and lizards are able to bask on dead and live saw grass blades and on larger clumps of saw grass. Both salamanders and frogs are numerous in the wide range of marshes, and frequent the water lily and flag marshes as areas for egg laying. They also readily exploit saw grass mounds constructed by alligators for nesting and the nests and platforms of round-tailed muskrats. The frogs and toads that are abundant include the pig frog (*R. grylio*), southern leopard frog (*R. sphenocephala*) cricket frog (*Acris gryllus*), little grass frog (*Pseudacris ocularis),* green treefrog (*Hyla cinerea),* squirrel tree frog (*Hyla squirella*), and chorus frog (*Pseudacris nigrita*). Both the southern toad (*Bufo terrestris)* and the oak toad (*Bufo quercicus*) are common in wet prairies and saw grass marshes. The exotic Cuban treefrog (*Osteopilus septentrionalis*) is not as common in open marshes as it is in ruderal and forested ecological communities, but is expanding its range rapidly into more remote marsh and prairie habitats (Dalrymple 1994b).

The cottonmouth (*Agkistrodon piscivorus*), mud snake (*Farancia abacura*), and water snakes of the genera *Nerodia*, *Regina,* and *Seminatrix* are all very abundant, as are the soft-shelled turtle (*Apalone ferox*), snapping turtle (*Chelydra serpentina*), sliders and cooters (*Trachemys* and *Pseudemys* spp.), stinkpot (*Sternotherus odoratus*), and mud turtles (*Kinosternon* spp). The only common lizard in saw grass marsh is the green or Carolina anole (*Anolis carolinensis*), which occurs in high abundances. The southeastern five-lined skink (*Eumeces inexpectatus*) and ground skink (*Scincella lateralis*) are common in the wet prairies during the dry season. In general, about 75 percent of the 72 species of South Florida amphibians and reptiles (Duellman and Schwartz 1958) seasonally move from uplands and marshes into seasonally flooded wet prairies at different times during the course of a hydroyear (Bernardino and Dalrymple 1992, Dalrymple 1994b). This seasonal shift in

habitat use helps to emphasize the role of a mosaic of habitat types required to sustain the normal trophic dynamics of South Florida freshwater wetlands (O'Hare and Dalrymple 1997).

Fishes

Williams *et al*. (1985) gave extensive details and reviews of habitat characteristics of freshwater marsh and lake littoral zones that are beneficial to forage fish, sport fish, and overall wetland quality. They also emphasize the role of periodic drawdowns, as have Frederickson and Laubhan (1994) in improving overall quality of marshes for vegetative interspersion, habitat quality, forage fish populations, and habitat for fish nesting.

The saw grass marsh has a limited native fish community (Dineen 1984, Loftus and Kushlan 1987) that is generally dominated by small species of detritivores, omnivores and insectivores, with cyprinodontids and poecilliids composing 50 percent of the total in the study by Loftus and Kushlan (1987). Common species include: mosquito fish (*Heterandria formosa*), flagfish (*Jordanella floridae*), bluefin killifish (*Lucania goodei*), top minnows (*Gambusia* spp.), and small centrachids such as Everglades pygmy sunfish (*Elassoma evergladei*), bluespotted sunfish (*Enneacanthus gloriosus*), and other sunfishes (*Lepomis* spp.). Some species show dramatic adaptations for withstanding drought, with eggs that can undergo long dry periods (Harrington 1959) or by tolerating very low oxygen levels via hemoglobin polymorphisms (Lodge 1974). Others show significant annual mortality and residual populations surviving in subterranean refugia (O'Hare and Dalrymple 1997).

Quantitative samples were made by Loftus and Ecklund (1994) to compare the hydropattern effects for diversity and density of fishes in the Everglades NP Shark Slough marshes west of the L-67 extension canal, and in the area to the east of the canal in the Northeast Shark River Slough (NESRS). Fish densities in NESRS were much lower than in the Everglades NP, even after prolonged flooding from 1982 to 1985. They theorized that the carrying capacity of NESRS marshes for fishes was greatly reduced due to long-term effects on the detrital food chain.

In discussing the largemouth bass (*Micropterus salmoides),* that they considered the "most highly prized freshwater game fish in Florida," Williams *et al.* (1985) state: "Florida bass are largely oriented to the littoral zone, preferring shallow, highly vegetated areas. Blocknet samples taken from Lake Kissimmee showed a littoral/limnetic population density ratio of 10:1 for harvestable sized bass (greater than 25 cm TL), while the littoral/limnetic density ratio for nearby Lake Tohopekaliga was 16:1 in 1977. In the southern Everglades, long-term data sets are available for fish communities in alligator holes (Nelson and Loftus 1998), and in spike rush dominated slough marshes in the southern Everglades (Trexler *et al.* 1998). These studies included periods of drought, as well as the most recent high water conditions of the 1990s. In both cases the authors were hesitant to draw conclusions, citing sampling biases (large versus small fish species, and lag time between water stages and fish community structure). They have re-emphasized the need for long-term

monitoring and the need to standardize sampling methods. In general, Trexler *et al*. (1998) felt that their data suggested that species richness is slightly higher in long-hydroperiod marshes than in short hydropattern marshes (wet prairies). They also felt the evenness is greater in longer-hydropattern marshes due to the predation on abundant small species of fishes by larger piscivorous fishes. Finally, their data indicate that fish densities peak at intermediate hydroperiods, and that standing crop increases with hydroperiod, due to the bias of the rare but heavier, large species found in longer-hydroperiod settings (Loftus and Ecklund 1994).

Aquatic Macroinvertebrates

Nationwide numerous aquatic larval or nymphal stages as well as adult invertebrates are imperiled. In South Florida, most aquatic macroinvertebrates are poorly known and/or the actual preferred aquatic habitats used by the juvenile stages are not documented (Franz 1982). Nevertheless, they play a vital role in the food chain and overall ecosystem dynamics.

Turner (1996) investigated the use of emergent plant stems by apple snails in the Blue Cypress Water Management Area in the St. John's River Water Management District in Indian River County. The plants most commonly used for egg laying by apple snails were *Cladium jamaicense*, *Crinum americanum*, *Pontederia cordata*, and *Sagittaria lancifolia*. Turner recommended that marsh management to promote apple snail populations involves maintaining a heterogeneous community of broad-stemmed emergent aquatic plants at moderate density. In the much shorter-hydropattern wet (marl) prairies of the southern Everglades, in Everglades NP, apple snails seldom used any emergent plant other than *Sagittaria lancifolia.* The *Sagittaria* were always located in solution holes with deeper water and longer hydroperiods than the surrounding matrix of sparse saw grass and muhly prairies.

In marshes and canals and along rivers and lakes, large floating mats of the exotic water hyacinth (*Eichornia crassipes*) shade out the submerged native plants of open marshes, including native forage foods for apple snails. Compounding the problem are the direct and indirect effects on apple snails of herbicidal treatment of aquatic pest plants (Bryan 1996). Because the apple snail is a staple prey item for such a wide range of species, including Everglade snail kites, limpkins, grackles, young alligators, many turtles, raccoons, and otters, it is an important indicator of the status and health of a wide range of South Florida wetlands.

The crayfish (*Procambarus alleni)* is another very important food item for a wide range of freshwater marsh and wet prairie predators, including wading birds, raccoons, alligators, turtles, snakes, larger frogs, and fishes. Sampling for crayfish abundance in the upper St. John's River basin by Jordan *et al.* (1996a) showed significantly higher densities of crayfish in denser marsh vegetation, with an average of over 25 crayfish per square meter (10.8 sq ft) in marshes with high stem densities, and an average of less than 5 per square meter in slough habitat. Jordan *et al.* (1996b) performed laboratory experiments on habitat preferences for vegetation common to the study area.

They found that crayfish preferred vegetated habitats over open habitats both during the day and night, but crayfish were more likely to use open water sites at night. Large crayfish were shown to prey on smaller crayfish. When the predatory largemouth bass was introduced to lab aquaria with various size classes of crayfish, there was reduced survival of smaller-sized crayfish but no effect on adult crayfish. Predation was lower when the complexity of the vegetation in experimental tanks was increased.

Plants

Plants in the marshes and wet prairies show a wide range of adaptations for dealing with floods and anaerobic conditions, droughts and aerobic conditions, fire, and reproduction. In general, saw grass stems are eaten by few or no herbivores, while the stems and leaves of flag, lilies, and some of the grasses, submerged plants, and woody species are valued by a wide range of insects, mammals, and turtles. The seeds of many marsh plants are important seasonal food for water birds and wading birds, especially ducks. The below-ground plant tissue is often the preferred food of a number of marsh dwelling mammals including the round-tailed muskrat, and white-tailed deer (Kushlan 1990).

Most marsh types are dominated by fewer than 10 species (Craft *et al.* 1995, Kushlan 1990, Olmsted and Armentano 1997). Wet prairies have much higher species richness. In their comparison of species richness in marshes and wet prairies in Taylor Slough, Olmsted *et al.* (1980) listed 70 species in muhly prairies, 89 species in sparse saw grass prairies, 18 in spikerush flats, and 8 in open sloughs (ponds). In most studies of sparse saw grass prairie and muhly prairie, only 1 to 3 species make up over 90 percent of the cover in plot samples. Additional studies have documented over 100 species in marl prairies of muhly or mixed saw grass and muhly grass (Dalrymple and Doren 1998, Olmsted *et al.* 1980, Werner 1975).

Wildlife Species of Concern

Federally listed species that depend upon or utilize the marsh and wet prairie communities in South Florida include: Florida panther, Key deer (*Odocoileus virginianus clavium*), Lower Keys rabbit (*Sylvilagus palustris hefneri*), Silver rice rat, Audubon's crested caracara (*Polyborus plancus audubonii*), bald eagle (*Haliaeetus leucocephalus*), Cape Sable seaside sparrow, Everglade snail kite, Florida grasshopper sparrow (*Ammodramus savannarum floridanus*), wood stork (*Mycteria americana*), and eastern indigo snake (*Drymarchon corais couperi*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

Saw grass marshes and wet prairies are not preferred habitat for Florida panthers, bobcats, or white-tailed deer (Harlow 1959, Loveless 1959b, Smith and Bass 1994). Nevertheless, all of these species are traditional users of the Everglades wetlands, especially during dry seasons and droughts. Florida panthers and white-tailed deer frequently cross wetlands to move between Everglades NP and Big Cypress National Preserve, and during the drought

years of 1989 to 1991 one Florida panther in Everglades NP became a common predator on alligators during radiotracking studies of the species (Dalrymple and Bass 1996).

In the southern Everglades, Miller (1993) and Smith *et al.* (1996) stated that adult bucks spent more time alone, and prefer to spend time on tree islands. Isolated bucks in the dense cover of tree islands may be easier to stalk by panthers. They also noted that females tend to stay in groups in more open prairie habitat. Such groups may be more difficult to approach and stalk by panthers. Moreover, the reduced rate of deer kills in the wet months of July through September in Everglades NP (Dalrymple and Bass 1996) correspond to the months when bucks are more commonly associated with groups of does in open prairie habitat (Smith *et al.* 1996), and again this may make close approach by stealth more difficult for panthers to successfully kill deer.

In the Big Cypress National Preserve, Miller (1993) found adult male deer to be twice as likely to use hardwood tree islands as females. Miller also suggested groups of female deer may use open habitat more often as part of a predator avoidance behavior.

In evaluating bobcat predation on fawns in the Big Cypress, (Land 1991) pointed out that peak rates of bobcat predation on fawns were in June and July, and that rates of fawn kill were much lower from August to December. The acquisition of additional upland habitat, especially for movement and dispersal corridors (Cox *et al.* 1994) is fundamental to the long-term preservation of the Florida panther and its main prey. But, in the Everglades, extended periods of natural or human-caused flooding in the WCAs and Big Cypress National Preserve have led to numerous documented periods of high mortality in white-tailed deer populations, that have significant effects on their predators (Loveless 1959b, Harlow and Jones 1965, Jansen 1998). Restoring hydropatterns that include seasonal drydowns for access to marsh habitat and isolated tree islands is essential to the preservation of these species in the Everglades (Harlow and Jones 1965, Maehr 1997, Smith and Bass 1994).

The **Florida sandhill crane** (*Grus canadensis pratensis*) is a non-migratory bird that utilizes the freshwater marshes and wet prairies in South Florida. This species differs from its related *G.c. canadensis* by being much larger. Nesting typically occurs in shallow ponds, marshes, and lakes with thick emergent vegetation such as: *Pontederia*, *Sagittaria*, and *Panicum*, or bog button (*Sclerolepis* spp.), saw grass, and/or cattails. It tolerates limited human disturbance, but is threatened by continued habitat loss due to hydrologic alterations for agriculture and development. The Florida sandhill crane is listed as threatened by the State of Florida.



White ibis. *Original photograph by Barry Mansell.*

The **white ibis** (*Eudocimus albus*) is a colonial breeding, medium-sized wading bird with a long decurved bill, long legs, and a long neck; which is extended in flight. The species typically nests in trees or shrubs near water, especially in wooded swamps or other marsh vegetation. It is often associated in nesting with smaller *Egretta* herons and is most sensitive to intrusion when nesting or roosting. The white ibis is State-listed as a species of special concern.

The **round-tailed muskrat** is a FWS species of management concern. Maidencane marshes, cattail marsh, and even sugar cane fields are used by this species (Lefebvre 1992*)*. Preferred marsh habitat has water levels that do not exceed 50 cm (20 in), with soft substrates of peat or sand that are deep enough to permit it to burrow down to the water table during dry periods (Birkenholtz 1963, Tilmant 1975). The major threats to this species include drainage practices in marsh systems, poor management of agricultural soil conservation, prescribed burning practices in salt marshes and fresh water marshes, and mechanical harvesting practices in sugar cane fields. Isolation of small populations by urbanization makes re-establishment of local populations more difficult.

This species remains poorly studied. At one time, its population numbers may have been much greater than today. Like the northern muskrat (*Ondatra zibethicus*), it is capable of rapid recovery from periods of drought and flooding (Birkenholtz 1963), but it may never have played as significant a role as a major herbivore in marsh ecosystems that its northern counterpart has (Weller 1982, 1994).

The South Florida population of the mink, commonly called the **Everglades mink** (*Mustela vison evergladensis)* is listed as threatened by the State of Florida. While mink are common in northern Florida, they are rarely seen in South Florida, and most of the information on the species comes from road-killed specimens and from sightings along levees (Smith 1980). The preferred habitat is shallow freshwater marshes and wet prairies in southern Collier

County, northeastern Monroe County, and Miami-Dade County. It also uses swamps and salt marshes. Mink were once common and trapped around Lake Okeechobee; there are no current records of the species in the lake area (Humphrey 1992). Humphrey (1992) noted that museum specimens only verify the current range to extend as far north as Interstate Highway 75 (Alligator Alley) and as far east as the Florida Turnpike. The mink is so poorly known that it is difficult to make clear recommendations for habitat management, and additional research appears fundamental to a better understanding of the South Florida population.

The **Cape Sable seaside sparrow** is currently the subject of intense evaluations with regard to modified water deliveries in Water Conservation Area 3 and the Everglades NP (COE 1998). These sparrows live in wet prairies dominated by muhly grass and short sparse saw grass (Howell 1932, Werner 1975, Curnutt 1996). Habitat conditions may change from year to year due to flooding by excessive rains or due to drought. Hydroperiod dictates the length of the nesting season; however, rising surface water abruptly halts breeding activity. Eastern meadowlark behaviors are very similar to that of the Cape Sable seaside sparrow. The preservation of the vegetational communities that are beneficial to the Cape Sable seaside sparrow will also benefit a very wide range of other species of animals and plant species, including the meadowlark.

Cape Sable seaside sparrows nest during a period from late February through early August, with most activity occurring in April and May, when the marl prairies are dry. Their variable cup-shaped nests are usually on or within 20 cm (7.9 in) of the ground, composed of sedge or coarse grass, and filled with finer materials (Werner 1975). Therefore, even slight shifts in water depth can cause significant nesting mortality from flooding.

Loss of wet prairie habitat along the eastern edge of the southern Everglades has reduced the habitat available for the eastern sub-population. In addition, excessive discharges of water through the S-12 structures in the southern boundary of WCA 3A has severely reduced the reproductive potential of the western subpopulation (Curnutt 1996).

The high rainfall from 1994-1998, including El Nino effects, resulted in most of the SFWMD basins having water levels at or near capacity, requiring excessive releases from Lake Okeechobee through the Caloosahatchhee and St. Lucie drainage systems, with significant impacts on associated estuaries. Additionally, the high water conditions in WCA 3A and continued releases of water through the S-12 structures led to an emergency status evaluation of Cape Sable seaside sparrow habitat needs (COE 1988). As of March 1998, the COE and SFWMD have been diverting water from WCA 3A to WCA 3B (see habitat recommendations for the species in this chapter, and then southward through canal C-111 to give relief to the western core population of the Cape Sable seaside sparrow.

Wherever it is found, the activities of the **American alligator** as a major predator and landscape architect have led to the use of the term “keystone” species to emphasize its ecological importance in wetlands dynamics (Hines 1979, Kushlan 1974, Kushlan and Jacobsen 1990, Mazzotti and Brandt 1994). While the species rapidly recovered from the endangered status, it deserves



American alligator. *Original photograph by Dawn Jennings.*

special attention and emphasis in any discussion of the fauna and community dynamics of Florida's wetland marshes and prairies.

Alligators feed on snails, crayfish, amphibians, mammals, birds, and reptiles, including themselves (Barr 1997, Delaney and Abercrombie 1986, McNease and Joanen 1977). Alligators excavate and maintain "gator holes" that serve as aquatic refugia during the dry season. Without alligators, there are fewer ponds to serve as dry season refugia for fishes and aquatic invertebrates and, therefore, less prey for the populations of wood storks and other wading birds (Craighead 1968, Mazzotti and Brandt 1994). Finally, alligator nests serve as important egg-laying sites for other reptiles (Kushlan and Kushlan 1980).

Fragmentation of alligator habitat includes two components: (1) reduction in total habitat area, which primarily affects population sizes and thus extinction rates; and (2) redistribution of the remaining area into disjunct fragments, which primarily affects dispersal and thus immigration rates; both components cause extinctions (Wilcove *et al.* 1986).

A population of alligators lives in the Lower Keys that moves through and feeds in many different habitats, including open waters, tidal mangroves, hardwood hammock, pine rockland, freshwater marsh, and buttonwood basins. On some islands, they maintain the only year-round water holes that exist.

Recent research (Guillette *et al.* 1994, Rice and Percival 1996) has identified reduced hormonal levels correlated with reduced reproduction in alligators in central and northern Florida marsh and lake systems related to contaminant levels. In the southern Everglades, biopsies of alligators have identified elevated mercury levels in limited samples (Roelke *et al.* 1991).

A natural source of mortality in alligator populations is egg mortality caused by flooding; egg loss can become excessive due to large and/or rapid water discharges associated with water management (Kushlan and Kushlan 1979, Kushlan and Jacobsen 1990, Ogden 1976). The most recent extensive studies of alligator populations in the Everglades NP indicate that the major

problem facing the alligators in the park since scheduled deliveries of water began in 1971 has been excessive nest flooding (Kushlan and Kushlan 1979, Ogden 1976).

Plant Species of Concern

Federally listed plant species that depend upon or utilize the freshwater marsh and wet prairie communities in South Florida include the Okeechobee gourd (*Cucurbita okechobeensis)*. The biological account and recovery tasks for this species are included in "The Species" section of this recovery plan.

Numerous other species, including some State-listed species, are under threat by improper water management practices. Some species are associated with wetlands, but are not wetland or aquatic plants. These include: epiphytic orchids, bromeliads, and ferns that are found in swamps or low-lying pinelands but have distributions that include shorter-hydroperiod wet prairies and marsh ecotones. This is especially true in the southern Everglades ecotones between pine rockland and wet prairies, and cypress and mixed hardwood swamps and wet prairie. (refer to Appendix C for a list of other species that utilize freshwater marshes and wet prairies).

The **twospike crabgrass** (*Digitaria pauciflora*) is a herbaceous perennial grass that is known from freshwater marshes and wet prairies. This species also occurs in pine rocklands. *Digitaria pauciflora* is shade intolerant and requires periodic burning to reduce competition from woody vegetation. The number of remaining plants has been estimated at fewer than 10,000 individuals. It is currently restricted to a range of approximately 8,000 ha (31 square miles). Fire suppression and exotic plant invasion are the greatest threats to the species. The species has been listed by the State of Florida as an endangered species.

The **Edison's ascyrum** (*Hypericum edisonianum*) is a colonial shrub that utilizes wet prairies in South Florida. Periodic burning during the dry seasons has helped maintain the species. Insect pollination of the showy white flowers is believed to occur. The species is threatened by loss of habitat due to hydrologic alteration, development, and agriculture. *Hypericum edisonianum* is listed by the State of Florida as an endangered species.

Ecology

Physical Regulating Factors for Freshwater Marshes and Wet Prairies

The major factors regulating freshwater marsh and wet prairie dynamics are: (1) hydropattern; (2) water quality; (3) sea level change; (4) hurricanes and tropical storms; (5) freezes; (6) fire regime; (7) salt water intrusion; (8) non-endemic or exotic pest species; and (9) water management and flood control practices (DeAngelis and White 1994, Duever *et al*. 1994, Wanless *et al.* 1994).

Some of the above factors are natural phenomena in which no human intervention is involved. Others, however, such as fire, saltwater intrusion, and water management, are more frequently human-induced and/or regulated activities that can be altered to improve ecosystem structure and function.

Perhaps the more pressing issues fall into the socio-economic realm of land use and planning and involve human population expansion, potable water supply, urbanization, and agricultural practices. DeAngelis and White (1994) have stressed the importance of understanding the relationship between the temporal and spatial relations in each of these types of disturbance and regulating factors in order to prioritize management and restoration objectives.

Davis *et al.* (1994) discussed all the factors that may have contributed to shifts in vegetative cover within the Everglades basin. They discussed previous work that related shifting vegetation patterns to fire regimes, soil depths, and drainage trends (both pre- and post-flood control development). They were not able to come to a conclusion on the role of the various factors, nor the importance of specific temporal periods in affecting the shift in vegetative cover types. In general, Davis *et al*. (1994) did stress that the significant shift to saw grass was related to a reduction in overall system productivity, especially for periphyton, lower consumers, and forage fishes and wading birds. In essence the remaining portions of the "river of grass" have too much tall dense emergent "grass" (saw grass or cattails) and not enough of the less dense and more open marsh types to sustain the historical abundance diversity and productivity of the region.

Regardless of the extent or geographic location, South Florida freshwater marshes and wet prairies are generally considered to be a function of the distinctive array of physiological and morphological adaptations of the species to survive under low nutrient conditions. For the deeper marsh types, these include adaptations to prolonged hydroperiods in anaerobic soil conditions and rapid growth response after fires. For the shorter-hydroperiod wet prairie these include wide tolerances to drought and flooding, in aerobic soils, and rapid growth response after fires. So much of our understanding of the natural ecological conditions and regulating factors has been derived from studies done after the human modification of the system had begun (Beard 1938, Davis 1994, Egler 1952), that it is best to expand on the ecological issues in relation to our current knowledge based on empirical and modeling studies on the status and trends of freshwater marshes and wet prairies.

David (1996) reviewed vegetation data collected in WCA 3A from 1978 through 1984 relative to changes in water delivery. He noted that *Rhynchospora tracyii* was more common in areas that had been able to dry down, and suggested that regular seasonal dry down of marsh allowed the residual seed bank for this species to germinate and recapture some areas. In the absence of regular dry down, this species as well as many other species of *Rhynchospora* were absent from this region. However, *Rhynchospora tracyii* is also found in short-hydropattern wet prairies on marl soils of Everglades NP (Olmsted *et al.* 1980; Dalrymple, Everglades Research Group, personal communication 1998) that regularly have much shorter hydroperiods and depths of flooding. In this habitat, the species seed bank experiences regular periods of dry down that permit it to persist. Conversely, Loveless (1959a) considered *Rhynchospora tracyii*, in what he called *Rhynchospora* flats, to be "usually covered with surface water for longer periods of time than any of the other communities, excluding the sloughs, and, except during abnormally dry years, the water level rarely recedes more than

a foot below the surface of the ground." The relationship between soils, hydrology, and plant species preferences is not clear, and much more information on habitat requirements is needed to avoid premature and rigid definitions of indicator species of freshwater marsh and wet prairie types (David 1996). Moreover, many other wetland plants listed as obligatory or facultative wetland by the Federal and State listings show extremely wide ranges of habitat use (Godfrey and Wooten 1979, 1981).

Fire

Fire is critical to controlling the degree of expansion of hardwood perennials, trees, and tree islands into adjacent herbaceous wetlands, because fires limit the build up of peat (Craighead 1971, Gunderson and Snyder 1994, Wade *et al.* 1980). When fires are suppressed or infrequent, peat builds up and willow (*Salix carolina),* buttonbush (*Cephalanthus occidentalis),* wax myrtle (*Myrica cerifera),* and the exotic pest species Brazilian pepper (*Schinus terebinthefolius),* Australian pine (*Casuarina* spp.), and melaleuca (*Melaleuca quinquenervis)* rapidly invade. Once these species have invaded a marsh or prairie, future fires simply increase their rates of expansion, due to their fire adaptations (Ewel 1986, Myers 1983, and Wade *et al*. 1980). Therefore, the timing of fire and post-fire flooding combine to strongly regulate the mosaic of herbaceous and forested wetland types that is critical to overall ecosystem function and, therefore, meet the requirements of the widest range of plant and animal species (the basic multi-species recovery goal).

Whether the fires are prescribed burns, or wildfires, the timing of the fire event in relation to flooding is critical (Davis *et al*. 1994, Gunderson 1994, Herndon and Taylor 1986, Wade *et al*. 1980). Fires in the dry season or early wet season burn back the fuel load of many wetland types, and this is especially well documented for saw grass marshes. The marsh plants rapidly begin to resprout from growing tips buried deep in thick protective stems or from underground rhizomes and root systems. However, rapid reflooding after fire does not give them new growth time to reach heights that will tolerate the flooding, and may result in death to the regenerating vegetation. Frequently, this leads to a complete transformation from one community type to another (*e.g*. from saw grass to muhly prairie, or saw grass marsh to maidencane or beakrush marsh). Vegetative density in saw grass marshes varies with hydrology and fire frequency (Alexander and Crook 1984). Davis *et al*. (1994), David (1996), Gunderson (1994), and Alexander and Crook (1984) noted "decadent" stands of saw grass marsh in areas where fire had been excluded for many years, and pointed out that the dead stem densities get so great as to crowd out live stems, resulting in hardwood colonizations (*e.g*. willow and buttonbush).

Patterns of fire and fire suppression may have a significant role in obtaining reasonable ranges of productivity for South Florida freshwater marshes and wet prairies (Robertson 1953, 1954; Olmsted *et al*. 1980; Wade *et al*. 1980). For example, after a fire, saw grass can reach a height of 20 to 40 cm (8 to 16 in) in 2 weeks (Forthman 1973), and maidencane shows rapid regrowth within 30 days postburn. Herndon and Taylor (1986) emphasized the rapid accumulation of tissue mass in muhly prairies with regard to fire frequency and effects. Werner (1975) evaluated muhly prairies occupied by Cape Sable seaside sparrows after fires, and

this led him to suggest an important relationship between fire frequency and sparrow nesting habitat value. In all of the above reviews, the effective regulation of water depth after fire was essential to allowing sufficient regrowth of the native plant community. Currently managed fires coordinated with water flow are not effectively practiced in most freshwater marsh and wet prairie settings.

Trophic Status

Trophic status refers to the fertility of a wetland and is a direct function of nutrient loading. Oligotrophic, nutrient-poor, wetlands generally have plant communities that provide habitat for sport and forage fish, but lack of nutrients inhibits production so that total biomass and potential harvest of fish is low. The low nutrient supply also inhibits periphyton and phytoplankton production in open water areas, so that fish populations are severely limited. In its original state, the Everglades system was oligotrophic, and much of the southern Everglades, especially Everglades NP, remains so today. But increased levels of phosphorus and nitrogen runoff from agricultural lands in the EAA through the WCAs, and thick mats of exotic floating vegetation (*e.g.* water hyacinth) have resulted in rapid eutrophication of the northern Everglades (Bryan 1996, Davis and Ogden 1994, Snyder and Davidson 1994).

The Everglades marshes and wet prairies are basically a detritus or "brown" food chain (Odum 1983), *i.e.,* the majority of net primary production dies without being consumed by herbivores, and becomes the nutrient source for a complex decomposer/detritovore-based food chain. The deep peat soils of the long-hydropattern marshes are generated by the high rate of net primary production that decomposes slowly in low-oxygen conditions. The marl soils of the shallower short-hydropattern prairies are produced by a function of blue-green algae and green algae incorporating the dissolved calcium carbonate from the underlying limestone bedrock into their cell walls. Annual drying down results in large amounts of dead periphyton to contribute this to calcium carbonate as marl soils (Browder 1981, Browder *et al.* 1994).

Comparison of estimates of standing crop of forage fish per unit area for open marsh systems versus saw grass or cattail marsh have proven difficult and often misleading. Moreover, the estimates vary widely, and are significantly affected by sampling methods and hydrological conditions (Loftus and Eklund 1994). Part of the problem with comparisons of forage fish standing crops is that they do not include information on the actual availability to consumers, *e.g.* foraging wading birds.

Diseases and Parasites

Frederick and Spalding (1994) have reviewed the literature on the occurrence of a wide range of diseases and parasitic infestations in wading and water birds. They noted that general emaciation, lack of fatty tissues, and decreased muscle mass may be related to a variety of conditions including sublethal levels of contaminants. They found outbreaks of eustrongyloidosis caused by a nematode in some colonies in the Everglades, and noted that increased nutrient loads and physical alterations of foraging sites have been implicated in the

occurrence of this condition. Considering how many wading birds are currently found foraging in polluted small ponds near point sources of pollution, as well as along many canal edges, it is likely that shifts in water quality, and increased biomagnification of nutrients and contaminants in the tissues of prey species are probably being passed on to these top predators.

Status and Trends

Loss of Spatial Extent and Shifts in Plant Community Coverage

Dredge and fill operations and flood control structural management, including dikes and canals with levees, have had a major role in affecting the distribution, interspersion, and productivity of freshwater marshes and wet prairies. Dredging and filling in wetlands permanently destroys habitat vital to biological productivity and fishery resources. Shallow vegetated areas of marsh and littoral zones are extremely important to the production of forage fishes by serving as breeding, nursery, and refuge habitat.

Throughout South Florida, there has been progressive loss of total functional coverage of freshwater marshes and wet prairies due to development, excessive drainage, exotic plant infestations, water management restrictions on volume and timing of flow, and eutrophication. While many isolated freshwater marshes and wet prairies still occur in South Florida, they are usually degraded and isolated from connections with upland habitats that are so critical to the interspersion of habitats required for complete ecosystem structure and function (Hartman 1992, Weller 1994). In the Everglades region, vast amounts of peripheral wetlands are being invaded by exotic pest plant species.

Jordan *et al.* (1997) reviewed their quantitative findings from an analysis of marsh communities in the northern Everglades in the Arthur R. Marshall Loxahatchee NWR. They point out that the pre-drainage landscape of the area was comprised of long-hydropattern marshes, saw grass marsh, sloughs, and tree islands overlying peat. Using multivariate statistics, they found strong quantitative relationships of slough habitat with *Utricularia* spp. and *Nymphaea odorata*, of long-hydropattern marsh with *Eleocharis cellulosa*, *E. elongata*, and *Rhynchospora tracyii*, and of saw grass marsh with *Cladium jamaicense*. Jordan *et al*. (1997) found that sloughs, long-hydropattern marshes (wet prairies on peat) and saw grass marshes "occupy a gradient of decreasing water depth. The significance of this finding is that small differences in topography among habitats (especially wet prairies and saw grass stands) have been masked and the ability to determine the roles fire and hydroperiod play in structuring Everglades landscape has been hampered...."

In evaluation of changes in vegetation types through time, Davis *et al*. identified not only a significant reduction in the overall regionwide extent of Everglades natural plant communities, but a significant trend for saw grass to replace wet prairie/slough.

Bancroft *et al.* (1994) and Hoffman *et. al.* (1994) have pointed out that significant shifts in the extent and distribution of tree islands have had a significant effect on the pattern of foraging activity in relation to wading bird rookeries in southern Florida. They recommend modifications in the pattern of water

deliveries more closely mimicking the natural system to promote a more complex mosaic of forested and graminoid wetland communities to enhance wading bird habitat. In wet prairies, numerous studies have identified shifts in species composition in Everglades NP related to fire and/or hydropattern changes (Armentano *et al.* 1998b, Herndon and Taylor 1986, Herndon *et al.* 1991, Olmsted *et al*. 1980). These authors, as well as Alexander and Crook (1984), Davis *et al.* (1994) Gunderson (1994), and Kushlan (1990) all recognized that some of the shifts in marsh and wet prairie distribution and species composition are strongly related to a history of disturbance near canals associated with increased nutrient loadings, alterations in the hydropattern, and alterations in the pattern of fire.

The current patterns of spatial distribution and coverage by freshwater marsh and wet prairie types have shifted in all regions of the Everglades. Perhaps the most distinctive shift in species distribution in wet prairies has been in the southeastern marl prairies. A large proportion of the peripheral wet prairies of the southern Everglades were transformed into agricultural lands and others have been transformed into housing developments (Light and Dineen 1994, National Audubon Society 1997). Perhaps the clearest example of these management modifications are seen in the North East Shark River Slough east of the original Everglades NP boundary. The problems associated with the trends identified by Fennema *et al*. (1994) have also been identified in the empirical data from studies of freshwater fishes and invertebrate communities (Loftus and Eklund 1994, Nelson and Loftus 1998), in the Everglade snail kites, the wood stork and other wading birds (Bancroft *et al.* 1994, Frederick and Collopy 1994, Hoffman *et. al.* 1994, Ogden 1994), and the American alligator (Mazzotti and Brandt 1994).

Additional empirical data regarding hydropattern and water quality impacts in the managed system come from the period of high water conditions experienced from 1994 and into the 1997 to 1998 "El Nino" effects (Armentano 1998a). Impacts were identified on everything from plant communities such as periphyton and tree islands in the freshwater marsh mosaic to Florida Bay salinity, as well as impacts on a wide range of fauna including the Cape Sable seaside sparrow, Everglade snail kite, wood storks and other wading birds, white-tailed deer, small mammals, freshwater and estuarine fishes, American alligator, and other reptiles.

Water Budget and Discharge Management

Overall, the data from empirical studies and models indicate that the current C&SF system is inadequate for the regional water budget for both natural systems and human population needs. Water in excess of amounts needed to reach ecological goals for the estuaries is still being shunted down canals out to Lake Worth Lagoon, and other estuaries in the study such as the Indian River and Caloosahatchee River. The consensus of opinions (Davis and Ogden 1994) is that we must recapture much of the peripheral wetlands that border the WCA's. In a review of the 1980-1989 records for total discharge from the C&SF project's water control system, Light and Dineen (1994) noted that out of a total average annual discharge of 4,113,000 acre-feet (5,058,990,000 cu m), 80 percent goes to the Atlantic Ocean, 13 percent gets to the Shark River Slough, 2 percent to Taylor Slough, and 4 percent enters Barnes Sound and northeast Florida Bay. The proposed Modified Water Deliveries Plan to

Everglades NP, including the acquisition of North East Shark River Slough, the C-111 project for improving the area over which water flows to Florida Bay and Barnes Sound, and the National Audubon Society's (1997) suggested expansion of the original SFWMD Lower East Coast Buffer (LEC) or Water Preserve Areas (WPA) are all initiatives that will increase the amount of wetlands available for storing water, restoring sheet flow, enhancing natural functions in peripheral wetlands, and reducing water losses from canals to estuaries and bays (SFWMD 1995).

Natural System Model vs. Managed System Hydropatterns

Using models to simulate the natural system's hydropattern in comparison to the hydropattern with current water management practices of the southern marshes, below Lake Okeechobee, Fennema *et al*. (1994), demonstrated prolonged hydroperiods and increased depths of flooding in many portions of the original region that were classified as shorter-hydropattern wet prairies and saw grass marsh. In their comparison, they made it clear that the current pattern of water storage in the SFWMD's system of canals, levees, and WCAs, including the Arthur R. Marshall Loxahatchee NWR, has resulted in significant changes in conditions that are causing a loss in peripheral wet prairies and freshwater saw grass marshes, an increase in the area of prolonged flooding in some areas that were naturally drier, and a simultaneous drying of large areas that were deeper marshes (flag marshes, water lily marshes and sloughs) (Davis and Ogden 1994).

Pulsed Discharges with Rapid Reversals of Flow vs. Attenuated Sheet Flow

Many reviews of current water discharge practices have emphasized the shift from natural slow attenuated sheet flow driven by rainfall events to rapid pulsed discharges through point sources of release at water management structures with decreased sheet flow. They also recognize that within-year rapid reversals in flow are caused by the opening and closing of water release structures that rapidly change standing water levels resulting in sudden elevations and decreases in water levels may severely impact reproductive and foraging success for a wide range of species (Light and Dineen 1994; COE 1992, 1994). The sooner the marsh system is restored with more natural flows and levels, the better the chances are of recovering the ecosystem.

Water Quality and Eutrophication

Water quality, especially eutrophication from increased phosphorus and nitrogen runoff from agricultural lands and cattle ranches, has become an increasingly high-profile issue, and is well documented to rapidly alter the successional dynamics of wetland complexes (Davis *et al*. 1994, Porter and Sanchez 1994. The vast majority of literature is on the natural vegetation of the South Florida marshes and prairies that are adapted to low-nutrient conditions (Gunderson 1994, Kushlan 1990, Wade *et al*. 1980). Increases in phosphorus,

in particular, permit plant species that are capable of rapidly absorbing and growing under higher-nutrient conditions to expand their ranges until they begin to create monocultural stands. The best documented cases of this phenomenon are the replacement of saw grass marshes by cattail marshes. The issues surrounding the levels and sources of eutrophication remain controversial (Bottcher and Izuno 1994, Craft *et al.* 1995, Davis *et al*. 1994).

Fertilizers are widely used in South Florida to maintain high levels of agricultural productivity. From July 1, 1990 through June 30, 1991, fertilizers sold in South Florida contained 140,000 tons of inorganic nitrogen and 56,000 tons of phosphate. Nutrient loading from the Everglades Agricultural Area (EAA) and urban areas have significantly increased nutrient concentrations, particularly phosphorous (Stober *et al*. 1996). This has resulted in increased soil phosphorous content, changed periphyton communities, loss of native saw grass communities, increased organic matter in water, loss of dissolved oxygen, conversion of wet prairie plant communities to cattails, and loss of important wading bird habitats (Stober *et al*. 1996). Nutrient loading from the EAA has been associated with eutrophication in the WCAs having greater than 50 ppb phosphorous concentrations.

The natural background levels of phosphorous in the Everglades are 10 ppb or less. The Miccosukee Tribe has set a standard of 10 ppb for phosphorous in water quality standards for tribal lands. Craft *et al.* (1995) found that additions of phosphorus, and nitrogen plus phosphorus had a significant effect on species composition in their slough plots, with a decline in the *Utricularia* spp. and periphyton mat after one year. At the same time, there was a rapid expansion of *Chara* spp. until this submersed macroalga had replaced the floating mat of vegetation as the dominant vegetation. They observed no significant changes in the macrophyte species diversity or expansion of cattails during the 2 years of their study on saw grass or mixed saw grass and cattail (*Typha dominguensis*) plots. They considered replacement of the floating mat of *Utricularia* spp. and periphyton by *Chara* as an early indicator of phosphorus enrichment in Everglades waters.

The major threats to sustaining the current distribution of saw grass marsh have to do with alterations of hydropattern, increased eutrophication of water, especially by phosphorus associated with agricultural and cattle land runoffs, and encroachment of native and exotic plant species that aggressively expand into stressed saw grass marsh habitat. *Typha* spp. are documented as being able to replace saw grass as hydroperiods are prolonged in water conservation areas, and when nutrient loads are anthropogenically increased (Davis *et al*. 1994, McPherson *et al*. 1976, Wiggins and Bottcher 1994).

Weller (1994) and Williams *et al*. (1985) point out that early in the eutrophication process there are benefits to fish populations and habitat conditions, but a point is reached where the system becomes degraded. Increasing nutrient loading eventually can lead to hypereutrophic conditions, with increased density of marsh plants (cattails, periphyton, phytoplankton, water lilies, and water hyacinth), decreased dissolved oxygen, increased algal biomass and phytoplankton turnover and development of mucky sediments, declines in sport and forage fish populations, and increase in “rough fish” populations.

Herbicide/Pesticide and Mercury Contaminants

Pesticides have also been widely used in agricultural and urban areas in South Florida for more than 50 years to control insects, fungi, weeds, and other undesirable organisms. Because of year-round warm temperatures and moist climate, Florida agriculture requires vigorous pest control, thus while Florida agricultural production ranks about 30th in the nation, pesticide use per acre is in the top five. The compounds used vary in their toxicity, persistence, and transport. Since the late 1960s, persistent organochlorine pesticides have been detected in fish that are part of the Everglades food chain (McPherson 1973, Haag and McPherson 1997). Some more persistent pesticides, such as DDT, Chlordane, Dieldrin, and Aldrin have been banned for use in Florida, but their residues still occur in the environment. Although pesticides are usually applied to specific areas and directed at specific organisms, these compounds often become widely distributed and are potentially hazardous to nontarget biota (McPherson and Halley 1996). Herbicides including Atrazine, Bromacil, Simazine, 2-4-D, and Diuron, which have the highest rate of application, are among the most frequently detected pesticides in Florida's surface waters (Shahane 1994). By far the most frequently detected insecticides in surface waters are the chlorinated hydrocarbon ones that are no longer used in the state, such as DDD, DDE, DDT, Dieldrin, and Heptachlor.

Chlorinated chemicals, such as polychlorinated biphenyls (PCBs), dioxins, and furans, which are generated and used primarily in urban and industrial areas, pose serious concern to fish, wildlife, and human populations (Colborn *et al*. 1993). Although most uses of PCB's have been banned since the late 1970s, these persistent chemicals are still found in the environment and continue to pose potential threats to fish, wildlife, and humans. In recent years, many organochlorine pesticides and PCB's have been linked to hormone disruption and reproductive problems in aquatic invertebrates, fishes, birds, and mammals (Colborn *et al*. 1993). In a study of nine species of ciconiiform birds, Spalding *et al*. (1997) found that geographic location within South Florida affected the levels of contaminants, including chlorinated hydrocarbons, lead, cadmium, and copper. Chlorinated hydrocarbons were found in highest concentrations and most frequently from brain tissue samples of nestlings from the Lake Okeechobee area. Rodgers (1997) evaluated egg and liver tissues for pesticide and heavy metal levels in eight species of waterbirds in the EAA. Mercury, lead, DDT, DDE, Dieldrin, Heptachlor, Trans-nonachlor, Chlordane, Endrin, Toxophene, and PCBs were found in low concentrations in most samples. The concentrations were below levels currently considered to have significant impacts on birds, but a few birds had alarmingly high levels of some contaminants.

The evidence of mercury contamination in fish and wildlife in South Florida freshwater ecosystems is extensive. Piscivorous freshwater sport fish and alligators in many watersheds have high mercury levels in their tissues (Ware *et al*. 1990, Eisler 1987). After discovering the extent and severity of mercury in fish in 1989, the State Health Officer issued advisories to anglers, warning against consumption of several species throughout more than 1,000,000 acres of the Everglades, and advised restricted consumption of others over most of the State. Besides human health concerns, ecological resources may be at risk as well. In the early 1990s, three Florida panthers inhabiting the Everglades died. Mercury was determined to be the proximate cause of death in one and a contributing cause of

death in the other two cases (Roelke *et al*. 1991). High mercury levels have been detected in the endangered wood stork and other birds (Sundlof *et al*. 1994). There is much concern that the 50-year decline in wading bird numbers in South Florida may be a result of increased mercury exposure; intensive studies are underway to further define this concern.

Trends in mercury accumulation in South Florida, as evidenced by sediment profiles, show that mercury deposition has increased approximately fivefold since 1900 (Rood *et al*. 1995). The deposition rate of mercury by rainfall measured today is at least double that of other remote sites in North America (Guentzel *et al*. 1995). Some of that deposition must result from the threefold anthropogenic enhancement of the global mercury cycle, making this a significant fraction, if not a majority, of the deposition (Dvonch *et al*. 1995, 1996); extensive studies are underway to define local source-receptor relationships with greater precision.

Storms

Major storms can be a significant and unpredictable element affecting the structure of freshwater wetlands. While most emphasis is placed on hurricanes and the degree of damage they have on forested and coastal plant communities, this damage is associated with high winds and storm surges (Armentano *et al*. 1997, Craighead and Gilbert 1962). The major impact of tropical storms in wetlands is not from wind damage, but from extensive flooding (Light and Dineen 1994). The tropical storms, whether of hurricane strength or not, that are of most importance are those of large geographic coverage that drop high amounts of rainfall as they pass through (COE 1994). A good example of such a storm was tropical storm Dennis in the fall of 1981. This storm arrived at the end of a serious drought, when water managers were desperately trying to conserve water. The storm stalled over the Everglades, and dropped 51 cm (20 inches) of rain in a 24-hour period, and led to extensive flooding. This storm occurred during Herndon and Taylor's (1986) study of fire effects on wet prairies, and they noted that young saw grass shoots regrowing in one of their burned plots were completely flooded and died due to the heavy rainfall. The high water levels during this storm resulted in the decision to cut open the earthen dams in the southern C-111 canal. Massive amounts of freshwater were released into Barnes Sound causing serious impacts on the coastal marshes, prairies, estuarine and bay animal and plant communities (COE 1994).

While high winds associated with severe storms topple trees and are a serious impact on forested uplands and swamps, they are only of concern in wetlands and estuaries when they carry a high storm surge of salt water into the ecotones of estuaries. Hurricanes Donna and Andrew are good examples of hurricanes that had severe wind storm and tidal surge impacts that dramatically changed the structure of coastal mangrove communities for decades afterwards, as well as severely damaging pinelands and hardwood hammocks (Craighead and Gilbert 1962). Hurricane Andrew was so compact and moved through South Florida so quickly that rainfall was of secondary importance and of little consequence. Hurricane Georges of September, 1998 sent a storm surge over the middle of Big Pine Key and inundated 40.5 to 81 ha (100 to 200 acres) of freshwater wetlands with saltwater. Subsequently non-salt tolerant plant species have died out. In general, hurricanes are considered a natural, unpredictable part of the natural

ecological setting of the study area, and are recognized as impacts that have severe and long-term effects on the mosaic of South Florida's plant communities (DeAngelis and White 1994, Duever *et al*. 1994).

In recent years, there is more awareness of "El Nino" effects which have prolonged impacts with periods of excessive rainfall, extended high water levels, and unpredictable patterns of storm fronts often accompanied by tornadoes (Duever *et al.* 1994, Robertson and Frederick 1994). The 1998 high water levels in South Florida resulted in releases of very high amounts of water through the Caloosahatchee and St. Lucie River drainages, causing serious impacts on estuaries, and filling Lake Okeechobee and the WCAs to capacity. Overall, these high water levels result in typical conflicts with regard to which species and vegetative communities will suffer the most impact (estuaries, lake and riverine marshes, WCA marshes, or downstream wet prairies).

Freezes

During the dry season (winter months) in non "El Nino" years, South Florida may experience periods of rapid storm front movement accompanied by high winds and very low temperatures. In some instances, the ambient air temperatures and wind chill factors result in serious freezes that are especially detrimental to native tropical plant species, especially in hardwood hammocks. There are often major economic losses experienced by row crop, tropical orchard and citrus farmers. However, these freezes are of minor consequence in the non-forested wetlands of the region (Duever *et al.*1994).

Saltwater Intrusion, Sea Level Rise, and Global Warming

Perhaps the most subtle and underappreciated driving force in the natural dynamics of South Florida's ecology is changing boundaries between the freshwater aquifers and salinity gradients in the underground aquifer system (*e.g*. Egler 1952), and rising sea level and global warming (Wanless *et al*. 1994). Salt water intrusion is strongly related to freshwater storage levels in aquifers, flood control, water management discharge practices, and expanding demand for potable water from the rapidly increasing human population. Sea level rise is certainly a longer-term and more difficult factor to contend with. Together, these factors result in shifts in estuarine and coastal plant communities inland with the displacement and reduction in freshwater marshes and prairie community types (Wanless *et al.* 1994).

Exotic Pest Plants

There are more than 900 exotic (non-indigenous) plant species in Florida (Schmitz 1994). Many of these species are rather benign, but a significant and growing number of plant species are currently considered non-indigenous pest species. These species invade disturbed and natural sites, especially wetlands. Many develop into monocultures that exclude most if not all native plant species, and significantly alter the plant and animal species composition and food chains of the communities they invade (Schmitz and Brown 1994). According to the Environmental Pest Plant Council (EPPC) there are 31 Category I non-indigenous plant species that are currently known to be widely distributed in Florida and have invaded and disrupted native plant communities (Schmitz 1994). The largest amount of land colonized by exotic pest plant

species is forested and non-forested wetlands. Well over 416,667 ha (one million acres) of wetlands are currently invaded with aquatic weeds and wetland -shrubs and trees, including torpedo grass (*Panicum repens*), hydrilla (*Hydrilla verticilata*), water hyacinth, melaleuca, Brazilian pepper, Australian pine, Old World and Japanese climbing ferns (*Lygodium* spp.), air potato (*Dioscorea bulbifera*), tropical soda apple (*Solanum viarum*), water spinach (*Ipomoea aquatica*), and water lettuce (*Pistia stratiotes*). Melaleuca currently has invaded nearly 208,333 ha (a half million acres) of southern Florida's wetlands, and aggressively expands into saw grass marsh and wet prairies. Hydrilla currently infests more than 31,250 ha (75,000 acres).

Many of the fully aquatic species (hydrilla, water hyacinth, water lettuce) can rapidly expand via the hundreds of miles of canals and ditches dug for flood control and water management. In the SFWMD alone, there are 1,167,895 ha (2,802,947 acres) that must be managed for non-indigenous pest species (Thayer and Ferriter 1994). The 2,240 km (1,400 miles) of canals within the district make up only 7, 953 ha (19,087 acres) of this total area to be managed, but are a critical focal area for establishment and invasion of the total managed area.

Melaleuca rapidly expands into marshes and wet prairies regardless of hydropattern, and the seeds are rapidly dispersed by wind, especially after wild- fires (Bodle *et al*. 1994, Wade *et al*. 1980). In a study of melaleuca invasion in the southeastern Everglades, as melaleuca cover increased beyond 75 percent, it created a closed canopy that reduced sunlight penetration to the understory and, therefore, reduced primary productivity in the water column, especially in the periphyton and submerged macrophytes (O'Hare and Dalrymple 1997). This had a dramatic effect on the primary consumers and detritovore macroinvertebrates (*e.g.* apple snails, crayfish), resulting in overall lower abundance and productivity in the understory. Areas with less than 75 percent canopy closure had aquatic species diversity and abundances typical of areas without melaleuca invasion (O'Hare and Dalrymple 1997). Complex patterns of hydrology, and gapping in forest canopy due to wind storms and fires permits light penetration and the persistence of productive pockets of aquatic life even within some dense stands of melaleuca.

Programs of aerial spraying and the introduction of biological controls for exotic pest plant species have made great advances in stemming the expansion of at least some exotics. Melaleuca expansion is a persistent problem, but the recent application of aerial spraying and biological control through the introduction of insects that feed on melaleuca appear promising. While initial experimental control of melaleuca by aerial herbicidal treatments is encouraging, "the continuing problem has been how to manage the seed drop from dying melaleuca trees. Each tree can easily hold millions of seeds which are released when treated with herbicide" (Jordan 1994). There is little or no funding available to monitor the seed germination rates after herbicidal treatments and the Federal and State agencies have been reduced to using volunteer days to attempt some evaluation of success (Jordan 1994).

Brazilian pepper alone has expanded into 291,667 ha (700,000 acres) of upland and wetland habitat, and is especially invasive of short-hydropattern prairies and abandoned farm land in the rocky glades region of the east Everglades, as well as coastal mangrove communities (Dade County 1979,

Dalrymple *et al.* 1993, Doren and Jones 1994, Ewel *et al.* 1982). Brazilian pepper is being effectively removed from former farmlands in the Hole-in-the-Donut of Everglades NP, and productive wetlands are replacing them on the managed lands (Dalrymple 1994a, Dalrymple and Doren 1998, Resources Management International 1998). The restoration methods can be used on hundreds more acres of abandoned lands, such as the Frog Pond, and on illegally rock-plowed and/or filled wetlands in the east Everglades (Dalrymple *et al.* 1993). The method involves removing the rock-plowed topsoil, and scraping the surface to the limestone bedrock (below grade). The surface of the site is lowered by this action, and therefore is more likely to have a longer hydropattern. This prevents future germination of Brazilian pepper, and promotes wetland plant and animal re-colonization of the areas (Dalrymple 1994a; Dalrymple *et al*. 1993, Dalrymple and Doren 1998).

Hydrilla and other aquatic pest plant species are controlled by herbicidal treatments, mechanical removal, and biological control agents. The majority of control efforts are in Florida's lakes, rivers and canals (Schardt, 1994). Without continued efforts to reduce focal points of runoff via canals and control structures and water impoundment in sub-basins, all marsh and wet prairie systems will continue to degrade while increasing millions of dollars are spent per year in programs to control and eradicate pest plant species (Center *et al.* 1994, Schardt 1994).

Exotic Fauna

There is an ever-increasing array and range expansion of exotic species (Schmitz and Brown 1994) including the walking catfish (*Clarias batrachus*), Asian swamp eel (*Monopterus albus*), the live bearing pike killifish (*Belonesox belizanus)*, and cichlids of the genera *Astronotus*, *Cichlasoma*, *Hemichromis*, and *Tilapia* in South Florida (Courtenay 1994, Dineen 1984, Loftus and Kushlan 1987, O'Hare and Dalrymple 1997). Native piscivorous fishes and larger fish species are generally uncommon in saw grass marsh. Loftus and Kushlan (1987) attributed this to a combination of the high density of plant stems, shallow waters that inhibit movement, and dissolved oxygen levels that are often low. The invasive Asian swamp eel could be an exception and this large piscivore appears able to expand into the saw grass marsh. Also, the relatively small piscivorous exotic pike killifish and the increasingly common Nicaraguan cichlid, *Cichlasoma managuensis,* (O'Hare and Dalrymple 1997) may have significant impacts on the future structure of the saw grass marsh community due to direct and indirect effects (Mathews 1998). The range of exotic animals, from invertebrates such as fire ants (*Solenopsis invicta*) to mammals such as armadillos (*Dasypus novemcinctus*), that have invaded Florida is still being evaluated, but it includes some species that have had severe impacts on native communities (see chapters in Schmitz and Brown 1994 for a review).

Management

As pointed out by Weller (1982) in his classic paper on the management of freshwater marshes for wildlife, the two main objectives are "the preservation

of marshes in a natural and esthetically pleasing state with or without manipulation" and "to maintain high productivity of characteristic flora and fauna in freshwater marsh units."

A number of authors discuss a wide variety of management methods that can be employed to improve the design of marshes. The following management practices or principles are suggested (Weller 1982, 1994): (1) system management, rather than species-by-species management, results in widespread benefits to all wildlife and plants; (2) management to produce early plant successional stages results in longer-lasting benefits, and creates diverse habitat niches; (3) for improved habitat heterogeneity in wetland complexes, all units in an area should not be managed in the same manner at the same time; (4) wetland:upland ratios that preserve natural patterns should be used; and (5) natural or artificial simulation of drawdown is advised, especially within subregions of the system that will benefit productivity in marshes, littoral and limnetic zones (Fredrickson and Laubhan, 1994, Kadlec 1962; Meeks 1969, Williams *et al*. 1985).

Positive activities for freshwater marshes and wet prairies on existing and proposed managed lands in South Florida include the following:

(1) Re-establishment of seasonally variable hydropatterns to ensure a mosaic of freshwater marsh, wet prairie, and littoral zones with emergent and submerged (open water) vegetation.

(2) Re-establishment of sheet flow into freshwater marshes and wet prairies with a reduced reliance on canals to channel water between sub-basins.

(3) Development of water treatment marshes and stricter regulations, including Best Management Practices (BMPs) on agricultural land and adjacent managed lands. Enforce existing water quality standards and regulations.

(4) Promotion of new funding sources at the State and Federal level to continue with the planned land acquisitions related to P2000 and Save Our Rivers (SFWMD 1998). Restoration or reclamation of adjacent forested swamp and upland habitat is needed to provide suitable habitat for water birds, wading birds, and raptors, and areas of dry land for basking and egg laying for most semi-aquatic animals.

(5) Acquisition, restoration, or reclamation of drainage basin elements to existing managed wetlands, and of upland travel lanes and cover for upland animals that would seasonally use the wetlands.

(6) Prescribed burning in many marsh systems to control pest plant species, and re-invigorate plant communities. As Birkenholtz (1963) and Weller (1994) have pointed out, herbivore population increases and fire schedules are effective means for altering encroachment of dense emergent sedge and grass marsh types into open marsh types.

(7) Management of lakes and rivers to enhance or restore littoral zone marsh systems is becoming more commonly practiced on a local and regional level. Weller (1994), as well as the State of Florida's water management districts and GFC, have emphasized the value of lake management techniques such as drying down of lake margins, removal of excess organic matter in basins and exotic plant control to promote more natural basin morphology and soil conditions for re-establishment of marsh/littoral habitat. Current examples managed by the SFWMD include the de-channelization of portions of the Kissimmee River, now canal C-38 (SFWMD 1995, 1998) and GFC projects in Lake Trafford (Lake Trafford Task Force Conceptual Plan document: Gail Gibson, personal communication 1998), Stick Marsh, and Tenoroc FMA (King and Cates 1994, King *et al.* 1994).

(8) Regulation of biomagnification of contaminants in the food chain. The current combined programs of "Eastward, Ho!" and Brownspace reclamation in inner cities help reduce pressure for westward development into the periphery of wetlands, especially the Everglades, and simultaneously help clean up existing areas of contamination.

The two greatest priorities for freshwater marsh and wet prairie ecological restoration are reduction to natural background levels of nutrients and re-establishment of natural levels of seasonal sheet flow to recover the greatest possible spatial extent of the communities. The increased spatial extent of the natural system is the most fundamental way to ensure the range of water depths and hydroperiods beneficial to the diversity of freshwater marsh and wet prairie communities and listed species with varying ecological requirements.

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Restoration of Freshwater Marshes and Wet Prairies

Restoration Objective: Restore natural water quality, increase the spatial extent, and restore natural hydropatterns and seasonal flows to freshwater marshes and wet prairies in South Florida.

Restoration Criteria

South Florida must restore and preserve the highly threatened Kissimmee River-Lake Okeechobee-Everglades drainage system, as well as freshwater marsh and wet prairie habitats that are associated with other lakes and creeks, and isolated freshwater marshes and wet prairies. The recovery of listed plant and animal species, and the continued existence of other species of concern, including the American alligator, apple snail, and migratory birds, depends upon the restoration of these communities. Restoration of freshwater marshes and wet prairies must also assure flood control and aquifer recharge for drinking water and agriculture.

The restoration objective will be achieved when (1) the Kissimmee River is restored to its natural basin; (2) Lake Okeechobee water quality and water storage are restored to more natural conditions; (3) the Water Conservation Areas, including the Arthur C. Marshall Loxahatchee NWR have water quality and sheet flow, and hydropatterns restored to more natural conditions; (4) Everglades NP and Big Cypress National Preserve have water quality, sheet flow and hydropatterns restored to natural conditions; (5) the Northeast Shark River Slough (NESRS) addition to Everglades NP and the eight and one half square mile area (8.5 SMA) of the East Everglades land purchases are completed and sheet flow is restored; (6) the lands currently identified by the COE, SFWMD and the National Audubon Society as Water Preserve Areas are added to the spatial extent of the system to provide additional natural wetlands, flood control, and aquifer recharge; (7) the SOR additions are made through the use of all possible conservation land funding methods (SOR, CARL and Federal financial assistance); (8) prescribed burning is restored to the management of the marsh and wet prairie systems; (9) exotic biota including Brazilian pepper, melaleuca, Australian pine, hydrilla, and water hyacinth are eradicated or controlled; (10) the integrity of the marshes and wet prairies are ensured and maintained through a sound water management program of delivery schedules, and water storage patterns to be derived from the Central and South ern Florida (C&SF) Restudy; and (11) the distinction between wet prairie and marsh habitat conditions,

Community-level Restoration Actions

1. Restore the maximum spatial scale to the natural ecosystems.

1.1. Support and accelerate land acquisition programs by expanding funding and staffing for land transfers.

Current land acquisition programs (P 2000, CARL, SOR, *etc*.) are guided by highly sophisticated gap analyses to set priorities (Cox *et al*. 1994, 1997), to improve core areas for listed species and reduce habitat fragmentation to increase the likelihood of long-term metapopulation survival.

Combined Federal and State programs have been enacted to acquire the Northeast Shark River Slough (NESRS), the Frog Pond, and the Addition Lands to the Big Cypress National Preserve. The Save Our Rivers Program (SFWMD 1998) has acquired or plans acquisition of lands associated with the Frog Pond, L31N, Corkscrew Regional Ecosystem Watershed (CREW), C-111, East Coast Buffer Strip (also called the Water Preserve Areas (see below), Kissimmee Prairie Ecosystem, Kissimmee River upper and lower lake basin watersheds, Kissimmee Chain of Lakes, Shingle Creek, Everglades Agricultural Area stormwater treatment areas (STAs), Indian River Lagoon, Lake Lizzie, Lake Walk-in-Water, and boundary modifications for the Southern Glades and Model Lands Basin, Loxahatchee Slough, and North Fork St. Lucie River. The Save Our Rivers program also includes completion of outstanding land interests in the water conservation areas (WCAs). Critical to the continuation and completion of these land acquisition programs at the State level is renewing the funding sources to extend a program similar to P2000 into the 21st century.

The acquisition of the remaining NESRS lands, Water preserve area (WPA) lands for a buffer strip and additional water storage capacity for implementation of the Modified Water Delivery plan to Everglades National Park has fallen behind schedule, and the current period of high waters (1994 to 1998) has created conditions that make it very clear that the SFWMD is beyond its capacity to store water. Massive amounts of water are being shunted out through the Caloosahatchee River, St. Lucie drainage system, and the remaining canals to the estuaries in the coastal areas. Also, the water deliveries to Everglades NP continue to be drained toward the west, which damages the wet prairies through flooding, and the eastern prairies and marshes by over-drying.

The high water levels in Lake Okeechobee endanger the Lake's natural marsh littoral zones, as well as the structural integrity of the Herbert Hoover Dike. An accelerated rate of purchase of peripheral wetlands for inclusion in the WATER PRESERVE AREA buffer system is recommended.

The GFC has developed a sophisticated set of documents to evaluate the criteria and priorities for land acquisition for federally and state listed species (Cox *et al*. 1994, 1997). The priorities are based on a complex effort that coordinates all available information on listed species, and critical habitats or vegetational community types to identify strategic habitat conservation areas (SHCAs) in relation to current managed lands, as well as lands identified as critical by other agencies, or institutions (*e.g.* CARL, SOR, P2000, FNAI). The results of these reports are of great significance in identifying the geographic gaps that need to be acquired or protected (*e.g.* by less-than-fee methods) to preserve listed species, vegetational community types, and ecosystems.

Cox *et al.* (1994, 1997) have pointed out that the land cover types most well represented in current publicly managed lands are wetlands, including marshes and wet prairies. They point out that these cover types are, in a sense, over-represented in the current publicly managed land system, and made strong arguments for the need for land acquisitions in other cover types or vegetative communities, such as scrub, and pine flatwoods. But the high percentage of wetlands in public ownership, and the current and planned land acquisitions of additional wetlands are consistent with local State and Federal wetland protection legislation, and critical for a very large number of federally and state listed species associated with these cover types.

1.2. **Manage acquired lands for ecosystem benefits.** A major problem is not how many hectares of marsh and wet prairie are currently listed as managed areas or how many more hectares are acquired, but how they will be managed. Many land acquisitions do not end up being used to increase the spatial extent of the ecosystem, but rather are used for water treatment. A current example of this problem involves Miami-Dade County's Environmentally Endangered Lands and The Nature Conservancy lands between Biscayne NP and the Homestead Air Base. These lands may be used for stormwater retention and treatment with the planned privatization and commercial expansion of the airbase (SFWMD 1997b, U. S. Air Force 1994).

Some water management alternatives that are currently being discussed are counterproductive to maintaining water quality and natural system structure and function. For example, one option to implement a water control system around the eight and one-half square mile East Everglades residential area (8.5 SMA) will require back-pumping water that will lower water quality in the North East Shark River Slough.

In order to replace the pattern of rapid pulsed discharges and reversals of water levels with more natural attenuated sheet flow, land must be acquired to permit the wider areal extent of rainfall to drain off and water management releases to occur. The SFWMD stormwater treatment areas will also be used to redirect water flows from the northern Everglades EAA region. The releases will be designed to expand and enhance sheet flows to the water conservation areas (WCAs)

1.3. **Restore existing freshwater marshes and wet prairies**. The SFWMD (1998) in cooperation with other State, local, and Federal agencies should include the "Lower East Coast Buffer Plan" in the C&SF Restudy recommendations. The restudy is intended to develop water budgets and delivery schedules for all of southeast Florida. The projects under consideration include the Lower East Coast (LEC) buffer or water preserve areas as a series of wetlands along the development boundaries between the WCAs and Palm Beach, Broward, and Miami-Dade counties to serve as water preserve and storage areas. Some of the portions of this system of water preserve areas (WPAs) have been identified as having significant biological value (*e.g.* the Pennsuco Everglades in Miami-Dade County), and will be considered as valuable areas for ecological restoration of the spatial extent of the eastern peripheral freshwater marshes and wet prairies of the southeastern Everglades.

The Keys Environmental Restoration Trust Fund rehabilitated several acres of freshwater wetlands on Big Pine Key that are important to Key deer, Lower Keys rabbit, alligators, Key mud turtle (*Kinosternum bauri bauri*), wading birds, and other species. Restoration was achieved through fill removal and blockage of non-natural tidal influence.

Many other examples of laudable restorations exist and should be supported. The ecosystem restoration plan currently being enacted for Lake Trafford (Lake Trafford Task Force Conceptual Plan document, Gail Gibson, written communication 1998) is an excellent example of a plan to restore lake and marsh hydrology, reduce nutrient loadings, control phytoplankton blooms and *Hydrilla*, improve fisheries and wildlife habitat, and integrate the restoration into the Corkscrew Regional Ecosystem Watershed (SFWMD 1998). Another example is the restoration of short

hydroperiod and marsh conditions on approximately 4,000 ha (9,880 acres) on former farmlands in the Hole-in-the-Donut of Everglades NP (Dalrymple 1994a, and Dalrymple and Doren (1998). This restoration prevents future germination of Brazilian pepper, and promotes wetland plant and animal re-colonization of the areas (Dalrymple 1994a; Dalrymple *et al*. 1993, Dalrymple and Doren 1998, Resources Management International 1998). All of these efforts will increase the spatial extent of functional wetlands for in a wide range of hydropatterns.

1.4. **Support modeling efforts** to evaluate plans and progress for ecosystem restorations. The USGS ATLSS modeling program (USGS 1997) is one of several initiatives to develop a landscape level model for evaluating future water delivery scenarios, as well as for evaluating impacts to single species, and entire trophic levels. This program should be supported because it is the only modeling program that incorporates both single species models and multi-species models in a spatially explicit landscape.

Additional support for the Natural Systems Model and the modified water deliveries ("Modwaters") C-111 Project efforts are needed.

Modeling efforts are needed for predicting rates of success of stormwater treatment of agricultural runoff (Moustafa 1997). Modeling efforts to develop the best possible program for use of the proposed Water Preserve areas and the WCAs must include assessments of studies of seepage rates from WCA2. Alternative water storage technologies including Floridan aquifer storage and retrieval methods should be supported.

1.5. **Support reclamation programs that expand the spatial extent** of marshes and prairies and lake and riverine littoral zones. The easiest way to begin improving on current conditions is to selectively modify current design characteristics that are most amenable to both water management and habitat enhancement. For example: besides structural modifications for improved simulation of natural hydropatterns to regional lakes, rivers, and marsh systems, a number of additional actions should be considered for wildlife habitat improvement. Such actions include increased peripheral forested land, especially upland habitat, including native tree islands and littoral edge tree stands to improve ecotones between marsh and upland/forested habitat. Inclusion of island systems in artificial lakes and reclaimed rock mining pits, where native macrophytes and trees will be recruited, will promote water and wading bird foraging, roosting, and breeding habitat. Such areas would be isolated from human disturbance and mammalian predators (also see Hammond and Mann 1956, Sargeant 1982). King *et al.* (1985) have developed a series of guidelines for habitat reclamation on phosphate-mined lands, *e.g.* Tenoroc FMA near Lakeland, Florida (also see King and Cates 1994). Effective plans have also been developed for restoration of the Peace River and especially the Upper Saddle Creek (DEP 1997, and King *et al.* 1994). Construction of points of land, isthmuses, or spits of land along shorelines will be beneficial to overall productivity, habitat diversity, and maintenance of upland-wetland species requirements (Newman and Griffin 1994).

1.6. **Promote legislative initiatives** that improve on water use practices. State of Florida reform legislation was enacted in the 1972 Water Resources Act (Chapter 373) including amendments to insure more appropriate water budgets to multiple users, including the natural systems (Gsteiger and Loftin, 1997). Most importantly, the legislation protects natural systems by requiring Florida's water management districts

to ensure the sustainability of the natural systems and to establish minimum flows and levels for these systems. Scientific peer review for validating the data used in developing minimum flows was also required. The law should prevent wasting water by limiting the duration of water use permits, providing guarantees to current water permit holders when new users apply for limited water resources, providing equity in evaluation of water use permits, and providing certainty of water supply to existing and anticipated uses by requiring planning and water resource development technologies.

While there are still some controversial issues to be resolved in finalizing the best legislation, including the role of agricultural users that have not required permits previously, the most important issue regarding protection and enhancement of the spatial extent of functional marsh and wet prairies is the identification of minimum flows and levels. This and future legislation must recognize that a range of flows and water levels are required to sustain the largest spatial extent and most diverse range of marsh and wet prairie conditions, and that no single minimum flow level will be adequate to ensure long-term health of the natural systems.

2. Restore natural water quality to the system.

2.1. Provide initiatives for water quality improvement in relation to agricultural practices. SFWMD is developing six stormwater treatment areas (STAs) between the EAA and the WCAs in order to channel agricultural runoff away from Lake Okeechobee, and the WCAs. An experimental version, at a smaller scale, known as the Everglades nutrient removal project (ENR) has been operating since 1994. The ENR is a 1667 ha (4,000 acre) marsh retention area where runoff is held and phosphorus is absorbed by marsh plants. The ENR is experimental and intended to determine if the STAs will meet the Phase One goal of reducing phosphorus levels to 50 parts per billion (ppb) in water released into the WCAs. This is the largest constructed wetland designed for agricultural runoff in the country. To date, the SFWMD estimates (SFWMD 1997a) phosphorus reduction of 83 percent, estimated as a reduction to 22 ppb of phosphorus, which exceeds the expected Phase One level goal. SFWMD is continuing land acquisition and development of the full scale STAs. Debate remains over the actual success of the pilot nutrient removal. The agreement between the State and Federal agencies allows for continued acquisition and construction while these permitting and technical issues are clarified. STA 6 "section one" is operating now. STA-1 West, STA 2, and STA-5 are to be operating by early to mid 1999. The remaining STA element will not be operating until 2002 and later (SFWMD 1997a).

The ultimate goal is that water delivered to South Florida should not cause an imbalance of natural populations of flora and fauna. At the Phase Two level of this project agricultural phosphorus outflow concentrations should be down to 10 ppb or less when they leave treatment areas and enter the WCAs. The SFWMD is also proceeding with required evaluation of alternative technologies for phosphorus reduction, including chemical additives, STAs with chemical pre-treatment, and a method requiring passing STA water through an area of submersed vegetation with limerock for further filtration of phosphorus (SFWMD 1997a). The Miccosukee Tribe has promulgated water quality standards to protect tribal lands which include a large portion of the Everglades.

Similar efforts are underway in other portions of South Florida including the Kissimmee River drainage system. In Boney Marsh (Highlands County) a 0.48 sq. km (0.19 sq. mile) wetland was constructed to evaluate the role of overland flow in

relation to phosphorus removal (Moustafa 1997). Much of this work is oriented to the development of larger projects throughout the SFWMD.

2.2. **Support public education** regarding proper disposal of hazardous wastes, and continue studies of the sources and effects of mercury and other contaminants and their relations to diseases and chronic sublethal effects in plants and animals in wetland food chains. The potential long-term food chain impacts from the wide range of contaminants and their relation to human activities may be the most underfunded and serious problem we face in the future.

3. **Support and increase funding for eradication and control of exotic pest species.** As reviewed above, funding and support is required to continue to control the expansion of exotic pest species of aquatic plants, trees, and animals in wetlands (Center *et al.* 1994, Jordan 1994, Schardt 1994, Thayer and Ferriter 1994). In particular, follow-up field studies of the effectiveness of biological control agents for melaleuca will require significant funding. Expanded quarantine facilities to permit more elaborate and detailed evaluations of other biological control agents are severely needed. Finally, some significant effort must be made to coordinate the agencies and inform the public regarding the elimination of exotic species of plants and animals.

Flowing Water Swamps

FNAI Global Rank:	**G3/G4**
Federally Listed Plants:	**S2/S4**
Federally Listed Species in S. FL:	**5**
State Listed Species in S. FL:	**79**

Flowing water swamp. *Original photograph by Deborah Jansen.*



Flowing water swamps are seasonally inundated forested wetlands located along or within drainage channels. They include the floodplain wetlands along clearly defined rivers, as well as the strands and sloughs that characterize shallower and more diffuse flowways. Because these systems are typically deep swamps subject to long-term flooding, few have been successfully converted to other land uses. However, most have been degraded to some extent by logging, drainage, impoundment, melaleuca invasion, and/or pollution from agricultural or urban runoff. Appropriate timber management, hydrological restoration, and exotic species control are the greatest management concerns. In comparison to most South Florida ecological communities, a substantial percentage of flowing water swamp has already been placed under conservation management. Preservation and restoration of headwater systems, flatwoods and prairie buffers are more critical to the long-term preservation of flowing water swamps than acquisition of additional floodplain and strand swamps.

Synonymy

Flowing water swamps include: FNAI's floodplain swamp, freshwater tidal swamp, slough, and strand swamp, NRCS's cypress swamp, and cypress hardwoods, and the Society of American Foresters' (SAF) bald cypress, bald cypress-tupelo, water-tupelo, swamp-tupelo, southern red cedar, cabbage palmetto, sweetbay-swamp, and tupelo-redbay. Synonymies for each of these communities are provided in the synonymy tables at the end of the account. Note that some of these definitions include northern types that do not occur in South Florida.

Distribution

In the northern part of South Florida, flows are funneled into rivers lined with floodplain swamps. Further south,

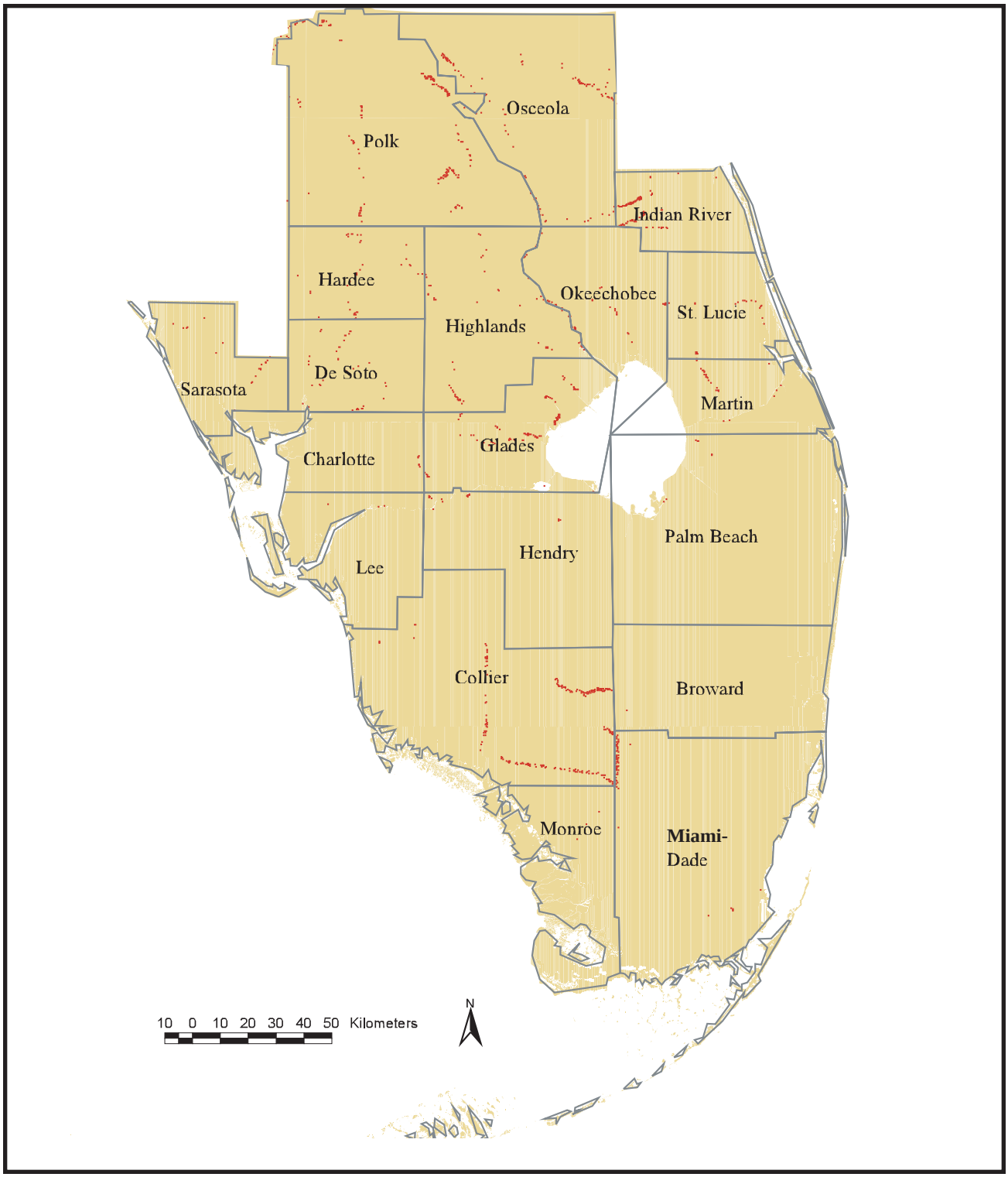


Figure 1. The occurrence of forested flowing water wetlands in South Florida (adapted from USGS-BRD 1996)

where the landscape has less relief, water moves across the landscape slowly through diffuse shallow channels. Strand swamps grow within these flowways (Figure 1).

Description

Topography and Geology

Floodplain swamps and associated riverine systems occur along streams that have eroded channels through the landscape. Strand swamps are generally situated in troughs in a flat limestone plain.

Soils

Strand swamps have sandy soils along their shallower fringes and increasingly deep peat soils towards their deeper central channels. The best developed forests are on deep peat that acts as a wick to draw moisture from groundwater up into the root zone during droughts.

Vegetative Structure

Strand swamps have small young "pond cypress" trees towards their outer edges, grading into larger and older "bald cypress" towards the interior, giving a strand a distinctly rounded cross-sectional profile. (Because pond cypress *Taxodium ascendens* and bald cypress *Taxodium distichum* can be recognized as clearly different in these field situations, the two names are used here. Although some authorities persist in considering these different species, most ecologists now regard them as morphological variations reflective of different growing conditions.) In the central part of the strand, there may be open ponds or deeper sloughs dominated by pop ash (*Fraxinus caroliniana*) and pond apple (*Annona glabra*).

Floodplain swamps have less distinctive gradation in tree sizes, but exhibit considerable variation in response to differences in substrate features.

Vegetative Composition

Typical strand swamp vegetation includes cypress, red maple (*Acer rubrum*), cabbage palm (*Sabal palmetto*), strangler fig (*Ficus aurea*), swamp bay (*Persea palustris*), sweetbay (*Magnolia virginiana*), royal palm (*Roystonea regia*), coastal plain willow (*Salix caroliniana*), wax myrtle (*Myrica cerifera*), myrsine (*Rapanea punctata*), buttonbush (*Cephalanthus occidentalis*), poison ivy (*Toxicodendron usneoides*), swamp lily (*Crinum* spp.), leather fern (*Acrostichum* spp.), and royal fern (*Osmunda regalis*). The canopy plants are mainly temperate, while the understory and epiphytic plants are generally tropical. The deeper sloughs are characterized by a subcanopy of pop ash and/or pond apple abundantly festooned with tropical epiphytes.

Wildlife Diversity

Typical strand swamp animals include white-tailed deer *(Odocoileus virginianus),* gray squirrel *(Sciurus carolinensis),* raccoon *(Procyon lotor),* river otter *(Lutra canadensis),* little blue heron *(Florida caerulea),* great egret *(Casmerodius albus),* blue-grey gnatcatcher *(Polioptila caerulea),* ribbon snake (*Thamnophis sauritus sackenii*), cottonmouth (*Agkistrodon piscivorus*), opossum *(Didelphis virginianus),* wood rat *(Neotoma floridana),* bobcat *(Felis lynx),* mink *(Mustela vison evergladensis),* marsh rabbit *(Sylvilagus palustris),* red-winged blackbird *(Agelaius phoeniceus),* common grackle *(Quiscalus quiscala),* boat-tailed grackle *(Quiscalus major),* limpkin *(Aramus guarauna),* red-shouldered hawk *(Buteo lineatus),* barred owl *(Strix varia),* American alligator *(Alligator mississippiensis),* Florida banded water snake *(Nerodia fasciata pictiventris),* soft shelled turtle *(Apalone ferox),* southern leopard frog *(Rana sphenocephala),* green treefrog *(Hyla cinerea),* barking treefrog *(Hyla gratiosa),* squirrel tree frog *(Hyla squirella),* southern dusky salamander *(Desmognathus auriculatus),* lesser siren *(Siren intermedia),* two-toed amphiuma *(Amphiuma m. means),* mosquito fish *(Gambusia spp.),* yellow bullhead *(Ameiurus natalis),* swamp darter *(Etheostoma barratti),* sailfin molly *(Mollienesia latipinna),* flagfish *(Jordanella floridae),* least killifish *(Heterandria formosa),* bowfin *(Amia calva),* warmouth *(Chaenobryttus coronarius),* Florida gar *(Lepisosteus* spp.), and bluespotted sunfish *(Enneacanthus gloriosus).*

Wildlife Species of Concern

Federally listed species that depend upon or utilize the flowing water swamp community in South Florida include: Florida panther *(Puma (=Felis) concolor coryi),* bald eagle (*Haliaeetus leucocephalus*), wood stork (*Mycteria americana*), Kirtland's warbler (*Dendroica kirtlandii*), and eastern indigo snake (*Drymarchon corais couperi*). Tanner (1942) reported that the ivory-billed woodpecker (*Campephilus principalis*) occurred adjacent to swamps dominated by bald cypress and hardwoods. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

Florida panthers utilize the strand swamp systems of southwest Florida. Any efforts to control impacts of feral hogs on such swamps should be balanced with concern for the role these exotic animals have in maintaining the panther food base in these marginal habitats.

The **American swallow-tail kite** *(Elanoides forficatus)* prefers tall pines and cypress trees for nesting and requires a diverse mosaic of swamp and floodplain forest, vegetated margins of rivers and lakes, hardwood hammocks, bayheads, prairies, sloughs, and mangroves for foraging (Meyer and Collopy 1990).

Large flat-topped cypress in the interior of Corkscrew Swamp and other major strand swamps are critical nesting habitat for the **wood stork** (*Mycteria americana)*. These birds breed successfully only when water levels are dropping during drought periods, but they will abandon their rookeries if the ground



Osprey. *Original photograph by Barry Mansell.*

beneath the nests goes dry. Therefore maintenance of long hydroperiods in the deep sloughs within old-growth cypress swamps is essential to this species.

The **osprey** is one of four subspecies distributed throughout the world, with *Pandion haliaetus carolinensis* being the North American variant. In Florida, the osprey is afforded the status of a state species of special concern for Monroe County only. The osprey occurs throughout Florida wherever there are sufficient bodies of open water for fishing. Nests are constructed on the tops of cypress, mangrove, pine trees, utility poles, radio towers, channel markers (Schreiber and Schreiber 1977) and even in shrubs or on the ground as in the Florida Bay area (Ogden 1977). In eastern North America, the osprey is considered stable except for the declining Florida Bay population in Everglades NP (Kushlan and Bass 1983, Poole 1989). Ospreys are considered somewhat tolerant to human activity which makes them particularly vulnerable to entanglement in fishing monofilament, striking power lines, shooting, waterfront development, and human-induced changes in food availability. This species is highly susceptible to environmental contaminants, although there is no known threat from heavy metals, PCBs, and pesticide contamination.

Bald eagles frequently nest in old flat-topped cypress, so maintaining old-growth trees in strands near open water is important to this species. In addition to being federally listed, the bald eagle is State threatened.

Plant Species of Concern

Many **tropical epiphytes** are dependent upon the warm moist microclimate of strand interiors for survival of winter freezes. They typically grow on the rough bark of pond apple and pop ash trees in the central sloughs, where they are also sheltered from the wind and securely anchored to resist destruction during hurricanes. Most of these are State listed tropical orchids and bromeliads that reach the northern limits of their ranges in these situations. A few are globally

rare species. Tropical epiphytes listed by FNAI for strand swamps include: birds nest spleenwort (*Asplenium serratum*), tailed strap fern, (*Campyloneuron costatum*), many flowered catopsis (*Catopsis floribunda*), nodding catopsis (*Catopsis nutans*), cowhorn orchid (*Cyrtopodium punctatum*), clamshell orchid (*Encyclia pygmaea*), Acuna's epidendrum (*Epidendrum blancheanum*), night-scented orchid (*Epidendrum nocturnum*), pendant epidendrum (*Epidendrum strobiliferum*), Fuch's bromeliad (*Guzmania monostachia*), hanging clubmoss (*Huperzia dichotoma*), delicate ionopsis (*Ionopsis utricularioides*), blunt leaved peperomia (*Peperomia obtusifolia*), frost-flower orchid (*Pleurothallus gelida*), ghost orchid (*Polyrrhiza lindenii*), fuzzywuzzy air plant (*Tillandsia pruiosa*), entire winged bristle fern (*Trichomanes holopterum*), and brown-flowered vanilla (*Vanilla phaeantha*). All of these species are listed as endangered by the State, and all are found in Fakahatchee Strand in Collier County.

Ecology

Hydrology

The normal strand swamp hydroperiod is 200 to 300 days with a maximum water depth of 46 to 76 cm (18 to 30 inches). Water is deepest and remains longest near the center where the trees are biggest.

Longer hydroperiods slow growth rates, since cypress do not grow when inundated. Extended hydroperiods may also prevent cypress reproduction by inhibiting seed germination or drowning seedlings. The latter is especially true when inundation occurs during the growing season (Brandt and Ewel 1989). Submergence during the dormant period of flood tolerant species may be less detrimental. Likewise, brief periods of inundation under clear, cool water is less detrimental than under warm, turbid water (Putnam *et al.* 1960 cited in Brandt and Ewel 1989).

During periods of prolonged drought, cypress may be outcompeted by shrubs and hardwoods. In southwest Florida, where the water table is receding, hardwoods are replacing cypress (Craighead 1971 cited in Brandt and Ewel 1989).

Cypress grows much better in flowing water than in standing water, probably due to increased aeration and nutrient availability. In a flowing water swamp, cypress may grow to twice the height and produce two to five times the biomass (dry weight) as in a similar pond swamp (Dickson and Broyer 1972 cited in Wharton *et al.* 1976).

Sea-level rise can be expected to have noticeable effects on the freshwater tidal swamps near the mouths of rivers before evidence is obvious in most other systems. Existing tidal swamps will change into mangrove forests and tidal effects will influence floodplain swamps previously beyond their reach.

Fire

Fire occurs in strand swamps on a cycle of perhaps 30 to 200 years, with the largest trees on the deepest peat towards the center of the strand burning least frequently. Fire is essential for maintenance of this community; without fire, hardwood invasion and peat accumulation would convert a strand to a hydric hammock in a few hundred years. Periodic fire is further necessary to reduce

understory vegetation and allow for cypress regeneration. Frequent fire, however, can destroy seed sources and young trees and retard the growth of mature trees. While cypress is very tolerant of light surface fires, intense fire may kill the above-ground portion of the tree. Cypress is capable of resprouting from the stump, but muck fires burning deep into the peat can kill the trees entirely, lower the ground surface, and ultimately transform a strand into a slough. In many strands, past fires have eaten away areas of the peat deposits and created deeper pond apple and pop ash sloughs.

Soil Disturbance and Succession

Increased soil bulk density resulting from compaction impedes root penetration, reduces aeration, and restricts the movement of air and water (Hanna 1981 cited in Brandt and Ewel 1989). Cypress seeds may not germinate as well in compacted soils where drainage has been compromised (Brandt and Ewel 1989).

Status and Trends

Although a number of researchers have estimated wetland loss rates in Florida, little of this data is refined enough to permit meaningful estimation of the extent to which flowing water swamps have been lost. Between 1940 and 1980, Florida's total forested area declined by 27 percent (Knight and McClure 1982 cited in Noss *et al.* 1995). Since 1970, forested wetland communities throughout Florida have been reduced by 17 percent (Noss *et al.* 1995).

Land cover changes in Florida since European colonization have been estimated based upon mapping of historic vegetation types (Davis 1967, Cox *et al.* 1997). Of Florida's original swamps, 67 percent of the cypress and 63 percent of the hardwoods still exist (Cox *et al.* 1997). Of these remaining forested wetlands statewide, 33 percent of the cypress and 25 percent of the hardwoods have been protected through public ownership to be managed as natural areas (Cox *et al.* 1997).

Using 1985 to 1989 Landsat satellite imagery for Florida, another mapping analysis estimated that managed areas protect 58 percent of the remaining shrub swamps, 34 percent of the cypress swamps, and 25 percent of the hardwood swamps (Kautz *et al.* 1993 cited in Cox *et al.* 1997).

Comparative analysis of 1986 and 1991 Landsat imagery showed that St. Lucie County lost 3.4 percent of its floodplain forest and 1 percent of its floodplain swamp, strand swamp, and slough during this 5-year period (Duever *et al.* 1992).

Habitat fragmentation and associated hydrological impacts are the major causes of degradation of flowing water swamps. Changes in the landscape matrix have had and continue to have major impacts on flowing water swamps. Conversion of adjacent pinelands and prairies to pastures, farm fields, citrus groves, and residential developments has restricted the normal movement of fires, sheetflow, and wildlife essential to ecological processes within these communities.

Improperly designed roads have impounded upstream strand swamps and converted them to less productive basin swamps with vegetation stressed and degraded by excessively long hydroperiods. There is concern that the logging

trams in the Fakahatchee Strand have impeded water flows such that regeneration of the cutover cypress forest there is not proceeding as it should.

Borrow pits, surface mines, and wellfield drawdowns can lower water tables and impact hydrology in strands, sloughs, and headwater swamps.

Development of much of the surrounding landscape has increased the amount of runoff that must be absorbed by the remaining wetlands. Intentional drainage of irrigated agricultural lands into wetland systems is compounding the problem in many areas. In such places as Flatford Swamp, which drains from Manatee County into the Myakka River system in Sarasota County, cypress trees up to 60 to 70 years old have died from the stress of the artificially lengthened hydroperiod. Similar problems have been reported in the Sebastian area, primarily to the north in Brevard County, but within wetland systems that extend into Indian River County, and in St. Lucie County.

In the United States, agricultural practices account for greater than 87 percent of recent wetland losses (Nelson 1989 cited in Noss *et al.* 1995).

Agricultural runoff also poses a contamination threat. Not only does it commonly contain pesticides, but it is typically enriched with fertilizer residues. These fertilizers contain nutrients that promote eutrophication. Since fertilizer composition is unregulated and many fertilizer components originate as industrial byproducts, such runoff can also be a source of toxic waste contamination.

Cypress strands have been used to purify secondarily treated wastewater (Brandt and Ewel 1989). This introduces excess organic matter, nutrients, and minerals to the wetland system. "Major changes observed in swamps receiving treated effluent are the development and persistence of a continuous cover of duckweed (*Lemna* spp., *Spirodela* spp., and *Azolla carolinensis*) (Ewel and Odum 1984), development of anoxia in the water (Dierberg and Brezonik, 1984), and an increase in passerine bird populations together with elimination of amphibian reproduction (Harris and Vickers 1984)" (Brandt and Ewel 1989).

Exotic species invasion is an increasing problem in flowing water swamps. Exotic plants reported from this community include: melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), Japanese climbing fern (*Lygodium japonicum*), skunk vine (*Paederia foetida*), and aquatic soda apple (*Solanum tampicense*).

Exotic animals include: feral hog (*Sus scrofa*), house cat (*Felis silvestris*), Cuban tree frog (*Osteopilus septentrionalis*), and walking catfish (*Clarias batrachus*).

Historically, commercial interest in forested wetlands was limited to timber harvest, with little attention paid to long term management techniques (Brandt and Ewel 1989). The mature cypress, which were especially valuable for their resistance to decay, were almost all harvested during the logging boom that peaked in the 1920s (Brandt and Ewel 1989). The total volume of standing cypress timber reached its lowest point in 1933, but has steadily increased during the last 60 years (Brandt and Ewel 1989). The second-growth trees currently available do not produce the same quality of decay-resistant lumber as the old-growth trees did; they are primarily used for fenceposts, stakes, mulch, and pulp (Terwilliger and Ewel 1986 cited in Brandt and Ewel 1989). Clearcutting is widely practiced due, in part, to the fact that all sizes of trees can be made into chips for mulch (Brandt and Ewel 1989). The cypress mulch industry is more active in north Florida, but some South Florida cypress is harvested for this purpose.

Cypress knees are harvested and sold for lamp bases, floral arrangements, and various other kinds of curios and decorative items. Since the knees' function is poorly understood, the impact of their removal is unknown.

Numerous other materials are occasionally harvested from flowing water swamps. Deer, hogs, and other game animals are hunted here, which affects herbivore-vegetation and predator-prey relationships. Illegal collection of tropical orchids and bromeliads has had significant impacts on rare species. Collection of medicinal herbs is increasing in all habitats and may impact swamp vegetation in the future.

Cattle grazing to some degree impacts the outer edges of many strand swamps, although cattle rarely venture into the swamp interiors.

Beekeeping practices may have serious effects on pollinator ecology. Exotic honeybee colonies are maintained in or near many strand swamps, where they can rely on abundant melaleuca nectar when other food is scarce. How this affects native pollinators and the reproduction of native plants is unknown. Beekeeping also poses hazards to black bears, since beekeepers sometimes shoot bears who foil their electric fences and raid their hives.

Management

Land Protection

Preservation of headwaters systems, remaining high-quality natural buffers, and flowing water swamps situated in intact landscape matrices is the highest land protection priority.

Table 1 lists conservation lands that protect important flowing water swamps. There is currently an effort to get a bill through the Florida legislature mandating Florida Division of Forestry involvement in the management of all State lands. Proponents of this legislation are seeking to write into it a provision that would permit logging of mature timber, including old-growth cypress.

Regulatory Mechanisms

The natural resource conservation elements of county comprehensive plans, county and State development permitting policies, pollution control and vegetation management regulations, and DEP and water management district water resource protection and wetlands permitting procedures help protect flowing water swamps. Underfunded enforcement programs limit the effectiveness of these regulations, however.

Restoration Projects and Programs

Historically, most wetlands restoration efforts have been directed at marsh ecosystems. Only within the past 15 to 20 years have there been significant attempts to restore forested wetlands (Clewell and Lea 1990). Given the timeframe necessary for forest regrowth, most of these projects are still too new for critical evaluation.

Forested wetland restoration efforts have been focused on two types of situations: reforestation of lands cleared for agriculture and subsequently abandoned (where the main objective is to establish a forest canopy) and restoration of wetlands cleared for surface mining projects (where the objective

has been to replace the full spectrum of tree species and undergrowth components), with considerable attention given to establishing the appropriate hydrology and hastening soil development (Clewell and Lea 1990).

Based on a review of forested wetlands restoration projects, Clewell and Lea (1990) have identified six critical factors which interact to determine whether or not a project will be successful. They are hydrology, substrate stabilization, rooting volume, soil fertility, control of noxious plants, and herbivore control.

Specifically, cooperation among engineers, hydrologists, and soil scientists must be encouraged to ensure that water delivery timing, depth, and quality are synchronous with the natural systems being emulated (Clewell and Lea 1990). Flood tolerance varies widely among different species and among different size classes within species and is also dependent upon stage of the growing season (Bedinger 1979). Newly planted vegetation is particularly susceptible to water stress.

Topographic relief should be planned with substrate stabilization in mind as project sites are often open and subject to erosion which hinders the establishment of trees and undergrowth (Clewell and Lea 1990).

Soil volume must be considered as roots need an adequate volume of soil to anchor themselves and exploit moisture and nutrients (Clewell and Lea 1990). Rooting volume may be limited by depth to the wet season water table and mechanical resistance where soil density has been increased by compaction caused by heavy equipment at project sites (Clewell and Lea 1990).

Soil fertility varies considerably with the project site. Fertilization is usually necessary to prevent trees from languishing so long as saplings that they are suppressed by weeds (Clewell and Lea 1990).

Control of noxious plants is necessary where their proliferation threatens to suppress desirable species. Certain tall weed species may be beneficial as shelter for young trees (Clewell and Lea 1990).

Nutrient enrichment problems from sewage have been cleaned up in the Shingle Creek area of Osceola County.

On a regional scale, restoration of pine flatwoods and prairie buffers is more important to flowing water swamps than wetland restoration in itself. Proper watershed management is critical.

Management Strategies and Techniques

SWFWMD has budgeted funds for research into biological control of skunk vine. Japanese climbing fern is promptly treated with herbicide when detected on SJWMD lands.

Timber harvest in cypress swamps ranges in intensity from clearcutting to thinning. The most frequently prescribed silvicultural systems are clearcutting and seed-tree cutting. There is no clear evidence that any method is significantly superior for assuring subsequent cypress regeneration, but it is clear that a seed source must be left on or adjacent to the site, that severe fires following a harvest can prevent regeneration, and that profound changes in hydroperiod, water levels, soil aeration, and/or understory vegetation can hinder seed germination and seedling survival (Brandt and Ewel 1989). When an isolated cypress stand is harvested, seed trees must be left or sufficient light must be available to assure

coppice production (sprouting from the stump). In larger swamps, clearcutting is acceptable if the harvest is conducted in small blocks to ensure good seed distribution from trees on the edges. Where cypress is selectively removed, cypress seedlings and saplings are likely to be outcompeted by more shade-tolerant hardwoods and coppicing may not be reliable.

Planting cypress will hasten the establishment of a new stand. Seedlings should be tall enough to escape inundation and should be protected from herbivory (Brandt and Ewel 1989).

Informal roads and trails can create wide muddy swaths and gullies through wetlands. Various types of web mats can be used to stabilize such trails. Geoweb has been used successfully for this purpose on SJWMD lands in Osceola County.

Tracks from recreational vehicles, logging trucks, and other machinery can create deep ruts in soft wetland soils. As water levels subsequently rise and fall, fish and other organisms may be trapped within these pools, which affects the food chain by influencing mobility of predators and prey. Mosquitoes have been observed to be more numerous under such circumstances (Wharton *et al.* 1976).

Synonymy Tables:

FLOODPLAIN SWAMP

Kuchler	113/Southern floodplain forest
Davis	7/Cypress swamp forests
	8/Swamp forests, mostly of hardwoods
NRCS	17/Cypress swamp
	21/Swamp hardwoods
Myers & Ewel	Freshwater swamp forests-floodplain forests
SAF	101/Bald cypress
	102/Bald cypress-tupelo
	103/Water tupelo-swamp tupelo
FLUCCS	613/Gum swamp
	621/Cypress

Other synonyms include river swamp, bottomland hardwoods, seasonally flooded basins or flats, oak-gum-cypress, elm-ash-cottonwood, NWTC Zones II - III, slough, backswamp, and oxbow.

Synonymy Tables: *cont.*

FRESHWATER TIDAL SWAMP

Kuchler	113/Southern floodplain fForest
Davis	7/Cypress swamp forests
	8/Swamp forests, mostly of hardwoods
NRCS	17/Cypress swamp
	21/Swamp hardwoods
Myers & Ewel	Freshwater swamp forests-floodplain forests
SAF	73/Southern red cedar
	74/Cabbage palmetto
	101/Bald cypress
	102/Bald cypress-tupelo
	104/Sweetbay-swamp tupelo-redbay
FLUCCS	613/Gum swamp
	615/Stream and lake swamps
	621/Cypress
	624/Cypress-pine-cabbage palm

Other synonyms include tidewater swamp and rivermouth swamp.

SLOUGH

Kuchler	113/Southern floodplain forest
Davis	7/Cypress swamp forests
NRCS	17/Cypress
	21/Swamp hardwoods
Myers & Ewel	Freshwater swamp forests-sloughs and strands
SAF	101/Bald cypress
FLUCCS	621/Cypress

Other synonyms include flag pond, gator hole.

Synonymy Tables: *cont.*

STRAND SWAMP

Davis	7/Cypress swamp forests
Kuchler	113/Southern floodplain forest
NRCS	17/Cypress swamp
Myers & Ewel	Freshwater swamp forests-sloughs and strands
SAF	101/Bald cypress
FLUCCS	621/Cypress

Other synonyms include cypress dome or pond, cypress head, gum pond, cypress gall, and pine barrens pond.

Where Florida Game and Fresh Water Fish Commission's (GFC) Cypress Swamp or Hardwood Swamp communities occur in more-or-less linear systems with flowing water, they can be categorized as Pond Swamps.

The following GAP categories can be classified as Pond Swamps when they occur in more-or-less round and isolated basins or depressions:

18	I.B.2.N.(d,e)....	Cold-deciduous temporarily or seasonally flooded/saturated forest (=swamp forest)
19	I.B.2.N.e.180	*Taxodium ascendens* Forest Alliance
20	I.B.2.N.f.060	*Taxodium distichum* semipermanently flooded Forest Alliance
21	I.C.1.N.c....	Seasonally flooded tropical or subtropical semi-deciduous forest
23	I.C.3.N.c....	Seasonally flooded mixed needle-leaved evergreen - cold-deciduous forest (=mixed swamp forest)
29	II.A.2.N.b....	Seasonally flooded temperate broad-leaved evergreen woodland
32	II.B.1.N.d.010	*Taxodium ascendens* Tropical Woodland Alliance

Where the following GAP category occurs within or adjacent to another Flowing Water Swamps type, it may also be included in this community:

36	III.A.1.N.c.030	*Myrica cerifera-Ilex cassine* Shrubland Alliance

Table 1. Proposed conservation lands important to flowing water swamps

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
Alafia River Corridor		SWFWMD Project, part of an interlocal agreement between SWFWMD and Hillsborough County's Environmental Land Acquisition and Protection Program (ELAPP)
Atlantic Ridge Ecosystem	Includes outstanding baygalls and some forested sloughs	1997 CARL Bargain 2, SFWMD Project
Catfish Creek		1997 CARL Priority 22, SFWMD Project
Charlie Creek System	Drainages along the main channel of Charlie Creek and tributaries (Bee Branch, Buckhorn Creek, Little Charley Bowlegs Creek and Old Town Creek) form a series of swamps and sloughs. This system drains into the Peace River.	SWFWMD Project
Charlotte Harbor	Site includes strands and domes in a flatwoods matrix, but melaleuca invasion is a major problem.	1997 CARL Priority 14
Corkscrew Regional Ecosystem Watershed		1997 CARL Bargain 8, SFWMD Project
Cypress Creek/Trail Ridge	Cypress and pine have been logged out of hydric hammocks and basin swamps north of SR 70 and flows from Cypress Creek, which historically passed under SR 70, have been routed west through a ditch along the north side of the highway. Most of the historic slough remains intact south of SR 70, where very little logging or ditching has been done. The Carlton lands include an impressive stand of virgin cypress (FNAI Basin Swamp EOR #066). There are bayheads and cypress domes and a band of hydric hammock (Van Swearingen Creek) in the Trail Ridge area along the west side of Bluefield Road.	SFWMD Project
Fakahatchee Strand		1997 CARL Mega/Multiparcel 5
Fisheating Creek	Habitats include cypress slough/mied hardwood swamp forest, emergent marshes, willow thickets, baygalls, and openwater ponds and runs. New CARL boundaries include valuable matrix of dry and wet prairies, baygalls, and cutthroat seeps. Feral hogs are a problem.	SFWMD
Green Swamp	There are good strand swamps with hydric hammock islands on the Jahna property owned by sand mining company, but associated uplands have been cleared. The Overstreet tract in the southwest corner of the site has cypress domes, cypress strands, hydric hammocks, and floodplain swamps, which drain into Little Gator Creek, then into the Withlacoochee River.	1997 CARL Priority 20 and 1997 CARL LOF 1, SJWMD SOR and P-2000 Project, SWFWMD Project.

Table 1. ***cont.***

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
Jack Creek	The forested wetlands along Jack Creek are dominated by a mixture of evergreen trees such as loblolly bay, sweetbay, and magnolia, along with red maple, blackgum, and cypress.	SWFWMD
McDaniel Ranch	This site includes major cypress strands including two virgin stands grading into a large area of hydric hammock in a healthy mosaic with expanses of marsh and wet prairie. The best natural areas are concentrated along the western and southern edges.	SFWMD conservation easement project. The McDaniel family will retain ownership and management responsibility with rights to use for timber management, cattle grazing, lease hunting, and eco-tourism.
Myakka River	The project includes a 4.5 mile stretch of the Myakka River and its forested floodplain.	SWFWMD Project
Myakka River/Charlotte Harbor		SFWMD Project, includes 9,900 acres jointly acquired through the CARL program.
North Fork St. Lucie River	Greater than 80 percent of this site is floodplain wetlands, including hardwood swamp, hydric hammock, sawgrass marsh, and mangrove types.	1997 CARL Bargain 20, SFWMD Project
Okaloacoochee Slough	Wet flatwoods and hydric hammocks, dominated by live oaks and cabbage palms, fringe sawgrass. Recommended management is continued native range grazing with no pasture improvement or fertilization.	1997 CARL Bargain 14, SFWMD Project
Osceola Pine Savannas	This is an area of old beach ridges and intervening swales, with high quality longleaf pine flatwoods interrupted by cypress strands, cypress domes, and wet prairies.	1997 CARL Priority 24
Peace River Corridor		SWFWMD Project
Ranch Reserve	Headwaters of Blue Cypress Creek. Includes high quality cypress strands, cypress domes, and hydric hammocks in a flatwoods matrix.	1997 CARL LOF 4, SJWMD SOR and P-2000 Project. Conservation easements are key to protection strategy.
RV Griffin Reserve		SWFWMD Project, supports existing facilities of Peace River/Manasota Regional Water Supply Authority
Save Our Everglades	Natural communities include cypress forest, pine flatwoods, hammock, mixed swamp forest, wet and dry prairies and freshwater marsh. Serves as the headwaters to the Fakahatchee Strand.	1997 CARL Mega/multiparcel 3

Table 1. ***continued***

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
Six Mile Cypress II	Cypress swamp, interspersed with numerous openwater sloughs and fringed with pine flatwoods, transitional hardwoods, wet prairies, and melaleuca stands.	SFWMD
South Fork St. Lucie River		SFWMD Project, Martin County, FCT
Upper Econ Mosaic	Econlockhatchee River swamp.	1997 CARL Priority 26
Upper Lakes Basin Watershed	Reedy Creek Swamp is an extensive area of mixed hardwood/cypress swamp running for nearly 25 miles through western Osceola County, from the boundary of the Reedy Creek Improvement District to Cypress Lake. It includes the Huckleberry Islands and totals more than 30,000 acres. Lake Marion Creek is in Polk County and flows from Lake Marion north and then southeasterly to Lake Hatchineha. The project area totals approximately 17,300 acres, 3,800 of which are within the Southwest Florida Water Management District. Most of the project is forested swamp and needs no restoration. Reedy Creek Swamp has been fairly well protected because of its large size and inaccessibility. Unless hight-density urban encroachments or damaging silviculture operations are permitted in the future, the swamp shoud be able to buffer itself. Exotic vegetation is not a problem, and it does not appear that hydrologic restoration will be necessary. The natural habitats within the Lake Marion Creek area are generally in good condition, although development has destroyed some scrub areas. The size of the property and the deep swamps allows the interior portions to remain buffered from activities along the ridge.	SFWMD Project, SFWMD envisions assistance from SWFWMD and CARL.
Upper Peace River Corridor		SWFWMD Project

Table 2. Managed areas important to flowing water swamps

MANAGED AREA	MANAGING ENTITY
Avon Park Air Force Range	DOD
Collier-Seminole State Park	DEP
Corkscrew Swamp Sanctuary	NAS
Fakahatchee Strand State Preserve	DEP
Florida Panther National Wildlife Refuge	FWS
Jonathan Dickinson State Park	DEP
North Fork St. Lucie Aquatic Preserve/ North Fork St.Lucie River State Buffer Preserve	DEP and SFWMO

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Restoration of Flowing Water Swamps

Restoration Objective: Prevent further reduction in area of flowing water swamps, protect all remaining high quality habitat, and restore and manage protected lands to maintain ecological processes and biodiversity, including normal hydroperiods and flow regimes.

Restoration Criteria

The recovery objective will be achieved when: (1) a reserve design incorporating all currently protected tracts and remaining high quality habitat has been developed and implemented; (2) flowing water swamps are protected through acquisition or cooperative agreements with landowners; (3) appropriate management plans have been prepared and funded for all lands within the reserve network; (4) restoration has been successfully initiated such that ecological processes are operating normally; and (5) natural succession and restoration actions through funded management programs can be expected to re-establish community structure and biodiversity on all significant degraded sites within the reserve network.

All systems within the reserve network must have adequate natural buffers and secure headwaters. Hydrological management for normal hydroperiods and flow regimes must be assured. Mature forests and core reserve swamps must be managed to achieve old-growth characteristics. Buffer zone swamps used for timber production must be managed sustainably.

Community-level Restoration Actions

1. Prevent further destruction or degradation of existing flowing water swamps.

1.1. Acquire threatened flowing water swamps and their upland buffers and headwaters.

Table 2 presents land acquisition proposals that incorporate important Flowing water swamps that should be protected.

Other important areas that should be protected include:

Bruner Cypress Swamp on Jane Green Creek in Osceola County (FNAI floodplain swamp EOR # 002). This is a stand of virgin cypress with trees up to 1.7 m (5.5 ft) dbh with swampbay, needle palm, and royal fern in the understory.

Strand swamp with virgin cypress in Hendry County, west of Cow Bone Island on Seminole Reservation lands (FNAI EOR #001).

Floodplain swamp in Lee County (FNAI EOR #027). It is dominated by pop ash with abundant epiphytes and includes a slough with a 1.5 to 3.0 m (5 to 10 ft) waterfall at the upper end.

There are many other flowing water swamps worthy of protection within local conservation systems. Natural landscapes, including healthy examples of such swamps, should be regarded as high priorities for local conservation efforts.

1.2. **Promote conservation easements and landowner agreements** to protect flowing water swamps and their upland buffers and headwaters.

Telegraph Swamp in eastern Charlotte County is a particularly important site in need of a formal easement or landowner agreement.

1.3. **Enforce regulatory protection of forested wetlands**. Lands are seldom adequately monitored to ensure compliance, and penalties and enforcement are often inadequate to motivate adherence to the law. Increased funding for regulatory monitoring and enforcement programs is needed at all levels.

1.4. **Prevent degradation of existing preserves.** Conservation lands should be maintained according to management plans that ensure that flowing water swamps, along with their associated wetlands, upland buffers, and headwater systems, are protected from degrading land uses.

1.5. **Protect flowing water swamps from pollution.** Flowing water swamps should be protected from both point-source and non-point-source pollution.

2. **Manage flowing water swamps within the context of restoration objectives.**

2.1. **Restore natural fire regimes.** Emphasize landscape-scale burning that permits fires to burn into the edges of wetlands naturally. Minimize swamp-edge firebreaks. Recognize the need for occasional catastrophic fires to burn into the peat to rejuvenate sloughs within strand systems.

2.2. **Control exotic plants and animals.** Control melaleuca invasion. Aggressively seek out and eliminate infestations of Japanese climbing fern and skunk vine. Control feral hog populations (with consideration for panther food base). Monitor other exotics in flowing water swamps and promptly initiate control programs for those that threaten to become problematic.

2.3. **Restore hydrology.** Within the context of regional hydrological restoration, manage flowing water swamps to maintain hydroperiods, water levels, and flow regimes within the ranges found in natural systems.

2.4. **Restore soils**. Restore hydrological patterns and control fire to permit accumulation of peat in drained or burned swamps. In severely degraded systems, consider increasing water and nutrient levels on a temporary basis to accelerate the soil development process.

2.5. **Restore ecosystem structure and composition** by manipulating existing populations of native species, augmenting populations of native species, and reintroducing extirpated plants and animals.

2.6. **Protect flowing water swamps from point-source and non-point source pollution.** Acquire or otherwise monitor and control buffers.

3. **Maintain flowing water swamps in a natural condition.**

3.1. **Provide analogs for ecosystem functions such as fire regimes.** Evaluate alternatives to catastrophic fire (dredging, *etc*.) for rejuvenation of sloughs within strand systems.

3.2. Continue to control exotic plants and animals in perpetuity.

3.3. Monitor for extirpations and extinctions and negative population trends of imperilled species, including pollinators, dispersers and soil organisms.

3.4. Monitor and correct for both point-source and non-point-source pollution.

4. Re-create flowing water swamps where they have been destroyed by human activities. Use research conducted by the Florida Institute of Phosphate Research, the University of Florida Center for Wetlands, the National Audubon Society's Ecosystem Research Unit, and others to recreate flowing water swamps according to the guidelines of the Society for Ecological Restoration.

4.1. Restore ecosystem structure, including soils and soil organisms, hydrology, plants, and animals.

4.2. Restore ecosystem functions by controlling exotics and aggressive native weeds, restoring natural fire regimes, restoring natural biological interactions (food webs, nutrient cycling, *etc.*).

4.3. Restore ecosystem composition for late-succession species and rare species.

4.4. Protect flowing water swamps from both point-source and non-point source pollution.

5. Create flowing water swamp analogs where they have been destroyed by human activities to the extent that a legitimate natural community can no longer be restored.

5.1. Restoration of ecosystem structure would need to consider physical landforms, drainage patterns, soils and soil organisms, and endemic flora and fauna.

5.2. Restoration of ecosystem functions would include control of exotics and aggressive native weeds, restoration of hydrologic processes, restoration of fire regimes, and the creation of natural biological interactions (food webs, nutrient cycling**,** *etc*.).

5.3. Restoration of ecosystem composition would need to consider late-succession species, rare species, and protection of the community from pollution.

6. Connect appropriate habitats.

6.1. Connect ecological systems. SFWMD's regional connection projects are especially important to flowing water swamps. The Myakka River project targets lands between the rivermouth Myakka SF and the Myakka River SP complex of public lands. The R.V. Griffin Reserve Addition tract (Toledo Blade) will maintain a natural corridor between the Myakka River SP complex and the lower Peace River floodplain. Although SWFWMD's Bright Hour Watershed project includes only minor areas of forested wetland, its recent protection though less-than-fee acquisition will help to maintain a connection between the Fisheating Creek system and the Peace River corridor. The Charlotte 1 project could eventually preserve a critical connection between Telegraph Swamp/Cecil Webb and the Peace River corridor, if targeted lands on Shell and Prairie Creek are also acquired.

The Upper Lakes Basin Watershed project, while protecting much of the Reedy Creek and Lake Marion Creek basins, also encompasses the headwaters of the Kissimmee complex (Kissimmee-Lake Okeechobee-Everglades).

The Belle Meade project will provide a significant linkage between Collier-Seminole SP and the future Golden Gates Estates SF. The proposed Golden Gates Estates SF is part of the Save Our Everglades project that protects the headwaters of the Fakahatchee Strand State Preserve.

6.2. Protect/restore landscape matrix. Preserve/restore flatwoods and prairies adjacent to and upstream of flowing water swamps wherever possible. Change wetland permitting regulations so that flatwoods buffers can be restored as wetland mitigation. Protection of remaining natural buffers and restoration of additional upland systems is especially needed along the Peace River, where much of the landscape matrix has been agriculturally altered.

6.3. Ensure maintenance of linkages critical to key species and functions**.**

7. Conduct Research.

7.1. Determine distribution of remaining habitat.

7.1.1. Develop strategies for gathering, synthesizing, and groundtruthing data to permit FNAI's floodplain forest, floodplain swamp, freshwater tidal swamp, slough, and strand swamp natural communities to be readily distinguished on GIS maps.

In particular, clarify distinction between wet flatwoods and cypress on National Wetland Inventory maps.

7.1.2. Assess and supplement available data.

7.2. Improve reference ecosystem information regarding community composition, biodiversity, and site-to-site variability**.**

7.3. Investigate roles of pollinators, mycorrhizae, seed dispersers, and other critical or imperilled species.

7.4. Evaluate predator-prey relationships in landscape context.

8. Monitor community-level processes, community structure, and community composition including rare and imperilled species.

9. Increase public awareness for flowing water swamp communities.

Pond Swamps

FNAI Global Rank:	**G3/G4**
FNAI State Rank:	**S2/S4**
Federally Listed Species in S. FL:	**7**
State Listed Species in S. FL:	**33**

Pond Swamp. *Original photograph by Betty Wargo.*



Pond swamps are seasonally inundated forested wetlands located around or within landscape depressions. They include the lake border swamps and major wetlands within large landscape basins, as well as smaller cypress domes and gum ponds. The dwarf cypress savannas that cover vast shallow basins in the Big Cypress subregion are also categorized as pond swamps. Although many small and/or shallow pond swamps have been cleared and converted to agricultural or residential uses, most of the larger systems are still extant. (A notable exception is the great pond apple swamp that once bordered the southern edge of Lake Okeechobee. It was diked off, drained, cleared, and planted to sugarcane. Subsequent oxidation has caused soil subsidence that has completely altered the character of this landscape.) Most of the remaining systems have been degraded to some extent by logging, drainage, impoundment, melaleuca invasion, and/or pollution.

Increased hydroperiods, nutrient enrichment, and contamination from agricultural runoff are major problems, since pond swamps are often surrounded by farmlands and water is typically diverted from these lands into the wetlands. Appropriate timber management and exotic species control are also significant management concerns. In comparison to most South Florida ecosystems, a substantial percentage of pond swamp has already been placed under conservation management. Most of these swamps are located within disturbed landscapes that do not adequately buffer the wetlands or permit normal between-habitat interactions. Preservation and restoration of natural landscape matrices of flatwoods and prairies are the most critical long-term need for pond swamp preservation.

Synonymy

Pond swamps include FNAI's basin swamps and dome swamp, NRCS's cypress swamp, Society of American Foresters' (SAF) slash pine-hardwood, and pond cypress, water-tupelo, and swamp tupelo. Synonymies for each of

these communities are provided in the synonymy tables at the end of the account. Note that some of these definitions include northern types that do not occur in South Florida.

Distribution

Pond swamps are abundantly scattered throughout South Florida (Figure 1). Larger basin swamps and lake border swamps are more common towards the northern end of the region, whereas cypress domes dot the landscape almost everywhere. Dwarf cypress savannas, which can be categorized as a very shallow and diffuse type of basin swamp, characterize the Big Cypress Swamp.

Description

Topography and Geology

Dome swamps typically develop in flat karst landscapes where sand has slumped around or over a sinkhole, creating a conical depression.

Larger basin swamps can occupy almost any kind of landscape depression. Many are thought to have developed in oxbows of former rivers or in ancient coastal swales and lagoons from periods with higher sea levels.

Soils

Dome soils are composed of peat, which is thickest toward the center of the dome. This peat is generally underlain by acidic sands and then limestone. Some domes have a clay lens that helps retain water.

Basin swamp soils are generally acidic, nutrient-poor peats, often overlying a clay lens or other impervious layer.

Vegetative Structure

Dome swamps have small young “pond cypress” trees towards their outer edges, grading into larger and older “bald cypress” towards the interior, giving a dome a distinctly rounded cross-sectional profile. (Because pond cypress *Taxodium ascendens* and bald cypress *Taxodium distichum* can be recognized as clearly different in these field situations, the two names are used here. Although some authorities persist in considering these different species, most ecologists now regard them as morphological variations reflective of different growing conditions.) The typical central pond creates the doughnut shape that characterizes these systems on aerial photographs.

Basin swamp structures vary. In theory, a mature system would have the wide variety of tree sizes characteristic of an old-growth forest, but logging has altered the structure of almost all such swamps.

The shallow and diffuse type of basin swamp that covers most of the Big Cypress Swamp is characterized by scattered stunted bonsai-like “hatrack” or “toy” cypress, which are seldom over 3 to 4.6 m (10 to 15 ft) tall, though they are old trees and may have large buttresses.

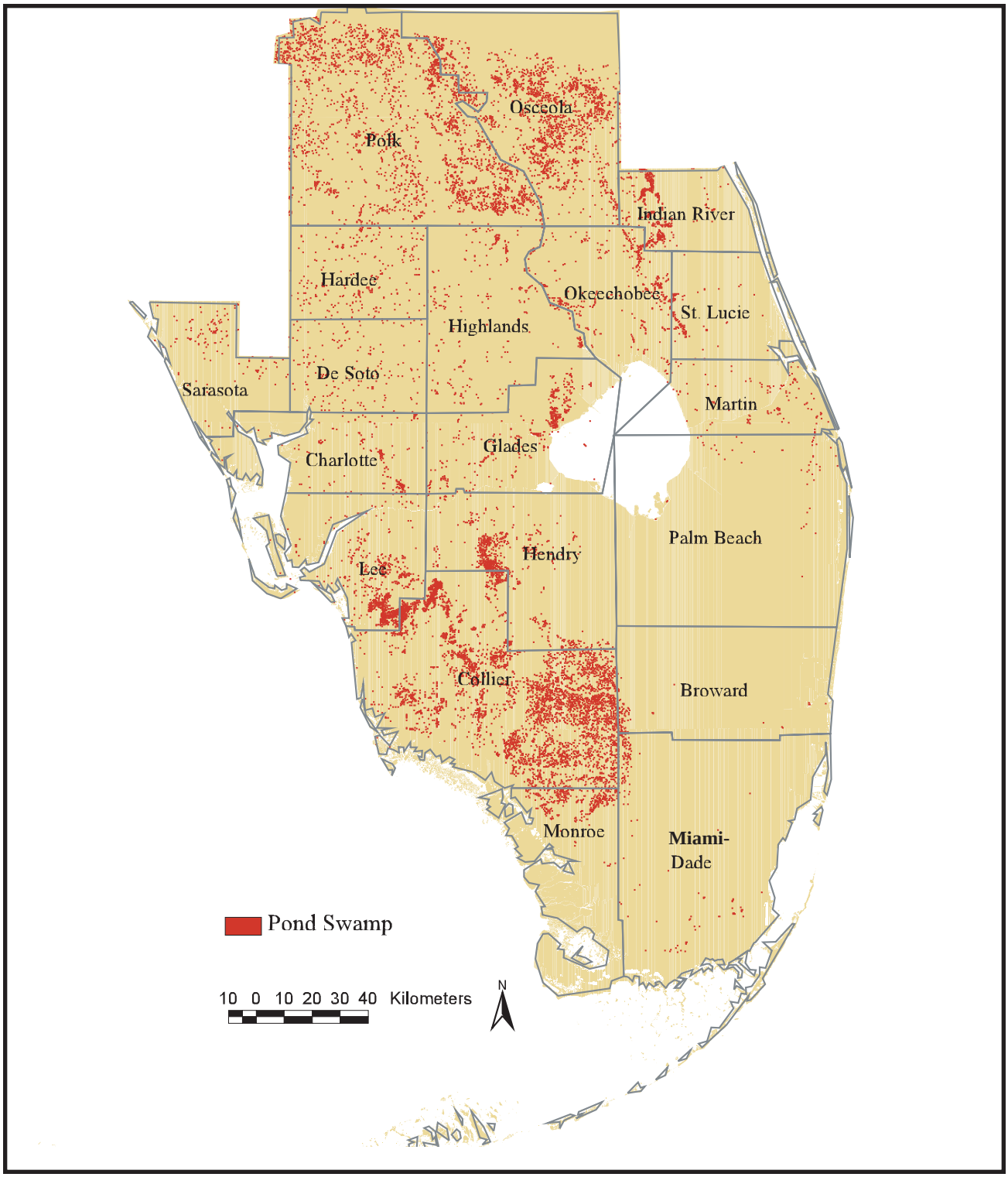


Figure 1. The occurrence of forested pond swamps in South Florida (adapted from USGS-BRD Landsat TM imagery).

Vegetative Composition

Typical dome swamp plants include pond cypress, red maple (*Acer rubrum*), dahoon (*Ilex cassine*), swamp bay (*Persea palustris*), sweetbay (*Magnolia virginiana*), coastal plain willow (*Salix caroliniana*), wax myrtle (*Myrica cerifera*), buttonbush (*Cephalanthus occidentalis*), St. john's wort (*Hypericum* spp.), chain fern (*Woodwardia* spp.), poison ivy (*Toxicodendron radicans*), laurel greenbrier (*Smilax laurifolia*), Spanish moss (*Tillandsia usneoides*), and fireflag (*Thalia geniculata*).

Dominant basin swamp plants include blackgum (*Nyssa sylvatica* var. *sylvatica*), cypress, and slash pine (*Pinus elliottii*). Other typical plants include red maple, swamp bay, sweetbay, loblolly bay (*Gordonia lasianthus*), Virginia willow (*Itea virginica*), wax myrtle, buttonbush, laurel greenbrier, and Spanish moss.

Wildlife Diversity

Typical dome swamp animals include raccoon (*Procyon lotor),* bobcat (*Felis lynx*), gray squirrel (*Sciurus carolinensis*), white-tailed deer (*Odocoileus virginianus*), wood stork (*Mycteria americana*), wood duck (*Aix sponsa*), swallow-tailed kite (*Elanoides forficatus*), barred owl (*Strix varia*), pileated woodpecker (*Drycopus pileatus*), great crested flycatcher (*Myiarchus crinitis*), rusty blackbird (*Euphagus carolinus*), striped mud turtle (*Kinosternon bauri*), eastern mud turtle (*Kinosternon subrubrum*), eastern mud snake (*Farancia a. abacura*), cottonmouth (*Agkistrodon piscivorus*), oak toad (*Bufo quercicus*), southern cricket frog (*Acris gryllus dorsalis*), pinewoods treefrog (*Hyla femoralis*), little grass frog (*Pseudacris ocularis*), and narrowmouth toad (*Gastrophryne carolinensis*).

Typical basin swamp animals include Florida black bear (*Ursus americanus floridanus*), raccoon, river otter (*Lutra canadensis*), gray squirrel, wood duck, hawks, great horned owl (*Bubo virginianus*), barred owl, pileated woodpecker, songbirds, chicken turtle (*Deirochelys reticularia*), striped mud turtle, crayfish snake (*Regina alleni*), cottonmouth, cricket frog, and little grass frog.

The Carolina parakeet (*Conuropsis carolinensis carolinensis*), now extinct, was documented as feeding heavily on cypress seed (Sprunt 1954). Since the parakeets customarily flew many miles between feeding and roosting sites, it is logical that this species may have played a significant role in cypress seed dispersal. Absence of this dispersal agent might explain the problems with cypress regeneration now observed isolated pond swamps.

Wildlife Species of Concern

Federally listed species that depend upon or utilize the flowing water swamp community in South Florida include: Florida panther *(Puma (=Felis) concolor coryi),* bald eagle (*Haliaeetus leucocephalus*), wood stork (*Mycteria americana*), Everglade snail kite (*Rostrhamus sociabilis plumbeus*), Kirtland's warbler (*Dendroica kirtlandii*), and eastern indigo snake (*Drymarchon corais couperi*). Tanner (1942) reported that the ivory-billed woodpecker



Swallow-tailed kite. *Original photograph by Barry Mansell.*

(*Campephilus principalis*) occurred adjacent to swamps dominated by bald cypress and hardwoods. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

The **Big Cypress fox squirrel** (*Sciurus niger avicenna*) requires a landscape mosaic, including pine and cypress, in close proximity. The State of Florida has designated the Big Cypress fox squirrel as a threatened species.

The **American swallow-tail kite** *(Elanoides forficatus)* prefers tall pines and cypress for nesting and requires a diverse mosaic of swamp and floodplain forest, rivers and lake margins, hardwood hammocks, bayheads, prairies, sloughs, and mangroves for foraging (Meyer and Collopy 1996).

Plant Species of Concern

Federally listed species that depend upon or utilize the pond swamp community in South Florida include the Okeechobee gourd *(Cucurbita okeechobeensis okeechobeensis).* A biological account and recovery tasks for this species is included in "The Species" section of this recovery plan.

The **Okeechobee gourd** requires a sunny slough habitat with branching shrubs to climb on. It was originally most common in the pond apple swamp along the southern edge of Lake Okeechobee. Restoration of similar pond apple swamps, therefore, creates opportunities for reintroduction of this endangered species.

Ecology

Current knowledge of the ecology and conservation status of seasonally ponded isolated wetlands in the southeastern United States is summarized in Kirkman *et al.* (1998).

Hydrology

Dome swamps often derive much of their water through runoff from surrounding uplands, but they may also be connected with underground channels in which, case subterranean flows would dominate the hydrological regime. These wetlands generally function as reservoirs that recharge the aquifer when adjacent water tables drop during drought periods.

The normal hydroperiod for dome swamps is 200 to 300 days per year with water being deepest and remaining longest near the center of the dome.

A basin swamp may have a perched water table that can act as a reservoir, releasing groundwater as adjacent upland water tables drop during drought periods. The typical hydroperiod is approximately 200 to 300 days.

Fire

Fire is essential for the maintenance of a cypress dome community. Without periodic fires, hardwood invasion and peat accumulation would convert the dome to a hydric hammock or bayhead. Dome swamps dominated by bays are close to this transition.

Fire frequency is greatest at the periphery of the dome and least in the interior, where long hydroperiods and deep peat maintain high moisture levels for most of the year. The normal fire cycle might be as short as 3 to 5 years along the outer edge and as long as 100 to 150 years towards the center. The profile of a dome swamp (*i.e.*, smaller trees at the periphery and largest trees near the center) is largely attributable to this fire regime. The shorter hydroperiods along the periphery permit fires to burn into the edge more often, occasionally killing the outer trees.

Cypress is very tolerant of light surface fires, but muck fires burning into the peat can kill them, lower the ground surface, and transform a dome into a pond.

Occasional fires are essential for the maintenance of cypress-dominated basin swamps. Blackgum- and hardwood-dominated basin swamps burn less often, while pine-dominated basin swamps burn more frequently.

Typical fire intervals in basin swamps may be anywhere from 5 to 150 years. Cypress and pines are very tolerant of light surface fires, but muck fires burning into the peat can kill the trees, lower the ground surface, and transform a basin swamp into a lake.

Status and Trends

Although a number of researchers have estimated wetland loss rates in Florida, little of this data is refined enough to permit meaningful estimation of the extent to which flowing water swamps have been lost. Between 1940 and 1980, Florida's total forested area declined by 27 percent (Knight and McClure 1982 cited in Noss *et al.* 1995). Since 1970, forested wetland communities throughout Florida have been reduced by 17 percent (Noss *et al.* 1995).

Land cover changes in Florida since European colonization have been estimated based upon mapping of historic vegetation types (Davis 1967, Cox *et al.* 1997). Of the forested wetland communities, open scrub cypress has been least impacted with 87 percent of its historic acreage intact (Cox *et al.* 1997). Whereas 67 percent of Florida's original cypress swamp forests and 63 percent of the

swamp hardwood forests still exist today, only 38 percent of the original wetland hardwood forests remain. The percentage of these remaining forested wetlands in Florida that have been protected through public ownership to be managed as natural areas are as follows: 87 percent of open scrub cypress, 33 percent of cypress swamp forests, 25 percent of swamp hardwood forests, and 15 percent of wetland hardwood forests (Cox *et al.* 1997).

Using 1985 to 1989 Landsat satellite imagery for Florida, another mapping analysis estimated that managed areas protect 58 percent of remaining shrub swamps, 34 percent of cypress swamps, and 25 percent of hardwood swamps (Kautz *et al.* 1993 cited in Cox *et al.* 1997).

Comparative analysis of 1986 and 1991 Landsat imagery showed that St. Lucie County lost 41.5 percent of its dome swamps during that 5-year period (Duever *et al.* 1992).

Changes in the landscape matrix have had and continue to have major impacts on pond swamps. Conversion of adjacent pinelands and prairies to pastures, farm fields, citrus groves, and residential developments has restricted the normal movement of fires, sheetflow, and wildlife essential to ecological processes within these communities.

Development of much of the surrounding landscape has increased the amount of runoff that must be absorbed by the remaining wetlands. Intentional drainage of irrigated agricultural lands into wetland systems is compounding the problem in many areas. Pond swamps are especially vulnerable to such impacts because they often occur as small wetlands surrounded by agricultural lands.

In the United States, agricultural practices account for greater than 87 percent of recent wetland losses (Nelson 1989 cited in Noss *et al.* 1995).

Agricultural runoff also poses a contamination threat. Not only does it commonly contain pesticides, but it is typically enriched with fertilizer residues. These fertilizers contain nutrients that promote eutrophication. Since fertilizer composition is unregulated and many fertilizer components originate as industrial byproducts, such runoff can also be a source of toxic waste contamination.

Borrow pits, surface mines, and wellfield drawdowns can lower water tables and impact pond swamp hydrology.

Cypress domes have been used to purify secondarily treated wastewater (Brandt and Ewel 1989). This introduces excess organic matter, nutrients, and minerals to the wetland system. "Major changes observed in swamps receiving treated effluent are the development and persistence of a continuous cover of duckweed (*Lemna* spp., *Spirodela* spp., and *Azolla carolinensis*), development of anoxia in the water [Dierberg and Brezonik 1984], and an increase in passerine bird populations together with elimination of amphibian reproduction [Harris and Vickers 1984]" (Brandt and Ewel 1989).

Exotic species invasion is an increasing problem in flowing water swamps. Exotic plants reported from this community include: melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), Japanese climbing fern (*Lygodium japonicum*), and skunk vine (*Paederia foetida*).

Exotic animals include: hog (*Sus scrofa*), house cat (*Felis silvestris*), Cuban treefrog (*Osteopilus septentrionalis*), and walking catfish (*Clarias batrachus*).

Historically, commercial interest in forested wetlands was limited to timber harvest, with little attention paid to long-term management techniques (Brandt and Ewel 1989). The mature cypress, which were especially valuable for their

resistance to decay, were almost all harvested during the logging boom that peaked in the 1920s (Brandt and Ewel 1989). The total volume of standing cypress timber reached its lowest point in 1933, but has steadily increased during the last 60 years (Brandt and Ewel 1989). The second-growth trees currently available do not produce the same quality of decay-resistant lumber as the old-growth trees did; they are primarily used for fenceposts, stakes, mulch, and pulp (Terwilliger and Ewel 1986 cited in Brandt and Ewel 1989). Clearcutting is widely practiced due, in part, to the fact that all sizes of trees can be made into chips for mulch (Brandt and Ewel 1989). The cypress mulch industry is more active in north Florida, but some South Florida cypress is harvested for this purpose.

Cypress knees are harvested and sold for lamp bases, floral arrangements, and various other kinds of curios and decorative items. Since the knees' function is poorly understood, the impact of their removal is unknown.

Numerous other materials are occasionally harvested from pond swamps. Deer, hogs, and other game animals are hunted here, which affects herbivore-vegetation and predator-prey relationships. Poaching of epiphytes may deplete populations of abundant species (like *Tillandsia fasiculata*) and seriously impact less common ones. Collection of medicinal herbs is increasing in all habitats and may impact swamp vegetation in the future.

Although cattle rarely venture into the larger basin swamps, grazing has degraded many cypress domes.

Bee keeping practices may have serious effects on pollinator ecology. Exotic honeybee colonies are often maintained in wetland landscapes, where they can rely on abundant melaleuca nectar when other food is scarce. How this affects native pollinators and the reproduction of native plants is unknown. Bee keeping also poses hazards to black bears, since bee keepers sometimes shoot bears who foil their electric fences and raid their hives.

Management

Land Protection

Preservation of remaining high quality pine flatwoods and prairie buffers and pond swamps in intact landscape matrices is the highest land protection priority.

Conservation Acquisitions and Agreements

Table 1 lists conservation lands that include important Pond Swamps.

Regulatory Mechanisms

The natural resource conservation elements of county comprehensive plans, county and State development permitting policies, pollution control and vegetation management regulations, and DEP and water management district water resource protection and wetlands permitting procedures help protect pond swamps. Underfunded enforcement programs limit the effectiveness of these regulations, however. Better enforcement of existing regulations is more critical than enactment of new ones.

Restoration Projects and Programs

Historically, most wetlands restoration efforts have been directed at marsh ecosystems. Only within the past 15 to 20 years have there been significant attempts to restore forested wetlands (Clewell and Lea 1990). Given the timeframe necessary for forest regrowth, most of these projects are still too new for critical evaluation.

Forested wetland restoration efforts have been focused on two types of situations: reforestation of lands cleared for agriculture and subsequently abandoned (where the main objective is to establish a forest canopy) and restoration of wetlands cleared for surface mining projects (where the objective has been to replace the full spectrum of tree species and undergrowth components, with considerable attention given to establishing the appropriate hydrology and hastening soil development (Clewell and Lea 1990).

Based on a review of forested wetlands restoration projects, Clewell and Lea (1990) have identified six critical factors which interact to determine whether or not a project will be successful. They are hydrology, substrate stabilization, rooting volume, soil fertility, control of noxious plants, and herbivore control.

Specifically, cooperation among engineers, hydrologists, and soil scientists must be encouraged to ensure that water delivery timing, depth, and quality are synchronous with the natural systems being emulated (Clewell and Lea 1990). Flood tolerance varies widely among different species and among different size classes within species and is also dependent upon stage of the growing season (Bedinger 1979). Newly planted vegetation is particularly susceptible to water stress.

Topographic relief should be planned with substrate stabilization in mind as project sites are often open and subject to erosion which hinders the establishment of trees and undergrowth (Clewell and Lea 1990).

Soil volume must be considered as roots need an adequate volume of soil to anchor themselves and exploit moisture and nutrients (Clewell and Lea 1990). Rooting volume may be limited by depth to the wet season water table and mechanical resistance where soil density has been increased by compaction caused by heavy equipment at project sites (Clewell and Lea 1990).

Soil fertility varies considerably with the project site. Fertilization is usually necessary to prevent trees from languishing so long as saplings that they are suppressed by weeds (Clewell and Lea 1990).

Control of noxious plants is necessary where their proliferation threatens to suppress desirable species. Certain tall weed species may be beneficial as shelter for young trees, however (Clewell and Lea 1990).

On a regional scale, restoration of pine flatwoods and prairie buffers is more important to pond swamps than wetland restoration in itself.

Management Strategies and Techniques

SWFWMD has budgeted funds for research into biological control of skunk vine. Japanese climbing fern is promptly treated with herbicide when detected on SJWMD lands.

Timber harvest in cypress swamps ranges in intensity from clearcutting to thinning. The most frequently prescribed silvicultural systems are clearcutting and seed-tree cutting. There is no clear evidence that any method is significantly

superior for assuring subsequent cypress regeneration, but it is clear that a seed source must be left on or adjacent to the site, that severe fires following a harvest can prevent regeneration, and that profound changes in hydroperiod, water levels, soil aeration, and/or understory vegetation can hinder seed germination and seedling survival (Brandt and Ewel 1989). When an isolated cypress dome is harvested, seed trees must be left or sufficient light must be available to assure coppice production (sprouting from the stump). Where cypress is selectively removed, cypress seedlings and saplings are likely to be outcompeted by more shade-tolerant hardwoods and coppicing may not be reliable.

Planting cypress will hasten the establishment of a new stand. Seedlings should be tall enough to escape inundation and should be protected from herbivory (Brandt and Ewel 1989).

Informal roads and trails can create wide muddy swaths and gullies through wetlands. Various types of web mats can be used to stabilize such trails. Geoweb has been used successfully for this purpose on SJWMD lands in Osceola County. Tracks from recreational vehicles, logging trucks, and other machinery can create deep ruts in soft wetland soils. As water levels subsequently rise and fall, fish and other organisms may be trapped within these pools, which affects the food chain by influencing mobility of predators and prey. Mosquitoes have been observed to be more numerous under such circumstances (Wharton *et al.* 1976).

Synonymy Tables:

BASIN SWAMP

Kuchler	113/Southern floodplain forest
Davis	7/Cypress swamp forests
	8/Swamp forests, mostly of hardwoods
NRCS	17/Cypress swamp
Myers & Ewel	Freshwater swamp forest-depression or basin wetlands
SAF	85/Slash pine-hardwood
	100/Pond cypress
	103/Water tupelo-swamp tupelo
FLUCCS	614/Gum swamp
	616/Inland ponds and sloughs
	621/Cypress

Other synonyms include gum swamp, bayheads.

DOME SWAMP

Kuchler	113/Southern floodplain forest
	112/Southern mixed forest
Davis	7/Cypress swamp forests
NRCS	17/Cypress swamp
Myers & Ewel	Freshwater swamp forests-depression or basin wetlands
SAF	85/Slash pine-hardwood
	100/Pond cypress
	103/Water tupelo-swamp tupelo
FLUCCS	613/Gum swamps
	616/Inland ponds and sloughs
	621/Cypress

Other synonyms include cypress dome or pond, cypress head, gum pond, cypress gall, pine barrens pond, non-alluvial depressional wetland, limesink pond, and (in Georgia) grady pond and citronelle pond.

Synonymy Tables: *cont.*

Where the Florida Game and Fresh Water Fish Commission's (GFC) Cypress Swamp or Hardwood Swamp communities occur in more-or-less round and isolated basins or depressions, they can be categorized as pond Swamps.

The following GAP categories can be classified as pond swamps when they occur in more-or-less round and isolated basins or depressions.

18	I.B.2.N.(d,e)....	Cold-deciduous temporarily or seasonally flooded/saturated forest (=swamp forest)
19	I.B.2.N.e.180	*Taxodium ascendens* Forest Alliance
20	I.B.2.N.f.060	*Taxodium distichum* Semipermanently flooded Forest Alliance
21	I.C.1.N.c....	Seasonally flooded tropical or subtropical semi-deciduous forest
23	I.C.3.N.c....	Seasonally flooded mixed needle-leaved evergreen-cold-deciduous forest (=mixed swamp forest)
29	II.A.2.N.b....	Seasonally flooded temperate broad-leaved evergreen woodland
32	II.B.1.N.d.010	*Taxodium ascendens* Tropical Woodland Alliance

Where the following GAP category occurs within or adjacent to another Pond Swamps type, it may also be included in this community:

36	III.A.1.N.c.030	*Myrica cerifera-Ilex cassine* Shrubland Alliance

Table 1. Proposed conservation lands important to pond swamps

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
Alston Tract	Scattered cypress domes.	SWFWMD Project
Belle Meade	Dwarf cypress savannas.	1997 CARL Priority 3
Bright Hour Watershed	Mostly dry prairie with some basin swamps and a classic 100-acre baygall with gordonia. Six major slough systems within the proposed acquisition make up much of the headwaters of Prairie and Shell Creeks.	SWFWMD Group "C" Project (Land to be Evaluated)
Catfish Creek		1997 CARL Priority 22, SFWMD Project
Charlie Creek System	Drainages along the main channel of Charlie Creek and tributaries (Bee Branch, Buckhorn Creek, Little Charley Bowlegs Creek and Old Town Creek) form a series of swamps and sloughs. This system drains into the Peace River.	SWFWMD Project
Charlotte 1	Scattered cypress domes. Protects the headwaters of Telegraph Swamp.	SWFWMD Group "C" Project (Land to Be Evaluated)
Charlotte Harbor Flatwoods	Site includes strands and domes in a flatwoods matrix, but melaleuca invasion is a major problem.	1997 CARL Priority 14
Cypress Creek/Trail Ridge	Cypress and pine have been logged out of hydric hammocks and basin swamps north of SR 70, and flows from Cypress Creek, which historically passed under SR 70, have been routed west through a ditch along the north side of the highway. Most of the historic slough remains intact south of SR 70, where very little logging or ditching has been done. The Carlton lands include an impressive stand of virgin cypress (FNAI Basin Swamp EOR # 066). There are bayheads and cypress domes and a band of hydric hammock (Van Swearingen Creek) in the Trail Ridge area along the west side of Bluefield Road.	SFWMD Project
Fox Branch	Scattered cypress and mixed hardwood swamps.	SWFWMD Group "C" Project (Land to Be Evaluated)
Green Swamp	There are good strand swamps with hydric hammock islands on the Jahna property owned by sand mining company, but associated uplands have been cleared. The Overstreet tract in the southwest corner of the site has cypress domes, cypress strands, hydric hammocks, and floodplain swamps, which drain into Little Gator Creek, then into the Withlacoochee River.	1997 CARL Priority 20 and 1997 CARL LOF 1, SJWMD SOR and P-2000 Project, SWFWMD Project
Hall Ranch		1997 CARL Bargain 18

Table 1. ***cont.***

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
Horse Creek	Mixed hardwood swamps. Includes portions of large headwaters swamps in the upper portion of the Horse Creek watershed. Threatened by proposed phosphate mining on adjacent lands.	SWFWMD Group "C" Project (Land to Be Evaluated)
Loxahatchee Slough	Agriculturally disturbed habitat mosaic including pine flatwoods, cypress domes, and wet prairies. Heavily infested with melaleuca and other exotic vegetation.	SFWMD Project
Osceola Pine Savannas	This is an area of old beach ridges and intervening swales, with high quality longleaf pine flatwoods interrupted by cypress strands, cypress domes, and wet prairies.	1997 CARL Priority 24
Parker-Poinciana	Includes mesic flatwoods, a large cypress/bay head, logged-over flatwoods, and hydric hammock along the Lake Hatchineha shoreline.	SFWMD Project
Ranch Reserve	Headwaters of Blue Cypress Creek. Includes high quality cypress strands, cypress domes, and hydric hammocks in a flatwoods matrix.	1997 CARL LOF 4, SJWMD SOR and P-2000 Project. Conservation easements are key to protection strategy.

Table 2. Managed areas important to pond swamps

Managed Area	Managing Entity
Avon Park Air Force Range	DOD
Collier-Seminole State Park	DEP
Three Lakes Wildlife Management Area	GFC
Triple N Ranch Wildlife Management Area	GFC

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Restoration of Pond Swamps

Restoration Objective: Prevent further reduction in area of pond swamps, protect all remaining high quality habitat, and restore and manage protected lands to maintain ecological processes and biodiversity. Restoring and maintaining swamps within a healthy fire-maintained flatwoods and prairie landscape mosaic is critical.

Restoration Criteria

The recovery objective will be achieved when: (1) a reserve design incorporating all currently protected tracts and remaining high-quality habitat has been developed and implemented; (2) pond swamps are protected through acquisition or cooperative agreements with landowners; (3) appropriate management plans have been prepared and funded for all lands within the reserve network; (4) restoration has been successfully initiated such that ecological processes are operating normally; and (5) natural succession and restoration actions through funded management programs can be expected to re-establish community structure and biodiversity on all significant degraded sites within the reserve network.

Pond swamps within the reserve system must be adequately buffered from urban and agricultural runoff.

Community-level Restoration Actions

1. Prevent further destruction or degradation of existing pond swamps.

1.1. Acquire threatened pond swamps.

Table 2 presents land acquisition proposals that incorporate important pond swamps that should be protected. Other important areas that should be protected include: (1) cypress domes within flatwoods matrix on Sarasota County ranchlands and: (2) basin swamp in Collier County, 8.86 km (5.5 mi) northeast of Belle Meade (FNAI EOR #013).

There are many other pond swamps worthy of protection within local conservation systems. Natural landscapes, including healthy examples of such swamps, should be regarded as high priorities for local conservation efforts.

1.2. Promote conservation easements and landowner agreements to protect pond swamps. Appropriate agreements should be negotiated with landowners.

1.3. Enforce regulatory protection. Lands are seldom adequately monitored to assure compliance, and penalties and enforcement are often inadequate to

motivate adherence to the law. Increased funding for regulatory monitoring and enforcement programs is needed at all levels.

1.4. **Prevent degradation of existing preserves**. Conservation lands should be maintained according to management plans to ensure that pond swamps, along with their associated flatwoods and prairie matrices, are protected from degrading land uses.

1.5. **Protect pond swamps from pollution**. Pond swamps should be protected from both point source and non-point source pollution. Special measures should be developed to protect them from agricultural runoff from surrounding farmlands.

2. Manage pond swamps within the context of restoration objectives.

2.1. **Restore natural fire regimes**. Emphasize landscape-scale burning that permits fires to burn into the edges of wetlands naturally. Minimize swamp-edge firebreaks.

2.2. **Control exotic plants and animals**. Control melaleuca invasion. Aggressively seek out and eliminate infestations of Japanese climbing fern and skunk vine. Control feral hog populations (with consideration for panther food base). Monitor behavior of other exotics in pond swamps and promptly initiate control programs for those that threaten to become problematic.

2.3. **Restore hydrology**. Within the context of regional hydrological restoration, manage pond swamps to maintain hydroperiods and water levels within the ranges found in natural systems.

2.4. **Restore soils**. Restore hydrological patterns and control fire to permit accumulation of peat in drained or burned swamps. In severely degraded systems, consider increasing water and nutrient levels on a temporary basis to accelerate the soil development process.

2.5. **Restore ecosystem structure and composition** by manipulating existing populations of native species, augmenting populations of native species, and reintroducing extirpated plants and animals.

2.6. **Protect seepage swamps from point source and non-point source pollution.** Design restoration projects to restore entire landscapes of integrated upland and wetland communities so that wetlands are buffered from agricultural and urban runoff.

3. Maintain pond swamps in a natural condition.

3.1. **Provide analogs for ecosystem functions such as fire regimes.**

3.2. **Continue to control exotic plants and animals in perpetuity.**

3.3. **Monitor for extirpations and extinctions,** and negative population trends of keystone and rare species, including pollinators, dispersers and soil organisms**.**

3.4. **Monitor and correct for both point source and non-point source pollution.**

4. **Restore pond swamps where they have been destroyed by human activities.** Use research conducted by the Florida Institute of Phosphate Research, the University of Florida Center for Wetlands, and others to recreate pond swamps according to the guidelines of the Society for Ecological Restoration.

4.1. **Restore ecosystem structure,** including soils and soil organisms, hydrology, plants, and animals.

4.2. **Restore ecosystem functions** by controlling exotics and aggressive native weeds, restoring natural fire regimes, and restoring natural biological interactions (food webs, nutrient cycling, *etc*.).

4.3. **Restore ecosystem composition** by introducing rare and late-succession species.

4.4. **Protect pond swamps from both point-source and non-point-source pollution.**

5. **Create pond swamp analogs where natural communities have been destroyed by human activities to the extent that a legitimate natural community can no longer be restored.**

5.1. **Restoration of ecosystem structure** would need to consider physical landforms, drainage patterns, soils and soils organisms, and endemic flora and fauna.

5.2. **Restoration of ecosystem functions** would include controlling exotics and aggressive native weeds, restoring hydrologic processes, restoring fire regimes, and creating natural biological interactions (food webs, nutrient cycling, *etc*.)

5.3. **Restoration of ecosystem composition** would need to consider late-succession species, rare species, and protection of the community from pollution (point source and non-point source).

6. **Connect appropriate habitats.**

6.1. **Connect ecological systems.** Pal-Mar, a project in northern Palm Beach and southern Martin Counties, is a critical connection between J.W. Corbett WMA and Jonathan Dickinson SP. When acquired, this will complete a 50,587 ha (125,000 acre) ecological greenway stretching from Dupuis Reserve close to Lake Okeechobee to Jonathan Dickinson SP.

The Belle Meade project will provide a significant linkage between Collier-Seminole SP and the future Golden Gates Estates SF.

6.2. **Protect/restore landscape matrix.** Preserve/restore flatwoods and prairies adjacent to pond swamps wherever possible. Change wetland permitting regulations so that flatwoods buffers can be restored as wetland mitigation.

6.3. **Assure maintenance of linkages critical to key species and functions.**

7. **Conduct research.**

7.1. **Determine distribution of remaining habitat.**

7.1.1. **Develop strategies for gathering, synthesizing, and groundtruthing data to permit better identification of pond swamps.** In particular, devise ways to more readily distinguish FNAI's basin swamp in GIS mapping and clarify the distinction between wet flatwoods and dwarf cypress savanna (especially where the original community is obscured by melaleuca invasion) on National Wetlands Inventory maps.

7.1.2. **Assess and supplement available data**.

7.2. **Improve reference ecosystem information regarding community composition, biodiversity, and site-to-site variability.**

7.3. **Investigate roles of pollinators, mycorrhizae, seed dispersers, and other critical or keystone species.**

7.4. Evaluate predator-prey relationships in landscape context.

8. Monitor community-level processes, community structure, and community composition.

9. Increase public awareness of pond swamp communities.

Seepage Swamps

FNAI Global Rank:	**G3/G4**
FNAI State Rank:	**S2/S4**
Federally Listed Species in S. FL:	**5**
State Listed Species in S. FL:	**38**

Seepage swamps are forested wetlands characterized by saturated soils rather than periodic inundation. They include baygalls at the base of seepage slopes, bayheads in peat-filled depressions or at the downstream ends of Everglades teardrop islands, and hydric hammocks on low sand or limestone rises within periodically inundated wetland systems. Many of these systems have been drained and converted to agricultural uses. Much of the classic baygall that once fringed the tip of the Lake Wales Ridge was cleared so that the rich muck soil could be used for growing caladiums and gladiolias. Many seepage swamps have been damaged by hydrological alterations that have lowered the groundwater table or by pollution from agricultural or urban runoff. Water level manipulations in the Everglades have stressed bayheads with excess surface water in some situations and allowed them to dry out and lose their soil to peat fires in others. Large numbers of cabbage palms (*Sabal palmetto*)are removed from hydric hammocks for landscaping. Restoration of hydrological regimes and preservation of natural landscape buffers are the most critical long-term needs for preservation of seepage swamps.

Synonymy

Seepage Swamps include FNAI's hydric hammock, baygall, and bog (bayhead); NRCS's wetland hardwood hammocks, and shrub bog and; Society of American Foresters' (SAF) southern red cedar, cabbage palmetto, slash pine-hardwood, sweetbay-swamp, and tupelo-redbay. Synonymies for each of these communities are provided in the snynonymy tables at the end of the account. Note that some of these definitions include northern types that do not occur in South Florida.

Distribution

Baygalls originally occurred in linear bands below seepages in the northern part of South Florida where

topographic relief is sufficient to create slopes. (Most of them have now been so fragmented that linear patterns are seldom evident except where baygalls form a transition zone between uplands and floodplain wetlands along streams.) Bayheads are scattered throughout the regional landscape, but are most abundant in areas with numerous cypress domes (like the Green Swamp), where they represent an advanced stage of dome succession with peat accumulation in the absence of severe fire. They are also abundant in the Everglades, where they characteristically grow on organic soil built up downstream of limestone-based hardwood hammocks. Hydric hammocks also occur throughout the region, but tend to be more extensive where they are associated with river floodplains (Figure 1).

Description

Topography and Geology

Baygalls typically develop at the base of a slope where seepage maintains a saturated peat substrate. Bog-type bayheads occur on acidic peat soils that have accumulated in a depression. The peat may fill the depression or be an island or isolated mass floated into position by high water. Hydric hammocks occur on low, flat, wet sites where limestone is often at or near the surface.

Soils

Baygall and bayhead soils are typically composed of peat with an acidic pH (3.5 to 4.5). Hydric hammocks generally grow on sands with considerable organic material that, although generally saturated, are inundated only for short periods following heavy rains.

Vegetative Structure

Baygalls and bayheads are dense evergreen forests or shrub thickets with a spongy understory of sphagnum moss and ferns. The canopy is composed of tall, densely packed, generally straight-boled evergreen hardwoods dominated by sweetbay (*Magnolia virginiana*), swamp bay (*Persea palstris*) red bay (*Persea borbonia*), and loblolly bay (*Gordonia lasianthus*). There is typically a more or less open understory of shrubs and ferns and a ground surface of sphagnum mats interlaced with convoluted tree roots.

Hydric hammocks are open forests dominated by cabbage palms and laurel oaks (*Quercus laurifolia*) mixed with other hardwoods. They often have minimal understory and a floor carpeted by fallen palm fronds.

Vegetative Composition

In baygalls and bayheads, the typical plant species include: red bay, sweetbay, loblolly bay, red maple (*Acer rubrum*), slash pine (*Pinus elliottii*), wax myrtle (*Myrica cerifera*), dahoon (*Ilex cassine*) gallberry (*Ilex coriacea*), Virginia willow (*Itea virginica*), buttonbush (*Cephalanthus occidentalis*), coco plum (*Chrysobalanus icaco*), laurel greenbrier (*Smilax laurifolia*), poison ivy

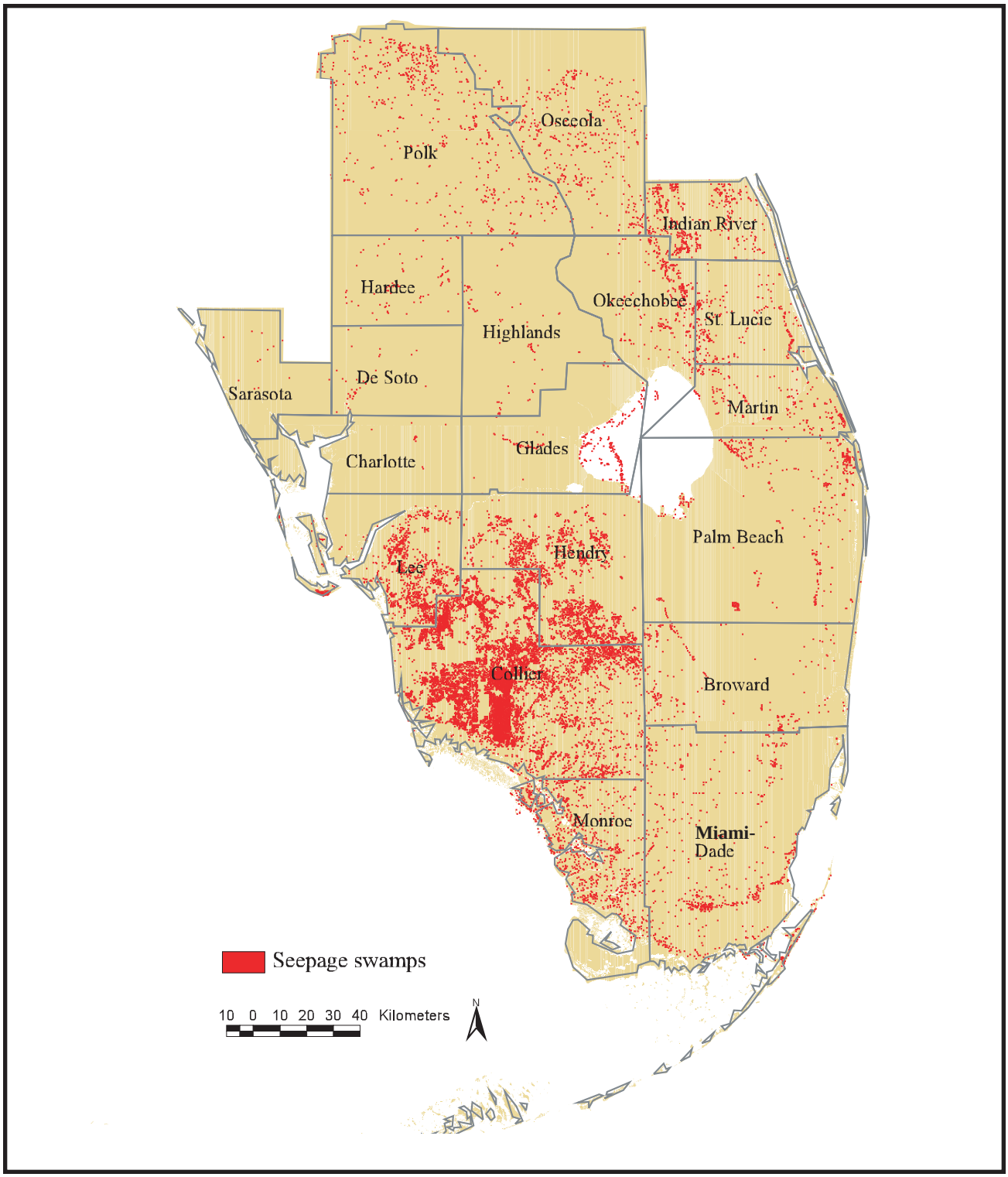


Figure 1. The occurrence of seepage swamps in South Florida (adapted from USGS-BRD 1996)

(*Toxicodendron radicans*), cinnamon fern (*Osmunda cinnamomea*), chain fern (*Woodwardia* spp.), netted chain fern (*Woodwardia areolata*), and sphagnum moss.

Typical hydric hammock plants include cabbage palm, laurel oak, red maple, swamp bay, sweetbay, water oak (*Quercus nigra*), dahoon, myrsine (*Rapanea punctata*), sugarberry (*Celtis laevigata*), wax myrtle, saw palmetto (*Serenoa repens*), poison ivy, royal fern (*Osmunda regalis*), peppervine (*Ampelopsis arborea*), rattan vine (*Berchemia scandens*), Virginia creeper (*Parthenocissus quinquefolia*), and several species of ferns.

Wildlife Diversity

Typical baygall and bayhead animals include Florida black bear *(Ursus americanus floridanus),* southeastern shrew, short-tailed shrew *(Blarina brevicauda),* squirrel treefrog *(Hyla squirella),* little grass frog *(Pseudacris ocularis).*

Hydric hammock animals include gray squirrel (*Sciurus carolinensis),* flycatchers, warblers, and green anole (*Anolis carolinensis).*

Wildlife Species of Concern

Federally listed species that depend upon or utilize the seepage swamp community in South Florida include: Florida panther *(Puma (=Felis) concolor coryi),* bald eagle (*Haliaeetus leucocephalus*), wood stork (*Mycteria americana*), Kirtland's warbler (*Dendroica kirtlandii*), and eastern indigo snake (*Drymarchon corais couperi*). Tanner (1942) reported that the ivory-billed woodpecker (*Campephilus principalis*) occurred adjacent to swamps dominated by bald cypress and hardwoods. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

The **Florida black bear** is state listed as threatened. This species utilizes a wide variety of extensively forested landscapes, including pine flatwoods, hardwood and cypress swamps, cabbage palm forests, sand pine scrub, and mixed hardwood hammocks (Maehr 1992). The black bear has a large home range, low population density, and a low reproductive rate. These characteristics make it particularly vulnerable to habitat loss and fragmentation. Poaching and highway collisions are also issues of special concern. Because the Florida black bear's diet varies temporally and geographically (Maehr and Brady 1982a, 1984a, 1984b), timber management and prescribed burning schedules need to be evaluated.

The **American swallow-tail kite** *(Elanoides forficatus)* prefers tall pines and cypress trees for nesting and requires a diverse mosaic of swamp and floodplain forest, vegetated margins of rivers and lakes, hardwood hammocks, bayheads, prairies, sloughs, and mangroves for foraging (Meyer and Collopy 1996).

Limpkins (*Aramus guarauna*)are found along the wide and well-vegetated shallows of rivers and streams statewide, as well as around lakes in peninsular Florida and in marshes, broad swales, strand swamps, sloughs, and



Limpkin. *Original photograph by Betty Wargo.*

impoundments in South Florida (Rodgers *et al*. 1996). Their diet consists of apple snails, other snails, freshwater mussels, lizards, insects, frogs, worms, and crustaceans. Nesting occurs in a mat of aquatic vegetation. Because apple snails depend on freshwater quality and abundance for the health of their forage plants and their own physiological needs, altered hydrology, pollution, and exotic plant proliferation are the notable threats to snail populations (Rodgers *et al*. 1996). The limpkin's apparent dependence on the apple snail is its chief vulnerability. The limpkin will probably remain locally wherever apple snails are abundant. Limpkins forage by sight and touch when wading on the bottom or by walking on dense mats of floating vegetation. Natural seepage swamps provide optimal water depths for limpkin foraging. The State of Florida has designated the limpkin as a species of special concern.

Plant Species of Concern

Plants considered as imperiled by FNAI and Florida Department of Natural Resources (1990) that occur in bayhead or hydric hammock communities include: star anise (*Illicium parviflorum*), hand fern (*Cheiroglossa palmata*), ray fern (*Actinostachys pennula*), ghost plant (*Lephaimos parasitica*), auricled spleenwort (*Asplenium auritum*), terrestrial peperomia (*Peperomia humilis*), and Tampa vervain (*Glandularia tampensis*).

Hand fern *(Cheiroglossa palmata)* grows as epiphytes in the "boots" (leaf bases) of cabbage palms, where it thrives on the warm humid atmosphere of the hydric hammock. Without this warmth and humidity, it is vulnerable to droughts and freezes. The fires that typically maintain cabbage palm stands usually destroy hand ferns, however. This means that hydric hammocks with hand ferns must be carefully managed so that the burning necessary for maintenance of the palm groves does not eliminate the ferns. It also suggests that these ferns might be reintroduced to hammocks where such sensitive fire management is now feasible.

Ecology

Hydrology

Baygalls are fed by seepage from upslope communities, although downslope high water tables may also contribute to soil saturation where they are located along floodplains.

The hydrologic regime of bog-type bayheads is dominated by capillary action that draws water up from below. Significant surface flooding is rare in these hydrologically stable systems.

Hydric hammocks typically flood for brief periods seasonally, but the hydroperiod seldom exceeds 60 days per year. If the water table is lowered, a hydric hammock will gradually change into a mesic system. If the hammock is flooded for more extended periods than normal, many trees will eventually die and be replaced by more hydrophytic species.

Fire

Since baygalls rarely dry out enough to burn, the normal fire interval in these communities is probably 50 to 100 years or more. After a fire, bay trees usually resprout from the roots and replace themselves, but severe fires may change a baygall into a different community. If only a small amount of surface peat is removed, this may become a wet flatwoods community. If the ground surface is lowered considerably, willows may invade, followed by a cypress-gum community. With recurrent fire, the site will become a shrub bog.

Fire frequency in bog-type bayheads is highly variable. In shrub bogs they may normally occur every 3 to8 years, whereas in woody bayheads every 50 to 150 years is probably a more reasonable estimate.

Because of their damp soils and the sparseness of herbaceous ground cover, hydric hammocks rarely burn. Those with abundant cabbage palms are an exception, however. In these communities, the flammable palm fronds readily carry fires that favor survival of the fire-resistant palms over other components of the hammock flora. This feedback loop results in the palm-dominated hammocks that characterize fire-maintained prairie landscapes.

Status and Trends

Although a number of researchers have estimated wetland loss rates in Florida, little of this data is refined enough to permit meaningful estimation of the extent to which seepage swamps have been lost. Between 1940 and 1980, Florida's total forested area declined by 27 percent (Knight and McClure 1982 cited in Noss *et al*. 1995). Since 1970, forested wetland communities throughout Florida have been reduced by 17 percent (Noss *et al.* 1995).

Land cover changes in Florida since European colonization have been estimated based upon mapping of historic vegetation types (Davis 1967, Cox *et al*. 1997). Of the forested wetland communities, 54 percent of the areas of abundant cabbage palms and 38 percent of the original wetland hardwood forests remain. The percentage of these remaining forested wetlands in Florida

that have been protected through public ownership to be managed as natural areas are as follows: 18 percent of the areas of abundant cabbage palms and 15 percent of the wetland hardwood forests (Cox *et al*. 1997).

Using 1985 to 1989 Landsat satellite imagery for Florida, another mapping analysis estimated that managed areas protect 58 percent of remaining shrub swamps, 25 percent of bay swamps, and 25 percent of hardwood swamps (Kautz *et al.* 1993 cited in Cox *et al*. 1997).

Comparative analysis of 1986 and 1991 Landsat imagery showed that St. Lucie County lost 5.9 percent of its hydric hammocks and 1 percent of its bayheads during that 5-year period (Duever *et al*. 1992).

In the Lake Placid-Sebring area, 607 ha (1,500 acres) of Lake Wales Ridge baygall has been converted to caladium production (Miller 1997).

Changes in the landscape matrix affect seepage swamps. Conversion of adjacent lands to pastures, farm fields, citrus groves, and residential developments interferes with normal interactions between habitats.

Development of much of the surrounding landscape has increased the amount of runoff that must be absorbed by the remaining wetlands. Drainage of irrigated agricultural lands into seepage swamps can change the hydrological regime to one dominated by flooding, rather than saturation, and lead to vegetation changes resulting in eutrophic hardwood swamps.

In the United States, agricultural practices account for greater than 87 percent of recent wetland losses (Nelson 1989 cited in Noss *et al*. 1995).

Agricultural runoff also poses a contamination threat. Not only does it commonly contain pesticides, but it is typically enriched with fertilizer residues. These fertilizers contain nutrients that promote eutrophication. Since fertilizer composition is unregulated and many fertilizer components originate as industrial byproducts, such runoff can also be a source of toxic waste contamination.

Borrow pits, surface mines, and wellfield drawdowns can lower water tables and impact seepage swamp hydrology. Conversely, bayheads may be transformed into swamps, and hydric hammocks may lose their upland flora components when weir levels are set too high.

Exotic species invasion is an increasing problem in drained and/or disturbed seepage swamps. Exotic plants reported from this community include: melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), Japanese climbing fern (*Lygodium japonicum*), and skunk vine (*Paederia foetida*).

Exotic animals include: hog (*Sus scrofa*), Cuban treefrog (*Osteopilus septentrionalis*), and walking catfish (*Clarias batrachus*).

Although the species that grow in seepage swamps are generally not in demand for timber, many materials are occasionally harvested from these habitats. Deer, hogs, and other game animals are hunted here, which affects herbivore-vegetation and predator-prey relationships. Collection of medicinal herbs is increasing in all habitats and may impact seepage swamp vegetation.

The Seminole and Miccosukee Indians have traditionally used various materials from these ecosystems, including cabbage palm fronds for chickee roofing and “swamp cabbage” (hearts of palm) for food. Swamp cabbage has also been part of the traditional diet of the Cracker settlers and their descendents.

Removal of cabbage palms for landscaping has become an increasingly common practice. Large numbers of mature palms are dug from South Florida hydric hammocks and shipped to urban areas as far away as south Texas.

Cattle grazing to some degree impacts the outer edges of many seepage swamps, although cattle rarely venture far into these habitats.

Beekeeping practices may have serious effects on pollinator ecology. Exotic honeybee colonies are maintained in or near many seepage swamps. How this affects native pollinators and the reproduction of native plants is unknown. Beekeeping also poses hazards to black bears, since beekeepers sometimes shoot bears who foil their electric fences and raid their hives. Since seepage swamps are important bear habitat, such interactions are of particular significance in these areas.

Management

Land Protection

Preservation of seepage swamps in intact landscape matrices with secure hydrological regimes is the highest land protection priority. Table 1 lists conservation lands that protect important seepage swamps.

Regulatory Mechanisms

The natural resource conservation elements of county comprehensive plans, county and state development permitting policies, pollution control and vegetation management regulations, and DEP and water management district water resource protection and wetlands permitting procedures help protect pond swamps. Underfunded enforcement programs limit the effectiveness of these regulations, however. Better enforcement of existing regulations is more critical than enactment of new ones.

Restoration Projects and Programs

Historically, most wetlands restoration efforts have been directed at marsh ecosystems. Only within the past 15 to 20 years have there been significant attempts to restore forested wetlands (Clewell and Lea 1990). Given the timeframe necessary for forest regrowth, most of these projects are still too new for critical evaluation.

Forested wetland restoration efforts have been focused on two types of situations: reforestation of lands cleared for agriculture and subsequently abandoned (where the main objective is to establish a forest canopy) and restoration of wetlands cleared for surface mining projects (where the objective has been to replace the full spectrum of tree species and undergrowth components, with considerable attention given to establishing the appropriate hydrology and hastening soil development (Clewell and Lea 1990).

Based on a review of forested wetlands restoration projects, Clewell and Lea (1990) have identified six critical factors that interact to determine whether or not a project will be successful. They are hydrology, substrate stabilization, rooting volume, soil fertility, control of noxious plants, and herbivore control.

Specifically, cooperation among engineers, hydrologists, and soil scientists must be encouraged to ensure that water delivery timing, depth, and quality are synchronous with the natural systems being emulated (Clewell and Lea 1990).

Flood tolerance varies widely among different species and among different size classes within species and is also dependent upon stage of the growing season (Bedinger 1978). Newly planted vegetation is particularly susceptible to water stress.

Topographic relief should be planned with substrate stabilization in mind, as project sites are often open and subject to erosion which hinders the establishment of trees and undergrowth (Clewell and Lea 1990).

Soil volume must be considered as roots need an adequate volume of soil to anchor themselves and exploit moisture and nutrients (Clewell and Lea 1990). Rooting volume may be limited by depth to the wet season water table and mechanical resistance where soil density has been increased by compaction caused by heavy equipment at project sites (Clewell and Lea 1990).

Soil fertility varies considerably with the project site. Fertilization is usually necessary to prevent trees from languishing so long as saplings that they are suppressed by weeds (Clewell and Lea 1990).

Control of noxious plants is necessary where their proliferation threatens to suppress desirable species. Certain tall weed species may be beneficial as shelter for young trees, however (Clewell and Lea 1990).

Management Strategies and Techniques

Note that SWFWMD has budgeted funds for research into biological control of skunk vine (Kelley 1998) and that Japanese climbing fern is promptly treated with herbicide when detected on SJWMD lands.

Informal roads and trails can create wide muddy swaths and gullies through wetlands. Various types of web mats can be used to stabilize such trails. Geoweb has been used successfully for this purpose on SJWMD lands in Osceola County.

Synonymy Tables:

HYDRIC HAMMOCK

Kuchler	113/Southern floodplain forest
Davis	8/Swamp forests
	12/Hardwood forests
SCS	12/Wetland hardwood hammocks
Myers & Ewel	Temperate hammocks-hydric hammocks
SAF	73/Southern red cedar
	74/Cabbage palmetto
FLUCCS	617/Mixed wetland hardwoods

Other synonyms include Gulf hammock.

BAYGALL

Kuchler	112/Southern mixed forest
Davis	2/Pine flatwoods
	8/Swamp forests, mostly of hardwoods
SCS	12/Wetland hardwood hammocks
	22/Shrub bog
Myers & Ewel	Freshwater swamp forests-titi swamps, bayheads
SAF	85/Slash pine-hardwood
	104/Sweetbay-swamp, tupelo-redbay
FLUCCS	611/Bay swamps
	614/Titi swamps

Other synonyms include seepage swamp, bayhead, bay swamp, sandhill bog.

Synonymy Tables: *cont.*

BOG (INCLUDES BAYHEAD):

Kuchler	112/Southern mixed forest
Davis	8/Swamp forests, mostly of hardwoods?
SCS	22/Shrub bog
Myers & Ewel	Freshwater swamp forests-shrub bogs
FLUCCS	310/Herbaceous

Other synonyms include bog swamp, shrub bogs, evergreen shrub bogs, wet scrub/shrub systems.

GFC's Bay swamp can be considered roughly equivalent to seepage swamps.

The following GFC's GAP analysis categories are included within Seepage Swamps:

3	I.A.3.N.f.010	*Magnolia virginiana-Chrysobalanus icaco forest* Alliance (which is included in FNAI's Bog)
9	I.A.4.N.e.020	Sabal palmetto-*Quercus virginiana* temporarily Flooded Forest Alliance (equivalent to the fire-maintained version of FNAI 's hydric hammock
53	III.C.2.N.e.	Saturated mixed evergreen-cold-deciduous shrubland
22	I.C.2.N.c.	Seasonally flooded mixed broad-leaved evergreen-cold-deciduous forest (equivalent to FNAI's hydric hammock)

Where associated with the above types, the following GFC's GAP analysis community may also be classified under seepage swamps:

36	III.A.1.N.c.030	*Myrica cerifera-Ilex cassine* Shrubland Alliance

Table 1. Proposed conservation lands important to seepage swamps

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
Allapattah Flats	The southwest corner of this site incorporates a major hydric hammock with tropical components to the flora. This area has been affected by grazing and soil subsidence.	1997 CARL Bargain 15, SFWMD Project
Atlantic Ridge Ecosystem	Includes outstanding baygalls and some forested sloughs.	1997 CARL Bargain 2, SFWMD Project
Bright Hour Watershed	Mostly dry prairie with some basin swamps and a classic 100-acre baygall with gordonia. Six major slough systems within the proposed acquisition make up much of the headwaters of Prairie and Shell creeks.	SWFWMD Group "C" Project (Land to be evaluated)
Catfish Creek		1997 CARL Priority 22, SFWMD Project
Cypress Creek/Trail Ridge	Cypress and pine have been logged out of hydric hammocks and basin swamps north of SR 70, and flows from Cypress Creek, which historically passed under SR 70, have been routed west through a ditch along the north side of the highway. Most of the historic slough remains intact south of SR 70, where very little logging or ditching has been done. The Carlton lands include an impressive stand of virgin cypress (FNAI Basin Swamp EOR # 066). There are bayheads and cypress domes and a band of hydric hammock (Van Swearingen Creek) in the Trail Ridge area along the west side of Bluefield Road.	SFWMD Project
Fisheating Creek	Habitats include cypress slough/mixed hardwood swamp forest, emergent marshes, willow thickets, baygalls, and openwater ponds and runs. New CARL boundaries include valuable matrix of dry and wet prairies, baygalls, and cutthroat seeps. Feral hogs are a problem.	SFWMD Project
Green Swamp	There are good strand swamps with hydric hammock islands on the Jahna property owned by sand mining company, but associated uplands have been cleared. The Overstreet tract in the southwest corner of the site has cypress domes, cypress strands, hydric hammocks, and floodplain swamps, which drain into Little Gator Creek, then into the Withlacoochee River.	1997 CARL Priority 20 and 1997 CARL LOF 1, SJWMD SOR and P-2000 Project, SWFWMD Project
Jack Creek	The forested wetlands along Jack Creek are dominated by a mixture of evergreen trees such as loblolly bay, sweetbay, and magnolia, along with red maple, blackgum, and cypress.	SWFWMD Project
McDaniel Ranch	This site includes major cypress strands including two virgin stands grading into a large area of hydric hammock in a healthy mosaic with expanses of marsh and wet prairie. The best natural areas are concentrated along the western and southern edges.	SFWMD conservation easement project. The McDaniel family will retain ownership and management responsibility with rights to use for timber management, cattle grazing, lease hunting, and eco-tourism.

Table 1. ***cont.***

Proposed Conservation Area	Notes on Forested Wetlands	Notes on Conservation Proposal
North Fork St. Lucie River	Greater than 80 percent of this site is floodplain wetlands, including hardwood swamp, hydric hammock, sawgrass marsh, and mangrove types.	1997 CARL Bargain 20, SFWMD Project
Okaloacoochee Slough	Wet flatwoods and hydric hammocks, dominated by live oaks and cabbage palms, fringe sawgrass. Recommended management is continued native range grazing with no pasture improvement or fertilization.	1997 CARL Bargain 14, SFWMD Project
Oslo Riverfront Conservation Area		SJWMD SOR and P-2000 Project, Indian River County
Parker-Poinciana	Includes mesic flatwoods, a large cypress/bay head, logged-over flatwoods, and hydric hammock along the Lake Hatchineha shoreline	SFWMD
Ranch Reserve	Headwaters of Blue Cypress Creek. Includes high quality cypress strands, cypress domes, and hydric hammocks in a flatwoods matrix.	1997 CARL LOF 4, SJWMD SOR and P-2000 Project. Conservation easements are key to protection strategy.
Upper Lakes Basin Watershed	Reedy Creek Swamp is an extensive area of mixed hardwood/cypress swamp running for nearly 40.2 km (25 miles) through western Osceola County, from the boundary of the Reedy Creek Improvement District to Cypress Lake. It includes the Huckleberry Islands and totals more than 12,141 ha (30,000 acres). Lake Marion Creek is in Polk County and flows from Lake Marion north and then southeasterly to Lake Hatchineha. The project area totals approximately 7,001 ha (17,300 acres), 1,538 ha (3,800 acres) of which are within the Southwest Florida Water Management District. Most of the project is forested swamp and needs no restoration. Reedy Creek Swamp has been fairly well protected because of its large size and inaccessibility. Unless high-density urban encroachments or damaging silviculture operations are permitted in the future, the swamp should be able to buffer itself. Exotic vegetation is not a problem, and it does not appear that hydrologic restoration will be necessary. The natural habitats within the Lake Marion Creek area are generally in good condition, although development has destroyed some scrub areas. The size of the property and the deep swamps allows the interior portions to remain buffered from activities along the ridge.	SFWMD Project, SFWMD envisions assistance from SWFWMD and CARL.

Table 2. Managed areas important to seepage swamps

Managed Area	Managing Entity
Avon Park Air Force Range	DOD
Collier-Seminole State Park	DEP
Three Lakes Wildlife Management Area	GFC
Triple N Ranch Wildlife Management Area	GFC

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Restoration of Seepage Swamps

Restoration Objective: Prevent further reduction in area of seepage swamps in South Florida, protect all remaining high quality habitat, and restore and manage protected lands to maintain ecological processes and biodiversity. Restoration and maintenance of water sources and hydrological regimes is critical.

Restoration Criteria

The recovery objective will be achieved when: (1) a reserve design incorporating all currently protected tracts and remaining high-quality habitat has been developed and implemented; (2) seepage swamps are protected through acquisition or cooperative agreements with landowners; (3) appropriate management plans have been prepared and funded for all lands within the reserve network; (4) restoration has been successfully initiated such that ecological processes are operating normally; and (5) natural succession and restoration actions through funded management programs can be expected to re-establish community structure and biodiversity on all significant degraded sites within the reserve network.

The reserve design must include appropriate linkages between major systems and incorporate the matrix of habitats necessary to maintain interactions between communities.

Appropriate water supplies and delivery must be assured for maintenance of normal hydrological conditions in all seepage swamps within the reserve system. Protection from unnaturally severe droughts and fires must be assured.

Community-level Restoration Actions

1. Prevent further destruction or degradation of existing communities.

1.1. Acquire threatened seepage swamps.

Table 2 presents land acquisition proposals that incorporate important seepage swamps that should be protected. Other important areas that should be protected include:

Baygalls along the mangrove edge at Pelican Bay in Collier County (FNAI EORs # 007 and 008) and similar nearby sites, if any of these still exist. Such baygalls have southernmost extensions for northern plants like jack-in-the-pulpit and represent an unusual coastal variation of the community.

Baygall in Osceola County, east of Lake Davenport (FNAI EOR #016). This site also includes diverse xeric habitats.

Hydric hammock in Osceola County, parallel to Bull Creek (FNAI EOR #027).

There are many other seepage swamps worthy of protection within local conservation systems. Natural landscapes, including healthy examples of such swamps, should be regarded as high priorities for local conservation efforts.

1.2. **Promote conservation easements and landowner agreements.** Appropriate agreements should be negotiated with landowners.

1.3. **Enforce regulatory protection.** Wetlands are seldom adequately monitored to assure compliance and penalties and enforcement are often inadequate to motivate adherence to the law. Increased funding for regulatory monitoring and enforcement programs is needed at all levels.

1.4. **Prevent degradation of existing preserves.** Conservation lands should be maintained according to management plans that assure that seepage swamps and their water sources are protected from degrading land uses.

2. **Manage seepage swamps within the context of restoration objectives.**

2.1. **Restore natural fire regimes.** Emphasize landscape-scale burning that permits fires to burn into the edges of wetlands naturally.

2.2. **Control exotic plants and animals.** Aggressively seek out and eliminate infestations of Japanese climbing fern and skunk vine. Control feral hog populations (with consideration for panther food base). Monitor other exotics in seepage swamps and promptly initiate control programs for those that threaten to become problematic.

2.3. **Restore ecosystem structure and composition** by manipulating existing populations of native species, augmenting populations of native species, and reintroducing extirpated plants and animals.

2.4. **Protect seepage swamps from point source and non-point source pollution.** Design restoration projects to restore entire landscapes of integrated upland and wetland communities so that wetlands are buffered from agricultural and urban runoff.

3. **Maintain seepage swamps in a natural condition.**

3.1. **Provide analogs for ecosystem functions such as fire regimes.**

3.2. **Continue to control exotic plants and animals in perpetuity.**

3.3. **Monitor for extirpations and extinctions,** and negative population trends of imperilled species, including pollinators, dispersers and soil organisms.

3.4. **Monitor and correct for both point source and non-point source pollution.**

4. **Restore seepage swamps where they have been destroyed.** Use research conducted by the Florida Institute of Phosphate Research, the University of Florida Center for Wetlands, and others to recreate seepage swamps according to the guidelines of the Society for Ecological Restoration.

4.1. **Restore ecosystem structure** including soils and soil organisms, hydrology, plants, and animals.

4.2. **Restore ecosystem functions** by controlling exotics and aggressive native weeds, restoring natural fire regimes, hydrologic processes, and natural biological interactions (food webs, nutrient cycling, *etc*.)

4.3. **Restore ecosystem composition** for late-succession species and rare species.

4.4. **Protect seepage swamps from both point-source and non-point-source pollution.**

5. **Connect appropriate habitats.**

5.1. **Connect ecological systems.** Pal-Mar, a project in northern Palm Beach and southern Martin counties, is a critical connection between J.W. Corbett WMA and

Jonathan Dickinson SP. When acquired, this would complete a 50,587 ha (125,000 acres) ecological greenway stretching from Dupuis Reserve close to Lake Okeechobee to Jonathan Dickinson SP.

5.2. Protect/restore landscape matrix. Preserve/restore uplands associated with seepage swamps. Change wetland permitting regulations so that upland recharge areas that feed seepage systems can be restored as wetland mitigation.

5.3. Assure maintenance of linkages critical to key species and functions.

6. Conduct research.

6.1. Determine distribution of remaining seepage swamp habitat.

6.1.1. Develop strategies for gathering, synthesizing, and groundtruthing data to permit seepage swamp types to be readily distinguished on GIS maps.

6.1.2. Assess and supplement available data.

6.2. Improve reference ecosystem information regarding community composition, biodiversity, and site-to-site variability.

6.3. Investigate roles of pollinators, mycorrhizae, seed dispersers, and other critical or keystone species.

6.4. Evaluate predator-prey relationships in landscape context.

7. Monitor community-level processes, community structure, and community composition including rare and keystone species.

8. Increase public awareness. Landowners need to be taught to recognize seepage swamps as wetlands subject to wetland regulations. Because these communities are rarely flooded, it may be difficult to understand that they are wetlands.

Mangroves

FNAI Global Rank:	**G3**
FNAI State Rank:	**S3**
Federally Listed Species in S. FL:	**9**
State Listed Species in S. FL:	**46**

Red Mangrove. (*Rhizophora mangle*) *Original photograph courtesy of Florida Department of Environmental Protection.*



The mangrove forests of South Florida are a vital component of the estuarine and marine environment, providing a major detrital base to organic food chains, significant habitat for arboreal, intertidal and subtidal organisms, nesting sites, cover and foraging grounds for birds, and habitat for some reptiles and mammals. The relationship between mangroves and their associated marine life cannot be overemphasized. The mangrove forest provides protected nursery areas for fishes, crustaceans, and shellfish that are important to both commercial and sport fisheries.

The value and central role of mangroves in the ecology of South Florida has been well established by numerous scientific investigations directed at primary productivity, food web interactions, listed species, and support of sport and commercial fisheries. Mangroves are important in recycling nutrients and the nutrient mass balance of the estuarine ecosystem. They are one of the highest primary and associated secondary biologically productive ecosystems in the world. Mangroves provide one of the basic food chain resources for arboreal life and nearshore marine life through their leaves, wood, roots, and detrital materials. This primary production forms a significant part of the base of the arboreal, estuarine, and marine food web. Mangroves have a significant ecological role as physical habitat and nursery grounds for a wide variety of marine/estuarine vertebrates and invertebrates. Many of these species have significant sport fishery and/or commercial fishery value. Approximately 224,579 ha (554,515 acres) of mangroves remain in central and South Florida. This tropical ecosystem is a habitat unique in the continental United States. They deserve special protection because of this uniqueness and because of the multiple ecological functions they provide. Mangroves have a significant ecological role as habitat for endangered and threatened species, and species of special concern. For several of these species, the habitat is critical and vital to their continued survival. Mangroves serve as storm buffers

by functioning as wind breaks and through prop root baffling of wave action. Mangrove roots stabilize shorelines and fine substrates, reducing turbidity, and enhancing water clarity. Mangroves improve water quality and clarity by filtering upland runoff and trapping waterborne sediments and debris. Unaltered mangroves contribute to the overall natural setting and visual aesthetics of Florida's estuarine waterbodies. Through a combination of the above functions, mangroves contribute significantly to the economy of the coastal counties of South Florida and the State of Florida.

Synonymy

The sense of synonymy for mangroves is unusual in that the same term is used to describe both the individual tree species and the total plant community including the individual tree species. Synonyms for the term mangrove include tidal forest, tidal swamp forest, mangrove community, mangrove ecosystem, mangal (Macnae 1968), and mangrove swamp (Odum *et al.* 1982). The term mangal is used by researchers, authors, and the general public in the United Kingdom and other countries. Often mangal, or mangle, is used both for the red mangrove and the mangrove forest of which it is a part. The FLUCCS codes for mangroves include: 612 (mangrove swamps).

Distribution

There are approximately 55 mangrove species worldwide, with the center of diversity in Southeast Asia. Four species occur in South Florida: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*).

Mangroves are tropical species restricted by frost and vegetative competition to intertidal regions in tropical and subtropical sheltered waterbodies. Mangroves in the subtropical regions of South Florida represent the northern limits of tropical species that have been able to colonize because of the warm ocean waters and warm currents along the Florida coastline and dependably warm winters (Tomlinson 1986). The red mangrove is the mangrove tree most susceptible to damage from frost. White mangrove and buttonwood are less susceptible and the black mangrove is the most cold-tolerant of the Florida mangroves. Freeze damage to mangroves is well documented (Chapman and Ronaldson 1958, Lugo and Patterson-Zucca 1977) and frequently reported anecdotally.

The distribution of mangroves in North America has changed through geologic time. When the red mangrove evolved in the Cretaceous, Florida was a great coral reef in shallow seas. There may have been a few mangroves surrounding small islands and on the coastline in what is currently Georgia. Black and white mangroves evolved during the Eocene and extended as far north as South Carolina. During the Pleistocene, mangroves were absent from the Florida coastline and *Spartina* marshes dominated the estuarine intertidal zone. During the past few centuries, mangrove distribution has changed in response to short-term climatic fluctuations (Odum *et al.* 1982).

Red and white mangroves have been reported as far north as 29N latitude: near Ponce de Leon Inlet on the east coast and Cedar Key on the west coast of Florida. Black mangroves occur further north than reds and whites and have been

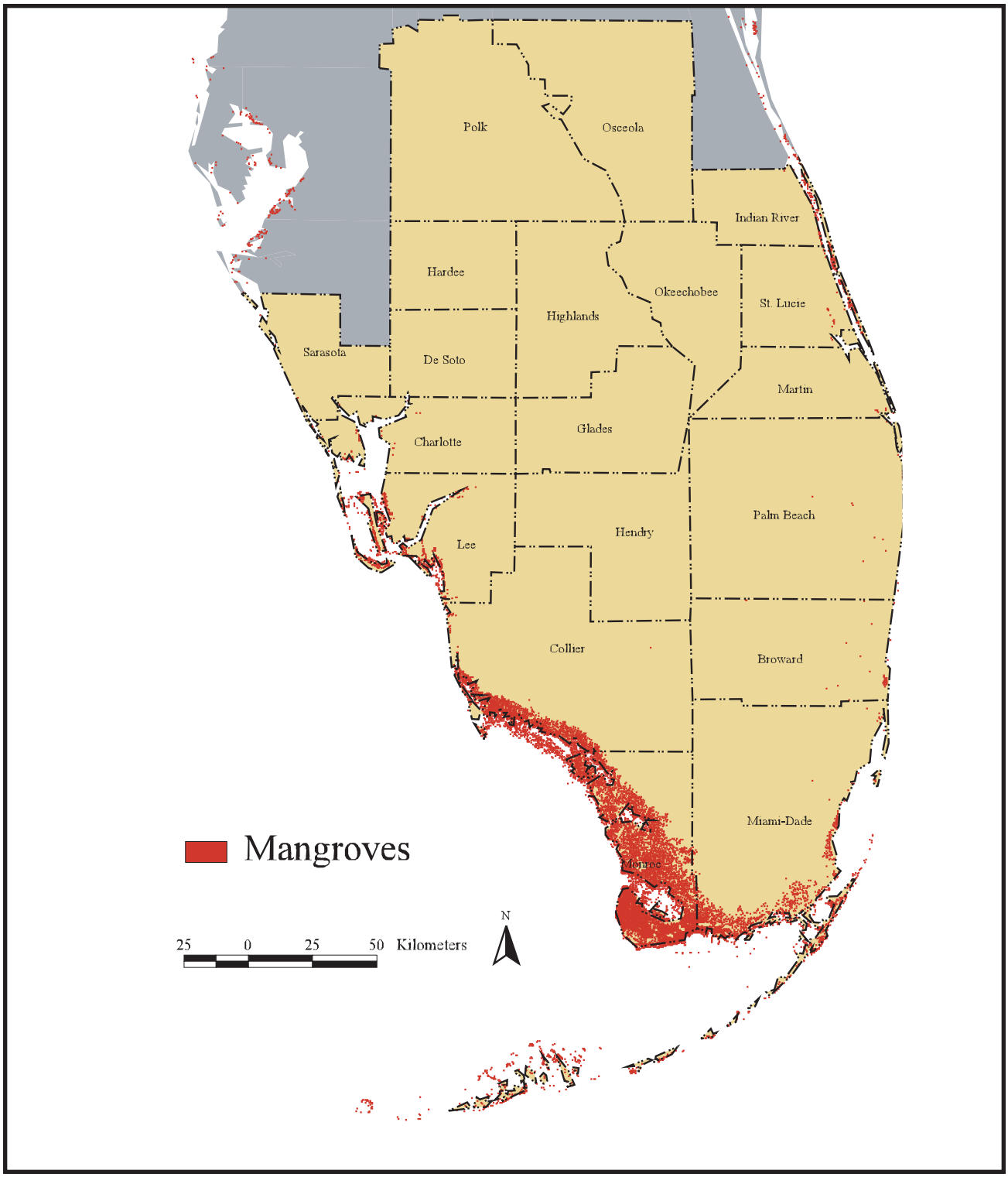


Figure 1. The distribution of mangroves in South Florida (adapted from USGS-BRD 1996).

reported as far north as 30N latitude on the east coast of Florida (Odum *et al.* 1982) and are distributed as a shrub around the Gulf of Mexico where vegetated shorelines have survived development. Over 90 percent of the mangroves in Florida occur in the four southern counties of Lee, Collier, Miami-Dade, and Monroe (Figure 1).

The availability of fresh water and nutrients influences the location, size, structure, and productivity of mangrove communities in South Florida. Mangroves reach their greatest abundance in southwest Florida where the positive interaction of fresh water and nutrient inputs with lower wave energy shorelines occur. In southeast Florida, mangrove development has historically been limited by the lack of fresh water and nutrients combined with narrow intertidal zones and high wave energy. Along the central east cost (Indian River Lagoon) and parts of the west coast (Charlotte Harbor and Sarasota Bay), mangrove communities support the continued existence of barrier islands against tidal and wave forces. The Everglades system changes from fresh water to an extensive mangrove community at its seaward margin of Florida Bay.

Fluctuations in sea-level rise along the Florida peninsula can limit the distribution of mangroves, particularly if the rate of sea-level rise exceeds the rate of mangrove forest growth and substrate accretion, and if the landward slopes provide no suitable habitat for forest retreat as sea-level rises (Wanless 1998). Areas with seawalls behind mangrove habitat prevent such shoreline adjustment.

The local distribution of mangroves is affected primarily by a variety of interacting factors that include microclimate, substrate type, tidal fluctuation, terrestrial nutrients, wave energy, and salt water. Sea-level rise, shore erosion, interspecific competition, and seed dispersal also affect local distribution to a lesser degree. The interrelations of these factors can alter the intertidal distribution of mangrove species. Mangroves are unique in that their morphological specialization, such as aerial roots, vivipary, and salt excretion or excluding abilities, allow them to adapt to these different rigorous environmental factors.

Description

Mangrove ecosystems are a mosaic of different types of forest, with each type providing different physical habitats, topology, niches, microclimates, and food sources for a diverse assemblage of animals. Mangroves have important structural properties including: the trapping and stabilization of intertidal sediments; the formation of organic soils and mucks; providing protection from wave and wind erosion; providing a dendritic vegetative reef surface in the subtidal and intertidal zones; and forming a structural complex of a multi-branched forest with a wide variety of surface habitats (Savage 1972).

Red mangrove

Red mangroves are distinguished by the dendritic network of aerial prop roots extending from the trunk and lower branches to the soil. The prop roots are important adaptations to living in anaerobic substrates and providing gas exchange, anchoring system, and absorbing ability. Within the soils, micro-roots stabilize fine silts and sands maintaining water clarity and quality. Red mangroves may attain heights of 25 to 38 m (82 to 125 ft) in the rich deltas of

riverine forests, but average 8 to 10 m (26 to 33 ft) on most fringing shorelines, and occur as smaller trees at their northern extents or in marginal habitats such as the coral rock salt ponds of the Florida Keys. Bark is grey and the interior red. Red mangroves can form a variety of crown shapes from short continuous scrubby crown to uneven discontinuous crowns. As trees age, gaining size and putting down large prop root supports, significant horizontal as well as vertical growth occurs. This horizontal growth habit has led to the metaphor of "walking trees." The leaves are shiny, deep green on the surface and paler underside. Flowers are small, white, four-petalled, four-bracted, and wind pollinated. The germinated seed produces a long (25 to 30 cm, or 10 to 12 in) pencil or torpedo-shaped propagule.

Black mangrove

Black mangroves have distinctive horizontal cable roots that radiate from the tree with short, vertically erect aerating branches (pneumatophores) extending 2 to 20 cm (0.8 to 7.9 in) above the substrate. The trees grow straight, attaining heights of 40 m (131 ft) and averaging 20 m (66 ft). The bark is dark and scaly. They have narrow, elliptic or oblong leaves that are shiny dark green above and pale almost cream green with short dense hairs below. The upper surface of leaves can be encrusted with salt excreted by the tree. The bilaterally symmetric white flowers are showy and pollinated by Hymenoptera (Tomlinson 1986). The black mangrove is the source of mangrove honey. The germinated seed produces a "lima bean size and shaped" propagule (Odum and McIvor 1990). Black mangroves are shade tolerant and sun intolerant when immature (Snedaker 1982). As it matures, the black mangrove becomes shade intolerant. This provides different growth forms in immature and mature trees.

White mangrove

White mangroves grow either in tree form or shrub form up to heights of 15 m (49 ft) or more. The growth form tends to be erect. Some white mangroves form erect, blunt-tipped pneumatophores if growing in anaerobic or chemically stressed soils. Bark is white and relatively smooth. Leaves are fleshy, flattened ovals with rounded ends. The same pale green color is on both upper and lower surfaces. Two glands are found at the apex of the petiole that excrete salt and extra floral nectar. Small yellowish flowers are found in alternate rows on the terminal ends of branches. These germinate into small "football-shaped" propagules (1 to 1.5 cm, or 0.4 to 0.6 in). In the northern part of their range, white mangroves may not propagate on the tree and true propagules are not formed.

All three mangrove species flower in the spring and early summer. Propagules fall from late summer through early autumn.

Buttonwood

Buttonwoods grow to 12 to14 m (39 to 46 ft) in height in a shrub or tree form, but do not produce a true propagule in Florida (Tomlinson 1986). Bark is grey and very furrowed providing attachment for epiphytes. Leaves are thin, broad-to-narrow, and pointed. There are two morphotypes: the green with medium green leaves found on peninsular Florida and the silver with pale pastel green

leaves historically limited to the Florida Keys but now widespread by nursery practices. It is thought the silver buttonwood is an adaptation to the rocky, dry habitats associated with the Keys archipelago. Two glands are found at the apex of the petiole that excrete extra floral nectar and salt. Tiny brownish flowers are found in a sphere on the terminal ends of branches. These produce a seed cluster known as the button. Buttonwoods are able to grow in areas seldom inundated by tidal waters. The mangrove adaptations to the osmotic desert of salt water, also adapted buttonwoods to arid areas of barrier islands and coastal strands.

Community Types

Six mangrove community types have been characterized based on their different geomorphic and hydrological processes (Lugo and Snedaker 1974). Overwash mangrove forests are islands frequently inundated or washed over by tides, resulting in high rates of organic matter. They usually contain red mangroves with a maximum height of 7 m (23 ft). Fringe mangroves form thin forests bordering waterbodies with standard mangrove zonation, attaining a maximum height of 10 m (33 ft). Riverine mangroves are in the floodplains and along embankments of tidal creeks and rivers but still get flooded by daily tides. Riverine forests have higher levels of productivity than the other mangrove community types as a result of increased nutrient availability, litter fall, and tidal flushing. All three species are present and the canopy layer can reach heights of 18 to 20 m (59 to 66 ft).

Basin mangrove forests occur in depressions along the coast and further inland that collect precipitation and sheetflow that are tidally influenced and can attain heights of 15 m (49 ft). Red mangroves are more common along the coastal areas, while black and whites dominate further inland. Influences from daily tides decrease further inland. In areas where salinity is concentrated by evaporation, black mangroves dominate and major tidal flushing occurs seasonally. Hammock forests grow on higher elevated, typically highly organic grounds and rarely exceed 5 m (16 ft) in height. These are often surrounded by other wetland types such as salt marsh. Scrub or dwarf forests are found in peninsular South Florida and the Florida Keys and rarely grow taller than 1.5 m (4.9 ft), which may be a result of fewer available nutrients and rocky substrates.

Mangrove forest canopy heights depend upon climate, topography, substrate type, and the extent of human disturbance. Undisturbed mature mangrove communities have a high, dense, complex, continuous canopy; whereas, in naturally disturbed mangrove areas, the canopy is lower with more irregular growth (Tomlinson 1986). Dense mangrove forests do not typically have understory plant associations, except for mangrove seedlings.

Areas of tree fall or other open canopy provide opportunity for other halophytic plants and young mangroves to flourish in available sunlight. Mangrove associates including up to 30 species of vascular plants occur in transitional areas with mangroves, but are not restricted to mangrove communities. Several saltmarsh grasses (*Juncus*, *Sporobolus*, *Monanthochloe*, *Distichlis*) and succulent herbs (*Salicornia*, *Sesuvium*, *Batis*) occur with

mangroves along transition zones of saline marshes. Smooth cordgrass (*Spartina alterniflora*) communities often colonize bare emergent areas near mangrove forests, but are eventually displaced by mangroves shading them.

Wildlife Diversity

Mangrove ecosystems are important habitat for at least 1,300 species of animals including 628 species of mammals, birds, reptiles, fish, and amphibians. They provide areas for breeding, nesting, foraging, and shelter (Odum *et al.* 1982, Beever 1989, Day *et al.* 1989, Odum and McIvor 1990). The mangrove forest provides a multitude of habitats for resident, seasonal, and transient organisms from adjacent terrestrial and marine habitats (refer to Appendix C). Many of the larger motile species are not restricted to mangroves, but are seasonal or opportunistic visitors. However, most invertebrate and some resident vertebrate species are totally dependent upon mangroves to survive and complete important life cycle functions (Tomlinson 1986). Fish and invertebrates from the marine environment are frequent visitors to mangrove communities, as are birds and mammals from nearby terrestrial systems.

Vertebrate species that utilize mangroves throughout the year are capable of tracking the changes in food availability as mangroves bloom, germinate, and fruit, and the subsequent changes in invertebrate and small vertebrate populations in response to these food resource changes. Other vertebrate species visit the mangrove habitat during the period that best suits their life cycle. The most seaward habitat is the mangrove fringe area containing red and/or black mangroves. The littoral and benthic components of this microhabitat contribute to the structure and resources available to organisms. As previously discussed, prop roots of red mangroves support a specific microhabitat for resident species (*e.g.*, tunicates, crustaceans, mollusks, fishes) that spend their entire life cycle either on or among the root systems. Transient species are not dependent upon prop roots, but use them intermittently for shelter, feeding, and/or breeding. The prop root system also provides an important nursery for organisms (*e.g.*, crustaceans, mollusks, fishes) that develop here and spend their adult lives elsewhere (Odum and McIvor 1990).

One hundred and ninety-one bird species known from South Florida are found in mangrove communities. Many of the birds associated with mangroves are neotropical migratory birds that utilize the habitat in their migration from northern breeding grounds to southern wintering grounds in autumn and their subsequent return in spring. The high productivity of mangrove ecosystems provides an energy source important for migrating bird species traveling on long distance routes (Day *et al.* 1989). These neotropical migratory birds are a focus of considerable concern since many species are apparently in decline due to habitat loss in northern breeding grounds, southern wintering grounds, and the stopovers in the migratory corridor in coastal Florida. Other birds, including shorebirds, ducks, and perching birds, migrate to their wintering grounds in South Florida and are found only in late autumn, winter, and early spring.

Mangrove canopies provide habitat for some species of songbirds that occur only in this habitat type, such as the black-whiskered vireo (*Vireo*

altiloquus), mangrove cuckoo (*Coccoyzus minor*), yellow warbler (*Dendroica petechia*), and Florida prairie warbler (*D. discolor*). The black-whiskered vireo nests primarily in red mangroves up to 5 m (15 ft) above the ground. Considered a rare bird species by FCREPA, the mangrove cuckoo requires large expanses of undisturbed forested mangrove and hardwood hammock habitat found primarily in the southernmost parts of Florida, from Charlotte Harbor to the Florida Keys (Smith 1996). The mangrove cuckoo nests on horizontal branches of mature mangrove trees. The yellow and Florida prairie warblers nest 3 to 6 m (10 to 20 ft) high in mangroves.

In addition to these mangrove endemic species, many estuarine birds utilize fringing mangrove forest as loafing areas and foraging perches. Included in this group are osprey (*Pandion haliaetus*), northern harrier (*Circus cyaneus*), sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), red-shouldered hawk (*Buteo lineatus*), broad-winged hawk (*Buteo platypterus*), short-tailed hawk (*Buteo brachyurus*), red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), peregrine falcon (*Falco peregrinus tundrius*), bald eagle (*Haliaeetus leucocephalus*), merlin (*Falco columbarius*), kingfisher (*Megaceryle alcyon*), eastern brown pelican (*Pelecanus occidentalis*), double-crested cormorant (*Phalacrocorax auritus*), anhinga (*Anhinga anhinga*), and a variety of wading birds. As loafing areas, this habitat provides resting areas near their food supplies. This allows the use of foraging habitat distant from nighttime roosts or nesting areas without the added energy cost of flight. For other species in this group, the height of the mangroves offers a better view of prey.

Twenty-four taxa of reptiles utilize the aquatic and arboreal habitats of the mangroves. Resident species include the mangrove water snake (*Nerodia fasciata compressicauda*), the threatened Atlantic salt marsh snake (*Nerodia fasciata taeniata*), rough green snake (*Opheodrys aestivus*), the threatened eastern indigo snake (*Drymarchon corais couperi*), yellow rat snake (*Elaphe obsoleta quadrivittata*), green anole (*Anolis carolinensis*), mangrove terrapin (*Malaclemys terrapin rhizophorarum*), American alligator (*Alligator mississippiensis*), and the endangered American crocodile (*Crocodylus acutus*). The threatened loggerhead sea turtle (*Caretta caretta*) and the endangered green sea turtle (*Chelonia mydas*) are found in association with mangrove-lined shorelines along tidal passes and within estuarine embayments.

Five amphibian species utilize the mangrove habitat for feeding and/or breeding. The most frequently encountered and abundant amphibians are tree frogs (*Hyla* spp.) and, unfortunately, the exotic marine toad (*Bufo marinus*). No State listed amphibians are found in mangrove habitats. The amphibian life cycle is poorly adapted to the saline environment required by mangroves.

The value of the red mangrove as the basis of the detrital food chain of estuarine waters is well documented (Odum *et al.* 1982, Seaman 1985, Hutchings and Saenger 1987). It is recognized that over 90 percent of commercial fishery species and at least 70 percent of sport fishery species depend upon the natural mangrove forest for food and habitat as a critical part of their life cycles (Lewis *et al.* 1985). In concert with seagrass beds, macrophytic algae, phytoplankton, benthic microalgae, and emergent marshes, the mangroves provide the primary

productive food base of the estuarine system. The detritus provided by decomposition of seasonally shed mangrove leaves is the food base for microcrustaceans and other detrital processors that are consumed by macrocrustaceans, small fishes, and other first order predators. The animals in turn are the prey of larger fish species such as snooks (*Centropomus* spp.), snappers (*Lutjanus* spp.), jacks (*Caranx* spp.), tarpon (*Megalops atlantica*), sheepshead (*Archosargus probatocephalus*), spotted seatrout (*Cynoscion nebulosus*), and redfish (*Sciaenops ocellatus*). Based on surveys performed during the preparation of the Charlotte Harbor Aquatic Preserve Management Plan, at least 230 species of fish utilize the mangrove ecosystem of Charlotte Harbor for food, shelter, breeding and/or nursery grounds (Beever 1988).

The dominant fish species of the basin mangrove forests are poeciliids, the mosquitofish (*Gambusia* spp.), the least killifish (*Heterandria formosa*), and the sailfin molly (*Mollienesia latipinna*). These cyprinodont fish are a fundamental link between primary producers and higher trophic level fish and wildlife species. The typical cyprinodont diet consists of plant and animal tissue, including periphyton, insect larvae, and vascular plant detritus. They subsequently are food for sport fish and wading bird species. Fourteen of the 54 freshwater fish species found in South Florida (Kushlan and Lodge 1974) utilize the mangrove wetlands during the wet season, high-runoff flow events (Odum *et al.* 1982).

Most of the 350 species of marine invertebrates in Charlotte Harbor are found in or depend on mangroves for habitat or food. The arboreal canopy provides habitat to both aquatic and amphibious resident and transient species (Simberloff and Wilson 1969, Beever *et al.* 1979, Odum and McIvor 1990). Approximately 264 species of arboreal arthropods inhabit the mangrove canopy, branches, and wood (Beever *et al.* 1979). Aquatic organisms, such as crabs and snails, spend part of their time in the water, but can also migrate up into the canopy of mangroves.

Wildlife Species of Concern

Federally listed species that depend upon or utilize the mangrove community in South Florida include: Florida panther (*Puma (=Felis) concolor coryi*), Key deer (*Odocoileus virginianus clavium*), Lower Keys rabbit (*Sylvilagus palustris hefneri*), West Indian manatee (*Trichechus manatus*), wood stork (*Mycteria americana*), American crocodile (*Crocodylus acutus*), bald eagle (*Haliaeetus leucocephalus*), rice rat (=silver rice rat) (*Oryzomys palustris natator*) (=*O. argentatus*), and eastern indigo snake (*Drymarchon corais couperi*). Biological accounts and recovery tasks for these species (except Gulf sturgeon) are included in "The Species" section of this recovery plan. Refer to Appendix C for a list of other species of concern that utilize the mangrove community.

The **Florida black bear** (*Ursus americanus floridanus*), listed as threatened by the State, is a forest habitat generalist with seasonal preference for wherever food is most available. Black bears utilize all the natural forested systems of South Florida, with a decided preference for ecotones, including the boundaries between mangroves and other plant communities. Documented movements of radio-collared Florida black bear in Lee and Collier counties and documented signs/sightings of Florida black bear in Charlotte, Collier, and Lee counties indicate that the large areas of relatively undisturbed mangrove forest, in

combination with hydric and mesic forests and the major wetland basins, provide the principal habitat of the black bear in southwest Florida (Maehr 1984, Brady and Maehr 1985, Maehr *et al.* 1988, Maehr and Wooding 1992). Bears are omnivores that feed on readily available food resources, such as the seasonal abundances of propagules and insects. Occasionally, fish and carrion are also eaten. Movement by individuals can be extensive and may be related to both mating and food availability. Black bears will swim between mangrove islands in Collier County.

The **Big Cypress (=mangrove) fox squirrel** (*Sciurus niger avicennia*), listed as threatened by the State, is found in mangroves south of the Caloosahatchee River, along the estuarine coast south to the western edge of the Everglades sawgrass marshes. The Big Cypress fox squirrel utilizes a wide variety of forested and non-forested upland and wetland systems including mangroves. The Big Cypress fox squirrel possesses a large territory from which it harvests seasonally available bounties of cones, nuts, and seeds. The fox squirrel forages on mangrove propagules, in particular, the black mangrove. Nesting occurs in pines, hardwoods, cypress, cabbage palms, bromeliad clumps, and black mangroves.

The **Everglades mink** (*Mustela vison evergladensis*) is found in the Big Cypress Swamp; the western edge of the Everglades; southern Lee County; Collier County; mainland Monroe and Miami-Dade counties (Allen and Neill 1952, Humphrey and Setzer 1989, Humphrey 1992). Mink are nocturnal and crepuscular predators of mammals, reptiles, birds, amphibians, fishes, and eggs. The species does not appear to be numerous and, given its period of activity, the literature on distribution is based primarily on road kills. The Everglades mink is found in a wide variety of shallow wetland systems, including mangrove swamps.

The **white-crowned pigeon** (*Columba leucocephala*) is a resident of the mangrove arboreal habitat for nesting and nearby tropical hardwood hammock areas for foraging. This herbivorous pigeon found from Biscayne Bay south through the Marquesas Keys is listed as a threatened species by GFC and FCREPA (Bancroft 1996). The white-crowned pigeon requires undisturbed mangrove communities for nesting and foraging. Over half of the State's pigeon population nest on islands in the Upper Florida Keys (Bancroft 1996). Nesting on the mainland is rare, but does occur (Strong *et al.* 1991). Most of the population migrates to the Caribbean for the winter breeding season, but some birds are present in South Florida year-round. Breeding occurs from March to June. The white-crowned pigeon's mangrove and hardwood hammock habitat continues to decline as residential and commercial development increases. The continued existence of this species in Florida and the Caribbean is dependent upon the integrity of its nesting and foraging habitat here in South Florida.

The **eastern brown pelican**, a State species of special concern, nests predominantly on overwash mangrove islands and forages over open water, mudflats, and seagrass beds in the shallow waters of estuaries, creeks, and nearshore areas. Brown pelican rookeries are located on isolated red mangrove islands with a substantial water depth barrier that protects the nests from mainland predators. Diet consists of fish of all sizes. Foraging consists of plummeting dives, short plunges, and swimming scoops of fish. Historically,

brown pelican populations were reduced as a result of pesticides. Today, the greatest threats to brown pelicans are still human-caused. Brown pelicans and their nesting/roosting/loafing sites are vulnerable to disturbance from construction activities and monofilament line entanglement. Brown pelicans are especially susceptible to death and injury caused by sport fishing equipment. It has been estimated that over 500 individuals die each year as a result of entanglement with fishing tackle (Schreiber 1978).

The **osprey** is a State species of special concern only in the Lower Florida Keys. It nests in a variety of trees (*i.e.*, principally tall mangroves) and on artificial structures, and forages in a variety of marine and estuarine habitats.

Tricolored heron (*Egretta tricolor*), **little blue heron** (*Egretta caerulea*), **white ibis** (*Eudocimus albus*), and **snowy egret** (*Egretta thula*) forage and nest in mangroves. Little blue herons and white ibis are the most common of the listed wading bird species observed in mangroves in southwest Florida (Beever 1992). Diet consists of small fish, crustaceans, insects, frogs, and lizards (Ogden 1978a). Nesting in mangroves typically occurs on overwash islands. They appear to prefer to forage in freshwater habitats even when nesting in saltwater wetlands. The little blue heron forages throughout the wet and dry season in mangroves. Adjacent tidal wetlands are used throughout the year with greater emphasis during low tides on seagrass beds. The snowy egret forages throughout the wet and dry season in mangrove wetlands of the proper depth to allow for their foraging methods. Snowy egrets are the third most abundant listed wading bird observed. Preferred foraging areas are the seagrass beds and mudflats adjacent to the mangroves. Their diet consists of crustaceans, insects, and small fish (Ogden 1978c).

Reddish egrets (*Egretta rufescens*) and **roseate spoonbills** (*Ajaia ajaja*) are obligate mangrove breeders. Reddish egrets forage on the sandbars and mudflats adjacent to mangroves, in an active fashion with spread wings and rapid steps over unvegetated bottoms. Reddish egrets are the least abundant of the listed wading birds associated with mangroves. Reddish egrets utilize a limited set of saltwater habitats that allow for use of their unique foraging method. Diet consists of crustaceans and small fish. Kale and Maehr (1991) indicate that red mangrove rookeries are used during the December through June breeding period. Roseate spoonbills use dry-down pools in the high marsh,and during low tides, adjacent to mangroves. Preferred foraging areas included sheltered coves. They often forage in groups and with other wading birds including wood storks, great egret (*Casmerodius albus*),white ibis, and snowy egret. Roseate spoonbills nest exclusively in mangrove forests, typically on overwash islands, and forage wherever concentrations of small fish and crustaceans allow the birds to utilize their unique bills for feeding (Ogden 1978b).

A wide variety of shorebird species forage on the mudflats of mangrove estuaries. Among the State listed species are the threatened **least tern** (*Sterna antillarum*); the **black skimmer** (*Rynchops niger*), a species of special concern; and the **American oystercatcher** (*Haematopus palliatus*) a species of special concern. Least terns and roseate terns require open beach or bare



Roseate spoonbill. *Original photograph by Betty Wargo.*

substrates for nesting near areas where schools of forage fish concentrate. American oystercatchers utilize oyster bars and mudflat areas in mangroves and nest on bare unvegetated shores. Foraging occurs throughout the year with seasonal movements tracking warmer conditions.

Mangrove clapper rails (*Rallus longirostris*) use high marsh and basin black mangrove forest areas. They forage on fiddler crabs and other small crustaceans. Mangrove clapper rails are resident in South Florida's mangrove and marsh ecosystems. Little is known of their life history due to their crepuscular to nocturnal activity period, the heavy cover of their preferred habitat, and the excellent camouflage of their plumage.

The **Lower Keys striped mud turtle** (*Kinosternon baurii*) is found in small ponds with salinities less than 15 ppt in the Lower Florida Keys typically in or at the edge of elevated hardwood hammocks (Dunson 1992). Pond vegetation includes mangroves, buttonwood, and cattails. When ephemeral pools dry down, turtles will seek refuge in rock ledges and in mangrove prop roots.

From Lemon Bay, Sarasota County, to the Ten Thousand Islands, Collier County, the estuaries of southwest Florida support at least 384 species of bony and cartilaginous fish (Beever 1988), including the **common snook** (*Centropomus undecimalis*), a State listed species of special concern, and the **Key silverside** (*Menidia conchorum*), listed as threatened by the State.

Some species that depend wholly, or primarily on the mangrove habitat are now imperiled because of loss and degradation of their habitat. **Mangrove rivulus** (*Rivulus marmoratus*) is a small fish living only in and around mangrove areas as far north as Indian River County south through the Keys and north to Tampa Bay on the west coast of Florida (Taylor and Snelson 1992). It is the only species of *Rivulus* in North America and has adapted to conditions

of varying water levels and low oxygen levels of the mangrove community. It is an important link in the food chain, as it has been found to constitute part of the diet of many organisms including the wood stork (Ogden *et al.* 1976). It is listed as a species of special concern by the State because of its limited distribution and vulnerability to loss of its habitat.

The **mangrove gambusia** (*Gambusia rhizophorae*) is another small fish species associated with red mangrove roots in southeastern Florida, mainly in Miami and the Florida Keys (Gilbert 1992).

The **mangrove tree crab** (*Aratus pisonii*) is found only in estuarine areas from the Indian River Lagoon and Tampa Bay south to the Florida Keys (Gore 1994a). This species is restricted to mangroves for its adult life cycle, especially red mangroves. It is one of the few crabs that also uses the arboreal canopy and can climb to the uppermost branches which it forages upon (Beever *et al.* 1979). The **mangrove crab** (*Goniopsis cruentata*) is restricted to mangrove forests in central and southern Florida mangrove areas (Gore 1994b).

Ecology

The value and central role of fringing red mangroves in the ecology of the South Florida estuarine ecosystems has been well established by numerous scientific investigations directed at primary productivity, food web interactions and support of sports and commercial fisheries (Odum and Heald 1972, Odum *et al.* 1982). Mangrove swamps are among the most productive plant communities in the world and are often a large proportion of the total area of tropical estuaries (Day *et al.* 1989). The high level of animal diversity in a community of so few plant species occurs because of the wide variety of spatial and temporal microhabitats. The complex structure of prop roots, pneumatophores, and main trunks provides living spaces for numerous organisms and cover from predation for large populations of small fishes, nektonic and benthic crustaceans, annelids, mollusks, and echinoderms. Aside from providing refuge, mangrove prop roots also provide shade which is important for thermoregulation in some organisms. This combination of shelter and food source makes the mangrove forest a rich nursery and feeding ground for the juvenile and adult forms of many commercially and ecologically significant species of fish and other vertebrates.

Many animals associated with mangroves, oyster bars, and open unvegetated waters by day forage in seagrass beds at night. Many estuarine fishes spend their early life in mangroves and then move as adults to complete life cycles in seagrass habitats. The highest quality seagrass beds are associated with mangrove-fringed shorelines. Animals associated with the mangrove/seagrass communities include herbivores, such as green turtles, manatees, sea urchins, blue crabs, fiddler crabs, and many fishes.

Landward from the shoreline, the mangrove forest intermixes with salt marsh species and provides habitat to organisms that can withstand changing water levels. Common saltmarsh species found in this ecotone are saltwort (*Batis maritima*), perennial glasswort (*Salicornia virginica*), and saltgrass (*Distichlis spicata*). As water levels change with daily tides and seasonal

influences, the organisms here migrate to adjacent permanent aquatic habitats. This area is an important foraging area during periods of low water because organisms get concentrated into small pools of water, making it easy for predators to capture prey. Juvenile endangered wood storks (*Mycteria americana)* are especially dependent on these conditions.

Further inland, the mangrove forest mixes with tropical hardwood hammock species. Organisms rely on the arboreal and terrestrial components of this transition community. Commonly associated hardwood species include cabbage palms (*Sabal palmetto*), Jamaica dogwood (*Piscidia piscipula*), West Indian mahogany (*Swietenia mahogani*), stopper (*Myrtus verrucosa*), poisonwood (*Metopium toxiferum*), black bead (*Pithecellobium keyense*), and gumbo limbo (*Bursera simaruba*) (Schomer and Drew 1982). The transition between these two adjacent communities provides an important ecotone, where species can take advantage of resources from both communities. Mammals and reptiles move from the hardwood forests to feed in the mangrove community.

Zonation

The standard zonation of mangroves consists of red mangroves in the lower and middle intertidal zone, black mangroves in the upper intertidal areas that are occasionally flooded, and white mangroves in patches on higher elevations that are less frequently flooded. Buttonwoods are located further inland in areas that are within the limits of the highest tides (Tomlinson 1986).

Mangrove forests are different than other vegetative communities in not experiencing traditional plant succession. Instead, mangrove communities experience replacement succession primarily as a function of sea-level rise, where mangroves must either keep up with the rise in sea-level or retreat from rising water levels. On shorter time scales, the mangrove community can experience fluctuations in habitat type and species composition as a result of changes in such factors as hydrologic patterns.

Substrate

Mangroves can grow on many different types of substrates and can alter their substrate through peat formation and sedimentation. Mangroves are found on fine inorganic muds, muds with high organic content, peat, sand, rock, coral, oysters, and some man-made surfaces if there are sufficient crevices for root attachment. Black mangroves grow best in soils of high salinity, red mangroves grow best in areas of estuarine salinity with regular flushing, and white mangroves grow best in areas with freshwater input on sandy soils. Red, black, and white mangroves can grow in completely anaerobic soils (Lee 1969).

Mangroves grow better in areas of low wave-energy shorelines, river deltas, and floodplains where fine sediments, muds, and clays accumulate and peats will form (Odum *et al.* 1982). Fluctuating tidal waters are important for transporting nutrients, controlling soil salinities, and dispersing propagules. Mangroves are denser along coasts with high levels of rainfall, heavy runoff, seepage, and a resultant increase in sedimentation which provides a diversity of substrate types and nutrient levels higher than that of sea water (Tomlinson

1986). Mangroves can grow in waters from high-to-low nutrient concentrations. In removing nutrients from surface waters, mangrove forests can be important nutrient sinks for an estuary.

Mangroves can modify soils by organic contributions and peat formation, particularly in southwest Florida and the north shoreline of Florida Bay. This peat appears to be primarily from red mangrove root material and can reach thicknesses of several meters. When mangrove soils are drained by human activity, they experience dramatic increases in acidity due to oxidation of reduced sulfur compounds in the formerly anaerobic soils. This creates "cat clays" which can kill all vegetation including the mangroves.

Salinity

Mangroves are facultative halophytic species (*i.e.*, salt water is not required for growth). They are limited to areas that are partially inundated by brackish or saline water and cannot persist solely in fresh water principally as the result of interspecific competition from much faster-growing freshwater wetland plants. Mangroves grow in surface waters with a range of salinities from 0 to 40 parts per thousand (ppt). Coastal salinities generally range from 18 to 30 ppt throughout South Florida, except in parts of the Indian River Lagoon, Florida Bay, and the Florida Keys, where hypersaline conditions of over 40 ppt seasonally occur. Red mangroves address salinity by excluding or storing salt, whereas black and white mangroves and buttonwood secrete salt.

Reproduction

All mangroves share two common reproductive strategies: dispersal by means of water and vivipary (*i.e.*, the embryo develops continuously while attached to the parent tree and during dispersal) (Odum *et al.* 1982). Dispersal of mangrove propagules is primarily by water currents and tides. The propagules of all three mangrove species float and remain viable for extended periods of time. During this dispersal period, the propagules continue to germinate in preparation for seedling establishment. Black and white mangrove propagules require a stranding period of 5 days or more beyond the influence of tides in order to take hold in the substrate; whereas, red mangrove propagules have the potential to become established in shallow water.

Mangroves are considered pioneer species because of their ability to establish on otherwise unvegetated substrates. Once individuals begin to colonize a disturbed area, same age communities are established with little variance in the structure because new development of successive colonizers is arrested by the closed canopy.

Biomass

The biomass of mangroves and the mangrove forest is predominantly above ground. Measures of biomass in a 1.5 m (5-ft) tall canopy are: 712 dry kg/ha (131 lb/acre) in the leaves; 1,140 dry kg/ha (210 lbs/acre) in leaf litter; no fruit and flowers; 3,959 dry kg/ha (729 lbs/acre) in the wood; and 3,197 dry kg/ha (588 lbs/acre) in the roots. In contrast, a 6.1 m (20-ft) tall canopy has 5,843 to

7,031 dry kg/ha (1,075 to 1,294 lbs/acre) in the leaves; 22,730 to 98,410 dry kg/ha (6,209 to 18,110 lbs/acre) in leaf litter; 28 to131 dry kg/ha (5 to 24 lbs/acre) in fruit and flowers; 57,960 to 128,510 dry kg/ha (10,666 to 23,649 lbs/acre) in the wood; and 17,190 to 27,200 dry kg/ha (3,163 to 5,005 lbs/acre) in the roots. The standing crop of a short canopy whether young, naturally stunted, or hedged is from 3.6 percent to 8.3 percent of an untrimmed mature red mangrove fringe. With reduced standing crop, annual gross primary production can be expected to be proportionally less.

The annual net primary production of a 1.5 m (5-ft) high red mangrove system is 18 percent of the annual net primary productivity of a mature system, which produces 20.5 metric tons C/ha/year (Teas 1979). In the form of mangrove detritus, the net primary production exported from a natural red mangrove fringe has been measured at 9.9 metric tons C/ha/year by Pool *et al.* (1975). Teas (1979) derived 10.6 metric tons C/ha/year for mature red mangroves and 1.3 metric tons C/ha/year for shrubby 5-foot tall red mangrove fringes. Short canopy mangroves provide only 12 to 19 percent of the detrital export of a mature untrimmed red mangrove fringe.

Due to special adaptations to anaerobic soils, mangroves can grow in areas of very low dissolved oxygen concentrations. Since photosynthesis is occurring above the water column, mangroves can grow in waters of relatively high color and turbidity. Mangroves contribute to the tannin colors of estuarine waters while stabilizing and settling turbidity. Mangroves can contribute total organic carbon to surrounding waters as part of the net primary production export to the food web.

Productivity

The primary production ability of mangrove leaves varies. The upper canopy contains “sun leaves” which are smaller with heavy cuticle and tannin cells which protect against the heat and ultraviolet (UV) radiation encountered in the upper parts of the tree. The lower canopy is composed of “shade leaves” which have larger surface area, more chlorophyll, less cuticle, and which are oriented to obtain maximum light in shade conditions. Once a leaf is formed to one of these morphologies, it cannot be changed. Lugo *et al.* (1975) demonstrated that in the red and black mangrove, sun leaves demonstrated twice the photosynthetic rate of shade leaves. At night, shade leaves have four times the respiration rate of sun leaves. Because of these morphologic differences, when a red or black mangrove is topped, frozen, or defoliated the tree loses its most efficient leaves. Exposed leaves not adapted to the heat, light, and UV rays are exposed to adverse conditions. As a result, both gross primary production and net primary production are severely reduced until new sun leaves are set if the tree lives. It is occasionally observed that shade leaves on surviving branches will wither, die, and drop under the heat of the sun when cutting is performed in the summer.

The detrital food base in natural mangrove systems follows seasonal cycles of leaf growth, chemical changes in leaf composition, and natural leaf drop. Although it is not yet fully investigated, a sequence of leaf chemistry changes occurs in the mangrove leaf which the red mangrove naturally drops. The

naturally dropped leaf is the oldest leaf in the red mangrove leaf cluster, has had chlorophyll removed rendering a yellow coloration from carotenes and xanthophylls, and has other substances including excess sodium and chloride. It is suspected that in most mangroves, the annual properly timed leaf fall is also a mechanism for the removal of excess salt prior to and concurrent with new growth and fruiting (Joshi *et al.* 1975, Saenger 1982). It is not unlikely that essential limited nutrients and trace elements are mobilized and removed from a leaf before it is dropped for use in the growth of new leaf.

Studies of South Florida estuarine food webs have found that 85 percent of the detrital food base is from red mangroves (Lewis *et al.* 1985). This detritus is predominantly leaves, but also includes leaf and propagule stalks, small twigs, roots, flowers, and propagules. These are fragmented by processors into detritus, decaying organic material coated and created by algae, fungi, bacteria, and protozoa. This detritus is further fragmented, consumed, and excreted by a number of primary consumers dominated by small crustaceans. The leaf base material itself is not directly consumed, but the algal, fungal, bacterial, and protozoal biomass is. This results in the excretion of a smaller detrital particle which again becomes the base for a detrital garden of microorganisms. This process is repeated many times utilizing the detrital particle to its full nutritive value to the estuarine ecosystem. Eventually, the particle attains a small enough size for use by filter and deposit feeders.

Entire trunks and large branches are not available to this system directly but have to be processed by a much slower system of marine and terrestrial borers and slow decay. If large volumes of cut material enter the aquatic or intertidal system in a short period, one of two things occur. If an abundant resident population of borers is present in the mangrove system and the weather is sufficiently warm at the time of cutting, unnaturally high abundances of wood-boring animals develop in the slash and, through time, their dispersed offspring attack the cut ends of the trimmed mangroves and healthy uncut trees. If the weather is cold and the local population of borers is low or absent, then the slash sits, does not decay, and can mineralize into unavailable cellulose. This has been directly observed in Lee County, where mangrove branches cut in 1979 remain intact and mineralized today and the area where these piles are located has not recruited new mangroves.

Status and Trends

The Coastal Coordinating Council estimated a total of between 162,000 ha (400,000 acres) to 219,000 ha (540,000 acres) of mangroves remaining in central and south Florida in 1974 (Lewis *et al.* 1985). The National Wetlands Inventory estimated a total of 272,973 ha (674,241 acres) of mangroves in 1982 (Lewis *et al.* 1985). By 1989, approximately 224,500 ha (554,515 acres) of mangroves remained in central and south Florida. These mangroves are a unique and critical component of Florida's estuarine ecosystems. The loss of mangrove productivity to Florida estuarine food chains is well documented for certain locations. Since the early 1900s, mangrove communities in South Florida have steadily disappeared (Lugo and Snedaker 1974). Most of the shoreline of South Florida's estuaries have been bulkheaded for development or impounded by dikes for mosquito control activities. Along the Indian River

Lagoon, 13,083 ha (32,315 acres) (92 percent) of red and black mangroves were impounded to control mosquito populations between 1955 and 1974 (Odum and McIvor 1990). Lake Worth Lagoon experienced an 87 percent loss of mangrove wetlands due to shoreline development occurring between 1940 and 1975 (P. Davis, Palm Beach County, personal communication 1998). Northern Biscayne Bay has lost 82 percent of its mangrove acreage (Harlem 1979). Lee County has lost 19 percent of its original mangroves (Estevez 1981). In the Upper Florida Keys, over 8,306 ha (15 percent) of the original mangrove forests were cleared for residential and commercial construction purposes by 1991. Statewide estimates vary on total mangrove losses. Conservative values of 3 to 5 percent were derived by Lindall and Saloman (1977); more recent work indicated a 23 percent loss (Lewis *et al.* 1985). This figure includes areas such as Charlotte Harbor where there has been a 19 percent increase in mangrove coverage due to the conversion of high marsh and salt flats through mosquito ditching.

Natural mangrove ecosystems provide a number of ecological functions that benefit humans. The economic importance of mangroves to the State income is significant. From 1980 to 1981, 5,224,539 recreational saltwater anglers spent 58,528,081 angler days fishing, which generated over $5 billion in direct and indirect income to the State economy (Bell *et al.* 1982). Using National Wetland Inventory acreage data, the value of an acre of mangroves in the Indian River Lagoon is $416 per acre ($1,027/ha) per year for commercial fisheries and $1,093 per acre ($2,700/ha) per year for sport fisheries. Using acreage data from the Coastal Coordinating Council (1974), the value of an acre of mangrove is $723/acre/year for commercial fisheries and $1,902/acre/year for sport fisheries. The annual economic estimates for the Indian River Lagoon fisheries dependent upon mangroves are $10,644,695/year for commercial fisheries and $28 million/year for sport fisheries.

Smaller, shorter mangrove canopies contribute less to fishery values than taller, natural canopies due to the reduction in net primary production. Utilizing conservative estimators, an evaluation of mangroves in Lee County found that, in 1970 dollars, a mature 6 m (20-foot) high canopy of red mangroves contributed $2,041/acre/year in commercial fisheries landings. In 1975 dollars, a 1.5 m (5-foot) high red mangrove canopy contributed $144/acre/year; whereas a 11 m (35-foot) high mangrove canopy contributed $6,514/acre/year. The values do not reflect recreational fisheries values which are six times the primary sales of commercial fisheries (Lewis *et al.* 1985).

The in-kind replacement value of a dead mature red mangrove is in the thousands of dollars. One nurseryman estimated the cost to raise a red mangrove from seedling to age 15 prior to transplanting would be over $11,000 with survival as low as 30 percent. The total replacement cost for one acre of dead mangroves to age 15 would be approximately $4.4 million at 100 percent survival or $14.7 million at 30 percent tree survival.

Management

Natural mangrove ecosystems do not require management other than being left alone. Mature mangrove systems are self-renewing and respond to perturbations of the natural cycles of freeze, flood, and storm without the need

for significant human intervention. Unfortunately, in South Florida, most mangrove systems have been degraded by human impacts either directly, as in spoil pile deposition or impoundment, or indirectly by alteration of basin hydrology, as in Florida Bay and the Everglades. Most management efforts require the removal of past effects as well as the prevention of continued or future human impacts.

Mangrove ecosystems are susceptible to both natural and human-induced impacts. The two natural forces that may negatively impact mangrove forests are hurricanes and sea-level rise. Large hurricanes are the primary natural factor that can cause extensive damage. In 1960, Hurricane Donna created damage over an area exceeding 40,000 ha (100,000 acres) with 25 to 100 percent loss of mature trees (Craighead and Gilbert 1962). Mangroves were killed by direct shearing at 2 to 3 m (6 to 9 ft) above the ground, by complete washouts of overwash islands, and by strangulation of air exchange from layers of marl, mud, and organic material over the prop roots and pneumatophores. The burial of aerial roots was the largest cause of death. Lugo *et al.* (1976) have hypothesized that severe hurricanes occur in South Florida on intervals of 25 to 30 years and that the mangrove ecosystem has adapted by reaching maturity during this cycle.

The two main human-caused changes affecting mangrove communities today are direct loss of habitat from coastal urbanization (*i.e.*, developing waterfront property and subsequent effects of channel dredging, spoil placement alterations, chemicals, debris, and formal landscaping) and the alteration in freshwater hydroperiod by water management practices (*i.e.*, mosquito control and major flow alterations). Man can alter the distribution and structure of mangrove communities through direct destruction by dredge and fill activities, and cutting those mangroves that remain. Alterations in the natural freshwater flow regime through diking, impounding, and flooding activities affect the salinity balance and encourage exotic vegetation growth. As a result of changing natural sheet flow, mangroves have experienced a change in water and soil salinities. With the decline in natural freshwater flow through the Everglades, red mangroves have invaded freshwater tributaries of the Taylor Slough drainage basin. Australian pine (*Casuarina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*) are two exotic plant species that invade mangrove communities as a result of changes in water flow (refer to Appendix E).

Although mangroves often live in areas with rapid sedimentation, heavy loads of fine flocculent material such as suspended dredge spoils that coat aerial roots can kill the trees. Extensive areas of mangrove in Collier County were killed in this way by the actions of hurricanes and by human coastal development with broadcast dredge spoil turbidity (Odum and Johannes 1975). Spoil pile creep is a common phenomenon on barrier islands and in the Florida Keys as adjacent mangroves roots are buried beneath unstabilized shell marl.

The functionality of mangroves in gathering sediments and other material also negatively acts as traps for trash, monofilament, and other marine debris that can significantly harm wildlife and listed bird species in particular. Regular (annual) volunteer clean-ups find tons of debris in mangrove ecosystems with monofilament line from recreational fishing typically in the top two items by

weight. Education will be important in this issue, but this needs to be supplemented by stricter enforcement of marine dumping regulations and perhaps development of biodegradable alternatives to current fishing lines.

Diking and Ditching

Diking (or impounding) mangroves to cut off tidal circulation with long-term flooding causes mass mortality in all species of mangroves, especially when the prop roots or pneumatophores are submerged (Breen and Hill 1969, Odum and Johannes 1975, Patterson-Zucca 1978, Lugo 1981). Impoundment flooding, used as a form of mosquito control, resulted in a 76 percent reduction in mangrove wetlands along the Indian River Lagoon. On the west coast, roadway development has killed thousands of acres of mangroves. Partial impounding by roads and fill for development has killed mangroves in places like Clam Bay in Collier County. When these formerly anaerobic mangrove soils are drained, they experience dramatic increases in acidity (ph=3.5-5.0) due to the oxidation of reduced sulfur compounds in the soils which can kill all vegetation including the mangroves within the impoundment.

The **Subcommittee on Managed Marshes**, an interagency task force, was formed to address management problems of mosquito impoundments (Indian River Lagoon NEP 1996). Under the guidance of this task force, improvements in management techniques were developed and implemented in the mid-1980s by local mosquito control districts. Known as Rotational Impoundment Management (RIM), these techniques involve some form of rotational schedule for alternating the flooding-and-drying cycles of impounded marshes. One RIM alternative consists of the installation of culverts through the dikes to allow natural tidal flows across these impounded wetlands and to provide fishery resources access to and from the diked marshes.

Trimming

The effects of mangrove hedging and improper trimming on productivity can be substantial, with losses of 8.6 tons of C/ha/year when a 6 m (20-foot) high canopy is reduced to 1.5 m (5 ft) in height. In an urbanized estuary where the majority of the shoreline could be subjected to hedging, this could result in the loss of approximately 87 percent of the local annual productivity of that particular mangrove ecosystem.

Of the mangrove species, the red mangrove is the least tolerant to trimming. Cut red mangrove branches do not regenerate well or at all, if they are greater than approximately 2.5 cm (1 in) in diameter (Gill and Tomlinson 1971, Beever 1989). Severe trimming kills mature red mangroves. White and black mangroves are less sensitive to trimming damage than red mangroves because of specific anatomical differences which allow coppicing from trunk and root stock. However, improper severe cutting of both white and black mangroves will kill these trees as well. Recovery potential of mangroves to pruning is as follows: white mangroves, highest recovery; black mangroves, moderate recovery; red mangroves, lowest recovery (Snedaker 1982).

Removing more than 30 percent of a red mangrove canopy produced significantly fewer propagules than those trees pruned less than 30 percent. Trees

pruned more than 50 percent were severely impacted. Red mangroves exhibit difficulty in initiating new shoots when severely disturbed (Snedaker 1982). Trimming of trees immediately preceding and during flower set, propagule growth, and major leaf set can reduce and damage the reproductive success and productivity export for that year.

A comparison of cut and adjacent natural mangrove fringes in seven of the eight southwest Florida aquatic preserves was performed, utilizing standardized methods of measurement of mangrove productivity (Heald 1971, Pool *et al.* 1975, Teas 1979, Beever *et al.* 1979, Twilley 1980). Statistically significant reductions in net primary productivity export, standing leaf crop, flower production, propagule production, and leaf clusters resulted from the cutting of a 5 m (16 ft) tall fringing red mangrove to less than 2 m (6 ft). Similarly, reduction in net primary productivity export, standing leaf crop, propagule production, and terminal branches resulted from cutting a 3 m (10 ft) tall fringing white mangrove area to 1 m (3 ft). Mangrove trimming significantly reduced habitat utilization by associated fauna. For the parameters measured, no net positive benefit of mangrove trimming/cutting could be confirmed. The documented evidence of this study and existing literature (Beever 1989) indicate that mangrove cutting is deleterious to the estuarine environment, the mangrove trees themselves, and the fauna which depend upon mangroves for habitat and primary production (Beever 1996).

Mangrove trimming does not match natural, seasonally timed, physiologically mediated leaf drop. In any trimming method, leaves of all ages and biochemistry are removed from the tree. There is no existing evidence in the literature or from field observation that mangrove trimming enhances the habitat value of the mangroves for any native species. For many of the birds and arboreal arthropods, reduction of canopy height and habitat complexity has deleterious effects. Many mangrove-dependent bird species will not roost overnight or nest in short canopies below 2 to 3 m (6 to 10 ft). When rookeries are cut, they are abandoned. The arboreal arthropod community depends directly on the structural diversity of the mangrove canopy including tree height, abundance of branches, and tree age. Trimming fringing mangroves results in shade reduction along the bank; shaded areas selectively attract a number of fish and other aquatic species.

The compliance level of permitted mangrove trimming in Florida is low (20 percent since Chapter 17-27 Florida Administrative Code was implemented) and violations significantly outnumber permitted projects. Enforcement staffing levels of DEP field personnel for South Florida averages one compliance staff per seven counties and one enforcement (independent of permitting) per 3.5 counties. This staff is responsible for all DEP compliance and violations for all permits in all wetlands in DEP jurisdiction. As a result, the ability of this staff to concentrate on, and the time allotted to, mangrove trimming is small compared to the extent of the resource and the number of permits and enforcement cases.

Herbicides

All mangrove tree species are particularly susceptible to herbicide damage (Tschirley 1969, Orians and Pfeiffer 1970, Westing 1971, Walsh *et al.* 1973, and Odum *et al.* 1982). The red mangrove is particularly sensitive due to the

small reserves of viable leaf buds (Teas and Kelly 1975). The stress of a single defoliation is sufficient to kill the entire tree. Defoliated forests are slow to recover in part because of high rates of siltation, turbidity, and low dissolved oxygen concentrations in the water from the loss of mangrove roots and the decay of dead mangroves (de Sylva and Michel 1974). Both residential landscape practices and ditch clearing by various entities have resulted in the destruction of mangroves.

Oil and Oil Spills

Oil drilling in or near mangrove shorelines has significant adverse impacts (Longley *et al.* 1978). Petroleum oils and their by-products kill mangroves by coating aerial and submerged roots and from direct absorption (Odum and Johannes 1975, Carlberg 1980). Some severe effects, including tree death, can take place months or years after a spill (Lewis 1979, 1980). Little can be done to prevent damage once it has occurred. Common dispersants used to combat oil spills are toxic to vascular plants (Baker 1971). Damage from the actions of mechanical abrasion, trampling, or compaction during cleanup can exacerbate negative environmental impacts. The continued ban on off-shore oil drilling in Florida is the best preventative for oil spill impacts. Double-hulled shipping of oil and other petroleum-based products should be required in and adjacent to mangrove estuaries.

Fire

Mangroves are not fire adapted and should not be burned (Wade *et al.* 1990). Care needs to be taken in land management controlled burning to not carry fire into mangrove systems from adjacent habitats that benefit from fire. There have been situations on public lands where this has happened.

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Restoration of Mangroves

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

Restoration Criteria

South Florida can contribute to the preservation of nationally significant wetlands, hydrology, aquifer recharge, and fish and wildlife habitat values by preserving the only geographic extent of this type of habitat within the continental United States. Benefits of restoring mangrove communities include: the conservation and recovery of listed plant and animal species, wide-ranging species, and neotropical birds; the recycling of nutrients and the nutrient mass balance of the estuarine ecosystem, including high primary and associated secondary biological production; the protection of the base arboreal, estuarine, and marine food web; the provision of physical habitat and nursery grounds for a wide variety of marine/estuarine vertebrates and invertebrates significant to sports and/or commercial fisheries; the protection of public and private lands and property by mangrove storm buffers and wind breaks; the stabilization of shorelines and fine substrates; the improvement of water quality and clarity by filtering uplands runoff and trapping waterborne sediments and debris. Finally, preservation of mangrove systems contributes to the overall natural setting and visual aesthetics of Florida's estuarine waterbodies and the economy of the coastal counties of South Florida and the State of Florida.

The restoration objective will be achieved when (1) the geographic extent of mangrove habitat in South Florida is identified; (2) mangrove habitat is preserved through land acquisition or private landowner cooperative agreements consistent with the GFC's *Closing the Gaps in Florida's Wildlife Habitat Conservation System* and Preservation 2000 Act Study (Biodiversity Conservation Analysis), current State and Federal land acquisition proposals, and regional wildlife habitat protection plans; (3) the hydrology and exotic plant management of mangrove wetlands are regionally applied to enhance, restore, and maintain plant and animal biodiversity; and (4) State regulations are adequately enforced resulting in no-net loss of mangrove habitat.

Community-level Restoration Actions

1. **Identify the extent of mangrove habitat.** Although the existing GIS information, aerial photography, and ground-truthed land cover information are available for this community throughout South Florida, a comprehensive regional analysis has not been conducted.

    1.1. **Detail the geographic extent of mangroves in South Florida.** This task should integrate existing GIS and other databases on land cover, soils, and hydrology, to correctly identify and separate mangrove from other wetland types, particularly Brazilian pepper.

1.2. **Update the GIS database for mangroves to monitor cumulative impacts.** As areas of mangroves are converted to other land uses, changes should be mapped to identify and analyze trends in habitat loss.

1.3. **Identify important habitat linkages.** Important areas include connecting the mangroves of north San Carlos Bay to the Estero Bay Buffer Preserve; Rookery Bay National Estuarine Research Reserve north to Gordon Pass; Charlotte Harbor State Buffer Preserves north and south to other preserves.

2. **Preserve remaining areas of mangrove habitat.** Direct loss of habitat resulting from land conversion, habitat degradation, and fragmentation continues unabated in South Florida. However, some of the best remaining areas of intact mangrove have been identified for land acquisition.

2.1. **Identify and acquire mangrove habitat critical to the recovery of wide-ranging listed species.** The acquisition and preservation of mangroves, including buttonwood forests, is critical to the recovery of federally and State listed species as well as for augmenting habitat for neotropical migrants.

2.1.1. **Complete purchase of the following CARL projects:** Cape Haze/Charlotte Harbor, Cayo Costa, Charlotte Harbor Buffer, Estero Bay Buffer, Myakka Estuary, Rookery Bay, Bear Point, Middle Cove, Blind Creek, King's Island.

2.1.2. **Complete purchase and management implementation of mangrove habitat within 15 km (9.3 mi) of wading bird rookeries and 30 km (18.6 mi) of wood stork rookeries.** This should include Lemon Bay, Gasparilla Sound, Charlotte Harbor, Pine Island Sound, Matlacha Pass, Estero Bay, San Carlos Bay, Rookery Bay, the Ten Thousand Islands, the Florida Keys, Florida Bay, Biscayne Bay, Lake Worth Lagoon, and the Indian River Lagoon.

2.1.3. **Protect coastal mangroves as raptor and bald eagle nesting habitat as well as neotropical migratory bird habitat.** Bald eagles prefer nest and perch sites on the largest, tallest trees available near large, open waterbodies in coastal South Florida. Neotropical birds require available foraging habitat as close to the coast as possible to facilitate migration across the Gulf of Mexico and Caribbean. Coastal mangroves in urban areas are subject to hedging. Pine Island in Lee County is an example of a mangrove area that should be protected.

2.1.4. **Complete purchase and management implementation of mangrove habitat within Priority I/II areas identified in the Florida Panther Habitat Preservation Plan.**

2.1.5. **Identify and acquire potential shoreline nesting habitat available to the American crocodile and mangrove terrapin in South Florida.**

2.2. **Complete purchase and management implementation of mangrove habitat in contiguous, connected, unfragmented patches for the conservation of biodiversity in South Florida.** Acquiring and preserving mangrove habitat will benefit nongame species, rare and unique species, and keystone species such as the mangrove tree crab, mangrove rivulus, mangrove prairie warbler, and various owl and raptor species.

2.2.1. Develop additions to existing Federal and State land acquisition proposals in areas identified as GFC Strategic Habitat Conservation Areas and in the 1990 Statewide Charrette, including the following: Estero Bay Watershed, San Carlos Bay, Cocohatchee River, West and East Charlotte Harbor, and the Imperial River drainage.

2.3. Use existing regulatory mechanisms to protect mangrove wetlands. Mangroves have significantly declined in areal extent, patch size, and quality in South Florida, primarily because of exemptions, inaccurate rules, lack of compliance review, and inadequate mitigation practices.

2.3.1. Stress avoidance of impacts of this habitat type as a regional wetlands permitting concern. Both consultants and permitting entities need to be educated on the importance of this habitat to fish and wildlife resources and the economy.

2.3.2. Re-evaluate the Federal and State permitting process and permit exemptions to assess impacts on mangrove habitat. Piecemeal development and speculative land clearing in urbanizing areas under exemptions results in fragmentation and loss of mangroves in the South Florida Ecosystem.

2.3.3. Require in-kind on-site and off-site wetland mitigation when avoidance and minimization criteria have been exhausted. Both consultants and permitting entities often assess credit mitigation on the basis of the wetland depth, not the landscape importance or biodiversity value. This results in mitigation plans using red mangroves even when black, white and buttonwoods are being impacted.

2.4. Protect mangrove communities from point source and non-point source pollution.

2.5. Implement cooperative habitat preservation and management programs with private landowners. Some mangrove habitat is in private ownership and some private landowners may not choose to participate in fee-simple land acquisition projects. Protection and management through alternate methods may conserve important ecosystems by providing landowners with economic incentives (*e.g.*, tax relief) and promoting good stewardship by ensuring that landowners view habitat as an asset, not a liability.

2.6. Support and implement cooperative regional greenways programs with landowners and other agencies. Greenways planning has successfully developed cooperative, local conservation plans that will establish, maintain, and manage landscape connections between important resource areas.

2.7. Promote the protection of mangroves by local governments. Use the GIS database to provide local governments with the location and areal extent of mangrove habitat to promote and improve resource planning within local comprehensive plans.

3. Manage and maintain mangrove habitat on public lands.

3.1. Implement effective habitat management techniques to maximize the biodiversity of the mangrove community. Mangrove may benefit from alternate management practices that are sensitive to hydrology, herbicide susceptibility, and

subtropical vegetation. Diversification of management techniques may increase biodiversity of impounded and marsh managed systems. Management of mangroves on a landscape scale will benefit listed species, wide-ranging species, wading birds, neotropical migrants, and endemic bird species, including the mangrove cuckoo, black-whiskered vireo, and Florida prairie warbler. Effective management techniques should include controlling exotic plants and animals without impacting non-target native species and preventing collection of rare plant species, such as bromeliads and orchids, on public lands.

3.2. **Ensure the continuance of habitat management on public lands.** State and Federal land managers are faced with funding deficits that prevent or reduce management actions. Perpetual funding sources for staff and equipment should be secured.

3.3. **Maintain important habitat linkages.** Public landowners should coordinate land acquisition and habitat management activities to ensure the protection of large, contiguous tracts of land that include a mosaic of native habitat types, including mangroves.

3.4. **Identify and prohibit incompatible public uses that degrade mangrove habitat.** Incompatible public uses that disrupt hydrology, pollute, encourage exotic plant or animal invasion, overharvest resources, or destroy habitat beyond the ability for effective management should be identified and eliminated.

3.5. **Monitor compatible adjacent land uses to protect the ecological function of mangroves.** Secondary and cumulative impacts to public lands can result from adjacent development, including loss of habitat, litter, chemical discharges, dumping, promoting exotic plant and animal invasion, alteration of adjacent hydrology, use of pesticides/herbicides, and noise/light pollution. Implementing land-use regulations to establish a wide buffer between mangrove habitat and upland development can eliminate or minimize these secondary and cumulative effects.

4. **Restore and enhance mangrove habitat, where feasible.**

4.1. **Identify locations of mangrove habitat that can be restored.**

4.1.1. Coastal areas where mangrove restoration efforts are either currently being conducted or should be considered include Indian River Lagoon, Lake Worth Lagoon, Biscayne Bay, Florida Keys, Charlotte Harbor, and Sarasota Bay.

4.2. **Restore the natural hydroperiod and tidal regime of mangrove communities.**

4.3. **Restore sheetflow hydrologic conditions by restoring the regional landscape to natural contour.** Much of South Florida has been significantly altered by public and private drainage projects that have resulted in both overdrainage and flooding of natural systems. Where possible, off-site, regional hydrological restoration actions may be necessary to restore mangrove functions. Areas where restoration should occur include the South Golden Gate Estates and Camp Keais Strand in Collier County, the Estero Bay Watershed in Lee County, and the Babcock-Webb Wildlife Management Area in Charlotte County and the Charlotte Harbor Flatwoods CARL project in Lee and Charlotte counties.

4.4. Re-establish important habitat links by constructing wildlife crossings. A wide variety of development and linear infrastructure projects fragment mangrove habitats. Future design and retrofit or rebuild of these projects should include culverts, undercrossings, overpasses, and other features that reduce wildlife mortality, preserve hydrology, and increase connectivity to adjacent habitat.

4.5. Encourage mitigation banks that restore and enhance mangrove systems, not monocultures.

5. Perform additional research on mangroves.

5.1. Continue and update studies on the utilization of mangrove communities by endemic and wide-ranging species, including the development of landscape-scale management recommendations for the recovery of these species in South Florida.

5.1.1. Inventory and characterize the importance of mangroves to avian populations, including neotropical migrants and wading birds.

5.1.2. Survey mangroves in southwest Florida for the American crocodile. Updated surveys for the American crocodile have not been conducted. The complete range of this species should be documented in order to recover the population.

5.1.3. Examine reptile and amphibian populations associated with ponded wetlands in mangrove ecosystems. Investigate the habitat requirements for the American crocodile and mangrove terrapin.

5.1.4. Examine invertebrate diversity and life cycles in mangrove habitat.

5.2. Monitor mangrove communities to evaluate biodiversity. Monitor community-level processes, structure, and composition, including rare and imperilled species. Improve reference information for community composition, biodiversity, and site-to-site variability.

5.3. Perform a hydrologic study of the flood attenuation and storm buffering potential of mangrove habitat under natural sheetflow conditions.

5.4. Examine the population dynamics by invasive exotics in the understory of mangrove habitat.

5.5. Examine the habitat value of buttonwood forests in South Florida.

5.6. Identify historical and geological trends in mangrove distribution relative to hydrology and sea-level in the mangrove communities of South Florida.

6. Increase public awareness concerning mangrove habitat. Identify mangroves in text, maps, and on resource presentations to raise public awareness of the different types of mangroves. Stress the important ecosystem function of isolated and ephemeral wetlands included in the mangrove community. Establish the landscape-scale importance of this community to wide-ranging species and the significance of regional losses of this habitat in South Florida.

6.1. Inform the public about the harm caused by marine debris, particularly monofilament line for fishing and polypropylene lines for lobster and stone crab traps, encouraging the use of biodegradable fishing line, proper fishing stewardship, and enforcement of marine dumping regulations.

6.2. **Inform the public about the need to maintain the off-shore drilling ban** in Florida waters with mangrove estuaries, and the need for double-hulled transportation of petroleum products in mangrove estuaries.

6.3. **Inform the public about the need to not trim mangroves** for view on public lands and on private waterfronts particularly in Aquatic Preserves.

Coastal Salt Marsh

FNAI Global Rank:	**G4**
FNAI State Rank:	**S4**
Federally Listed Species in S. FL:	**6**
State Listed Species in S. FL:	**27**

Coastal salt marsh. *Original photograph courtesy of U.S. Fish and Wildlife Service.*



Extending along the coastline of peninsular Florida, the salt marsh community of the South Florida Ecosystem is perhaps one of the most unique salt marsh systems in the United States. The mild subtropical climate of Florida supports a combination of temperate salt marsh vegetation and tropical mangroves that intermix to form an important transitional ecotone. To man, the salt marsh offers numerous recreational, commercial, and aesthetic values. To the ecosystem, it offers the foundation of life to a variety of resident and transient organisms; especially to the endangered Lower Keys rabbit (*Sylvilagus palustris hefneri*) and rice rat (*Oryzomys palustris natator*). Although almost 66 percent of salt marsh habitat is protected in South Florida, habitat continues to be lost to human-induced impacts such as dredge and fill operations, alterations of hydrology, and pollution. The restoration goal for salt marshes of the South Florida Ecosystem is to prevent further decline and increase spatial extent by attempting to re-establish its natural structure, composition, and ecological processes.

Synonymy

Salt marshes are communities of emerged halophytic vegetation in areas alternately inundated and drained by tidal action. The term salt marsh summarizes the saline conditions of the habitat and the emergent vegetation that dominate it (Zedler 1984). Coastal salt marsh is synonymous with the "coastal salt marsh" described by Davis (1967), Hartman (1978), and Cox *et al.* (1994); and "marine and estuarine tidal marsh" of FNAI (1990). The Florida Natural Areas Inventory (1990) defines salt marshes as "expansive inter- or supratidal areas occupied by rooted emergent vascular macrophytes cordgrass (*Spartina alterniflora*), needle rush (*Juncus roemerianus*), swamp sawgrass (*Cladium mariscoides*), saltwort (*Batis maritima*), saltgrass (*Distichlis spicata*), glasswort (*Salsola kali*), and a variety of epiphytes and epifauna." Salt marsh-related communities are characterized by differences in their dominant vegetation, location, and tidal flow and have been described as high marsh, *Salicornia*

marsh, *Juncus* marsh, salt pan, tidal marshes, and transitional zone. For the purpose of this account, the general term "salt marsh" is used to include all coastal salt marsh-related habitats (tidal marsh, salt marsh, brackish marsh, coastal marsh, coastal wetlands, tidal wetlands) with such common species as, *Spartina alterniflora, S. patens, Salicornia virginica, Juncus roemerianus, Distichilis spicata,* and *Batis maritima*.

Salt marshes have been studied extensively for many years with Ragotzkie *et al.* (1959), Chapman (1960) and Teal and Teal (1969) conducting some of the pioneering work. Thorough descriptions of general salt marsh ecology are given by Ranwell (1972), Adam (1980), Pomeroy and Wiegert (1981), and Mitsch and Gosselink (1986, 1993). Wiegert and Freeman (1990) and Montague and Wiegert (1990) provide overviews on southeast Atlantic and Florida marshes, respectively. The FLUCCS code for the coastal salt marsh community includes: 642 (saltwater marshes).

Distribution

Salt marshes form along protected intertidal areas and occupy narrow fringes to large expanses (several km) of shoreline. In the United States, salt marshes are most extensive along the eastern coast from Maine to Florida and in the Gulf of Mexico along Florida, Louisiana and Texas. Narrower belts of salt marshes are found on the west coast of the U.S., with more extensive systems along the Alaska coastline. Salt marshes are replaced by mangrove systems in tropical and subtropical regions (between 25 N and 25 S latitude). Approximately 1.7 million ha (4.1 million acres) of salt marshes are found in the U.S. (Field *et al.* 1991).

North Florida has the greatest extent of marshes, comprising over 70 percent of the total; 10 percent occurs in the Indian River Lagoon from Volusia to Martin County; and the remaining 20 percent is found in the rest of the South Florida area (Montague and Wiegert 1990). Although salt marshes are more abundant above the normal freeze-line in north Florida, they do extend into the coastal areas of South Florida where they merge with mangrove-dominated habitats. Similarities of salt marshes in four distinct regions in Florida are evident: northeast Florida, northwest Florida, Indian River Lagoon, and South Florida. Each region is characterized by differences in tidal range, wave energy, frequency and amplitude of tides, local topography, and temperature (Montague and Wiegert 1990).

Two of these regions, Indian River Lagoon and South Florida, are within the South Florida Ecosystem boundary. Salt marsh-related vegetation occurs in all of the South Florida coastal communities, but the extent varies in each area (Figure 1). On the east coast of Florida, salt marshes are found from Indian River County south to Miami-Dade and Monroe counties with more extensive coverage in Indian River, St Lucie, Miami-Dade, and Monroe counties. On the west coast, salt marshes are established in coastal areas of Collier, Lee, Charlotte, and Sarasota counties.

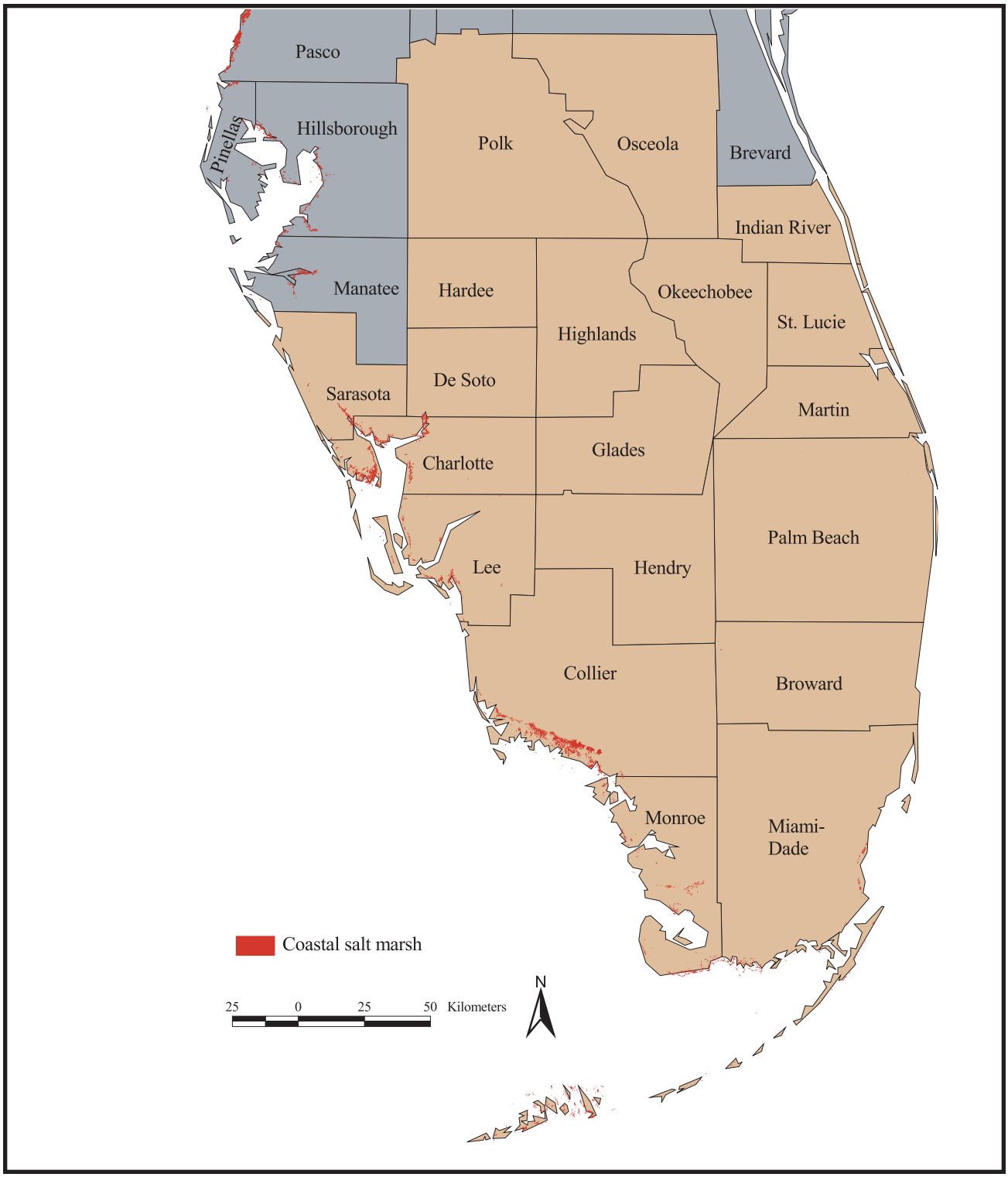


Figure 1. The occurrence of coastal salt marsh in South Florida (adapted from USGS/BRD 1996).

Description

Salt Marsh Formation

Salt marshes are found in flat, protected waters usually within the protection of a barrier island, estuary, or along low-energy coastlines. Situated between the land and the sea, salt marshes experience the effects of both salt and fresh water. Tidal effects are greatest on marsh areas below mean low water, while upland freshwater sources influence areas above mean high water. Tides flush saline waters over the intertidal zone and rivers carry freshwater in from upland sources, transporting with them sediments and nutrients necessary for the growth and formation of a marsh system. Within the low-lying protected areas, halophytic plants quickly grow and establish root systems. As tide waters flood over a marsh, suspended sediment settles out and accumulates around the stems of plants. Rivers and other upland sources also contribute sediments to the marsh by continually transporting and redepositing sediment. In the early development of a marsh, sedimentation increases and promotes the establishment and growth of additional plants. As the marsh matures, accretion slows and stabilizes with the surrounding sediment source, tidal regime, and topography.

The underlying theories of formation and zonation of salt marshes have been extensively reviewed (*e.g.*, Pomeroy and Wiegert 1981, Adam 1980, Montague and Wiegert 1990). One theory suggests salt marsh vegetation has the ability to trap and accumulate sediment and is responsible for its own development and zonation. The alternate theory suggests local physical and geological processes that influence topography, elevation, and water movement are responsible for the formation and zonation of salt marsh vegetation. In this view, marsh plants are not significant land builders but instead are opportunistic species that colonize those areas in which they are adapted. Both theories show evidence for the importance of both environmental and biological factors in determining the formation and structure of salt marshes.

Multiple factors interact to determine the formation, structure, and ecological processes of salt marshes including (1) climate, (2) hydrology, and (3) physical factors. Climatic factors include temperature and rainfall; hydrologic factors include tidal inundation and wave energy; and physical factors include elevation and slope, sediment and soil composition, and surface water and soil salinity. The most influential hydrologic factor of a salt marsh is tidal inundation, where the frequency and duration of tidal flooding determines the extent of the intertidal zone. Other factors that affect the hydrologic regime of a marsh are wave energy, climate, rainfall, freshwater flow, and evapotranspiration. The unique topographic features of South Florida affect the degree of submergence, which in turn influences the zonation of plant species. All of these factors are important for restoring ecological processes to salt marshes.

Climate

The mild subtropical climate in South Florida influences the distribution and unique composition of salt marsh communities found here. In South Florida, many subtropical and tropical types of vegetation, especially mangroves, are sensitive to the degree, duration, and frequency of low temperature events. Freezes are an erratic year-to-year event in Florida, occurring more frequently and

severely in northern and inland areas (Duever *et al.* 1994). Freezes inhibit or kill mangroves, allowing for the colonization by salt marsh vegetation like *Spartina* and *Juncus*. Droughts can also have adverse effects on the composition and structure of salt marsh communities and depending on the severity of the drought, can lead to the death of plants. Precipitation provides a major source of freshwater to the upland headwaters that drain into coastal salt marshes.

Hydrology

Hydrologic factors play an important role in the formation, composition and structure of salt marshes. Tidal exchange between the marsh and estuary promotes the necessary exchange of sediments, nutrients and organic matter, drainage, and vegetation zonation (Broome 1990, Seneca and Broome 1992, Mitsch and Gosselink 1986). The hydrologic cycle in salt marshes is dominated mostly by tides, but is also influenced by oceanic currents, evaporitic processes, winds, freshwater flow, and catastrophic events. Tidal amplitude and wave energy have the greatest effects.

In South Florida, tidal amplitude plays an important role in lower and upper limits of a marsh by influencing its physical, chemical, and biological processes. Low tidal ranges produce tides that are insufficient to enter the upper reaches of intertidal salt marshes, where high tidal amplitudes are able to extend further into the marsh and can form natural levees or berms. Low tidal amplitudes are more common in South Florida causing most of the salt marshes to be above mean high water. The smaller tidal amplitudes create only small levees or none at all. Tidal patterns along the east coast of Florida are strongly influenced by proximity to inlets. Close to inlets, tides can fluctuate more than half a meter, while far from inlets, tides fluctuate less than a few centimeters. The degree of flooding may be important in determining the abundance of salt marsh vegetation. Water depth, flooding duration, mechanical effects of waves, sediment availability, and erosional forces determine the upper and lower limits of colonization by vegetation. Tidal action can also cause the formation of levees, deltas, sandbars, mud flats, and tidal creeks.

On the southeast coast of Florida, there are semidiurnal tides that average about 60 cm (23.6 in) but are lower in the interior bays (15 cm [5.9 in]). Mixed tides, which reach 250 cm (8.2 ft), are common on the southwest coast within a narrow zone in eastern Ten Thousand Islands (Wanless *et al.* 1994). In the Keys, there are two high and two low tides of uneven amplitude; in the Upper Keys, a semidiurnal pattern exists, while in the Lower Keys, a mixed tidal pattern occurs (Schomer and Drew 1982). Tidal ranges along the Indian River Lagoon and in the Keys are usually lower than in other parts of South Florida (Crewz and Lewis 1991). Differences in seasonal and yearly tidal patterns are also found between Atlantic wetlands and Gulf Coast wetlands.

Most salt marsh species are not able to withstand heavy and continual wave action. High wave energy causes erosion of sediments and prevents the establishment of seeds and roots (Mitsch and Gosselink 1993). The long-term stability of marsh vegetation depends on its protection from excess wave activity. Wave energy is high along the eastern coast of Florida, whereas it is low along the southwest coast and Everglades region (Montague and Wiegert 1990).

The presence of freshwater can influence the abundance and diversity of plants and enhance plant growth. Freshwater flows from mainland to coastal areas through drainage basins, groundwater, and rainfall. Strong discharges occur during the wet season and during storms and hurricanes. The amount of fresh water is controlled by several factors, such as levels of rainfall, proximity to salt water, permeability of subsurface sediments, and elevation above sea level (Schomer and Drew 1982). Salt marshes in South Florida have been influenced by alterations in upland freshwater flow caused by human activities for coastal construction, mosquito impoundments, and flood control. Indian River Lagoon marshes impounded for mosquito control purposes collect freshwater. Reduced salinities in these areas encourage the invasion of oligohaline flora which are able to outcompete most halophytic species. Salt marshes in the Keys are isolated from mainland flows of freshwater and tend to have a different structure and composition. Flood control structures prevalent along the east and west coast concentrate and divert freshwater flows away from salt marshes, also altering their composition and zonation.

Physical Environment

Elevation and topography are important in determining the composition of the substrate, affecting moisture content and salinity, which influence plant growth. Most halophytic plants grow over a range of intertidal elevations and slopes, with each species dominating areas best suited for it's growth. Salt marsh vegetation usually establishes in protected or low wave-energy areas, where the deposition and accumulation of sediments create gentle sloping formations. Salt marshes are relatively flat with slopes between 1 to 3 percent and little topography except near tidal creeks and in the upper marsh area (Zedler 1984). A gradual slope provides stability for the establishment and growth of vegetation and allows for inundation by tides.

Salt marsh sediments originate from upland runoff, reworking of marine derived sediments, and organic production occurring within the marsh. Since marshes are formed from land and sea sources, the sediments display physical and chemical characteristics of both. Marsh sediments are mostly anaerobic, with a biogeochemical composition resembling sediment originating from the sea. The anaerobic environment within most sediments causes high levels of H_2S and low pH (Pomeroy and Wiegert 1981). Organic matter accumulation varies in different areas of the marsh depending upon the degree of plant, animal, and microbial activity. Large amounts of organic matter generally do not accumulate in most marshes because of tidal flushing, rapid litter turnover, and high rates of oxidation. Organic matter influences the sediment properties, availability of nutrients, soils, growth rates of marsh plants, and presence and abundance of invertebrates associated with sediments. Exchange between sediments and flooding waters occurs through diffusion, bioturbation, and seepage (Wiegert and Freeman 1990).

Although marsh sediments are mostly anaerobic, a thin layer of aerobic soil can form on the substrate surface and around plant stems. These soils are a combination of recently formed minerals and organic matter. The inorganic substrate contains a mixture of sand, silt, and clay, but sediment composition varies along a gradient from intertidal to high marsh. Soils are fairly uniform in grain size fractionation and tend to be a lightish brown-gray color.

In order for marsh plants to colonize an area, the soils have to be fairly stable until their root systems can contribute to the stabilization. The stability of salt marsh soils derived from marine sediment is affected by the soil's salinity, acidity, moisture and nutrients (Gallagher 1980). Saline waters flooding the marsh, elevation of marsh, soil texture, climatic factors (temperature, evaporation and rainfall), and vegetation composition all interact to influence soil salinity, ultimately influencing its stability. The acidity of the soil, especially low pH, can affect plant establishment and development. Elevated moisture contents can increase flow characteristics of soil and reduce soil stability. The availability of nutrients is also a determining factor on soil stability. Finer sands tend to be higher in nutrients than coarser grain soils.

In South Florida, most marsh sediments contain fairly high amounts of organic matter mixed with inorganic estuarine material. Sediments in the Keys tend to have high amounts of calcareous material and less organic matter, except in areas where mangrove peat has accumulated (Schomer and Drew 1982). A thin veneer of marl overlays the limestone rock, but in many places the limestone rock is exposed and does not provide optimal substrate for marsh plant colonization.

Nutrient availability is important in maintaining high productivity of salt marsh vegetation. Salt marsh systems tend to be eutropic and have the ability to assimilate and store large amounts of phosphorous in the sediment (Whitney *et al.* 1981). Phosphorus is readily available for direct plant uptake and plants are able to obtain most of their phosphorous needed for growth directly from the sediments. The growth of marsh plants is also dependent on the availability of nitrogen. Marshes tend to have a limited supply of nitrogen and the amount of nitrogen is determined by tides, physical and chemical exchanges with water and air, and biological activity (Whitney *et al.* 1981, Seneca and Broome 1992).

Fresh, brackish, and saline waters are distributed in a salt marsh along a gradient from the upland headwaters to the marine environment. Salt marshes occur in areas where salinities in the overlying water range from 0.5 ppt to that of seawater (30 to 32 ppt) (Wiegert and Freeman 1990). The salinity varies from moderate at flood tide, to high following evaporation at low tide, to low during rains at ebb tide (Gallagher 1980, Pomeroy *et al.* 1981). Halophytic plants are adapted to tolerate the salinities of both the overlaying water and soil waters. Tidal creeks have salinities similar to adjacent saline waterbodies. The salinity within the soils is also similar to that of overlying water bodies and depends on several factors including the frequency of tidal inundation, rainfall, drainage slopes and tidal creeks, soil texture, vegetation, depth to water table, freshwater inflow, fossil salt deposits (Mitsch and Gosselink 1993). Soil salinities range from 10 to 20 ppt, and can exceed 100 ppt in sand barrens (Wiegert and Freeman 1990).

Evaporation and concentration of salts is usually greater in the high marsh causing soil salinities to be higher than in regularly flooded salt marshes. As a result, the level of freshwater input, tidal inundation, and evaporation controls species composition and the level of productivity. Both *Spartina* and *Juncus* grow best in fresh water, but are able to withstand saline conditions. *Spartina patens* can tolerate salinities up to 28 ppt. *Juncus* can withstand higher soil salinity, but growth becomes impaired at too high salinities.

Dominant or Characteristic Plant Species

Salt marsh plants are salt-tolerant or halophytic species that have developed biological and physiological mechanisms to adjust to a range in environmental conditions. In South Florida, these plants have adapted to tolerate the stresses of salinity changes, periodic inundation, and extremes in temperature that are unique in the South Florida environment. Although most salt marsh species have a broad range of distribution in the intertidal zone, their abundance differs depending on the unique hydrological and physical characteristics discussed above.

Salt marsh plants normally distribute themselves along the elevation gradient from the creek bank to upland depending on their tolerance and adaptability (Montague and Wiegert 1990, Wiegert and Freeman 1990). Along the upper edge of the high marsh, common species include marsh elder (*Iva frutescens*), saltbush (*Baccharis halmifolia*), seaside golden rod (*Solidago sempervirens*), seablite (*Sueda linearis*), and Christmas berry (*Lycium carolinianum*). Numerous species are found in the high marsh above the mean high water level: salt grass (*Distichlis spicata*), saltwort (*Batis maritima*), glassworts (*Salicornia* spp.), leather fern (*Achrostichum aureum*), sea oxeyes (*Borrichia* sp.), cordgrasses (*Spartina* spp.), coastal dropseed (*Sporobolus virginicus*), key grass (*Monanthochloe littoralis*), salt jointgrass (*Paspalum vaginatum*), and seablite. Typical species located from the low to high marsh are smooth cordgrass (*Spartina alterniflora*), black needlerush (*Juncus roemerianus*), and sea lavender (*Limonium carolinanum*). In the salt marsh-mangrove transition zone, dominant mangrove species include red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Languncularia racemosa*) mangroves, and the mangrove-associated buttonwood (*Conocarpus erectus*) (Tomlinson 1986).

Community Types

The mild subtropical climate of South Florida supports a diverse community of both tropical and temperate flora. These conditions create different salt marsh communities than those typical of the southeast Atlantic and northern Gulf of Mexico. The community types and spatial extent vary due to latitudinal and geographic differences (Montague and Wiegert 1990). A transition between the more typical salt marshes and mangrove forests occurs on the east coast at about 30 N (Odum *et al.* 1982). Unlike the common *Spartina* or *Juncus* monotypic stands of north Florida, South Florida salt marsh vegetation is often intermixed with mangroves. The variety of salt marsh communities in South Florida includes (1) salt marsh-mangrove transition, (2) high marsh, (3) oligohaline marsh, (4) salt pan, and (5) salt marsh algae. These categories reflect characteristics typical of the South Florida Ecosystem, especially between different regions.

Salt Marsh-Mangrove Transition

A predominant type of salt marsh in South Florida occurs in association with mangroves, especially black. In this community, halophytic marsh vegetation grows in deep marl soils in association with small regions of peat accumulations that support mangrove and buttonwood trees (Schomer and

Drew 1982). This community flat tends to be at slightly higher elevations and is characterized by glasswort, saltwort, saltgrass, sea oxeye, marsh elder, and saltbush. These salt marsh communities are important transition zones or ecotones from fresh to salt-tolerant species. The freshwater-saltwater interface is altered by storms, winds or tides that shift water either inland or seaward creating a very harsh environment of salinity fluctuations. Usually conditions are more optimal for black mangrove overgrowth, but in areas where black mangroves are not overly dense, halophytic species like *Batis*, *Distichilis*, and *S. alterniflora* flourish. Severe cold fronts or freezes often kill or inhibit mangrove growth, allowing salt marsh vegetation to expand. Salt marsh vegetation also establishes along low edges of creeks and ponds. In South Florida, this salt marsh-mangrove transition community is found in waters protected from high wave energy. On the east coast, it is often in shallow sedimentary estuaries behind barrier islands. Along the southwest coast and Everglades region, the community is often interspersed in mangrove transitional areas. Good examples of this community type are found in the Everglades and Ten Thousand Islands area.

High Marsh

Another common salt marsh community in South Florida is the high marsh community. Similarly to north Florida, high marsh communities are typically located on higher elevations above mean high water and are not regularly flooded by tides (Montague and Wiegert 1990). In some areas, the high marsh community consists of monotypic stands of *Spartina* or *Juncus*. *Spartina alterniflora* is found in narrow strips seaward of red mangroves and *Juncus roemerianus* occurs in narrow strips or larger expanses along landward fringes. The high marsh can contain a variety of other halophytic species like *Salicornia* and *Distichilis* as well as mangroves. In *Spartina*-dominated communities, *S. patens* is found on the east coast of South Florida (*e.g.*, Biscayne Bay), while *S. alterniflora* is found along the west coast. Extensive areas of *Juncus*-dominated high marsh are found in Miami-Dade County, south of Homestead (Montague and Wiegert 1990).

Oligohaline Marshes

In parts of South Florida where salt marshes are significantly influenced by freshwater, a more oligohaline marsh forms containing a distinct flora composition and ecological role. These plant communities contain a mixture of true marine plants and freshwater plants that tolerate low salinities. Areas that receive substantial or continuous amounts of fresh water include the southern Everglades. Salt marshes along the Indian River Lagoons have shifted to more oligohaline environments due to past mosquito impoundment practices that isolated marshes and reduced tidal flushing. Typical species of oligohaline marshes are black needlerush, leather fern, cattails (*Typha domiguensis*), sawgrass (*Cladium jamaicense*), bulrush (*Scirpus robustus)*, and spider lily (*Hymenocallis palmerii*).

Salt Pans

Salt pans or barrens are bare, exposed, or water-filled depressions in a salt marsh, often covered by thin layers of blue-green algae (Wiegert and Freeman

1990). The high salinities of salt pans prevent most vascular vegetation growth, allowing only a few hardy species like saltworts and glassworts to survive. Sand barrens typically form in the high marsh where evaporation concentrates large amounts of salts in the substrate. Mud barrens form in depressions of the intertidal zone and retain water even during low tide. Pans are important habitat for migratory birds, especially waterfowl. Most pans are now associated with humans, where man has impeded natural hydrology or sheet flow by building dams, levees, or impoundments. In the South Florida Ecosystem, salt pans are found in all salt marsh communities, but are more common and extensive in the mangrove-associated *Juncus* marshes along the southwest coast (Montague and Wiegert 1990).

Salt Marsh Algae

The salt marsh algae community consists of mud algal flats dominated by several hundred species of benthic microalgae, phytoplankton, and some multicellular seaweeds (Pomeroy *et al.* 1981, Wiegert and Freeman 1990, Montague and Wiegert 1990). Many of these species are less productive than vascular plants but are an important nutritional source for zooplankton, detrital consumers like snails and fiddler crabs, and filter feeders such as bivalves. The species composition of marsh algae is dependent upon environmental factors like tidal amplitude, local topography, erosion of sediments, and the availability of light and nutrients. Although total species composition is not known for Florida salt marshes, common species include the diatoms *Cylindrotheca*, *Gyosigma*, *Navicula*, and *Nitzschia*, filamentous cyaobacteria *Anabaena*, *Microcoleus*, *Schizothrix*, red algae *Caloglossa* and *Bostrychia*; blue-greens *Lyngbya* and *Rivularia*, and green algae *Rhizoclonium*, *Ulva*, and *Enteromorpha* (Hustedt 1955, Pomeroy *et al.* 1981, Montague and Wiegert 1990, Wiegert and Freeman 1990).

Wildlife Diversity

Few animals have adapted to the high salinities and water conditions of the salt marsh environment, causing species diversity to be lower than adjacent terrestrial habitats. Animals that have adapted are often quite abundant. Specific information on faunal communities of South Florida salt marshes is sparse (Odum *et al.* 1982, Montague and Wiegert 1990). Most information comes from studies of north Florida marshes or other States.

Few species of fish, reptiles, or mammals are permanent residents of the salt marsh. Larger, long-lived species usually cannot adapt to the extreme environmental fluctuations, but instead are transient inhabitants. The primary users of the marsh include eight species of mammals, 11 bird species, and 6 reptile taxa (Cox *et al.* 1997, Enge *et al.* 1997). Mammals include rodents, minks, and rabbits; primary birds include rails, sparrows, wrens and numerous wading birds; and common reptiles include salt marsh snakes and terrapins. Over 500 species of insects have been reported in Florida salt marshes and 88 species of non-insect macroinvertebrates reported in the northeastern Gulf of Mexico (excluding oligochaete worms) (see Montague and Wiegert 1990). At least 10 species of fishes, 11 reptiles, 33 birds, 12 mammals, and 5 vascular plants are considered to be rare or endangered in Florida salt marshes FNAI (1997).

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the coastal salt marsh community in South Florida include: Lower Keys rabbit (*Sylvilagus palustris hefneri*), roseate tern (*Sterna dougallii dougallii*), rice rat (=silver rice rat) (*Oryzomys palustris natator* (=*O. argentatus*)), Key deer (*Odocoileus virginianus clavium*), wood stork (*Mycteria americana*) and bald eagle (*Haliaeetus leucocephalus*). Studies are being conducted to determine whether the Atlantic salt marsh snake (*Nerodia clarkii* (=*fasciata*) *taeniata*) utilizes the coastal salt marsh community. Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. State listed threatened and endangered species that occur in the coastal salt marsh community are included in Appendix C.

The endangered **rice rat** depends on large areas of adjacent or contiguous saline and freshwater wetland habitat. The rice rat is found only on twelve islands in the Lower Keys and populations occur at extremely low densities (Forys *et al.* 1996). Rice rats typically are dependent on salt marshes for shelter, foraging, and nesting (Goodyear 1987). Critical habitat for the rice rat includes salt marsh flats, salt marshes, swales, and adjacent transitional wetlands containing saltwort, glasswort, salt grass, sea ox-eye, key grass, and coastal dropseed.

The endangered **Lower Keys rabbit** primarily occurs in the grassy marshes and prairies of the Lower Keys (Forys and Humphrey 1992). Key vegetative species include grasses and shrubs (key grass, saltwort, glasswort, Gulf cordgrass (*Spartina spartinae*), saltmarsh fimbristylis (*Fimbristylis castanea*); sea ox-eye (*Borrichia frutescens*); sedges (*Cyperus* spp.); and sparse tree coverage by buttonwood (*Conocarpus erectus*) and blackbead (*Pithecellobium guadalupense*).

The **black skimmer** (*Rynchops niger*) utilizes the coastal salt marsh community in South Florida for breeding and loafing. Black skimmers are colonial nesters and are highly vulnerable to human disturbance and predators. In addition, a significant cause of breeding failure is flooding of nesting colonies by high tides. The major predators of black skimmer eggs and chicks include the raccoon (*Procyon lotor*), and laughing gulls (*Larus atricilla*). The State of Florida has listed the black skimmer as a species of special concern.

The **American oystercatcher** (*Haematopus palliatus*) uses coastal strand and coastal salt marsh for foraging. In South Florida, an important area for the American oystercatcher is Charlotte Harbor for Gulf Coast populations. Current population estimates for the Indian River and Mosquito Lagoon are about 60 birds. Estimates for other areas in South Florida are not available. Florida has listed the American oystercatcher as a species of special concern.

The State listed **least tern** (*Sterna antillarum*) utilizes coastal salt marsh in South Florida. There are no current reliable estimates of numbers of breeding least terns in Florida. In South Florida, least terns can be found nesting wherever open, sandy habitat is available. Least terns are colonial breeders that depend upon camouflaged eggs and group mobbing by adult birds for defense. The species adaptation to artificial sites such as dredged-material islands,



American oystercatcher
Original photograph by Betty Wargo.

construction sites, surface-mined lands, and roofs has expanded its local distribution. The State has listed the least tern as a threatened species

Ecology

Natural salt marsh processes include biotic interactions, primary production, decomposition, organic export, and energy flow. Little information is available to determine if humans are able to create or restore these natural processes. Although it is fairly easy to count the number of organisms in restored marshes, it is much more difficult to determine if restored marshes successfully re-establish ecological processes. It takes time and effective restoration techniques to attain structures and compositions comparable to natural marshes. Even with creation, enhancement or rehabilitation actions, man may not be able to create marsh systems that support ecological processes.

Microhabitat Types and Species Interactions

Salt marsh ecosystems are important habitat for several mammals, birds, reptiles, fish, and amphibians and provide areas for breeding, nesting, foraging, and shelter. Like the salt marsh vegetation, animals have developed biological or behavioral adaptations to tolerate fluctuating, harsh environmental conditions. Many of these species are not restricted to this community type, but are merely part-time users. Mangroves do not exemplify the close interdependence between plant and animals as other communities, but some species are totally dependent upon mangroves to survive. Fish and invertebrates from marine habitats are frequent visitors to salt marsh communities, as are birds and other organisms from nearby terrestrial systems. Salt marshes are important because they supply nutrients, provide habitat and structure, act as nurseries, and protect inshore habitats from sediment pollution. Reviews on salt marsh habitat and related fauna are provided by Montague and Wiegert (1990); Wiegert and Freeman (1990); and Mitsch and

Gosselink (1986, 1993). The following summaries characterize the ecology of three general salt marsh microhabitat types common in the South Florida Ecosystem.

Aerial Habitat

The salt marsh aerial habitat is similar to the terrestrial environment and provides habitat to both resident and transient species. The stems and leaves of salt marsh plants provide habitat for breeding, feeding, and shelter of numerous insects, spiders, snails, and crabs. Many of these organisms use the stems as a refuge from rising water levels. A variety of wading birds and migratory waterfowl feed on the aerial invertebrate community.

Benthic Habitat

The primary inhabitants of the benthic community include fungi and bacteria, meiofauna and megafauna; with each group playing an important part in the food web. Microbial fungi and bacteria live in and at the surface of the sediment and are the primary consumers of the benthic habitat. Meiofaunal organisms like protozoa, nematodes, and annelids forage on the primary consumers, and are then fed upon by larger invertebrates. Foraging invertebrates like polychaetes, gastropod mollusks, crustaceans, and amphipods forage along the sediment surface for algae, detritus and meiofauna. Filter feeders such as mussels, clams, and oysters filter food from the water column. Several species of reptiles, amphibians, birds, and mammals forage in these areas during periods of low water. During low tide, remnant small pools of water concentrate organisms, making it easy for predators to capture prey. The leaves and stems of salt marsh plants are used as nesting materials for some resident bird species and mammals. As water levels change with daily tides and seasonal influences, some organisms migrate to adjacent permanent upland habitats.

Aquatic Habitat

Tidal creeks and pools provide an aquatic component to the salt marsh habitat. They are especially important to marine fish and invertebrates that spend part or all of their life in the salt marsh (Odum *et al.* 1982). Tidal creeks and pools also provide aquatic organisms from nearby oceanic or estuarine habitats access to the salt marsh. A multitude of predatory birds, fish, crustaceans, mollusks, reptiles, and mammals use this avenue to hunt and capture available prey in the salt marsh.

Status and Trends

Limited data are available for determining the long-term trends in salt marshes. Original estimates of salt marsh coverage in Florida are approximately 163,652 ha (399,152 acres) (Cox *et al.* 1994). An estimated 45,895 ha (111, 940 acres) (28 percent) of salt marsh habitat has been lost since European colonization (Kautz *et al.* 1993). Of the current 117,757 ha (287,212 acres) of salt marsh habitat in Florida, over 77,735 ha (189,597 acres) (66 percent) are located in existing conservation areas (Kautz *et al.* 1993, Cox *et al.* 1994). Over 70 percent of salt marshes are located in northern Florida; 10 percent occur in the Indian

River Lagoon between Volusia to Martin County; and the remaining 20 percent is found in the rest of the South Florida area (Montague and Wiegert 1990).

South Florida salt marshes were not significantly modified by human activities until the early 20th century when many areas were permanently altered to accommodate the needs of a rapidly growing population. The common practice of constructing bulkheads and filling salt marsh areas for residential and commercial development not only destroyed many salt marshes, but also altered the natural hydrology. As a result, many salt marsh communities experienced a change in water and soil salinities, water levels, and tidal flushing regimes. Contaminants and pollutants have also been introduced into salt marshes. Changes in water flow have encouraged the invasion of exotic species like Australian pine (*Casurina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*). Exotics are conveyed by a variety of means, including water transport, birds, illegal dumping of vegetation and land clearing. Many exotics initially colonize along roadways or similarly cleared areas. Disturbed or denuded areas are often invaded by exotics before native salt marsh seedlings can establish themselves.

Efforts to control mosquitoes in South Florida began in the early 1930s with the use of ditching, impoundments, and pesticide spraying (Montague and Wiegert 1990, David 1992). Many salt marsh plants were killed from the semi-permanent flooding and salinity changes caused by impoundments. Unregulated dredging and filling occurred in South Florida until the early 1970s when Federal and State governmental policies were implemented to minimize impacts on salt marshes. Current Federal and State regulations normally require some degree of mitigation to offset the alterations or losses of wetland habitat; however, salt marsh habitat continues to be destroyed or altered today as coastal development continues in South Florida. Management efforts to control the population of mosquitoes continue today, although substantial progress has been made to minimize negative impacts on salt marshes.

Natural disturbances on salt marshes include fires, storms and hurricanes, drought, and floods. These events usually have a short-term, localized effect on salt marsh habitat and the community is generally able to recover fairly quickly. When these disturbances occur closely together, or are coupled with human-induced impacts, the effects can be catastrophic to the salt marsh community. Fires usually do not permanently affect salt marshes but may temporally affect soil composition, species composition and biomass (Schmalzer *et al.* 1991, Schmalzer and Hinkle 1992). Most salt marshes are affected by the storm surge more than the flooding or strong winds caused by tropical storms. One of the most significant impacts to salt marshes from hurricanes is the potential for rapid invasion of exotic vegetation into disturbed areas. South Florida has experienced 138 tropical storms between 1871 to 1981, with 78 of these as hurricanes (Duever *et al.* 1994).

Sea-level change is an important long-term influence on all salt marshes. Depending on the rate and extent of local sea-level change, salt marsh systems will respond differently (Titus 1987, Wanless *et al.* 1994). If rates of sea-level rise are slow, some salt marsh vegetation will migrate upward and inland and grow without much change in composition. If rates are too high, the salt marsh may be overgrown by other species, particularly mangroves, or converted to open bodies of water. If there is no accretion of inorganic sediment or peat, the seaward portions of the salt marsh become flooded so that marsh grass drowns and marsh

soils erode; portions of the high marsh become low marsh; and adjacent upland areas are flooded at spring tide, becoming high marsh. Sea-level rise in South Florida has been relatively constant for the past 3,200 years at around 0.4 mm/yr, (0.02 in/yr) but is now thought to be rising at rates of 3 to 4 mm/yr (0.12 to 0.16 in) based on tide measurements from Key West (Wanless *et al.* 1994). If sea-level rise continues at this present rate, many of Florida's coastal salt marshes will be impacted.

Management

Many Federal agencies have jurisdiction over the management of salt marshes including the FWS, COE, EPA, NOAA, NMFS, NPS, USGS, FEMA, and U.S. Coast Guard (USCG). The scope of their regulatory or management functions varies, but includes dredge and fill activities, maintaining navigable waters of the U.S., fish and wildlife protection, natural resource management, and water quality protection. In the South Florida Ecosystem, several federally protected areas containing salt marshes have been established, including Biscayne and Everglades national parks and Ding Darling, National Key Deer, Hobe Sound, and Ten Thousand Islands national wildlife refuges. Salt marshes are also provided partial protection through the Indian River Lagoon, Charlotte Harbor, and Sarasota Bay national estuary programs.

The State of Florida manages and regulates activities that may affect salt marshes, primarily through the DEP and GFC, as well as several other State agencies. Further management and protection of salt marshes is provided through the State's Surface Water Improvement and Management (SWIM) and Aquatic Preserve programs. SWIM plans have been developed for Indian River Lagoon, Biscayne Bay, Everglades, Charlotte Harbor, and Sarasota Bay. Aquatic Preserves include Indian River, Biscayne Bay, Card Sound, Charlotte Harbor system, and Estero Bay. Salt marshes are also protected in several of the State's parks and preserves. The issues of habitat acquisition and protection of biodiversity are being addressed by the State's Conservation and Recreation Lands (CARL), Preservation-2000, and Conservation-2000 programs. On the local level, city and county governments also participate in the management of salt marshes by developing and implementing management actions and plans to regulate activities in wetlands.

Management issues for salt marshes include dredge and fill activities, mitigation policies, shoreline stabilization projects, mosquito control practices, alteration of hydrology, exotic plant invasion, waste disposal and nutrient enrichment. All of these issues have had serious effects on the structure and function of salt marshes.

Mitigation

Similarly to other natural systems in South Florida, the greatest threat to salt marshes has risen from human activity. Although regulations are in place to protect salt marshes, mitigation is often used to minimize or compensate the destruction and alteration of these habitats. The effectiveness of mitigation in compensating for the loss of wetlands has had mixed success. Mitigated wetlands often fall short of replacing the structural and functional value of

natural, undisturbed systems. To evaluate the success of past mitigation efforts, Crewz and Lewis (1991) evaluated 33 wetland (including salt marshes) sites in Florida and found that the majority failed to meet the goals of the mitigation efforts. The failure resulted from a combination of poor design and planning, construction and planting techniques, monitoring methodologies, and regulatory review. Several of the sites failed to provide proper elevation, slope and drainage, substrate, vegetation planting quality, site design (size, location, and structure), and plant quality. The design and implementation of good monitoring programs could have identified many of the problems observed at the sites and allowed for efficient and effective correction.

Seven marine wetland (salt marsh and mangrove) mitigation sites in Manatee and Sarasota counties were also surveyed to determine the success of mitigation, degree of compliance with State permit criteria, and recommendations for improvement (Crewz 1992). All of the sites surveyed had some degree of non-compliance and many had problems resulting from shortcomings in the hydrological regime, site construction, vegetation planting, exotic plant invasion, and monitoring protocols. This comprehensive review exemplifies the necessity to conduct follow-up monitoring and enforce mitigation criteria if the long-term success of mitigation sites like these is to be ensured. A survey of past mitigation and restoration efforts has also been conducted in Biscayne Bay (Alleman 1981). Successful mitigation efforts were attributed to proper elevations, low wave energy, limited human disturbance, and a continuous monitoring program. Although avoidance of wetland impact is preferred, Alleman recommended the development of minimum success criteria and enforcement of compliance in order to ensure the success of future mitigation projects.

The results of these reviews show many of the wetland mitigation efforts were not successful for a variety of reasons. Success has usually been based primarily on survival and cover of vegetation and has not emphasized the importance of habitat quality and most importantly the function of the wetland. Since it is likely that mitigation will remain an alternative for offsetting wetland impacts, it is necessary to develop and implement specific goals or criteria to determine the level of success and to enforce the compliance of these criteria. The common and most sensible conclusion from evaluations such as these is to try to avoid the destruction or alteration of wetlands in the first place and only if necessary, accept mitigation as an alternative.

Mosquito Impoundments

Salt marsh impoundments were constructed as a management technique to decrease mosquito populations by continuously flooding areas during the mosquito-breeding season to prevent mosquitoes from laying their eggs. Starting in the early 1930s, more than 162 km^2 (62.5 sq. mi.) of wetlands were impounded in the Indian River Lagoon for mosquito control purposes (Indian River Lagoon NEP 1996). In St. Lucie County alone, over 460 km of ditches were constructed in the salt marshes to control mosquitoes. Today, there are 192 impoundments along the east coast of Florida; 85 of these are within the South Florida Ecosystem and encompass over 3,485 ha (8,500 acres) (Rey and Kain 1989). Ding Darling NWR manages mosquito impoundments on Sanibel Island on the west coast.

As marshes were impounded, the vegetative community experienced numerous changes. Isolated from regular tidal flushing with adjacent estuarine waters, the water levels in the impoundments often became entrapments for high levels of stagnant or fresh water. Many halophytic species like saltwort and glasswort could not survive the high water levels and were invaded and replaced by mangroves, primarily red. Mangrove colonization caused an accumulation of sediments, increasing the elevation of the marsh to the extent that the frequency and extent of tidal inundation was significantly reduced. The reduction of flushing influenced levels of salinity, dissolved oxygen, temperature, and sulfur compounds and caused the marshes to become stagnant. In areas where the salinity decreased significantly, freshwater vegetation took over, especially cattails (*Thypa* sp.). Today, properly managed impounded marshes consist largely of a mixture of high salt marsh and mangrove swamp.

The confinement of the salt marshes has also led to a reduction in the number of faunal species present, especially transient species that previously relied on tidal exchange to access the marsh (Harrington and Harrington 1982, David 1992). Numerous transient fish species were isolated from their former salt marsh habitat and the changes in water conditions could no longer support many of the estuarine organisms. Although some migratory birds benefited from the availability of habitat in the newly ponded marshes, many others were negatively affected. The most grave and irreversible impact was to the dusky seaside sparrow (*Ammodramus maritimus nigrescens*), which was driven to extinction in 1987 (Kale 1996).

On the short term, impoundment methods were successful in controlling mosquitoes, but the intensive maintenance turned out to be too costly to regularly uphold and many of the impoundments actually turned into mosquito breeding grounds. Recognizing the need to restore some of the natural integrity and function back to the salt marsh ecosystem, new methods were implemented to improve mosquito control while taking natural resource issues into consideration.

The current management practice for most impounded marshes uses the rotational impoundment management (RIM) approach (David 1992). The RIM is a method to seasonally control water levels to promote tidal flushing and habitat function while controlling mosquitoes. The RIM includes seasonal management, reduction in pesticide use, tidal range approximation, tidal range estimations, water quality improvements, restoration of vegetation, customized tidegate, aeration and pumping operations, drawdown operations to enhance wading bird use, and block or regional impoundment management (David 1992). Many of the impoundments in St. Lucie County are kept closed during the mosquito-breeding season (May to August) and open the remainder of the year (September to April). This strategy controls the mosquito population while providing essential tidal exchange needed during peak fish recruitment times (spring and fall) (David 1992). Management techniques to benefit wading birds focus on lowering water levels to concentrate fish for the wading birds to feed on.

Management efforts to restore high salt marsh to the impoundments include: planting of high marsh species, avoid excessively high water levels to prevent plants from drowning, controlling freshwater inflow and tidal exchange to promote appropriate salinities, and eliminating exotic plant invasion through direct removal or water-level practices.

Shoreline Stabilization

Coastal marshes are able to dissipate wave energy and accumulate sediment (Knuston 1988). Shorelines with salt marsh vegetation are often more resistant to storm damage than those without, although the amount of protection depends upon the type of salt marsh vegetation and density, salt marsh width, and the amount of wave energy. The greatest protection is usually provided by dense, wide salt marshes. Many of the dredge and fill activities in South Florida have removed shoreline vegetation through direct impacts or alteration of natural hydrological functions. The alteration and destruction of this habitat has, in many cases, resulted in unstable shorelines.

North Carolina State University and COE initiated the first studies on using salt marsh vegetation to stabilize shorelines in 1969 (Woodhouse *et al.* 1974, 1976). Attempts to conduct shoreline stabilization projects have been conducted throughout the U.S., especially in the Chesapeake Bay, Galveston Bay, San Francisco Bay, and Apalachicola Bay in Florida (Woodhouse 1979, Knuston and Innskeep 1982, Knuston and Woodhouse 1983). Knuston *et al.* (1981) and Knuston and Inskeep (1982) demonstrated the values of stabilization projects to dissipate wave energy caused by boat wakes and prevent excessive erosion. Early accounts of shoreline stabilization projects in Florida were reported by Courser and Lewis (1981) who planted smooth cordgrass to successfully stabilize 60 m (197 ft) of eroding shoreline along Tampa Bay, and Smith (1992) reported partial success of stabilization using smooth cordgrass along the Indian River Lagoon. Stabilization efforts using salt marsh vegetation continue to be carried out along shorelines and spoil islands in the South Florida Ecosystem.

Regions of Special Management Concern

Indian River Lagoon and Lake Worth Lagoon

The Indian River Lagoon estuary lies between the barrier islands and mainland of Florida's central east coast. It extends over 250 km (155 mi) from Ponce de Leon Inlet in Volusia County south to Jupiter Inlet in Palm Beach County. The Lagoon interacts with the saline waters of the Atlantic Ocean through the Sebastian, Fort Pierce, St. Lucie, and Jupiter inlets, providing tidal exchange with fresh water discharged into the lagoon from the Sebastian, St. Lucie, and Loxahatchee rivers. About 10 percent of salt marshes in Florida occur in the Indian River Lagoon, although the greatest expanses are found in the northern areas (Montague and Wiegert 1990). The salt marshes in the Indian River Lagoon are different than in other Florida estuaries because of unique latitudinal gradients, climatic conditions, wave action, and topographic changes (Montague and Wiegert 1990, Indian River Lagoon NEP 1996). Lake Worth is a shallow elongated estuarine system just south of the Indian River Lagoon in Palm Beach County. The majority of the natural shoreline of Lake Worth has been altered through bulkheading, leaving only 30 percent of the northern area vegetated with mangroves and associated salt marsh vegetation, and only 7 percent in southern portions (Dames and Moore, Inc, 1990).

The Indian River Lagoon is located in a zone where tropical and temperate flora and fauna meet, resulting in a higher species diversity than in any other

North American estuary (Indian River Lagoon SWIM 1994, Indian River Lagoon National Estuary Program [NEP] 1996). Marsh types are greatly influenced by the lagoon's tidal range, patterns of inundation, salinity, and topography. Most marshes are high marsh and occur above the mean high water line. In northern parts of the lagoon, the high marsh contains monotypic stands of black needlerush mixed with some salt grass, glasswort, sea oxeye, and saltwort and black and red mangroves. In southern marshes, saltmeadow cordgrass (*Spartina patens*) and salt grass dominate the high marsh area. South of Sebastian Inlet, an intermediate community of mixed salt marsh and mangrove vegetation is common. The low marsh zone has *S. alterniflora* mixed with red mangroves and continues approximately 10 m (32.8 ft) to the edge of mean high water line where it meets high marsh. On the barrier islands, the landward transition zone of mangrove communities mixed with high marsh species provides habitat to organisms that can withstand changing water levels.

The hydrologic regime of the Indian River Lagoon has been heavily influenced over the years by man's activities (Indian River Lagoon SWIM 1994, Indian River Lagoon NEP 1996). The salinities of many of the water bodies vary with the number of inlets and amount of seawater exchange. Residential and commercial construction in the late 1800s and early 1900s increased the need for inlets to increase commerce. To accommodate these needs, the St. Lucie Inlet was opened in the late 1800s resulting in greater exchange of water with the Atlantic Ocean. Freshwater systems like the St. Lucie River became more saline and estuarine as exchange continued. Lake Worth also historically consisted of mainly fresh water, but the opening of artificial inlets allowed for more saltwater exchange as well.

In the early 1900s, extensive drainage canals were constructed for agricultural purposes, and flood control projects were initiated in the 1930s following several destructive hurricanes. Between 1931 and 1945 several extensive droughts occurred causing marsh and peat fires. In the 1930s and 50s much of the salt marsh was impounded for mosquito control purposes and the Atlantic Intracoastal Waterway was expanded and deepened to allow for more navigable waterways, both of which further altered the hydrology of the Lagoon.

Over 16,400 ha (40,000 acres) of the salt marsh acreage in the Indian River has been impounded for mosquito control, causing isolation from the rest of the lagoon (Rey and Kain 1989). Many of the 192 impoundments are still isolated from the lagoon. Over 40 percent of the impoundments is privately owned, 40 percent are federally owned and the rest is county-owned. David (1992) provides an excellent, thorough account on the history of mosquito impoundments in St. Lucie County. The Subcommittee on Managed Marshes and local mosquito control districts develop and implement management strategies for mosquito control, vegetation, circulation, and fisheries and wading bird use. Most of the impoundments in Indian River and St. Lucie counties can be restored through reconnection with the lagoon using RIM. Other salt marshes that have been degraded by spoil disposal and ditching are also being restored by re-establishing tidal flushing and providing access to estuarine fauna. The salt marshes of the Indian River Lagoon also receive partial protection through the SFWMD and SJWMD SWIM Program and the Indian River Lagoon

NEP. Palm Beach County Department of Environmental Resources Management has conducted inventories of intertidal habitat along Lake Worth Lagoon and identified areas for restoration.

West Lake and Biscayne Bay

South of Lake Worth Lagoon, most of the salt marsh habitat in Broward County has been eliminated through urban construction, although exact estimates are not known. Remaining habitat is found along the shorelines of West Lake, which extends along the Atlantic Inland Waterway in Hollywood. West Lake is a 574-ha (1,400-acre) coastal wetland and mangrove preserve. Two prominent salt marshes in West Lake, Sheridan Street and Dania salt marsh, are found on slightly elevated areas and are dominated by *Borrichia arborescens* and *B. frutescens* (Broward County Parks and Recreation 1997). Broward County Parks and Recreation Division has developed a draft management and restoration plan for these two salt marshes.

Biscayne Bay is a shallow, well-mixed estuary along the southeastern portion of Florida, occurring primarily in Miami-Dade County, but extending into Broward. Salt marshes are found inland from the mangrove forest. Mangroves dominate most of the intertidal coastline. Two main types of salt marshes are found in Biscayne Bay: a saline flat and a higher marsh area. Saline flats are seasonally dry and dominated by sea purslane (*Sesuvium portulacastrum*) and saltwort. High marshes tend to be more inland with *Spartina* grasses and rushes. These salt marshes are different than west coast areas because they are dominated by *S. spartinae* instead of *S. alternifora*. The lack of *S. alterniflora* may result from overshading by dominant mangroves or a temperature regime that does not promote seeding (Biscayne Bay SWIM 1995). Salt marsh habitat is found throughout Biscayne Bay, with more extensive marshes found between U.S. Highway 1 and Turkey Point, and extending west of U.S. Highway 1 through Everglades NP, and interspersed in areas bordering Florida Bay and related water bodies. The salt marshes provide nutrient cycling, bird habitat, fish nurseries, filters for upland pollutants, shoreline protection, and water storage.

Historically, marshes along Biscayne Bay were dominated by freshwater (*e.g.*, *Cladium*), not halophytic species. With the man-made construction of upland canal systems and the subsequent reduction of freshwater flow, these freshwater areas turned more saline allowing for the growth and establishment of more saline vegetation (Teas 1976, EPA 1994). Most of the dredging and filling activities that eliminated or altered these areas were conducted in the mid-1960s. Today, dredge and fill activities, wave damage caused by heavy boat traffic and a decrease in water quality effect the stability of existing salt marshes (Biscayne Bay SWIM 1995).

Biscayne Bay was designated an Aquatic Preserve in 1974. Over 164 ha (400 acres) of tidal salt marsh and mangrove forests on Virginia Key are designated as a Critical Wildlife Area by the GFC. Over 123 ha (300 acres) of wetlands in Biscayne Bay have been restored in nine coastal wetland restoration projects by MetroDade DERM which has had quite good success with restoration and replantings of salt marsh vegetation (G. Milano, Dade County DERM, personal communication 1998). Restoration efforts include the

removal of bulkheads, species-specific elevation grading, creation of flushing channels, removal of exotic species, and planting of wetland species. Planting of *Spartina* has been used successfully in stabilizing shorelines. Mangroves colonize these areas and help stabilize the shoreline. A large part of the restoration success has been attributed to innovative partnerships and the utilization of cost-effective techniques.

Florida Keys

Three main salt marsh types are found in the Keys: (1) intertidal marshes, (2) grassy salt marsh, and (3) buttonwood transitional (Goodyear 1987, McNeese 1998). The lowest elevation zone is the intertidal marsh and is comprised primarily of halophytic species of glasswort, saltwort, and Key grass. Mangroves, especially black, are also found in this zone but do not dominate. The grassy salt marsh is situated on slightly higher elevations and is flooded primarily by spring or storm tides (Ross *et al.* 1992). This zone is dominated by the Gulf cordgrass interspersed with sea ox-eye and salt marsh fimbristylis (Forys and Humphrey 1992). The buttonwood transitional zone occurs at higher elevations than the other salt marsh habitats and is flooded mainly by storm tides. The open nature of the buttonwood canopy allows for the establishment of denser coverage of halophytes and grasses like salt grass, coastal dropseed, and sea ox-eye.

Salt marshes in the Florida Keys provide an essential transition between upland and intertidal habitats. Federally listed species such as the endangered rice rat, Lower Keys rabbit, and Key deer depend upon the stability and function of these transitional zones. Of these three, the Lower Keys rabbit relies most on these habitats to meet its foraging and reproduction requirements. Only 317 ha (773 acres) of marsh rabbit habitat remain in the Lower Keys. Most of this habitat occurs as small, fragmented, and disturbed patches (Forys *et al.* 1996). Salt marsh habitat in the Lower Keys is included in the designation of critical habitat for the rice rat. Apart from these endangered species, many other species also rely on the salt marsh habitat of the Keys.

Much of the original salt marsh habitat in the Keys has been destroyed or altered through the filling of wetlands for residential and commercial activities (FWS 1997). Remaining salt marsh habitat suitable for endangered species and other organisms is protected under local, State, and Federal law. About 33 percent of the salt marsh habitat lies within the boundaries of the National Key Deer Refuge and another 33 percent lies within Department of Defense property (Forys *et al.* 1996). The Florida Keys Environmental Restoration Trust Fund and FWS are currently restoring 2 to 2.5 ha (5 to 6 acres) of shallow estuarine ponds and enhancing the flushing of 21 ha (50 acres) of intertidal wetlands in Key West. Restoration activities include removing fill for roads, installing culverts, and removing exotic vegetation.

Everglades and Ten Thousand Islands

The majority of salt marshes within the Everglades and Ten Thousand Islands are found upland of the mangrove zone, between major estuaries, and in association with open ponds and black mangroves (Schomer and Drew 1982). Halophytic vegetation species like *Batis*, *Salicornia*, *Spartina*, and *Juncus*

establish in the transitional zone between the mangrove systems and the fresh water marshes or marl prairies (Russell *et al.* 1980, Schomer and Drew 1982). Large expanses of *Juncus* marsh are found in the interior margins of Buttonwood Levee and Cape Sable, as well as on the interior of some of the larger mangrove islands. Marshes dominated by *Spartina*, particularly *S. spartinae* are most dominant around Broad River and to the north (Schomer and Drew 1982). Many wading birds are dependent on transitional zone salt marshes and move between freshwater, estuarine, and marine foraging habitats depending on water levels (Bancroft *et al.* 1994). The salt marsh transition zone also provides important nursery habitat for many commercially and recreationally important fish species. Many other organisms depend on this habitat during different times of the year or periods of their life cycles.

The timing and volume of freshwater into salt marshes has been significantly altered by the diversion of water away from Shark River Slough and Taylor Slough and the impounding of water in the water conservation areas (Light and Dineen 1994, Fennema *et al.* 1994). The alteration of freshwater input has been suggested to cause Florida Bay waters to become more saline in more locations and for longer periods of time (McIvor *et al.* 1994). Alterations of freshwater flow has also decreased the abundance and availability of food and lowered the abundance of wading bird activity in these transition areas (Bancroft *et al.* 1994). Changes in freshwater deliveries are also responsible for the disturbance and reduction of important commercial fishes, lowered reproduction of faunal species like herons and ospreys, and distribution shifts of larger animals like crocodiles and manatees (McIvor *et al.* 1994).

Current restoration efforts led by Everglades NP and SFWMD are focused on trying to restore the quantity, quality and timing of freshwater delivery to the Everglades. This is predicted to have important effects on the fresh/salt water interface, although it is not known how they will be affected.

Rookery Bay

The Rookery Bay National Estuarine Research Reserve (NERR) is responsible for 38,950 ha (95,000 acres) of coastal wetlands along the southwestern coast of Florida in Collier County. Salt marshes in this area are located in a transition zone between the hydric pine flatwoods and mangrove forests, and are dominated by marsh and cord grasses, black needlerush, and salt grasses. Salt marshes in Rookery Bay have been most affected by residential and commercial construction activities that have caused direct damage or alteration of natural hydrologic patterns. Approximately 1,230 ha (3,000 acres) of salt marsh are currently under protection in Rookery Bay. Several endangered species and other resident and transitory species rely on these extensive wetlands.

Rookery Bay NEER has several ongoing restoration activities to enhance salt marshes and other coastal wetlands, including restoration of hydrology by installing culverts, removal of exotic vegetation, monitoring for water quality and pesticides, on-site and outreach education programs, and acquisition efforts. Currently, they are working with FWS and DEP to restore a 61.5 ha (150 acre) area along Henderson Creek containing a pine flatwood community that forms a transition into hydric pine flatwoods, salt marsh, and mangroves. The construction of roads has blocked the natural surface-water sheet flow into the area, including

the salt marsh. The site has also been heavily invaded by exotic vegetation (primarily *Melaleuca quinquenervia*). Efforts to restore this site include the eradication of exotic vegetation and the removal of the roads. One of the largest acquisition efforts in this area was the Deltona Settlement Agreement which involved the development rights for Marco Island and other areas in exchange for 5,330 ha (13,000 acres) of mostly salt marsh and mangroves. Other salt marsh areas are currently being acquired through the CARL program.

Charlotte Harbor Estuary

There are approximately 1,454 ha (3,547 acres) of salt marsh in the Charlotte Harbor Estuary, with coverage generally decreasing from north to south (Charlotte Harbor NEP 1995). Mangroves primarily dominate the shoreline, although there are patches of transitional salt marsh habitat. Within these zones, dominant species include cordgrass, saltgrass, glasswort, and seapurslane (*Sesuvium* spp.) (Drew and Schomer 1984). Monotypic stands of black needlerush are more common in slightly elevated areas with lower tidal inundation. *Spartina alterniflora* and *Juncus roemerianus* dominate salt marsh communities around the mouths of rivers (*e.g.*, Myakka and Peace rivers). Parts of the interior habitat of Sanibel Island have expanses of salt marsh dominated by *Spartina bakerii*.

Salt marshes in Charlotte Harbor Estuary have been directly destroyed or impacted from construction activities for residential and commercial purposes including construction for seawalls, drainage ditches for agriculture and mosquito control, boat facilities, and navigation channels. Man-made hydrological alterations have reduced the amount of freshwater flow from some rivers (*e.g.*, Myakka), while artificially increasing the flow through others (*e.g.*, Caloosahatchee). Over 50 percent of the salt marsh habitat adjoining the Charlotte Harbor system has been destroyed since 1945 (Charlotte Harbor NEP 1995). Approximately 400 linear miles of man-made canals were built in the 1950s to 70s, resulting in the loss of salt marsh habitat (Charlotte Harbor SWIM 1993). The interior salt marshes of Sanibel Island were heavily altered from human construction activities, hydrologic changes, and exotic vegetation invasion (Clark 1976).

The State of Florida Aquatic Preserve Program provides protection for several of the water bodies in the Charlotte Harbor Estuary including Lemon Bay, Cape Haze, Gasparilla Sound, Matlacha Pass, Pine Island Sound, and Estero Bay. Estero Bay falls into the SFWMD boundaries. The northern portion of Charlotte Harbor occurs under the SWFWMD jurisdiction and includes northern Charlotte Harbor, Gasparilla Sound and the Myakka and Peace rivers and their tributaries. The southern portion of the system is covered by SFWMD jurisdiction and includes the southern portion of Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay and the Caloosahatchee River drainage basin. The SWFWMD developed a Surface Water Improvement and Management plan (SWIM) in 1993. Both the Charlotte Harbor and Estero Bay estuaries have been incorporated into the National Estuary Program.

The Charlotte Harbor Estuary NEP is beginning restoration efforts and several projects have already been initiated. The Venus Lake Habitat

Restoration Project on Sanibel Island aims to create 0.6 ha (1.5 acres) of salt marsh and mangrove habitat from spoil uplands, remove exotic plants, and restore natural tidal flow on a 3.5 ha (8.5 acre) parcel. The Punta Gorda Wetland Restoration Project will restore a highly disturbed parcel of salt marsh in Punta Gorda. The restoration efforts will include the removal of exotics, primarily Brazilian pepper and Australian pine, excavation and grading of the shoreline, and replanting with salt marsh species like *Spartina alterniflora* and *S. patens*. This site will be designed to provide compatible recreational use as well. The DEP's Florida Marine Research Institute is currently conducting research to evaluate genetic and reproductive characteristics of smooth cordgrass to determine useful information for restoration projects.

Sarasota Bay

Sarasota Bay extends from Anna Maria Sound in the north to Venice Inlet in the south. Phillippi Creek, South Creek, Bowlees Creek and Whitaker Bayou provide freshwater to Sarasota Bay. Most of the natural shoreline has been eliminated but a few fragmented wetland areas of primarily mangroves interspersed with salt marsh vegetation remain (Sarasota Bay SWIM 1997). The watershed is split between two counties: Manatee and Sarasota, but only Sarasota County is within the South Florida Ecosystem boundary.

The salinity of Sarasota Bay has decreased since the late 1960s as a result of increased freshwater runoff from upland urban areas (Sarasota Bay SWIM 1997). Since 1950, there has been a 39 percent decline in intertidal wetlands (salt marshes and mangroves) attributed to historic land-use trends. Most remaining wetlands are small and fragmented. Completed wetland restoration projects include Leffis Key, Quick Point, City Island and Sixth Street. Priority areas for future wetland restoration in Sarasota County include Big and Little Edwards islands, Palmer Point, and Skiers Island.

Restoration Efforts

Restoration, on a landscape level, attempts to re-establish the natural structure, composition, and landscape processes that were historically lost as a result of human actions. To improve our ability to restore some of these processes, it is essential to establish measurable restoration goals and long-term monitoring programs to evaluate the success of the goals.

Salt marsh restoration is generally aimed at restoring a site to its pre-disturbance condition. Substantial progress in salt marsh restoration techniques has been made over the last three decades because of pioneering efforts in California, Maryland, and Louisiana. In South Florida, efforts to restore salt marshes were first initiated in the 1970s when it was recognized that indigenous flora and fauna were decreasing as a result of loss and alteration of habitat. Many restoration efforts have been conducted over the past two decades. Kruczynski (1982) discussed salt marsh replanting efforts on the Gulf coast of Florida and Crewz and Lewis (1991) provided one of the first reviews on salt marsh mitigation sites that evaluated the success and failure of restoration efforts. Several informative compilations of wetland restoration projects in the U.S. are available (*e.g.*, Lewis 1982, Kusler and Kentula 1990,

Lewis 1990, Thayer 1992). A comprehensive review of salt marsh restoration efforts in Miami-Dade County is currently being prepared (G. Milano, Miami-Dade County DERM, personal communication 1998). An accurate estimate of the amount of salt marsh habitat that has been restored in the South Florida Ecosystem is presently not available.

The process of attempting to re-establish salt marshes in the South Florida Ecosystem requires the ability to evaluate the structure, composition and ecological processes of the restored system. Methods on how to develop salt marsh restoration projects have been extensively addressed (*e.g.*, Zedler 1984, Kusler and Kentula 1990). Many of these accounts provide excellent suggestions on ways to establish salt marsh vegetation, but very few lend experience on how to re-establish natural ecological processes on a landscape level. Our knowledge of creating the structure of a salt marsh is much greater than our knowledge and ability to create a structural marsh capable of supporting abundant and diverse populations and promoting natural habitat processes. Factors important to the restoration of salt marshes in the South Florida Ecosystem include: structure (*e.g.*, hydrology, topography), composition (*e.g.*, species diversity, abundance), and ecological processes (*e.g.*, nutrient cycling, primary productivity).

Structure

The structure of a salt marsh is important in providing a functional habitat (*e.g.*, shelter and food) for flora and fauna to colonize. Habitat structure includes factors like hydrology, elevation and slope, and sediment and soil composition.

Hydrology

Hydrology is the most important variable in salt marsh restoration and plays a critical role in the establishment and growth of salt marsh vegetation. If proper hydrological conditions are established, the chemical and biological conditions will respond (Mitsch and Gosselink 1993). To ensure proper hydrological conditions, wave energy and tidal inundation considerations need to be met. The initial establishment and long-term stability of plants is affected by the amount of wave activity. Restoration areas in semi-protected areas with little direct wave impact are shielded from the erosional forces of wave action. Usually smooth cordgrass can withstand more dynamic wave environments than mangroves, but excessive wave action can be detrimental to cordgrass as well (Woodhouse *et al.* 1974, 1976; Crewz and Lewis 1991). Knuston *et al.* (1981) developed four useful factors to characterize wave climate: average fetch, longest fetch, shore configuration, and sediment grain size. A clearer understanding of the wave climate will be gained by evaluating these four factors and will benefit the potential planning of a successful restoration project.

Tidal flushing is important in maintaining the exchange of saline waters. Closed sites are isolated from regular tidal flushing of adjacent estuarine waters and are more susceptible to becoming entrapments for high levels of stagnant or fresher water. Several restored mitigation sites in Florida suffered from restricted flow exchange which led to oligohaline or hypersaline conditions, decreased water quality, and eutrophic conditions (Crewz and Lewis 1991). Oligotrophic habitats can lead to invasion of cattails, while hypersaline conditions stress plants

and inhibit growth or cause death of plants. Proper tidal inundation can met with the creation or maintenance of tidal creeks or channels that provide suitable drainage and tidal exchange. Channels improperly constructed can inhibit water flow and can decrease water quality by causing stagnant water conditions. Channels should be constructed or incorporated to maximize flushing of water, and prevent large areas of standing water while still remaining protected from extreme winds or wave action. Drainage avenues should be deep enough to retain water at low tide but not too much deeper than the access channel. Enclosed areas should be designed to prevent waters from becoming stormwater drainage from upland runoff of fertilizers and toxic compounds.

Elevation and Slope

Elevation and slope determine the extent of the intertidal zone, amount of tidal flushing, and zonation of plant species. Grading is usually necessary to establish appropriate elevations and slopes. Elevation requirements can be determined by observing the upper and lower limits of dominant plant species in a nearby natural marsh. Elevation limits are especially important in areas of small tidal amplitudes where restoration projects may be hindered by low tidal flushing. In their survey of 33 projects in Florida, Crewz and Lewis (1991) found the most common reason for the failure to successfully restore salt marsh habitat was improper elevation and slope requirements. Because most salt marshes exhibit unique characteristics, the following is a guideline for appropriate elevations in South Florida.

Some species are more dependent on proper elevation than others and their tolerance for elevation variations will differ (Zedler 1984). Smooth cordgrass can survive at slightly lower elevations, while black needlerush requires slightly higher elevation. Other species that are less tolerant of frequent tidal inundation, like saltmeadow cordgrass and salt grass, require planting at higher elevations. Appropriate planting elevations in South Florida range from +0.2 to +0.6 m (+1.9 ft) National Geodetic Vertical Datum (NGVD) for smooth cordgrass and +0.4 to +0.6 m (+1.3 to +1.9 ft) NGVD for needlerush (Crewz and Lewis 1991). For the Keys, elevation ranges may be slightly lower for these species due to lower tidal range and harsh substrate. Most salt marsh vegetation does not survive below the 0.0 NGVD (Beever 1986). Juvenile plants tend to be more sensitive to elevation than mature plants. Cordgrass seedlings have been found at +0.03 m (+1.3 ft) NGVD, while older, more established plants were found down to –0.01 m (-0.03 ft) NGVD (Crewz and Lewis 1991).

In a Tampa Bay restoration site, Crewz and Lewis (1991) found smooth cordgrass could be outcompeted at higher elevations by other species if salinity is too low and favors freshwater species like cattails. Lewis (1983) found elevation played a critical role in the successful establishment and growth of black needlerush; when elevations were too high, he found plants died and the area was colonized by more salt tolerant species; when elevations were too low, white mangroves outcompeted the black needlerush.

Salt marsh plants are also sensitive to the degree of stagnation (anoxia) and salinity extremes that can occur if elevations prevent proper tidal flushing (Zedler 1992). In impounded marshes of St. Lucie County, the number of culverts that

need to be installed to increase tidal flushing and prevent stagnation depends on the marsh's elevation (David 1992). Low elevation (+0.09 to 0.24 m [+0.3 to 0.8 ft] NGVD) marshes usually require more culverts to promote adequate tidal flushing, whereas those with high elevations (>0.40 m [1.3 ft] NGVD) required fewer.

Most marsh plants grow on a wide range of slopes, but gentle slopes reduce wave energy and provide greater area for plants to colonize. Gentle slopes usually between 1 to 3 percent provide the most optimal planting conditions (Seneca and Broome 1992). Slopes that are too flat can cause poor surface drainage resulting in pooling and high salinities. In these areas, high salinities prevent the establishment of seedlings and inhibit plant growth (Zedler 1984, Crewz and Lewis 1991). Slopes that are too steep can promote erosion and the transport of fine-grained sediment from upland to marsh areas. Crewz and Lewis (1991) found this to be the case in several restored sites in Florida where high slopes caused higher turbidity and reduced light penetration. These circumstances led to hypoxic conditions that ultimately inhibited plant growth. Slopes directed towards open water and tidal sources maximize proper tidal flushing, minimizing the likelihood of excess salinity or stagnant waters (Zedler 1984, Seneca and Broome 1992). The stabilization of the slope is as important as its incline. Unstabilized slopes can lead to increased erosion as well as the invasion of exotic plants that often colonize on disturbed soils (Crewz and Lewis 1991).

Sediment and Soil Composition

The goal of obtaining sediments for restoration purposes is to provide stable sediment that imitates the natural soil. It is important to ensure the initial soils are stable enough to support plant growth until the roots of marsh plants have the ability to contribute to the stabilization. Unstable and younger soils tend to erode faster than those soils that are stable or more mature (Gallagher 1980).

Dredging conducted to supply sediment for restoration projects often results in a variety of different parent materials low in organic matter (Gallagher 1980, Zedler 1992). In a comparison of natural versus constructed marshes, the soil composition of constructed marshes had less than half the organic matter content of natural marshes (Zedler 1992). These lower organic levels can impair microbial activities and prevent fauna from colonizing in the sediment. Mechanical operations for restoration tend to be easier on sandy soils, but these soils usually have a lower organic matter (Seneca and Broome 1992). Some hard rock and clay substrates are unsuitable for the colonization of planted marsh vegetation. Salt marsh plants were not able to colonize on the hard substrate found in two restoration sites in Key Largo and Stock Island (Crewz and Lewis 1991). The salinity of the substrate also influences the ability of plants to establish seeds and grow. Fairly high salinities were found to inhibit seed germination in California restored marshes (Zedler *et al.* 1982, Faber 1983, Zedler 1984). Dredged material may also contain contaminants such as pesticides, heavy metals, and petroleum products that can be released into the surrounding environment. Contaminants can be transferred from marsh soils to plants that can then transfer these substances to fish, mammals and

birds (COE 1978, Gardner 1980). Obtaining reference soil samples will help determine the suitability and stability of soil for a restoration project and minimize any adverse effects.

Soil Augmentation

Restoration efforts sometimes require the augmentation of marsh soils with nitrogen and different types of organic matter to accelerate plant growth. The response of marsh vegetation to fertilization depends on fertility of soil and the amount of nutrients supplied by tidal inputs, seepage, runoff, prescription, and nitrogen fixation (Seneca and Broome 1992). Soil augmentation efforts have had mixed success and the long-term effects of soil augmentation is not very well understood. In a North Carolina salt marsh restoration effort, nitrogen applied at the rate of 112 kg/ha and phosphorous at 49 kg/ha was effective in increasing plant growth (Seneca and Broome 1992). Fertilizers may enhance the initial growth of salt marsh vegetation and may improve plants' resistance to wave energy, but the continual application of fertilizers may interfere with the plants' ability to attain natural nutrient equilibrium (Zedler 1984, Seneca and Broome 1992). Unnecessary or overfertilization also interferes with plant growth. Overfertilization may alter natural root-to-shoot ratios, resulting in top heavy plants that are more susceptible to uprooting, or increase a plant's susceptibility to fungal infections (Crewz and Lewis 1991). Seneca and Broome (1992) found when nitrogen and phosphorous were added in the same fertilizer, nitrogen could inhibit the availability of phosphorus. Broadcast fertilizers have also been found to be ineffective in enhancing plant growth and may contribute to higher eutrophication in surrounding water. Zedler (1984) recommends that fertilizers should be incorporated into the substrate as separate slow time-release fertilizers or should be in a 3:1 N:P ratio if adding directly to a planting hole. The effectiveness of soil augmentation depends on application of nitrogen and phosphorous fertilizers at the time of planting and several years later.

Buffers

In addition to the site characteristics discussed above, buffer zones and limited human access are important considerations in a restoration plan. Buffer zones provide insulation and protection from both environmental and human influences as well as provide additional habitat and corridors for wetland species (Zedler 1984). Natural buffers consisting of native terrestrial or transitional vegetation maximize connection between upland and adjacent estuarine habitats. Intrusion by human activity at a site can interfere with marsh growth (Zedler 1984, Alleman 1981). Humans through direct trampling by foot or vehicular traffic and vandalism have damaged several wetland restoration sites in Florida (Crewz and Lewis 1991, Crewz 1992, Alleman 1981). Creating vegetated buffers around a restoration site provides an excellent way to limit human access. In several examples in Florida, restoration sites have restored natural habitat while providing some recreational human use (*e.g.*, Salvesen 1990, Broward County Parks and Recreation 1997, G. Milano, Miami-Dade County DERM, personal communication 1998).

Planting Techniques

General salt marsh planting techniques are now fairly standard and straightforward, although several considerations specific to South Florida are worth mentioning. Normally, the selection of plant species for restoration should be similar to species composition in nearby areas. In the South Florida Ecosystem, *Spartina alterniflora* is common along the southwest coast, but *S. spartinae* dominates in the coastal areas of Miami-Dade County and the Keys. Significant genetic variations in *Spartina alterniflora* are evident between Gulf and Atlantic coast populations and between different latitudes (Seliskar 1997). The transportation of species between these regions is strongly discouraged so gene pools are not disrupted or diluted. Seliskar (1997) found the internal function of a salt marsh is significantly altered when different genotypes were mixed together in the same marsh.

The availability of salt marsh seeds and plants for restoration is very limited in South Florida. Seed production of smooth cordgrass is patchier in South Florida populations than other locations and may be related to reproductive response at lower latitudes or susceptibility to predation and fungal infections (Crewz and Lewis 1991). Although smooth cordgrass can be somewhat easier to obtain than many other species, it is necessary to utilize a diversity of plant species in revegetating a site. Generally, sites planted with a variety of species over a topographic gradient from intertidal to upland areas are preferred (COE 1978).

For South Florida, the time of year will strongly influence the success of transplanted specimens. For most southeast marshes, optimal planting dates for smooth cordgrass are between April 1 and June 15 (Broome 1990). But with the unique weather patterns in South Florida, optimal planting times will vary. Crewz and Lewis (1991) recommended planting should occur between June and September to maximize wetter conditions. Extremes in weather that cause exceptionally dry conditions, high tides, or hot or cold temperatures are also not conducive to planting. Many salt marsh species are capable of tolerating high salinities, but greater biomass is usually produced at lower salinities (10 to 20 ppt) (COE 1978, Crewz and Lewis 1991). Extreme high tides and rainfall have washed away entire plantings (Zedler 1984). Considerations for tides and rainfall will vary between the different geographic zones in South Florida (*e.g.*, west vs. east coast vs. Keys).

Composition

Properly restored salt marshes are not expected to immediately provide the same flora and faunal composition as a natural marsh, but over time, the diversity and abundance of organisms should reflect those of natural systems. The vegetation composition determines the suitability of a site for colonization by various fauna. If restoration techniques are able to establish adequate structure, plants and animals should be able to utilize the habitat. The diversity and abundance of species in a restored marsh provide a partial indication of how effective habitat structure is, although they may not provide a true indication of ecological processes.

Several studies have evaluated the "success" of a restoration project by analyzing species composition over time. Benthic invertebrates are good indicators of habitat quality and food chain support (Pacific Estuarine Research Laboratory 1990). In comparisons between natural and restored marshes in San Diego, the abundance of benthic invertebrates (*e.g.*, bivalves, crustaceans, gastropods) in restored marshes was about half that of the natural marsh after 3 years; but after 15 years, composition was fairly similar (Pacific Estuarine Research Laboratory 1990). Since meiofauna and macroinvertebrates are less transient in nature, they rely heavily on established food chains common in stable, undisturbed sediments. Initially, restored marshes tend to lack the developed food chains necessary to support these organisms.

Colonization rates by fish vary depending on site characteristics but appear to be much faster than invertebrates. Although intertidal habitat was established in a restored mitigation marsh in Humboldt Bay, California, fish diversity and density was much lower than nearby natural marshes in initial surveys (Chamberlain and Barnhart 1993). The lack of fish was attributed to missing structural aspects like cover and food. Similar observations were made in North Carolina where an intertidal marsh was created from upland habitat (Broome 1990). After 3 years, nearby natural marshes had greater fish abundance and diversity than the created marsh. Fish composition in the created marsh finally reached levels equivalent to the natural marsh after 12 years. Opposite trends were found in restored Florida marshes. Kurz *et al.* (1998) found that four restored sites in Tampa Bay provided habitat for equal or greater abundances of fishes than natural marshes. Shortly after construction, fish abundances and diversity in restored marshes were almost equal to natural marshes. Restored marshes tended to provided habitat for nursery or transient fish species, while natural sites offered established habitat for resident species. From these studies, it is evident that different factors like time and habitat type will affect the colonization success of fish.

Bird species tend to colonize restored marshes fairly quickly, although this may be due to their transitory nature. Shortly after restoration of the San Diego marsh, bird colonization was fairly rapid, although species abundance and diversity was about half that of the natural marsh (Pacific Estuarine Research Laboratory 1990). The low number of birds was attributed to the inability of the restored habitat to provide adequate shelter and food. The transitory ability of most birds allows them the flexibility to utilize several marshes without being dependent on just one site.

Ecological Processes

Natural salt marsh processes include biotic interactions, primary production, decomposition, organic export, and energy flow. Little information is available to determine if humans are able to create or restore these natural processes. Although it is fairly easy to count the number of organisms in restored marshes, it is much more difficult to determine if restored marshes successfully re-establish ecological processes. It takes time and effective restoration techniques to attain structures and compositions comparable to natural marshes. Even with creation, enhancement, or rehabilitation actions, man may not be able to create marsh systems that support ecological processes.

Monitoring

Effective monitoring programs are essential in ensuring the success of all wetland restoration efforts. Monitoring is a way to measure the success of a project and determine if additional actions are necessary. Monitoring can detect whether replantings are necessary, if site characteristics (*e.g.*, elevation) are functioning properly, and new problems that may have arisen (*e.g.*, exotic plant invasion). Several publications are available that make recommendations for effective salt marsh monitoring programs (Woodhouse *et al.* 1974, COE 1978, Zedler 1984, Crewz and Lewis 1991, Broome 1990). Most monitoring programs have focused on measuring the amount of vegetative cover as an indicator of success. Although these vegetative variables are important, it is more critical to monitor the overall function and stability of a restored marsh by evaluating physical and chemical processes and fish and wildlife communities. Monitoring the status of those factors representative of the ecological processes of a salt marsh will provide a better indication of the marshes' long-term stability.

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Restoration of the Coastal Salt Marsh

Restoration Objective: Maintain the structure, function, and ecological processes of South Florida coastal salt marsh communities and increase their spatial extent in South Florida.

Restoration Criteria

South Florida can contribute to the restoration and preservation of coastal salt marsh ecosystems in Florida by restoring the natural structure, composition, and ecological processes of this community. The conservation and restoration of salt marsh habitat in South Florida will contribute to the recovery of several federally and State listed species, the protection and stabilization of other imperiled or rare species, provide additional nursery and breeding habitat, maintain or increase biodiversity, and restore hydrology to several coastal areas.

The restoration objective will be achieved when: (1) salt marsh habitat in South Florida is identified and characterized; (2) salt marsh habitat is protected through land acquisition; Federal, State or local management actions; and/or private cooperative agreements; (3) salt marsh structure, composition, and ecological processes are restored and maintained; (4) policies are implemented to prevent further degradation and alteration of salt marsh habitat; (5) if mitigation is necessary, specific success criteria and compliance procedures are developed and implemented to ensure mitigation projects sufficiently replace the structure, composition, and ecological processes of salt marshes; (6) salt marsh habitat in the Lower Keys is preserved and enhanced enough to support self-sustaining populations of salt marsh-dependent species, such as the Lower Keys rabbit and rice rat; (7) the biodiversity of salt marshes is returned to natural levels; (8) salt marsh habitat is enhanced and maintained to provide important nurseries and breeding grounds; and (9) at least 90 percent of exotic vegetation is removed permanently from salt marsh habitat.

Community-level Restoration Actions

1. **Identify and characterize the extent of remaining salt marsh habitat.** Salt marshes are found throughout most of South Florida, but specific information on community types and extent is not known.
    - 1.1. **Characterize habitat types.** Characterize different community types and determine the condition of both protected and unprotected salt marsh habitats.
    - 1.2. **Maintain and improve the GIS database for salt marsh habitat.** Compile and maintain salt marsh distribution information through the FWS and GFC Geographic Information System (GIS) databases.

2. **Preserve remaining salt marsh habitat.** Develop a salt marsh habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on salt marsh habitat.

   2.1. **Identify suitable areas for acquisition.** Develop a regional plan outlining priority salt marsh areas for acquisition, using a reserve design approach which takes such factors as connectivity, corridors, and fragmentation into consideration.

   2.2. **Continue federal acquisition efforts.** Continue salt marsh acquisition efforts within the National Key Deer Refuge, J.N. Ding Darling, Great White Heron, and Ten Thousand Islands, national wildlife refuges.

   2.3. **Support State, local, and non-government organization acquisition efforts.** Support entities in acquiring salt marsh habitat including State conservation easements, such as CARL and The Nature Conservancy.

   2.4. **Protect salt marsh habitat on private lands**. Protect salt marsh habitat on private land through acquisition, conservation easements and/or agreements. Develop agreements between the FWS and private landowners to minimize impacts such as alterations of hydrology and exotic plant invasion.

3. **Manage and enhance salt marsh habitat.** The main threats to salt marsh habitat are dredge/fill activities and alterations in hydrology. Over 66 percent of salt marsh habitat is presently in public ownership, but the remaining habitat is still highly vulnerable to man induced degradation and alteration. Identify areas in need of management and enhancement and implement appropriate management actions.

   3.1. **Manage ecosystem function.** Implement management actions that support or restore the structure, composition, and ecological process of salt marshes.

      3.1.1. **Provide suitable structure.** Implement management actions to ensure appropriate hydrology (*e.g.*, tidal inundation, wave force), elevation and slope, and sediment and soil composition.

      3.1.2. **Manage salt marsh composition.** Maintain native flora and fauna composition of salt marshes.

      3.1.3. **Manage for ecological processes.** Maintain water circulation and water quality, minimize contaminants, maintain or create transitional areas, and control non-native species.

   3.2. **Coordinate with Federal, State and county agencies to develop guidelines to improve mitigation policies.** Coordinate with various Federal, State, and local entities to develop policies that try to avoid the destruction or alteration of wetlands. If it is necessary to use mitigation as an alternative for offsetting wetland impacts, then develop specific mitigation standards that sufficiently replace the structural and ecological processes of natural, undisturbed systems. Enforce compliance with these success criteria.

   3.3. **Support implementation of Federal management programs.** Coordinate with and provide support for Federal management actions that maintain and benefit salt marshes such as those conducted by national parks, national wildlife refuges, and the National Estuary Program.

3.4. **Support the implementation of State management programs.** Coordinate with and provide support for State management actions that maintain and benefit salt marshes such as DEP and SWIM.

3.5. **Support the implementation of local management plans that benefit salt marsh habitat.** Coordinate with and provide support for local management actions to maintain and benefit salt marshes through various entities as county departments of environmental protection and parks and recreation.

3.6. **Support and encourage ongoing management efforts by mosquito control districts to restore salt marshes.** Coordinate with and provide support for efforts by county mosquito districts to maintain and restore salt marshes.

3.7. **Restrict access to salt marsh habitat if necessary.** Restrict access to sensitive salt marsh habitat to prevent damage caused by camping, homesteading, trash dumping, vehicular traffic, and detrimental recreational use.

3.8. **Establish buffers around sensitive salt marsh habitat.** Establish buffers to provide transitional habitat and corridors for wetland species and insulation and protection from environmental and human influences.

4. **Restore salt marshes**. Residential and commercial construction, alterations of hydrology, mosquito ditching, fill excavation, illegal solid waste disposal, and invasive exotic vegetation have degraded or eliminated salt marsh habitat. Identify areas in greatest need of restoration and initiate restoration efforts.

4.1. **Identify salt marsh areas in need of restoration.** Coordinate with Federal, State, local, and private entities to identify areas in greatest need of restoration and coordinate restoration efforts.

4.2. **Identify partners for restoration efforts.** Support restoration efforts that have innovative partnerships and use cost-efficient, yet effective techniques to enhance or restore salt marshes. Many successful restoration efforts have incorporated volunteers to remove exotic vegetation and plant salt marsh species.

4.3. **Identify sources for planting materials and ensure genetic stock.** Determine sources of plant material since the availability of salt marsh seeds and plants is limited in South Florida. Ensure growing conditions are compatible with restoration site conditions. Ensure transplantation of plant species from different areas does not disrupt or dilute gene pools.

4.4. **Restore ecosystem function.** Implement restoration actions to restore the structure, composition, and ecological process of salt marshes.

4.4.1. **Restore suitable structure.** Implement restoration actions to ensure appropriate hydrology (*e.g.*, tidal inundation, wave force), elevation and slope, and sediment and soil composition.

4.4.2. **Restore salt marsh composition.** Restore native flora and fauna composition of salt marshes.

4.4.3. **Restore ecological processes.** Restore water circulation and water quality, minimize contaminants, maintain or create transitional areas, and control non-native species.

5. **Identify, acquire, and manage salt marsh habitat to increase biodiversity, maintain important habitat for threatened, endangered, and imperiled species, and maintain nursery and breeding areas.**

   5.1. **Acquire, manage, and restore salt marsh habitat in the Lower Keys.** Conduct management and restoration actions to ensure salt marsh areas are able to support self-sustaining populations of Lower Keys rabbits, rice rats, and Key deer.

   5.2. **Acquire, manage, and restore salt marsh habitat used by other listed or imperiled species.** Conduct management and restoration actions to ensure salt marsh areas are able to provide essential functioning habitat for species like wood storks, bald eagles, manatees, crocodiles, wading birds, and other salt marsh species.

   5.3. **Manage and restore salt marsh to increase suitable habitat for nurseries and breeding grounds.** Several commercially important fishes use salt marshes for nursery grounds. Protect and improve these areas to enhance nursery habitat.

   5.4. **Manage and restore salt marsh habitat to increase biodiversity of native flora and fauna.** Past human impacts have reduced species diversity in South Florida salt marsh habitat. Although salt marshes have lower species diversity than most terrestrial areas, they do support numerous transient species. Maintain these habitats to increase biodiversity.

6. **Conduct research on salt marshes in South Florida by examining their structure, composition, and ecological processes.** Very little is known about the ecological processes of South Florida salt marshes. Additional information is needed to help restore and preserve these habitats.

   6.1. **Inventory flora and fauna composition of South Florida marshes and determine any differences between regions.**

   6.2. **Inventory and characterize the importance of salt marshes to threatened and endangered species.**

      6.2.1. **Investigate how threatened and endangered species use different habitat components of salt marshes for survival.**

      6.2.2. **Determine the effects of fragmented or degraded salt marsh habitat on endangered species, especially in the Lower Keys.**

   6.3. **Characterize the importance of salt marshes to other flora and fauna, especially less-known taxa like insects and marine invertebrates.**

   6.4. **Investigate the effects of hydrologic alterations on salt marsh processes.**

   6.5. **Investigate salt marsh nursery grounds.**

   6.6. **Continue to conduct genetic research of salt marsh vegetation.**

   6.7. **Investigate the effects of non-native species on salt marshes.**

   6.8. **Compare the ecology of marshes in different regions of South Florida, especially to the Keys.**

   6.9. **Compare restored marshes to natural marshes.**

   6.10. **Compare and evaluate salt marsh restoration techniques to determine the ability of different techniques to replace the structure, composition, and ecological processes of natural marshes.**

7. **Develop a long-term monitoring plan to evaluate status of salt marshes.** Monitor the extent of salt marsh habitat by updating the loss or change of habitat due to residential or commercial construction through GIS databases.

   7.1. **Monitor management and restoration activities.** Establish plans for corrections or modifications to management and restoration activities.

   7.2. **Conduct mitigation compliance and improve follow-up procedures.** Monitor mitigation projects for compliance and evaluate the effectiveness of success criteria.

   7.3. **Monitor biodiversity of salt marshes and use by fish and wildlife.**

   7.4. **Monitor the invasion/removal of exotic species in salt marsh habitat.**

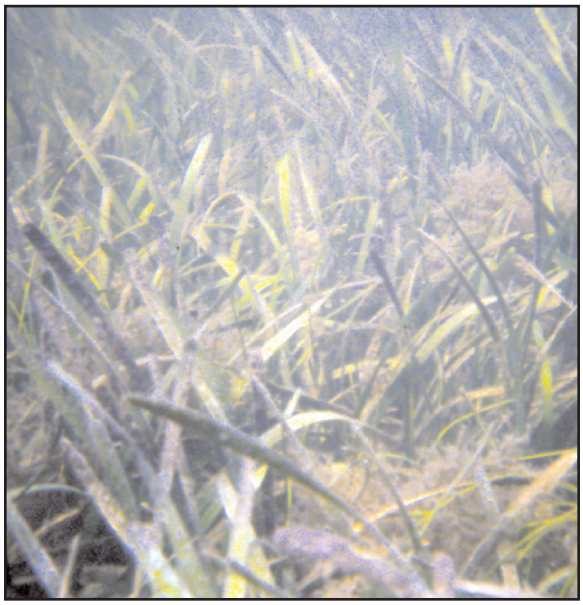
   7.5. **Hold annual workshops to evaluate salt marsh restoration efforts.**

8. **Increase public awareness of salt marsh habitat and instill stewardship.** Conduct workshops with the public to educate private landowners on appropriate management practices to preserve salt marsh habitat. Encourage private landowners to remove exotics, maintain natural hydrology, refrain from destroying salt marsh habitat, and restore disturbed areas. Develop volunteer restoration programs; coordinate with local parks to increase awareness of salt marshes; and coordinate with local school programs to develop hands-on educational programs for students. Prepare literature to provide information regarding the importance of salt marsh habitat and its preservation and conservation.

Seagrasses

FNAI Global Rank:	**G2**
FNAI State Rank:	**S2**
Federally Listed Species in S. FL:	**11**
State Listed Species in S. FL:	**26**

Turtle grass (*Thalassia testudinum*) *Photograph courtesy of Florida Department of Environmental Protection.*



Seagrasses are submerged vascular plants that can form dense vegetative communities in shallow water estuaries. Though not true grasses, these grass-like plants are termed "seagrasses" because they grow in highly variable salinity environments. Seagrasses are unique in that they carry out their entire life cycle completely submerged in salt water. Worldwide, there are more than 50 species capable of inhabiting this submerged environment, a relatively small number compared with the number of plant species in other environments. In South Florida, seven species of seagrass presently occur throughout this region's estuaries.

Seagrasses are a highly productive, faunally rich, and ecologically important habitat within the coastal lagoons and estuaries of South Florida. In terms of primary productivity, a seagrass bed can produce four to ten times the weight of organic matter as that produced by a cultivated corn field of the same size. Vast, extensive seagrass beds covering hundreds of kilometers may be composed of one to maybe four species. Yet, hundreds to thousands of species of flora and fauna may inhabit these beds, utilizing the food, substrate, and shelter provided by these submerged plants. Rapidly growing seagrass leaves provide food for trophically higher organisms via direct herbivory or from the detrital food web; the canopy structure formed by these leaves offers shelter and protection. This combination of shelter and food availability results in seagrass beds being the richest nursery grounds in South Florida's shallow coastal waters. As such, many commercial and recreational fisheries (*e.g.*, clams, shrimp, lobster, fish) are associated with seagrass beds.

Seagrasses have experienced declines in abundance and distribution due to water quality degradation and through the direct loss of habitat related to dredge and fill activities (*e.g.*, navigation channels, marinas) and boating impacts (*e.g.*, propeller scars and groundings). The degradation of water quality is largely the result of point source pollution (*e.g.*, wastewater discharge, agricultural

runoff, excessive freshwater discharge), nonpoint source pollution (*e.g.*, stormwater runoff, leaching from septic tanks), and the alteration of adjacent watersheds. The subsequent decline in seagrasses has significantly reduced the fisheries resources in South Florida.

Implementation of several protective and restorative measures has improved water quality and radically reduced the rate of habitat loss within South Florida's estuaries. Such measures include the regulation of dredge and fill activities, the elimination of wastewater discharge to surface waters, the treatment of stormwater runoff, and the rehabilitation of adjacent watersheds. Other significant actions include the establishment of management entities designed to preserve and protect biologically unique areas.

Synonymy

Seagrasses are also referred to as submerged aquatic vegetation and macrophytes, terms that may include both attached and drift macroalgae. FLUCCS codes for the seagrass community include: 510 (stream/waterways), 540 (bays/estuaries), 651 (tidal flats), and 652 (shorelines).

Distribution

Three seagrass species commonly occur in varying degrees of abundance throughout South Florida's coastal ecosystem: turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) (Zieman 1982). Three other species of seagrass are sparsely distributed within this range: star grass (*Halophila engelmannii*), paddle grass (*Halophila decipiens*), and Johnson's seagrass (*Halophila johnsonii*). In areas of reduced salinity, widgeon grass (*Ruppia maritima*) is often found intermixed with shoal grass. Unlike the other seagrasses, widgeon grass is actually a fresh water plant that has a pronounced salinity tolerance. Hence, its occurrence in estuaries with lowered salinities is commonplace.

The geographic distribution of seagrasses occurs in most of the coastal counties of Florida (Figure 1) (Zieman 1982, Zieman and Zieman 1989). The greatest abundance of seagrasses in the region is in an area that includes Florida Bay and the Florida Keys with approximately 587,770 ha (Sargent *et al*. 1995). The second largest seagrass bed (> 300,000 ha) occurs along the northwest Florida's Big Bend region, an area that extends from north of Tampa Bay to Apalachee Bay in the Florida panhandle (Livingston 1990). Seagrasses extend north of South Florida inshore of barrier islands along both coasts and are found within lagoonal systems, such as Sarasota Bay, Charlotte Harbor, Biscayne Bay, Lake Worth Lagoon, and the Indian River Lagoon. All seven seagrass species that are present in this region are found throughout this range. Turtle grass is most abundant in the Florida Keys and Florida Bay whereas shoal grass and manatee grass are more predominant along both coasts north of Monroe County. The lone exception is Johnson's seagrass, the distribution of which is limited to the east coast of Florida from Sebastian Inlet (Indian River County) to northern Biscayne Bay (Miami-Dade County). Relative to the other six species, Johnson's seagrass comprises less than one percent of the total abundance of seagrasses within its range (Kenworthy 1997).

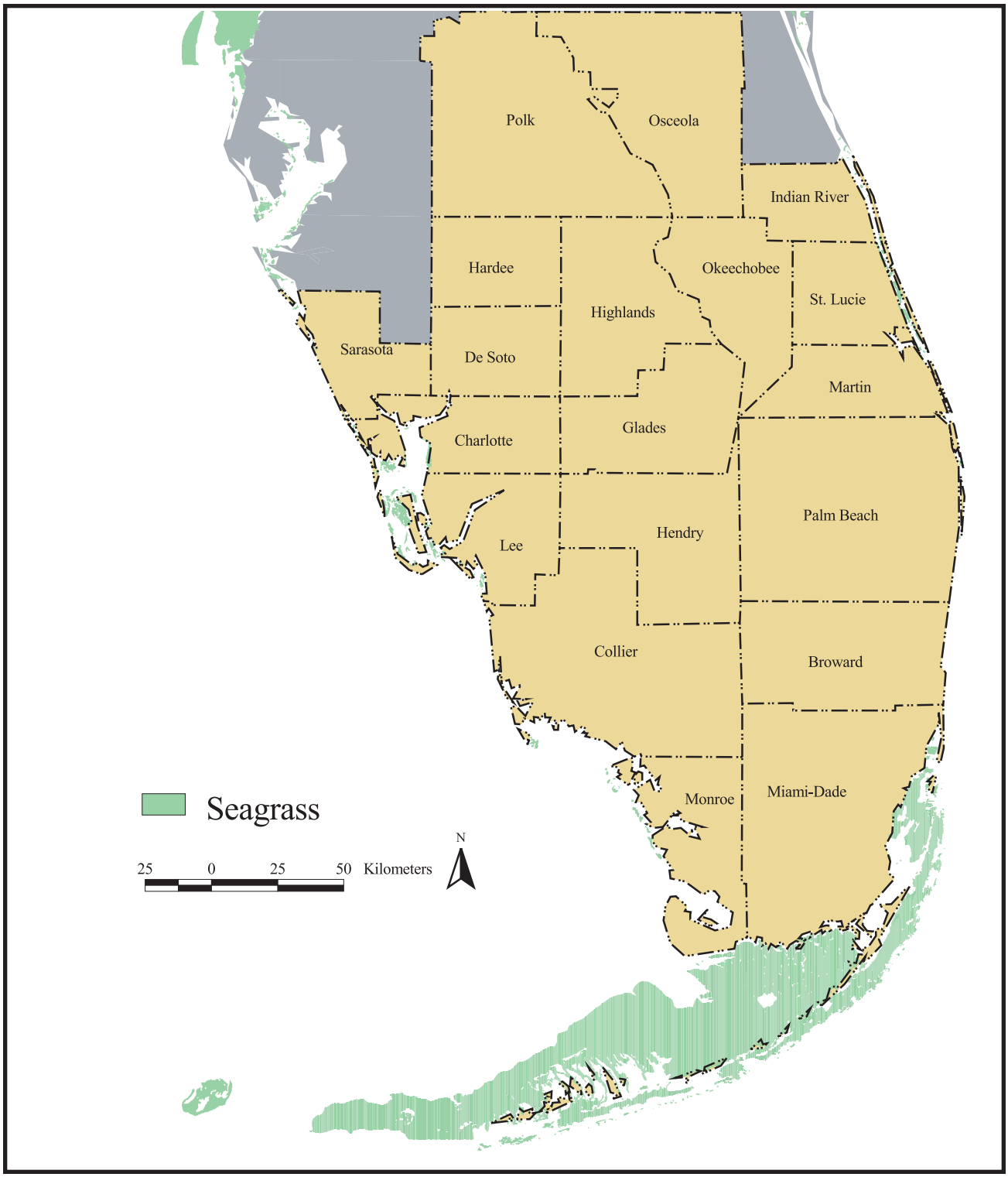


Figure 1. The distribution of seagrasses in South Florida (data from Florida Department of Environmental Protection).

The vertical distribution of seagrasses is controlled primarily by interactions between light availability and wave action and, secondarily, by substrate type and nutrient supply (Day *et al*. 1989). Seagrasses can influence the nature and depth of their own sediment bed by trapping and binding sediment particulates associated with damping wave and tidal energy (Burrell and Schubel 1977). Their physical structure stabilizes sediments and prevents the resuspension of particulate matter, thus helping to maintain water transparency or clarity (Kenworthy and Haunert 1991). Seagrass beds are often associated with substrate composed of a thick layer of highly sorted, fine-grained sediments. The density of seagrasses is typically greater where there is a reduction in wave action and ample nutrients are available in the sediments, although dense seagrass beds can occur in high-energy environments with sandy sediments.

Description

Seagrasses are vascular plants that can form dense vegetative communities in shallow water estuaries (Day *et al*. 1989). These plants have evolved the ability to carry out their entire life cycle completely submerged in the marine environment.

Structure and Composition

A remarkable similarity of vegetative appearance, growth, and morphology exists among the seagrasses. They have a linear form exhibited by a root system (rhizomes and roots) below ground and leaf structure (short shoots and leaf blades) above ground. Turtle grass, manatee grass, shoal grass, and widgeon grass are similar in appearance in that their leaves are long and either cylindrical (*i.e.*, manatee grass) or flat. The flat blades are either broad (*i.e.*, turtle grass) or narrow. The *Halophila* species differ from the other seagrasses in that the leaf structure is shorter with the blades resembling tufts or whorls.

Turtle grass is the largest and most robust of South Florida's seagrasses; Johnson's seagrass the most diminutive. Manatee grass is distinctive in having cylindrical leaves which are quite brittle and buoyant. As seagrass blades break off, they are exported from the immediate area by winds and currents. Shoal grass is recognized as the pioneer species in the successional development of seagrass beds.

For all the Florida seagrass species, the leaf structure emanates vertically from the horizontal rhizomes at regular intervals. From the rhizomes, which are just under the sediment surface, emerge the roots and root hairs into the surrounding substrate. Seagrass rhizomes range in diameter from 1 mm (0.04 in) for the *Halophila* group to 1 cm (0.4 in) for turtle grass. These plant components form a well-developed anchoring system and constitute the below-ground biomass of the plant. The leaf structure consists of short shoots from which leaf blades emerge into the water column. Leaf blades from these species range in width from 1 mm to 1 cm (0.04 to 0.4 in) and in length from 5 mm to 1 m (0.2 to 40 in). The leaf varies in shape for the *Halophila* group from oval to linear while the other species are essentially elongate. These components represent the aboveground biomass or standing crop of the plant.

Seagrass biomass consists of the weight of all living plant material (*e.g.*, roots, rhizomes, leaf structure) and is expressed in terms of mass per unit area. Seagrass biomass and the standing crop of seagrass beds are terms used to quantify the density of seagrasses. The majority of seagrass biomass is usually below the sediment surface. The robust root and rhizome system of turtle grass contains between 55 and 90 percent of the plant's total biomass (Zieman and Zieman 1989). Despite shallower, less well-developed roots and rhizomes, both manatee grass and shoal grass have a greater portion of their total biomass (53 to 89 percent) below the sediment surface, followed by widgeon grass with 50 percent (Lewis and Phillips 1980).

Each seagrass species can occur as a monotypic seagrass bed or can be found intermixed with the other species. In the Indian River Lagoon, some seagrass beds consist of all seven species with the *Halophila* species scattered throughout sparser areas within the bed.

Reproduction

Seagrasses reproduce sexually and asexually (or vegetatively). Vegetative reproduction in seagrasses accounts for their capacity to produce high biomass and extensive areal cover (Zieman and Zieman 1989). Information on sexual reproduction in seagrasses is limited, though there is an abundance of reproductive literature available on turtle grass. This species is sexually dimorphic, producing separate male and female flowers. In South Florida, turtle grass flowers develop in mid-May with fruits appearing 2 to 4 weeks later (Zieman 1982). According to Grey and Moffler (1978), turtle grass may also be dioecious, *i.e.*, separate male and female plants.

Most of the available literature on sexual reproduction for the other species is from studies conducted on the west coast of Florida. Phillips (1960) found flowering widgeon grass in Tampa Bay. Lewis *et al.* (1985) collected flowering manatee grass in the bay and found reproductive specimens of shoal grass in nearby waters. Sexual reproduction in Johnson's seagrass is unknown; male flowers have never been found. Hence, it is believed that Johnson's seagrass disperses primarily through vegetative reproduction.

Wildlife Species of Concern

Federally listed animal species that depend upon or utilize the seagrass community in South Florida include: American crocodile (*Crocodylus acutus*), green sea turtle (*Chelonia mydas*), loggerhead sea turtle (*Caretta caretta*), hawksbill sea turtle (*Eretmochelys imbricata*), leatherback sea turtle (*Dermochelys coriacea*), Kemp's ridley sea turtle (*Lepidochelys kempii*), roseate tern (*Sterna dougallii dougallii*), wood stork (*Mycteria americana*), bald eagle (*Haliaeetus leucocephalus*), and West Indian manatee (*Trichechus manatus*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan. For a complete list of State listed species that utilize seagrasses see Appendix C.

The coastal lagoons and estuaries are used as foraging habitat by several species of birds including the osprey (*Pandion haliaetus*), magnificent frigatebird (*Fregata magnificens*), least tern (*Sterna antillarum*), black

skimmer (*Rynchops niger*), American oystercatcher (*Haematopus palliatus*), and eastern brown pelican (*Pelecanus occidentalis*). The State of Florida classifies the osprey, American oystercatcher, eastern brown pelican, and black skimmer as species of special concern, and the least tern as threatened.

The **osprey** is one of four subspecies distributed throughout the world, with *Pandion haliaetus carolinensis* being the North American variant. In Florida, the osprey is afforded the status of a State species of special concern for Monroe County only. The osprey occurs throughout Florida wherever there are sufficient bodies of open water for fishing. Nests are constructed on the tops of cypress, mangrove, and pine trees (Ogden 1996), utility poles, radio towers, channel markers (Schreiber and Schreiber 1977) and even in shrubs or on the ground as in the Florida Bay area (Ogden 1977). In eastern North America, the osprey is considered stable except for the declining Florida Bay population in Everglades NP (Kushlan and Bass 1983; Poole 1989). Ospreys are considered somewhat tolerant to human activity which makes them particularly vulnerable to entanglement in fishing monofilament, striking power lines, hunting, waterfront development, and human-induced changes in food availability (Ogden 1996). This species is highly susceptible to environmental contaminants, although there is no current threat from heavy metals, PCBs, and pesticide contamination.

The **Eastern brown pelican** is a subspecies that occurs along the coastline from Venezuela to Maryland and in the Caribbean. The brown pelican is a marine species that nests and roosts on small islands (mostly < 5 ha) and prefers areas vegetated by mangroves (Nesbitt 1996). Sand bars have also been identified as an important "loafing" habitat (Schreiber and Schreiber 1982). Kushlan and Frohring (1985) reported a 40 percent decrease in numbers of pelicans in South Florida; however, since 1985, the overall status of the population nesting in Florida is improving. Increasing development leading to habitat degradation and decreased water quality are the most serious threats to the eastern brown pelican. In the 1960s and 70s, this species was found to be vulnerable to chemical contamination from pesticides and pollutants, such as DDT, PCBs, and Endrin. Fishing line is another notable source of mortality.

Wading birds, such as the roseate spoonbill (*Ajaia ajaja*), reddish egret (*Egretta rufescens*), great egret (*Ardea alba),* snowy egret (*Egretta thula*), little blue heron (*Egretta caerulea*), and tricolored heron (*Egretta tricolor*) frequently feed along the edges of shallow water seagrass beds. The State classifies the roseate spoonbill, reddish egret, snowy egret, little blue heron, and tricolored heron as species of special concern.

Fishes utilize the seagrass community for food and shelter. These include: common snook (*Centropomus undecimalus*), spottail goby (*Gobionellus stigmaturus*), mangrove rivulus (*Rivulus marmoratus*), and the key silverside (*Menidia conchorum*). The State lists the common snook and the mangrove rivulus as species of special concern, and the key silverside as threatened.

The **spottail goby** is a small fish (29 mm [1.14 in] standard length) known from Bermuda, Florida, Cuba, Belize, and Panama (Pezold 1984) with Florida populations ranging from Brevard to Monroe counties. The spottail goby has



Eastern brown pelican. *Original photograph by Betty Wargo.*

been consistently collected in Fort Pierce Inlet in seagrass beds consisting of manatee grass and shoal grass (Gilmore 1988). The spottail goby makes burrows on nearby sand bars in very shallow water (depth < 0.5 m). Physical disturbances and the degradation of water quality are major threats to the spottail goby's seagrass habitat.

The **key silverside**, the smallest known species of *Menidia* (53 mm [2.08 in] standard length), is limited to the Florida Keys from Long Key to Key West. The key silverside swims in shallow, protected, coralline pools surrounded by mangroves and often associated with turtle grass and macroalgae (Duggins *et al.* 1986). While this species is present at other locations within the Middle and Lower Florida Keys (*e.g.*, Long Key, Grassy Key, Big Pine Key, and Cudjoe Key), it seems to have disappeared from Key West. The extent of urban development is greater on Key West than the other islands; thus, the loss of habitat (*e.g.*, mangroves, seagrasses) can result in the extirpation of a small localized population.

Plant Species of Concern

A federally listed plant species that depends upon or utilizes the seagrass community includes the Johnson's seagrass. Although no biological account is included in this recovery plan, a brief description is provided below. The recovery plan for Johnson's seagrass is being developed by the U.S Department of Commerce's National Marine Fisheries Service.

The federally threatened **Johnson's seagrass** (*Halophila johnsonii*) is one of twelve species of the genus *Halophila*. Johnson's seagrass is rare and exhibits one of the most limited distributions of any seagrasses. Within its limited range (lagoons on the east coast of Florida from Sebastian Inlet to central Biscayne Bay), it is one of the least abundant species. Johnnson's seagrass' limited

reproductive capacity (apparently only asexual) and limited energy storage capacity, makes it unlikely to repopulate an extirpated area. Identifying characteristics of *Halophila johnsonii* include smooth foliage leaves in pairs 10 to 20 mm (0.39 to 0.79 inches) long, a creeping rhizome stem, sessile flowers, and longnecked fruits.

Ecology

Seagrasses have been identified as an important habitat linked to the productivity of our abundant fisheries (Ogden and Zieman 1977). This high productivity is largely in response to the inherent ecological functions of seagrasses (Zieman and Zieman 1989) which are: (1) seagrass growth is extremely rapid with the leaves growing at about 5 mm (0.20 in) per day and over 10 mm (0.40 in) per day under favorable circumstances; (2) the production of detritus and the promotion of sedimentation provide organic matter for the plants and maintain an active environment for nutrient recycling, *i.e.*, seagrasses take up nutrients from the sediments, transporting them through the plant and releasing them into the water column through the leaves; (3) the pathways for photosynthetically fixed energy is by direct grazing of living plant material, the utilization of detritus from decaying plant matter, or the export of living and detrital plant material from one location to another allowing for the distribution of energy away from its original source; (4) seagrasses stabilize sediments with the roots and rhizomes forming a complex, interlocking matrix, which binds the substrate and with the leaves impeding current flow to reduce water velocity near the sediment-water interface, which promotes settling of suspended particles as well as inhibits the resuspension of organic and inorganic materials; (5) the surface of seagrass leaves provide the substratum for attachments by a myriad of small algae and animals (*e.g.*, crustaceans, worms, sponges, bryozoans), which provide the basis for food to a variety of larger seagrass-associated animals (Virnstein *et al.*1983); and (6) seagrass beds serve as a place of both food and shelter for the juveniles of a variety of shellfish and finfish of commercial and recreational importance.

In the subtropical waters of South Florida, seagrass beds often bridge large areas between mangrove and coral reef communities. Many organisms that are primarily associated with mangrove communities or coral reefs often feed in adjacent seagrass meadows, which act as a transitional zone between these ecological communities.

The spatial distribution of a given seagrass species is a function of environmental conditions that include light, temperature, salinity, substrate, waves and currents, and the availability of nutrients (Day *et al.* 1989).

Light

Estuarine seagrasses are most common in soft sediments of semi-sheltered areas where depth and turbidity conditions allow sufficient light levels necessary for growth and maintenance. Morris and Tomasko (1993) indicate that light is the primary environmental factor controlling the survival and the depth distribution of seagrasses. More specifically, light in the range of wavelengths from 400 to 700 nm (known as photosynthetically active radiation) provides the predominant source of energy for seagrass photosynthesis to occur.

Turtle grass, manatee grass, and shoal grass require between 15 and 30 percent of the incident light (*i.e.*, light at the water's surface) for long-term survival; thus, they typically do not grow in water depths greater than 2 m (6.6 ft) for areas north of southern Biscayne Bay. The three species of *Halophila* appear to need less incident light (approximately 6 to 12 percent) in order to survive; hence, their occurrence in water as deep as 3 to 4 m (9.8 to 13.1 ft). Factors that weaken or attenuate light as it travels through the water column are phytoplankton blooms due to nutrient enrichment, turbidity, and water color due to dissolved organic material. Additional factors that affect light availability include shading either by epiphytes (small algae attached to the surface of seagrass blades) or by structures (*e.g.*, docks) located in shallow water seagrass beds.

Another factor that limits the depth distribution of seagrasses is exposure at the shallow end of the depth gradient (Kenworthy and Haunert 1991). Shoal grass usually grows in the shallowest water and tolerates exposure better than the other species. The next zone of seagrass is usually turtle grass, followed by manatee grass with the *Halophila* group in deeper water. In some locations (*i.e.*, around inlets), Johnson's seagrass occurs both on sandbars exposed during low tide as well as in 4-m (13.1-ft) deep tidal channels. Except for southern Biscayne Bay, Florida Bay, and the Florida Keys, the average maximum water depth for the vertical distribution of seagrasses in South Florida is approximately 2 m (6.6 ft). In the relatively clear waters of these areas, seagrasses can be found growing in water usually 6 to 7 m (19.7 to 22.9 ft) deep and even as deep as 10 m (32.8 ft).

As subtidal plants, seagrasses do not tolerate exposure well. When exposed to the air, they lose water continuously until they dry out. Exposed leaves usually die, then break off to be carried away with the current. Normally, the rhizomes are not damaged and the plants continue to produce new leaves.

Temperature

Turtle grass, manatee grass, and shoal grass prefer temperatures between 20 and 30°C (68 and 86°F), although shoal grass is more eurythermal than the other two species. Shoal grass, which is common in shallow water where temperature variations tend to be greater, has a greater tolerance to lower temperatures than either turtle grass or manatee grass. Seagrasses in deeper water are buffered from cold temperatures because the overlying water has a greater mass to be cooled.

Salinity

While each of the seagrasses can tolerate considerable short-term salinity fluctuations, they all have an optimum salinity range from 24 to 35 parts per thousand. As expected, shoal grass is broadly euryhaline, while manatee grass is more stenohaline with turtle grass intermediate in its salinity tolerance. The *Halophila* group is also more stenohaline, although Johnson's seagrass may be tolerant of reduced salinities. Widgeon grass, again not a true seagrass, can tolerate freshwater as well as hypersaline conditions.

Although seagrasses may tolerate lowered salinities, the photosynthetic rate in seagrasses is affected by changes in salinity. A decrease in salinity carries a corresponding decrease in the photosynthetic rate of turtle grass. Following the passage of a hurricane through South Florida in 1960, Thomas *et al.* (1961) concluded that the damage to turtle grass by excessive fresh water to have been more severe than the physical effects of the storm surge.

Sediments

Seagrasses grow in a wide variety of sediments from fine muds to coarse sandy material. As rooted plants, seagrasses require a sufficient depth of sediment for proper development. Sediments anchor the seagrass against the effects of water surge and currents, and provide the matrix for growth and nutrient supply. Sufficient sediment depth and physical stability is the single most important sediment characteristic for seagrass growth and development. Requirements for sediment depths vary with the different seagrass species. Shoal grass can colonize thin sediments in an area of minimal hydraulic stability because of its shallow, surficial root system. Although turtle grass can sparsely colonize thin sediment layers over rock, this species requires at least 10 cm (3.94 in) of sediment to achieve lush growth.

Seagrass blades can also affect the sediments they grow in. Dense seagrass blades greatly affect the concentration of fine-grained particles in sediments (Zieman 1982). For example, turtle grass blades can increase the percentage of fine-grained particles in sediment two to five times. The primary physical effects from seagrass blades are that they increase sedimentation rates, concentrate fine-grained particles, and stabilize the deposition of sediments. One of the ecological functions of a seagrass system is the ability to create a relatively low-energy environment in an area of high energy and turbulence. This is a key element in a plant's efficiency to stabilize sediments.

Nutrients

The primary constituents of plant material are carbon, nitrogen, and phosphorus. The accessibility of these components as dissolved nutrients is an important factor governing the production of seagrass. In general, seagrasses acquire most of their required inorganic carbon from free CO_2 and assimilate nitrogen and phosphorus from the sediments via their roots and rhizomes and from the water column via their leaves.

Productivity

The major sources of primary production in South Florida's coastal ecosystems are macrophytes, *i.e.*, seagrasses, macroalgae, and mangroves. Algal communities associated with seagrasses include benthic algae (attached to the substrate), drift algae, and epiphytic algae. Seagrass leaves provide a relatively stable substrate for epiphytic algae. The turnover of the epiphytic algal community is relatively rapid, since the lifespan of a single leaf is quite limited. A typical turtle grass leaf has a lifetime of 30 to 60 days (sometimes longer). The standing crop and productivity of epiphytes and their contribution to the trophic food web of a system is highly variable. In nutrient-poor waters, there are few epiphytes and, hence, very little contribution. Conversely, in nutrient-enriched waters, like the Indian River

Lagoon, epiphyte production is high. The relationship between these plants is that of an ectoparasite, *i.e.*, the relationship is beneficial to the epiphyte but detrimental to the seagrass. Thus, in areas of high nutrient supply, epiphyte grazers are extremely important in maintaining seagrass productivity.

Seagrasses themselves are very high in primary production and contribute large quantities of detritus to an ecosystem (Zieman 1982). In Florida Bay and the Keys, the standing crop of turtle grass beds may exceed 1,000 grams of dry weight per meter squared. As such, the contribution of seagrass production to this region's carbon budget may represent over 50 percent of the total production within the estuary. Again, the factors that reduce seagrass production are decreasing light levels, lack of nutrients, and increasing epiphytic growth on the leaves.

Habitat

The structure of seagrass beds provides living space for a diverse assemblage of mobile and sessile organisms (Harlin 1980, Stoner 1980). Biota present in seagrasses are classified in a scheme that recognizes the central role of the seagrass canopy (leaf blades) in organizing seagrass-associated communities. The principal groups of such organisms are epiphytic (living on plants), epibenthic (living on the sediment surface), infaunal (living within the sediments), and nektonic (living in the water column). Representatives among these groups include invertebrates (*e.g.*, polychaetes, gastropods, bivalves, shrimps, lobsters, crabs, urchins) and vertebrates (*e.g.*, fishes, reptiles, birds, mammals).

Seagrass beds serve as nursery habitat where post-larval stages of invertebrates and fishes develop to juvenile and adult phases (Virnstein *et al.* 1983, Lewis 1984). With their high productivity, extensive surface areas, and high blade densities, seagrasses provide protection from predators, a substrate for the attachment of sessile stages, and a plentiful food source. Notable examples of organisms that benefit directly from their development within seagrass beds include the pink shrimp (*Penaeus duorarum*), spiny lobster (*Panulirus argus*), and several species of recreationally and commercially important fishes [*e.g.*, spotted sea trout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellata*), snook (*Centropomus undecimalis*), mangrove snapper (*Lutjanus griseus*)]. For example, the pink shrimp harvest near the southwest coast of Florida was 4,535,970 kg (10 million pounds) per year prior to 1987. In the Indian River Lagoon, seagrasses have been estimated to provide almost $30,000 per ha annually in economic benefits based on fisheries alone (Virnstein and Morris 1996).

Seagrasses and associated epiphytes provide food for trophically higher organisms by direct herbivory, as detrital food webs within seagrass beds, and as detrital material exported out of a seagrass bed (Zieman 1982). Direct herbivory is best exemplified by green sea turtles and the West Indian manatee grazing in seagrasses. The detrital food web is another pathway of trophic energy transfer. Typically, seagrass blades die and break off from the shoots to form a layer of leaves on the sediment surface. This leaf litter is then subjected to bacteria, fungi, and other microorganisms that contribute to the decomposition of the plant material. The physical breakdown and reduction in particle size of decaying seagrasses facilitates its assimilation by filter feeders

(polychaetes) and deposit feeders (gastropods), which in turn, are fed upon by omnivores (shrimps) and carnivores (fishes).

Status and Trends

With few exceptions, most of South Florida's coastal ecosystem has been negatively affected either directly or indirectly from a number of man-made activities: hydroperiod alterations, loss of upland vegetation, shoreline modifications (*e.g.*, removal of vegetation, installation of seawalls), construction of causeways and bridges, dredging channels, increasing boat traffic, point-source pollution (*e.g.*, wastewater treatment facilities), nonpoint-source pollution (*e.g.*, stormwater runoff), and oil spills. The majority of these direct and indirect effects are the result of Florida's rapidly expanding population. Between 1970 and 1980, the State's coastal counties increased in population 44 percent, the greatest population increase in the nation during that period. Between 1988 and 2010, South Florida will have four of the top 10 counties nationwide in absolute population change. Specifically, over 1.3 million additional persons are projected to move to Lee, Miami-Dade, Broward, and Palm Beach counties by 2010. This growing population will result in significant losses of habitat and living resources; increase demands on water, energy, waste treatment and its disposal; and continue to diminish the environmental quality of the region. For example, almost 207,000 vessels are registered in Palm Beach, Broward, Miami-Dade, Monroe, Collier, and Lee counties. Aside from the increasing number of registered vessels, the average size and horsepower of these vessels are increasing as well, to the detriment of shallow water seagrasses. As coastal populations increase throughout South Florida, management of this growth to ameliorate the associated direct and indirect effects becomes crucial.

Water Quality Degradation

Urban, industrial and agricultural development, and the construction of the Central and Southern Florida Flood Control Project by the COE have had a profound effect on the region's coastal habitats. The "urban-developed ridge" of Miami-Dade, Broward, and Palm Beach counties has virtually eliminated the natural community structure and function of over 161 km (100 mi) of the southeast coast. Draining South Florida's interior wetlands into the adjacent estuaries has resulted in increased turbidity as well as nutrient and pollutant loadings (Indian River Lagoon NEP 1996).

While there is a lack of specific information on pesticide loads to South Florida's estuaries, recent studies indicate that pesticides can enter the estuary with stormwater runoff (Pait *et al.* 1992). High concentrations of trace metals (*e.g.*, copper, cadmium, lead, and zinc) are found in specific locations, characteristically near numerous and extensive boating facilities (*e.g.*, marinas). Pathogenic bacteria leaching from septic tanks into nearby estuaries, especially shellfish harvesting areas, pose a public health problem. Nutrients from sewage disposal systems can result in nutrification and eutrophication of nearshore areas.

Water management practices have resulted in the alteration of freshwater flow into the estuaries. Such discharges introduce contaminants and pollutants into these waterbodies. The frequency and timing of freshwater discharges have influenced the loss of seagrasses in Florida Bay (Florida Bay Interagency Working Group 1994). Episodic voluminous freshwater releases (due to excessive rainfall events) through control structures in the Caloosahatchee and St. Lucie rivers have a similar effect on the receiving estuaries, Charlotte Harbor and Indian River Lagoon, respectively, because of the reduction in salinity for extended periods. In addition, such freshwater releases/discharges carry pollutants, primarily nutrients and sediments. During 1990 to 1992, the total nutrient loading related to stormwater runoff into the Indian River Lagoon was estimated to be over 3 million pounds per year.

Habitat Loss

From the 1920s to the 1960s, Florida's coastal zone underwent tremendous alterations as a result of the lack of proper management of its explosive population increase. During this period, coastal communities arose from the mangrove marshes that dominated South Florida's estuarine landscape. Many of these communities were built by dredging and filling emergent and submerged wetlands for residential development. Associated with such communities were numerous man-made canals and waterways constructed to facilitate the demand for "waterfront" property. Channels were dredged through seagrasses to provide navigational access to and from waterfront properties. Throughout Florida, approximately 7,500 ha (18,532 acres) of submerged land have been filled by dredged material to facilitate residential and commercial development (Zieman 1982). Aside from the direct effect of burial, resuspended particles from spoil deposition reduce light levels thereby restricting primary productivity. Such rampant dredge and fill activities resulted in the destruction of seagrass beds throughout South Florida.

Another threat to seagrass communities has been, and continues to be, the increasing number of boats on Florida's coastal waterways. Used for recreation and/or work, many of these vessels operate in water shallower than their drafts, resulting in propeller scarring of seagrasses. Of the State's 1.1 million ha (2,718,100 acres) of seagrass, more than 70,000 ha (172,970 acres) have been lightly, moderately, or severely scarred by boat propellers (Sargent *et al.* 1995).

As the population began to increase in these newly erected coastal communities, nutrients from sewage discharged into South Florida's estuaries also increased. Nutrient enrichment in these embayments stimulated the production of epiphytes and phytoplankton which in turn inhibited the growth and survival of seagrasses. Hence, the loss of habitat due to physical disturbance and the degradation of water quality resulted in a decline in fisheries resources throughout South Florida's coastal ecosystem.

Aside from habitat degradation, fisheries resources have been dramatically affected by overfishing. With the decline in seagrasses, nursery and rearing habitat were significantly reduced. Furthermore, with an increase in population, there was a concurrent increase in pressure on the existing fish stocks. In Sarasota Bay, spotted seatrout landings were down 50 percent,

although seven times more recreational anglers were using the bay than in the 1950s (Sarasota Bay NEP 1995).

From 1950 to 1985, seagrass coverage declined approximately 35 percent in the Indian River Lagoon (Haddad and Harris 1985). Since the 1950s, seagrasses have declined almost 30 percent in Sarasota Bay (Sarasota Bay NEP 1995). Other estuaries that have experienced similar deceases in seagrass abundance and distribution include Lake Worth Lagoon, Biscayne Bay, Estero Bay, and Charlotte Harbor.

Recent seagrass assessments conducted in 1995 indicate that the overall change in seagrass coverage in the Indian River Lagoon from 1943 to 1992 has been a 20 percent decrease (R.W. Virnstein, SJRWMD, personal communication 1998). While seagrasses declined or disappeared in some sections of the lagoon, they increased in coverage in those areas where inlets have been stabilized and increased in size. Five of the six inlets along the lagoon are man-made; hence, their presence allowed the introduction of clear oceanic water into the lagoon, which influenced the growth of seagrasses near these estuarine connections.

Florida Bay

For Florida Bay, the decline in seagrasses was not the result of dredge and fill activities. Since most of the bay (220,200 ha [544,114 acres]) is within the boundaries of Everglades NP, it is protected from large-scale human-induced direct physical disturbances. Historically, seagrasses have been the dominant primary producers in Florida Bay. However, since 1987, massive seagrass mortality has occurred in the bay with over 18 percent of the total bay area affected (> 40,000 ha [98,840 acres]). The rate of seagrass "die-off" accelerated in 1992. Such massive habitat loss has substantially affected fish and wildlife resources. As a result of the seagrass die-off, the pink shrimp harvest decreased from 10 million pounds in 1986 to four million pounds in 1987, a decline of 60 percent.

The most likely cause for seagrass die-off appears to be physiological stress from high salinities and high temperatures in the 1980s coupled with the long-term anthropogenic reduction of freshwater inflow to Florida Bay (Florida Bay Interagency Working Group 1994). Additional stressors include sulfide toxicity as a result of photosynthesis/respiration imbalance and a disease which was also probably stress induced. An additional postulated cause of the Bay's seagrass mass mortality is nutrient enrichment from the mainland and the Keys.

Boating Impacts

Currently, the most common form of physical destruction to seagrasses is the dredging of plant material (blades as well as roots and rhizomes) by boat propellers and vessel groundings on shallow seagrass beds. This form of seagrass destruction, known as "prop scarring," occurs in shallow water areas throughout South Florida. In leading the State in total seagrass coverage, Monroe County also leads in scarred seagrass beds with almost 12,200 ha (30,146 acres). Zieman (1976) estimated that it takes several years for turtle grasses "to begin recovery" from prop scarring. Sargent *et al.* (1995) indicate

that a prop scar within a turtle grass bed averages 3 to 5 years to begin healing. However, a recent study indicates that moderate scarring (*i.e.*, minimal vertical relief in the scar) takes 12 to 15 years to begin recovery (J.W. Kenworthy, NMFS, personal communication 1998). Deeper scars require decades to recover. In Tampa Bay, Lewis and Estevez (1988) indicate complete seagrass-scar recovery may take as long as 10 years. This period is probably much longer in areas of poor water quality and where scarring is severe and repetitive; some scarred beds may never recover.

Another serious form of physical disturbance to seagrasses is from boat wakes. Based on data indicating decreased light penetration associated with weekend boat traffic, Kenworthy *et al.* (1988) found a possible cause-effect relationship between boating activities and increased turbidity. Seagrasses are sensitive to decreased light penetration. Increased boating activity and larger boats have resulted in chronic conditions of resuspended sediments and eroded seagrass beds along the edges of deeper channels, especially in the Upper and Middle Florida Keys (C. Kruer, Florida Keys Environmental Restoration Trust Fund, personal communication 1998).

Once seagrasses are lost within an embayment, that system's capacity to stabilize sediments is also lost. A negative cycle is initiated when resuspended sediments reduce the amount of light available for seagrasses to survive and grow, which reduces seagrass coverage, which reduces sediment stabilization, resulting in additional resuspended sediments.

Management

Much of Florida's distinctive character lies in the beauty of its natural features, especially its coastal areas. This natural beauty has always been one of Florida's major attractions for both residents and tourists. Ironically, the very features that have attracted people to Florida have been physically altered by the increased population pressure.

It was during the early 1960s that the public became aware of the importance of Florida's coastal environment. During this period, dredge and fill activities were regulated for the first time by the State of Florida. In 1972, the COE authorized dredge and fill activities nationwide in accordance with section 404 of the Clean Water Act. With the passage of the Warren Henderson Wetlands Protection Act of 1984, wetland regulations and permitting were standardized throughout Florida. Once these regulatory measures were implemented, the rate of habitat loss due to physical alterations began to decline.

Not all of the seagrass habitat in South Florida is in peril. Hobe Sound, southern Biscayne Bay, Card Sound, and some areas in the Florida Keys exhibit very healthy seagrass beds. It is those seagrass beds adjacent to urbanized coastal communities that have been ecologically stressed and physically damaged for several years. During the past two decades, several management programs designed to improve water quality and protect biological resources in coastal regions were implemented by the Federal government and the State of Florida. A summary of these management programs and a table listing them follows:

Aquatic Preserves

To protect the State's distinctive and unique coastal features for the enjoyment of future generations, the Florida Legislature created a series of aquatic preserves around the State in the late 1960s. Aquatic preserves are "submerged lands of exceptional beauty" that are to be maintained in their natural or existing conditions. In 1975, the Florida Aquatic Preserve Act was passed establishing a standardized set of management criteria for all aquatic preserves, both existing and future. Administered by the DEP, this set of management criteria was developed to eliminate or minimize the effects of specific activities on coastal resources such as seagrasses and mangroves. For example, dredging and/or constructing multi-slip docking facilities in seagrass beds is prohibited. There are several aquatic preserve programs around South Florida (Table 1).

Coastal Zone Management Program

Authorized by the Coastal Zone Management Act of 1972, the Coastal Zone Management (CZM) Program is a voluntary partnership between the Federal government and U.S. coastal states and territories. Through its partnerships, the CZM program serves to preserve, protect, develop, restore, and enhance the resources of the nation's coastal zone; to encourage and assist the states in exercising their responsibilities in the wise use of land and water resources of the coastal zone; and to encourage the preparation of special area management plans designed to protect significant natural resources, influence reasonable coastal-dependent economic growth, improve protection of life and property in hazardous areas, and improve predictability in governmental decision-making. In essence, the CZM program uses a comprehensive resource management approach by balancing land and water uses while protecting sensitive resources.

National Estuarine Research Reserves

On a national scale, the value of estuaries is tremendously important. These tidally influenced ecological systems provide habitat for millions of birds, mammals, fish, and other wildlife; function as a nursery ground for many marine organisms, including commercially valuable fish species; produce tremendous amounts of organic matter; filter water draining off uplands by removing sediments and nutrients; and function as a natural buffer between the land and the ocean by dissipating storm surges, thereby protecting private property. Recognizing the value of estuaries and the effect human activities would have on them, Congress created the National Estuarine Research Reserve System (NERRS) along with the passage of the Coastal Zone Management Act in 1972. Administered by the National Oceanic and Atmospheric Administration (NOAA), NERRS is dedicated to fostering a system of estuary reserves that represent the wide range of coastal and estuarine habitats found in the United States and its territories. In pursuing this goal, NERRS works with Federal and State authorities to establish, manage and maintain reserves, and to provide for their long-term stewardship. Research and education are the principal program components toward meeting this goal.

National Marine Sanctuaries

In creating the National Marine Sanctuary Program through the passage of the Marine Protection, Research, and Sanctuaries Act of 1972, Congress was extending the nation's protective interests beyond the estuaries and into the marine environment. Administered by NOAA, the mission of the National Marine Sanctuary Program is to identify, designate, and manage areas of the marine environment with significant ecological, conservation, research, educational, recreational, historical, and aesthetic qualities. The program's goals are to provide enhanced resource protection through conservation and management of the sanctuary; to support, promote, and coordinate scientific research on marine resources of the sanctuary; and to enhance public awareness and wise use of the marine environment.

National Estuary Programs

Congress continued its efforts toward protecting the nation's estuaries by establishing the National Estuary Program (NEP) under the Water Quality Act of 1987. Administered by the EPA, the NEP identified nationally significant estuaries threatened by pollution and development. The program's goals are to protect and improve water quality and to enhance living coastal resources through the preparation of a comprehensive conservation management plan (CCMP). Implementation of the CCMP ensures the ecological integrity of that particular estuary.

Surface Water Improvement and Management (SWIM) Programs

Florida's rapidly expanding population increased the number of point and nonpoint sources of pollution and resulted in the destruction of ecological communities. Consequently, many of Florida's natural surface water systems (*e.g.*, lakes, springs, rivers, bays, and estuaries) were becoming degraded, making them unable to support plant and animal life, unfit for recreation, and potentially hazardous to human health. In 1987, the Florida Legislature enacted the Surface Water Improvement and Management (SWIM) Act, which directed the State's five water management districts, with the cooperation of State agencies and local governments, to develop and implement plans to clean up and protect specific waterbodies. Hence, affected waterbodies were prioritized with a common SWIM goal established for each. Essentially, each system shall be improved and managed at a level of quality "that provides aesthetic and recreational pleasure for the people of the State; that provides habitat for native plants, fish, and wildlife, including threatened and endangered species; and that attracts visitors and accrues other economic benefits." Since SWIM, many coastal communities have implemented surface water management programs which have improved the quality of the water discharging into adjacent estuaries, thereby improving water quality within the waterbody itself. The three water management districts responsible for administering the following SWIM programs in South Florida are: St. Johns River Water Management District, South Florida Water Management District, and Southwest Florida Water Management District.

Florida Bay Program Management Committee

The Interagency Task Force, a multi-agency group established to implement the South Florida Ecosystem Restoration Initiative, created the South Florida Management and Coordination Working Group. The Working Group then created the Florida Bay Program Management Committee (PMC), an eight-member interagency committee, whose purpose was to integrate the science plan of Florida Bay into a regional ecosystem-based science program. Since 1994, the PMC has focused its efforts on integrating the data and developing the models essential for understanding the bay as an ecosystem that is strongly influenced by human forces. By collaborating with the member agencies on a research strategy for Florida Bay, the PMC's goal is to provide the scientific information critical to the restoration of the Bay, *e.g.*, the eventual recolonization of seagrasses throughout the Bay.

Another statewide management initiative is a program with the potential to reduce prop scarring and physical destruction of seagrasses by vessels. To be implemented by local governments, the program components include boater education, installing aids to navigation, increased enforcement, and designating limited-motoring zones. Monroe County is preparing to implement the Channel Marking Master Plan for the Florida Keys, which was completed in January 1998. Despite these measures, the scarring of seagrasses continues in the Keys largely due to an increase in the number of boats and in the number of boaters operating in shallow water seagrass beds.

Federal and State land management programs can extend protection over seagrasses when these submerged resources are within their boundaries. Such programs in South Florida include the Pelican Island NWR, Hobe Sound NWR, Biscayne Bay NP, Everglades NP, Crocodile Lakes NWR, John Pennekamp Coral Reef SP, National Key Deer Refuge, Great White Heron NWR, Key West NWR, Dry Tortugas NP, and J.N. "Ding" Darling NWR.

Currently, many of these management programs are having a beneficial effect on South Florida's estuaries. In some coastal embayments, seagrass coverage is increasing largely due to improved water quality conditions. Since April 1996, treated wastewater is no longer directly discharged into the Indian River Lagoon. The installation of baffle boxes designed to filter stormwater runoff has also improved water quality in the Lagoon. Seagrasses have recovered in parts of Biscayne Bay due to a reduction in turbidity. Boating traffic was eroding the shorelines of spoil islands located in the Bay. Once these shorelines were stabilized, turbidity decreased and water clarity increased. Even the seagrass community in Florida Bay has experienced some degree of recovery. While turtle grass is continuing to decline in western Florida Bay, shoal grass is revegetating some parts of eastern Florida Bay. Treating stormwater runoff has improved water quality conditions in Sarasota Bay by reducing nitrogen and contaminant loadings. Though not within the boundaries of the South Florida Ecosystem, Tampa Bay has experienced increased seagrass coverages, again, as the result of improved water quality conditions.

Table 1. State and Federal management programs that affect South Florida's estuaries listed by program name, date established/designated, and the status of its associated management plan.

PROGRAM NAME	DESIGNATED	STATUS OF MANAGEMENT PLAN
Aquatic Preserves		
Indian River Lagoon - Malabar to Vero Beach	1970	completed 1986
- Vero Beach to Fort Pierce	1970	completed 1985
- Jensen Beach to Jupiter Inlet	1973	completed 1985, revised 1990
North Fork St. Lucie River	1972	completed 1984
Loxahatchee River - Lake Worth Creek	1970	completed 1984
Biscayne Bay - Cape Florida	1970	no plan
Biscayne Bay - Card Sound	1974	no plan
Lignumvitae Key	1972	completed 1991
Coupon Bight	1972	completed 1992
Cape Romano - Ten Thousand Islands	1970	completed 1988
Rookery Bay	1975	completed 1988
Estero Bay	1975	completed 1983
Pine Island Sound	1970	completed 1983
Matlacha Pass	1972	completed 1983
Cape Haze	1975	completed 1983
Gasparilla Sound - Charlotte Harbor	1979	completed 1983
Lemon Bay	1986	completed 1992
Surface Water Improvement and Management (SWIM) Programs		
Indian River Lagoon - St. Lucie River	1987	completed 1989, revised 1994
Indian River Lagoon - Loxahatchee River	1988	completed 1989, revised 1994
Biscayne Bay	1987	completed 1988, revised 1995
Caloosahatchee	1987	no plan
Charlotte Harbor	1988	completed 1988, revised 1993
National Estuarine Research Reserves		
Rookery Bay	1978	completed 1995
National Marine Sanctuaries		
Florida Keys	1990	completed 1996
National Estuary Programs		
Sarasota Bay	1988	CCMP implemented 1995
Indian River Lagoon	1990	CCMP implemented 1995
Charlotte Harbor	1995	developing CCMP

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Restoration of Seagrasses

Restoration Objective: Maintain and increase seagrass habitat in South Florida.

Restoration Criteria

South Florida can contribute to the protection, enhancement, and restoration of seagrass ecosystems in Florida by maintaining or improving water quality conditions necessary for seagrass growth within the region's estuaries. The protection, enhancement, and restoration of seagrass habitat in South Florida will contribute to the recovery of listed plant and animal species as well as maintain the ecological functions associated with this community, such as high primary and secondary production; enhancing water quality by stabilizing sediments and removing nutrients; and providing shelter, foraging, and nursery habitat for numerous invertebrates and vertebrates important to recreational and commercial fisheries. The preservation of this community will enhance the overall natural setting and visual aesthetics of Florida's coastal landscape and contribute significantly to the economy of South Florida and to the State of Florida.

The restoration objective for seagrass habitat in South Florida will be achieved when: (1) the spatial extent of seagrasses has been identified; (2) the condition of existing seagrasses has been assessed by monitoring specific locations; (3) the relationship between light and water quality to seagrasses has been determined from these monitoring sites; (4) predictive models have been developed that link light attenuation and nutrient loadings to water quality and to epiphyte abundance; (5) the models set pollution load reduction goals to improve or maintain water quality conditions necessary for seagrass survival and growth; (6) management actions have been implemented that result in protecting, enhancing, and restoring seagrasses; and (7) additional protective measures have been implemented to prevent further physical disturbance of seagrass habitat. Increased seagrass distribution and abundance will be used as measures of success to inform the public in recognizing the importance of this community to fisheries resources, wading birds, and listed species such as the Florida manatee.

Community-level Restoration Actions

1. **Identify the extent of seagrass habitat.** Using existing GIS databases, satellite/thematic images and aerial photographs (scales =1:12,000; 1:24,000; or 1:48,000) coupled with ground-truthing efforts, produce maps of seagrass distribution and abundance as an initial step in evaluating the extent of seagrasses in South Florida. Many of the region's estuaries have already been mapped or are currently being mapped for seagrasses (*e.g.*, Indian River Lagoon, Biscayne Bay, Florida Bay, and the Florida Keys).

    1.1. **Conduct an inventory of seagrass habitat using available satellite/thematic imagery, aerial photographs, and ground-truthing efforts once every 3 years.** Water clarity conditions for aerial photography are best during winter to spring;

however, seagrass abundance is greatest in the summer. Ground-truthing verifies the interpretation of the large-scale aerial photographs.

1.2. Maintain the seagrass data obtained/collected from the inventory in a GIS database. Digitize the data into a GIS database (*e.g.*, ARC/INFO) from which maps can be produced.

1.3. Create a regionwide classification scheme of seagrass habitat. Classifying seagrasses as either dense continuous beds (seagrass beds with some sand patches; coverage > 50%) or patchy beds (sand areas with some patches of seagrass; coverage < 50%) improves the repeatability of determining seagrass coverage and is necessary to consistently map seagrass habitat.

1.4. Map the distribution and abundance of seagrasses throughout the region. Mapping the abundance of seagrasses can identify both "problem" and "healthy" areas. Problem areas can be investigated to identify the cause of the problem. Healthy areas can be designated for protection. Mapping can plot changes in the amount and density of seagrass coverage, thereby providing a trend analysis of this community type.

2. Assess the status and condition of existing seagrass habitat. Monitoring selected areas within the region will be used to determine if seagrass beds are healthy or stressed and whether conditions are stable, improving, or declining and to what degree.

2.1. Use low-level aerial photography to map the distribution and abundance of seagrasses in a selected area. Low-level aerial photography can record conditions and document changes in seagrass beds (0.1 to 10 m^2 [1.07 to 107.6 ft^2] in size) at selected sites on a small scale (0.1 to 10,000 ha [0.3 to 24,710 acres]).

2.2. Establish fixed transects to detect changes in depth distribution, abundance, and species composition of seagrasses. Sampling fixed transects can reliably detect fine-scale changes in depth distribution, abundance, and species composition over time.

3. Determine the relationship between light and water quality to seagrasses. Increases in turbidity and nutrients occur both in short pulses and over long periods of time. In order to determine the effects to South Florida's estuaries from episodic events, measurements (*i.e.*, monitoring) of photosynthetically active radiation, water quality, and seagrass cover and abundance need to be taken at the fixed transect sites. Implement site-specific monitoring protocols to identify causes of seagrass decline. Integrating these measurements should identify the effects light and water quality have on seagrasses.

3.1. Implement sampling protocols to measure photosynthetically active radiation. The sampling methodology includes, but is not limited to, using quantum sensors to measure light at the water's surface and underwater.

3.2. Implement monitoring protocols to sample water quality parameters. These parameters include, but are not limited to, temperature, salinity, dissolved oxygen, nitrogen, phosphorus, suspended solids, chlorophyll, turbidity, and color.

3.3. Implement sampling protocols to measure seagrass parameters. These parameters include, but are not limited to, percent cover, biomass, shoot density, canopy height, species composition, productivity, and abundance of drift and epiphytic algae.

4. **Develop predictive models that link light attenuation to water quality and to nutrient loadings and epiphyte abundance.** The most critical factor affecting seagrass distribution and abundance is light availability, which is a function of water quality. Hence, identifying the water quality constituents regulating light availability in the water column is an initial step. Understanding how nutrients and epiphytes affect light availability is just as crucial. These predictive models will be linked to identify pollutant load reduction goals for specific estuaries or specific segments within estuaries.

   4.1. **Develop a model that relates light attenuation in the water column to various water quality constituents.** Light attenuation will be modeled based on various water quality constituents influenced by hydrodynamic (circulation) forces. Predicted effects on light in the water column, linked with the findings from the site-specific monitoring, will then provide a predictor of stress imposed on seagrass systems.

   4.2. **Develop a model that relates nutrients to abundance of epiphytes and quantifies the resultant light attenuation.** Epiphytes can reduce light reaching the seagrass blade by 50 to 80 percent. Two factors known to influence epiphyte abundance are dissolved nutrients in the water column and grazers (*e.g.*, snails, small crustaceans) on the blade's surface. If grazers are absent, epiphytes can grow unchecked. The epiphyte light attenuation model will address the balance between nutrient effects and grazing effects.

5. **Implement management actions that will improve or maintain water quality conditions necessary for seagrass growth.** Improving the management of potential sources for degradation will provide better water quality, which produces healthy seagrasses and maintains biological productivity.

   5.1. **Based on seagrass light requirements, establish pollutant load reduction goals for a specific waterbody or even a segment within a waterbody.** Setting the pollutant load reduction goals for a particular waterbody should result in reduced loadings as predicted by the models. The management actions required to reach the pollutant load reducton goals can include stormwater treatment, wastewater reuse, and best management practices for upland use (*e.g.*, landscaping options such as a reduction in fertilizers).

   5.2. **Monitor these waterbodies or segments within them for the predicted responses to the implementation of management actions.** Continue surveying the fixed transects to detect changes in seagrass distribution, abundance, and species composition.

6. **Restore seagrass habitat, where feasible.** Restoration of lost seagrass beds requires adequate mapping of sites known to have been vegetated with seagrasses in the past; reducing excessive nutrients and suspended particulates to allow seagrass beds to recover naturally; and possibly replanting candidate sites.

   6.1. **Identify areas wherein stressed or lost seagrass beds are in need of restoration.** Once the pollutant load reduction goals have been set and the management actions implemented, seagrasses should recruit naturally into the site. However, certain conditions may require a site to be replanted with donor specimens from another location.

6.2. Rehabilitate seagrass communities where they have been destroyed by human activities (*e.g.*, prop scars) by replanting.

7. Preserve existing seagrass habitat. Most of South Florida's seagrass beds vegetate submerged land that is in sovereign ownership by the State. Much of this submerged land is under additional protection by the establishment of national parks, national wildlife refuges, a national marine sanctuary as well as the designation of a national estuarine research reserve and several aquatic preserves. Seagrass communities outside of these protective boundaries, especially those parcels in private ownership, require even greater attention. Such areas are often at risk from human activities simply because they do not have the unique resource designations that other areas have within South Florida.

7.1. Use existing regulatory authorities to protect seagrass habitat. Seagrasses are currently protected by law from human activities on State-owned submerged lands within designated aquatic preserves and within the boundaries of federally-designated areas, such as the Florida Keys National Marine Sanctuary, Biscayne NP, Everglades NP, and Rookery Bay National Estuarine Research Reserve. In those instances where seagrasses are damaged within these boundaries, enforcement of existing regulations is necessary.

7.2. Prevent the additional degradation of existing seagrass habitat. Implement a multiple approach management program to reduce prop scarring of shallow water seagrass beds. The management program should include increased boater education, installing channel markers, active enforcement, and establishing limited motoring zones. Over the long term, this comprehensive approach should reduce scarring to levels that do not significantly affect habitat quality and quantity.

7.3. Identify and acquire privately-owned submerged land vegetated with seagrasses. Public acquisition of these few tracts will preserve the seagrass habitat associated with them.

8. Promote research. Because of the problems experienced by Florida Bay, the effect of extensive phytoplankton blooms (*i.e.*, light availability, nutrient regimes) as well as slime mold disease (*i.e.*, *Labyrinthula*) on seagrass communities should continue to be investigated. In addition, the effects of freshwater flows (*i.e.*, quality, quantity, timing, distribution) on seagrasses should be investigated further.

9. Increase public awareness. Present literature, maps, and slide presentations on the importance of seagrass habitat in South Florida's coastal landscape. Emphasize the significance of the ecological functions and economic value associated with this community. Accomplishing this task will enlist support from the public at large to continue the protection, enhancement, and restoration efforts of seagrass habitat.

Nearshore and Midshelf Reefs

FNAI Global Rank:	**G1/G2/G3**
FNAI State Rank:	**S1/S2/S3**
Federally Listed Species in S. FL:	**8**
State Listed Species in S. FL:	**15**

Marine habitats usually fall under the stewardship of the National Marine Fisheries Service (NMFS). However, the Fish and Wildlife Service (FWS) is involved in marine habitat conservation through transfer fund agreements with the U. S. Army Corps of Engineers (COE). The COE civil works program includes beach nourishment and renourishment projects which affect the nearshore marine environment and the FWS, as an advisory agency, provides the COE with comments regarding the environmental aspects of those projects. Accordingly, this account represents a contribution toward existing recovery plans under NMFS' authority and, therefore, is limited to a brief discussion on reef ecology and management within the scope of FWS authority.

Synonymy

The term "nearshore reefs" is meant here to include all solid physical substrate below the mean high water line (MHW) and seaward of Atlantic Ocean or Gulf of Mexico shoreline which may be vulnerable to fill deposition and turbidity (loss of light penetration through the water column) associated with beach nourishment. The zone has been defined by the State of Florida Department of Environmental Regulation (DEP) as the area landward of the 4 m (13.1 ft) depth contour. This definition would exclude solid subtidal substrate within bays and estuaries. "Rock outcrops" or "rock substrate" could be considered synonymous; however, artificial reefs constructed of other materials could also be located within this zone. Midshelf reefs include those reefs between the 4 m (13.1 ft) isobath and the practical limits of dredging operations or about the 20 m (65.6 ft) depth isobath. The general term "hard bottom" has also been applied to these deeper reef areas. This term includes the solid substrate and epifauna which occupies the substrate.

The epifaunal assemblages associated with such substrate are varied and, accordingly, have been given

many names. The term nearshore reefs is not used in the Florida Natural Areas Inventory (FNAI) system of classification, but for the purposes of this plan, include: consolidated substrate, octocoral bed, sponge bed, worm reef, algal bed and composite substrate. Coral reefs, as defined by FNAI, have limited relevance to this discussion in that, they are generally too far offshore to be buried by beach fill, located where they are vulnerable only to the dredging operations associated with beach nourishment, and then, only in Miami-Dade County. Coral reefs should be distinguished from hard bottom which supports some reef-building corals. These hard bottom communities may extend as far north as Palm Beach County on Florida's east coast. Less relevant to this discussion but worth mentioning are the *Oculina* (ivory tree coral) reefs which occur in depths greater than 30.5 m (100 ft) from St. Lucie County to Jacksonville, and the intertidal vermetid reefs off of the Ten Thousand Islands which are remnant structures formed by the reef-building gastropod, *Petaloconchus* sp. In most areas neither reef-building (hermatypic) corals, octocorals, sponges, reef-building worms, nor algae dominate. Accordingly, the more general terms given in the preceding paragraph will be used most frequently in this discussion.

Distribution and Description

Geologically, the rock formations upon which reef communities develop are known as the Anastasia formation which form the backbone of the Atlantic coastal ridge (Stauble and McNeill 1985). This limestone formation is the result of several Pleistocene accretion events and is named for Anastasia Island were it was first described (Puri and Vernon 1964). Portions of the formation are exposed beneath the sea surface resulting in an extensive reef system.

Florida's reefs are not dominated by a single phylogenetic group, making specific classification difficult. Of the various types of reef, the coral reef, which is dominated by hermatypic corals, has the most structural complexity. These formations form the most popular image associated with the term "reef." Coral reefs are best developed in the U.S., primarily within the Florida Reef Tract (primarily in Monroe County). Most of the Florida Keys' coral reefs are well known due to the clarity of the water and the popularity of SCUBA diving. The ecology of coral reefs is described in some detail by Jaap (1984). The coral reefs in the Florida Keys are a trust resource of the National Oceanic and Atmospheric Administration (NOAA) and are protected as part of the Florida Keys National Marine Sanctuary. A special set of management plans has been developed for this resource (NOAA 1996).

Farther north, through Miami-Dade and Broward (Figure 1) counties on the east coast and Collier County on the west coast, water clarity and temperature declines as do reef-building corals. Although the range of hermatypic corals may extend as far north as Stuart on the east coast, the solid substrate is increasingly populated by soft corals (gorgonians). North of Stuart, the warm waters of the Gulf Stream are farther offshore, soft corals are fewer and hard bottom communities are more prevalent. Hard bottom communities are populated by sponges, small (ahermatypic) hard corals, tunicates, bryozoans, algae, and sabellariid worms. Such communities are typical of Florida's West coast from Collier County north; however, few studies have

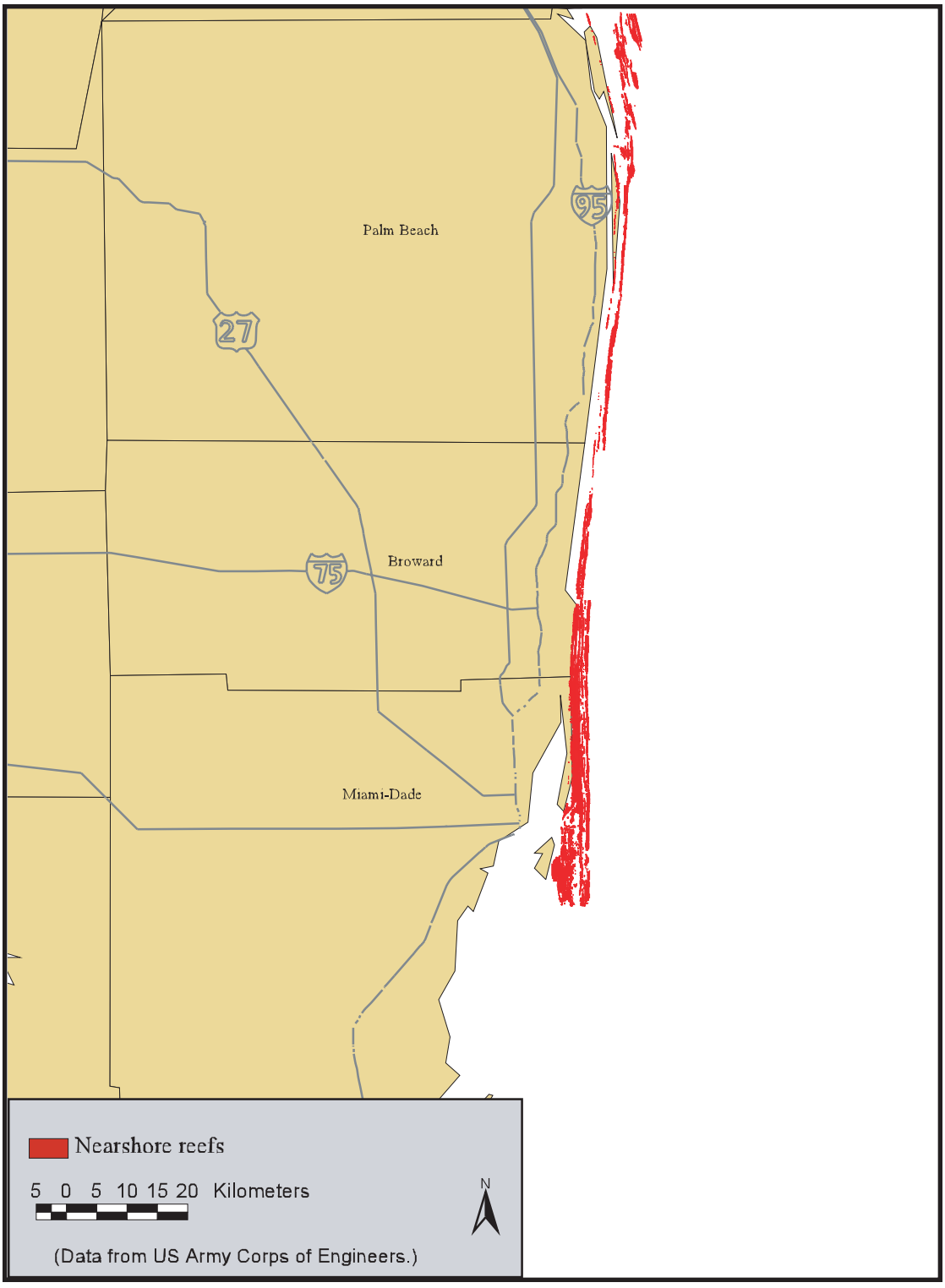


Figure 1. Nearshore reefs in Miami-Dade, Broward and Palm Beach counties, Florida (data from the U.S. Army Corps of Engineers).

been completed on sabellariid worms reefs on Florida's west coast. Consequently, most of the reef ecology referenced in this recovery plan has been obtained from research performed on the east coast.

Sabellariid worms can dominate the reef community and form a unique reef type known as "worm reef." These reefs are most often formed in high-energy surf zones between Martin and Brevard counties (Kirtley and Tanner 1968), thus may provide shoreline protection by reducing wave energy on the beach. Such reefs are composed of loosely cemented sand particles which are held together by a mucus secreted by the worms when building their casing. Sabellariid worm colonies provide habitat for over 325 species of invertebrates (Nelson 1989). Nelson and Demetraides (1992) found that, seasonally, abundances of isopod and amphipod species can be as high as 50,000 and 22,000 individuals per square meter, respectively. Algal species can also dominate some reef areas. Offshore of central Florida at Vero Beach, 109 algal species were identified by Juett *et al.* (1976).

Species Diversity and Ecology

Biodiversity of visible organisms is much higher on nearshore reefs than on sandy bottom. Epifaunal organisms flourish on the stationary foothold provided by the rock and are virtually absent in areas where shifting sands preclude settlement. Algae also flourish on this reef substrate. At the bottom of the food chain, algae provides a primary food source for a variety of organisms including: invertebrates, fishes, and even the endangered green sea turtle (*Chelonia mydas*). Fish are also more abundant on nearshore reefs. Approximately 192 species are known to inhabit the nearshore reefs of South Florida (Lindeman 1997). Vare (1991) recorded only seven species from observations over sand bottom in Palm Beach County. Lindeman (1997) counted 30 times more individuals per transect on nearshore reefs than per transect over adjacent sandy bottom.

Sessile Invertebrates

Reef fauna may be divided into sessile and motile components. The sessile component consists of primary producers and consumers or heterotrophs such as suspension and filter-feeding organisms. The exposed rock provides stable substrate for this epifauna which, through photosynthesis and filter and suspension feeding, provides basic organic material on which much of the reef's food web is based. Carbon fixed far offsite is concentrated on the reefs by filter-feeding organisms such as sponges and barnacles. These animals trap nutrient-rich phytoplankton as it is swept past the reef by wave- and wind-generated currents. Sessile cnidaria such as anemones and stinging hydroids capture zooplankton and other larger organisms which drift to them. The attached invertebrates contribute to the basic structure of the reef providing more holes and crevices and additional protection from predation for small motile invertebrates and fishes. Some filter-feeding polychaetes live in the sand among and around the rock outcrops of the reef. These are fed upon by reef dwelling fish such as the spotfin moharra (*Eusinostomus argenteus*) which

with protrusile mouthparts is adapted to extract the worms from the sand. These are, in turn, consumed by the common snook (*Centropomus undecimalis*) and other reef predators.

Mobile Macroinvertebrates

The most comprehensive list (325 species) of macroinvertebrates found on the nearshore reefs, compiled south of Sebastian Inlet, Indian River County by Nelson (1988, 1989), has been described by its author as incomplete. Nelson points to the scientific value which must exist in the unknown species which reside on nearshore reefs. This potential has been discussed by other researchers as well. Some gastropod species, for example, are rare and endemic to small nearshore reaches of the Florida coastline (Petuch 1988). These species could be in danger of extinction by shell collecting or by beach nourishment if small localized populations were to be buried by beach fill. There may be as many as 40 such species, most of which are trust resources of the NMFS. Their occurrence in U.S. waters renders them eligible for candidacy by the FWS and/or NMFS (E. Petuch, Florida Atlantic University, personal communication 1998).

Gastropod species which occur in the rocky intertidal zone are especially vulnerable to population decimation by shell collectors and beach nourishment. The existing populations of intertidal species could be habitat-limited. This habitat is rare on the east coast and the beachrock outcrops along Palm Beach and Martin counties, which are unique in Florida, represent the only extensive, naturally occurring rock cliffs found along the southeastern United States (Petuch 1988). *Cerithium lindae* occurs on beachrock shorelines from Fort Pierce (St. Lucie County) to Blowing Rocks near Jupiter (Palm Beach County) (Petuch 1987). *Nerita lindae*, a cryptic species, and *Modulus papei* have a similar, limited distribution. Two periwinkle species from this habitat have, as yet, to be named in the scientific literature.

Herbivorous invertebrates pass nutrients and energy to higher trophic levels. Herbivory in crustaceans is well documented (see Odum 1969 for one example). Isopods, shrimp, crabs, *etc*., consume sessile and epiphytic algae, then are themselves consumed by higher predators such as the sheepshead (*Archosargus probatocephalus*). Gastropods also are known to graze on algae passing nutrients and energy produced on the reef up the food web. Gastropod predators may include other invertebrates such as the Florida lobster (*Panulirus argus*) which is highly valued as food by humans.

Two invertebrate reef species are of particular importance for their commercial and recreational fisheries value. The Florida lobster makes up the most popular fishery of the nearshore reefs of southeast Florida. After spending its early postlarval life stages in estuarine habitats, the young lobsters move to nearshore reefs where they may spend a good part of their adult lives. Many of these adults move further offshore seasonally (Lyons *et al.* 1981). On Florida's west coast, the stone crab (*Menippe mercenaria*) is similarly important. Bert (1985, 1992) found that stone crabs are significantly more abundant along limestone outcroppings where crabs excavate holes beneath the rocks.

Fishes

Fish are attracted to the basic reef structure for shelter, foraging, and reproduction. The numerous crevices, holes, and undercut ledges provide refuge from larger predatory fish. It also provides a barrier to currents and substrate for attachment of demersile adhesive eggs. Lindeman (1997) states that approximately 16 fish species may utilize nearshore reefs as spawning habitat. Aside from this, the sessile organisms and associated symbionts provide a large diverse food base on which some fish species feed directly; others benefit from this indirectly by feeding on invertebrates such as small crabs and shrimp which are nurtured by sessile plant material and epiphytic algae. The role of fishes and other motile species in the ecology of coral reef systems has been discussed in detail by Sale (1991).

Although the list may be incomplete due to collecting difficulties, Gilmore *et al.* (1981) recorded 107 fish species utilizing the nearshore reefs of east-central Florida. Using new data and additional lists, Lindeman (1997) documented the occurrence of 192 species of fishes on nearshore hardbottom reefs of east Florida, an increase of 85 species. Smith (1976) gives a complete discussion on the distribution of nearshore and offshore reef fishes on Florida's west coast. To date, published information on abundances, other quantitative components and trophic interactions of the reef fish community is sparse. In the only quantitative study of nearshore hardbottom fishes, Lindeman (1997) and Lindeman and Snyder (in prep.), recorded sailor's choice (*Haemulon parrai*), silver porgy (*Diplodis argenteus*) and cocoa damselfish (*Pomacentrus variabilis*) as the most abundant species at two Jupiter (Palm Beach County) sites. In terms of mean numbers of species or mean numbers of individuals per transect, statistically significant differences did not exist between sites. Vose and Nelson (1994) discusses the food habits of gray tiggerfish (*Balistes capriscus*) residing on offshore artificial reefs compared to those on nearby natural reefs off Vero Beach, Florida. Other species were also discussed in his dissertation (Vose 1990).

Relatively abundant food fish species occur on nearshore and midshelf reefs. These include the sheepshead (*Achosargus prpbatocephalus),* the porkfish (*Anisotremus virginicus*), black margate (*Anisotremus surinamensis*), mutton snapper (*Lutjanus analis*), gray snapper (*Lutjanus griseus*), black sea bass (*Centropristis striata*), flounder (*Paralichthys dentatus*), and gray triggerfish (*Balistes capriscus*). Juveniles of commercial importance include the gag grouper (*Micteroperca microlepis*), red grouper (*Epinephelus morio*), and black grouper (*Epinephelus bonaci*). Another abundant predator on the reefs is the sport and food fish, the common snook. Many other species are collected for aquariums. These include angelfish (Pomacanthidae), butterflyfish (Chaetodontidae), wrasses (Labridae), damselfish (Pomacentridae) and doctorfish (Acanthuridae). The smaller tropical fish are important ecologically as prey for grouper, snook and other piscivores. Other important prey would include the silver porgy (*Diplodus argenteus*) and at least two species of mojarra (*Eucimostomus* sp.). All species present on the reef are of scientific importance and of some value to recreational divers.

Some fishes are dependant upon the reef during much of their life span. One such species is the striped croaker (*Bairdiella sanctaeluciae*) whose only known

breeding population on the North American continent resides on the nearshore reefs of Brevard, Indian River, and St. Lucie counties (Gilmore 1992). Other species settle out from their planktonic stage and spend their early life stages on the nearshore reefs. One of the most important functions of nearshore rock outcrops may be in providing nursery habitat for juvenile fishes. Survival of these early life stages plays a critical demographic role in determining adult population sizes (Richards and Lindeman 1987). Lindeman and Snyder (in prep.) found that more than 80 percent of the individuals on Jupiter area (Palm Beach County) nearshore reefs were early life stages.

Other species require the nearshore reef as a staging area from juvenile estuarine habitat to deep offshore reef habitat. Young snook are known to utilize the marshes and seagrasses of the Indian River (Gilmore *et al.*, 1983) before moving to deeper habitat as adults. Gag grouper (Ross and Moser 1995), red grouper (Moe 1969) and gray snapper and likely many of their congeners (Stark and Schroeder 1970) exhibit similar patterns in early life. Young grouper and snapper may remain on the nearshore reefs for several years and then continue to move offshore with continued growth to deeper reefs. In so doing, they are recruited into offshore commercial and recreational fisheries.

Wildlife Species of Concern

Federally listed species that depend upon or utilize the reef community include: West Indian manatee (*Trichechus manatus*), piping plover (*Charadrius melodus*), roseate tern (*Sterna dougallii dougallii*), loggerhead sea turtle (*Caretta caretta*), leatherback sea turtle (*Dermochelys coriacea*), Kemp's ridley sea turtle (*Lepidochelys kempii*), hawksbill sea turtle (*Eretmochelys imbricata*), and green sea turtle (*Chelonia mydas*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

Sea Turtles

The NMFS and the FWS have prepared recovery plans for the **green, loggerhead, leatherback, hawksbill** (NMFS and FWS 1991a, 1991b, 1992, and 1993, respectively), and **Kemp's ridley sea turtle** (FWS and NMFS 1992). Sea turtles are commonly sighted by SCUBA divers on the nearshore and midshelf reefs of Florida. It is becoming increasingly evident that this habitat is important to a variety of sea turtle species. Ehrhart *et al.* (1996) have studied sea turtles at the nearshore reefs off Sebastian in east-central Florida. For the years 1989 to 1995 they reported a mean capture rate of 6.28 green sea turtles per gill net km-hr. Loggerhead sea turtles appear to be less abundant on nearshore reefs as the mean catch rate of this species was 0.23 turtles per km-hr during the same period. Wershoven and Wershoven (1988) reported that in Broward County turtles were sighted in 106 out of 188 dives. Captured green sea turtles ranged in size from 27.4 to 67 cm (10.8 to 26.4 in) carapace length while captured hawksbill ranged from 34 to 60 cm (13.4 to 23.6 in). The peak capture rate per unit effort (hours of diving) occurred in June. Stomach content analysis of dead sea turtles recovered from the same area revealed that the benthic algae *Bryothamnion seaforthii* is an important food source for these

young turtles. Similarly, Meylan (1988) found that the hawksbill sea turtles she sampled appeared to feed almost exclusively on reef sponges.

Although the **common snook** prefers intermediate estuarine-mangrove conditions (Bohlke and Chaplin 1970), it is frequently seen by SCUBA divers utilizing the reef ecosystem. The distribution of the snook has been recorded from South Carolina to southeastern Brazil, including the Central American coast and Gulf of Mexico. The carnivorous snook feeds primarily on fishes and crustaceans, and can tolerate either wholly fresh or salt water. The young commonly inhabit back bays, shorelines, and shallow coastal streams. The species can be identified by its olive green coloration, and dull silvery sides with a black lateral line. In addition to its importance as a predatory species, the snook is highly prized by humans for sport and food. The State of Florida has classified the snook as a species of special concern.

The **Key silverside** (*Menidia conchorum*) is known from Long Key to Key West in Monroe County. Although the species is essentially a marine fish, it is tolerant of a wide range of salinities. Aquatic vegetation such as *Thalassia, Diplanthera,* and *Acetabularia* are often, but not always present. The diet of the Key silverside consists of animal microorganisms, with copepods, mysids, isopods, amphipods, and insects the most important. The Key silverside is currently listed by the State of Florida as a threatened species.

Status and Trends

Until recently, the extent of nearshore reefs in South Florida was virtually unknown. The Florida DEP (1997) coordinated an effort to consolidate the known information and to map solid substrate on the northeast and east central coast of Florida. This effort has resulted in the first reef atlas for that area.

The sea floor out to the 18.3 m- (60 ft) depth contour has recently been mapped in Miami-Dade, Broward, and Palm Beach counties with side scan sonar by the COE (1996); thus, in these counties the extent of reefs is well known (See Figure 1). Other mapped nearshore areas include Venice Beach in Sarasota County; Hutchinson Island in Martin County; Sand Key in Pinellas County and Vero Beach in Indian River County. In some instances, however, the surveys are out-dated due to the dynamics of sand movement in the nearshore area, or were done prior to construction of a beach project. The deposition of fill on the shoreline adjacent to these areas has undoubtedly changed bottom bathymetry considerably. Nevertheless, with deeper reef areas taken into account, we estimate that less than one percent of areas statewide which may contain hard bottom communities have been mapped.

Few areas have been monitored to the extent that trends in habitat change are apparent. To our knowledge, only the nearshore reefs of Palm Beach County have been photographed regularly and, from these data, some nearshore reef areas have been shown to increase within the last decade. Acreage is known to change over the course of time, but in most areas of South Florida, it is unknown whether the trend is toward increasing or decreasing net acreage.

With the absence of historical data, the health of the reef system is uncertain. Lindeman (1997) estimates that in southeast Florida alone, approximately 48 million cubic yards of offshore sediment has been deposited in the nearshore area

in the last 36 years. Unknown acreage of nearshore reef habitat has been buried by this practice and many more acres may have been degraded by chronic long-term turbidity and sedimentation. At least 80 million cubic yards is proposed to be deposited on the beaches of southeast Florida in the next 50 years based on renourishment intervals (COE 1996, Lindeman 1997). Some coral reef and offshore hard bottom acreage in the vicinity of the borrow areas has been damaged by direct contact with the dredge in Miami-Dade and Broward counties (Dade County 1988, 1990; Britt & Associates 1979). Additional reef damage occurred at Boca Raton when a steel tow cable was dragged across the substrate (R. Spadoni, Coastal Planning and Engineering, personal communication 1997).

Use of high-quality material for beach nourishment is critical to constructing an environmentally sound project (Goldberg 1988). Natural beaches generally contain much less than 5 percent silt and clay; however, given the quality of borrow material in South Florida, the 5 percent threshold may be a good target criteria (P. Davis, Palm Beach County Department of Environmental Resources Management, personal communication 1998). Finding a borrow area that has material of a similar composition can be difficult. Surface layers of offshore borrow material may be low in silt because of the winnowing effects of currents and wave action on the sea floor; deeper layers may contain higher quantities of silt. This is important when considering the effects of light attenuation due to resuspension of dredged materials. Placing silt-containing material on a beach may not only reduce photosynthesis on nearshore reefs but may also expose silt-laden layers of sediment to currents and wave action, inducing an increase in long-term turbidity around the borrow area.

Persistent long-term turbidity caused by beach nourishment projects may have profound biological consequences which are unknown as yet. Increased turbidity reduces light penetration which is critical to corals and algae that already may be stressed from sedimentation and turbid conditions. Under these conditions, chronic turbidity can be expected to stress organisms, reduce growth, and, in extreme conditions, may cause death. Telesnicki and Goldberg (1995) have demonstrated that adverse effects can take place in hard corals even with turbidity levels below the State threshold. Dodge and Vaisnys (1977) and Bak (1978) have also demonstrated adverse effects in corals. Similar effects may occur in related species.

Chronic turbidity from resuspension of fine sediments from the beach and near the borrow site may result in sublethal effects (*e.g.* reduced feeding or reproduction) which produce long-term consequences. Increased turbidity from resuspension of sediments may continue for years after dredging has stopped (Levin 1970, Courtenay *et al.* 1975, Dodge and Vaisnys 1977). In one instance, project-induced turbidity was reported to persist as many as 7 years (Courtenay *et al.* 1980). While the State of Florida's Department of Environmental Protection requires that turbidity levels remain below 29 Nephelometric Turbidity Units (NTU's) above background during dredging and filling for beach construction, the effects of this level of turbidity on reef communities is not known, as these effects of turbidity on hard bottom epifaunal assemblages has been poorly studied.

In addition to the effects of turbidity, deposition of suspended sediments may also occur when the sediments which cause turbidity fall out of the water

column. Griffin (1974) has recommended that the rate of sediment deposition from dredging operations should not exceed 200 mg/cm^2/day during any 7 day period; otherwise stress to reef building coral could result. One fourth of the coral species tested by Rogers (1983) were damaged when exposed to this deposition rate for 38 days. These sediments may also decrease populations of fish and echinoderms (Brock *et al.*, 1965, 1966), inhibit feeding of shellfish (Brehmer 1965), harm fish eggs (Wickett 1959), reduce photosynthetic production in plants, and trap phytoplanktyon carrying them to the bottom (Bartsch 1960).

Management

The Florida DEP, as co-sponsor in many beach nourishment projects, assesses the environmental effects of those projects. In many cases, the DEP has outlined requirements for habitat mapping, mitigation and monitoring prior to FWS involvement. The COE funds the FWS, in coordination with the NMFS and the GFC, to formulate recommendations on the environmental aspects of beach nourishment projects. The NMFS has recently proposed to designate nearshore reef as Essential Fish Habitat and is in the process of drawing guidelines for that designation.

In the past, beach fill has been deposited without adequate pre-project surveys of the impact area to determine the extent of habitat which may be lost or affected by the project. More recently, surveys of the physical environment have been performed, but complete qualitative biological surveys are not done. No quantitative biological surveys have been performed on project impact areas.

Once the locations of nearshore and midshelf reefs areas are known, and the project is designed to minimize burial and degradation due to turbidity and sedimentation, quantitative biological surveys of the epifauna and motile component of the projected impact area should be conducted to determine the population densities of key species prior to impact. An artificial reef should then be designed to maximize habitat values for those species. Too often, artificial reefs are created without a clearly defined purpose and without sufficient planning. The United States in particular has pursued an unsophisticated and frugal approach to artificial reef planning and construction. Scrap and discarded rubble, because of its low cost, is most commonly used (McGurrin, *et al.*, 1989) despite its inadequacy to provide suitable habitat for targeted species. With careful design and placement, fish population densities on artificial reefs can exceed those of natural reefs (Bohnsack and Sutherland 1985, Randall 1963, Smith *et al.* 1979). Accordingly, the Japanese have invested billions of dollars in developing techniques to create new habitat and increase seafood production (Grove *et al.* 1989, Sonu and Grove 1985). These efforts have been reported by Sheehy (1983), and Brock and Norris (1989) to have resulted in much more efficient reef technology. While costs per area of reef are higher, the increase in reef fish and epibenthic organism abundance per area over traditional U.S. reef technology may more than offset this cost (Sato 1985).

To correct the deficiencies in and fragmentation of the U.S. artificial reef program, the Secretary of Commerce was directed, under the provisions of the

National Fishing Enhancement Act of 1984, to develop and publish a long-term National Artificial Reef Plan to promote and facilitate effective artificial reef use based on the best scientific information available. A working plan was published by the NMFS in 1985 (Stone 1985). The plan as it pertains to Florida is currently undergoing revision by the Atlantic States Marine Fisheries Commission. To conform to the plan the project should have a list of species and user groups intended to benefit from the designed reef.

In recent years, research into artificial reef design effects on community structure have greatly increased our ability to optimize habitat value of designed reefs. Study on the effects of module spacing (Frazier and Lindberg 1994, Lindberg *et al.* 1990), reef size (Bohnsack *et al.* 1994), reef height (Bortone *et al.* 1994), reef shape (Dade County 1995, Kim *et al.* 1994), hole size (Eklund 1996, 1997) and number of chambers (Sheehy 1976) have been accomplished as of this writing.

As knowledge about the effects of design modifications on reef communities increases, it may become possible to design reefs to benefit key species or age classes. The evidence that natural nearshore reefs, not offshore reefs, provide nursery and juvenile staging habitat for many reef fish species (Lindeman 1997) suggests that constructing artificial reefs closer to shore may supplement natural nearshore reefs by providing additional nursery and juvenile staging habitat for many reef fish species. Ecklund (1996) has confirmed the intuitive sense that small hole sizes benefit small fishes. These findings lead to the conclusion that nearshore artificial reefs with numerous small scale features would increase benefits for juvenile fishes. Further refinements in our knowledge of the effects of such design features is inevitable and sorely needed.

As an example of how a user group can be targeted, it is clear in many cases that snorkelers are the largest user group which will incur losses by a beach fill project. In addition to recreating habitat to support fish, invertebrates, and algal species, artificial reefs mitigate for beach fill projects by also providing habitat for the snorkler. This requires certain design features. The structures must provide a scenic, safe, accessible and productive replacement for the nearshore reefs lost and degraded by the project. Accordingly, in addition to designing the reef to benefit species which are important by virtue of their scarcity or ecological role, some artificial reefs could be designed to benefit species which are popular among snorkelers.

Populations of reef dwelling species can be quantified to some extent and the artificial reef mitigation ratios can be adjusted accordingly. In light of the evidence that population densities on well-designed artificial reefs can exceed those of natural reefs, it is possible that with enough care in design and deployment, mitigation acreage could be less than the acreage of natural nearshore reef burial.

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Restoration of Nearshore and Midshelf Reefs

Restoration Objective: To prevent further losses of nearshore and midshelf reef habitat values (primary and secondary production, refuge habitat, nursery habitat, biodiversity, educational).

Restoration Criteria

The primary threat to the health of Florida's nearshore reef system is the deposition of beach fill. Rock outcrops within the beach fill areas are buried, the epifaunal organisms associated with those outcrops are smothered, and the habitat which the reef provides to motile fishes and invertebrates is lost. The zone of direct burial increases in time as the fill material relaxes or is washed seaward by wave action and is transported to adjacent areas by littoral drift. Impacts extend beyond the fill zone when the fill material contains high amounts of silt and clay. Suspended fine material not only reduces light penetration but may settle out of the water, degrading reef areas seaward of this zone. Midshelf reefs can similarly be affected by turbidity and sedimentation when the borrow site contains fine material. Midshelf reefs may also be damaged by direct contact with the dredge and dredge-related equipment.

A measurable criterion for meeting the stated restoration objective would be to prevent any further loss of nearshore reef (natural or artificial) acreage due to beach fill. That is, each acre lost by burial should be replaced by carefully designed and deployed artificial reefs. The above stated criterion is an interim criterion. The restoration objective of maintaining habitat *values* cannot be achieved until those values to threatened and endangered sea turtles, the vertebrate and invertebrate fisheries species mentioned in this report, and all other reef species which are of recreational or scientific importance, are understood. Life history information on the green sea turtle, for example, is incomplete (Ehrhart, *et al.* 1996). The value of South Florida's nearshore reefs to species which may only use nearshore reefs during a particular life stage, and for which basic life history information is lacking, cannot be measured with any confidence. The identification of factors which may limit a population is not possible. Degradation of nearshore reef habitat could have serious implications for populations of species if such habitat already represents a demographic bottleneck in the South Florida Ecosystem's carrying capacity for those species. The ultimate objective for restoration of the nearshore and midshelf reef systems would be to accomplish the basic research required to understand the value of the reefs to the species with which we are concerned, and to replace lost values through informed, responsible artificial reef design and deployment.

Community-level Restoration Actions

1. Prevent burial and degradation of existing habitat.

1.1. Map the location and extent of vulnerable reef areas using aerial photography, where possible. Impact reduction can only be achieved once the area within the beach fill template and the sea floor within one thousand feet of the borrow site have

been thoroughly mapped. The preferred method for mapping reefs within either zone is aerial photography. Ground-truthing of aerials is also necessary to eliminated false signatures, which are due to drift algae and schools of fish.

1.2. **Map vulnerable reef areas using side scan sonar.** Borrow areas, unless they are located in the shoal of an inlet, are in deeper water and farther offshore than the fill zone. Thus, frequently, side scan sonar rather than aerial photographs, must be used to map nearby bottom features. Like aerial photographs, side scan sonographs must be ground-truthed to create a reliable map of the sea floor.

1.3. **Locate project fill and borrow areas away from reef areas.** Once a project area has been thoroughly mapped, the project fill and borrow areas should be situated to minimize nearshore reef burial and sedimentation or mechanical damage to midshelf reefs.

1.4. **Establish buffer zones.** Establish minimum buffer area of 121.9 m (400 ft) between the dredge area and the reefs to help avoid excessive sedimentation and/or mechanical damage.

2. **Prevent net loss of habitat.**

2.1. **Mitigate for reef burial.** Recommend compensation for beach nourishment and renourishment projects once the applicant has demonstrated that all efforts have been made to avoid and minimize adverse affects to the reefs.

2.3. **Deploy mitigation prior to project construction.** Estimate the minimum acreage of natural reef expected to be buried by the project. At least half that acreage in artificial substrate should be deployed prior to project construction. This measure would provide refuge habitat for motile organisms displaced by the project.

2.4. **Measure impacts using aerial photography.** A new set of aerial photographs or new side scan sonographs of the nearshore should be taken as close to 1 year after the project is completed as possible (when the fill has equilibrated or "relaxed") and a measurement of the reef area buried by the project should be made. This is done through comparison with the aerial photograph taken before construction. The resulting acreage represents the acreage of artificial reef necessary to compensate for natural reef burial.

2.5. **Survey mitigation area.** Survey the area chosen for the mitigation to ensure that there is a solid subsurface beneath the sand so that the newly placed structure does not sink into the bottom to the extent that its value as mitigation is reduced.

2.6. **Use clean sand.** Use of sand with a silt content of 5 percent or less to reduce the resulting turbidity and sedimentation. Configure borrow areas based upon the goal of matching sand characteristics of the fill area as closely as possible.

3. **Monitor the effects of projects on nearshore and midshelf reefs.**

3.1. **Monitor offshore reef impacts.** Recommend that all applicants proposing to dredge for beach projects initiate and perform a thorough off-shore reef monitoring program.

3.2. **Improve monitoring capability.** In addition to buffer zones around the offshore reefs near the borrow area, develop a sensitive monitoring system with a 24 hour response capability. The system should be developed by, or in collaboration with, an expert in the physiological effects of turbidity and sedimentation on South Florida

offshore reef epibenthos, particularly the hard corals, octocorals and sponges. The system should provide advanced warning to the project sponsor and their contractors of an incident in which turbidity or sedimentation damage to reef organisms could occur. An array of transmissiometers in the vicinity of the potentially affected resources has been suggested.

3.3. **Limit sedimentation.** Within 1,000 feet of the affected reef/resources, install sediment traps both at the surface and near the bottom. Measurements should be taken during the construction phase. A sedimentation rate of 200 mg/cm^2/day, particularly on coral reefs, should not be exceeded.

4. **Restore areas to suitable habitat.** "Restoration" of reef habitat which has been buried by beach fill is probably unfeasible. Nearshore ocean bottom areas which once had reefs which were buried by beach fill can be enhanced by deployment of artificial reefs. Most beach projects have not been constructed with the benefit of before and after aerial photographs to assist in assessing actual acreage of reef burial. To attempt to restore an area which may have sustained such impacts, a list of the locations of past nourishments and renourishments of those areas would have to be made and historical aerials obtained in the hope that any historical reef bottom would be visible in those aerials. Alternatively, deployment of nearshore artificial reefs could be made at appropriate nearshore sites around the southern half of the State to achieve ecosystem-wide enhancement. The reefs should mimic natural reefs in form and function. Restoration of some midshelf habitat values has been accomplished in Miami-Dade County. Artificial reefs were constructed to replace values lost due to the dredge denuding reef during construction of the Sunny Isles project. Palm Beach County has restored some reef habitat values by constructing four mitigation reefs and one enhancement reef in the nearshore area, and approximately 35 enhancement reefs in the midshelf zone.

5. **Conduct Research**.

5.1. **Research needs are varied** and include gathering basic information on the life histories of reef inhabitants, population density studies of both natural and various artificial reef designs, and studies of the short- and long-term turbidity effects of beach construction and the effects of that turbidity on reef ecology. A standard protocol for censusing fishes and invertebrate populations on natural and artificial reefs should be adopted in order to allow comparisons from one reef type to another.

5.2. **Assess the value of reefs to sea turtles, other transient and resident inhabitants.** Additional study of the value of nearshore reefs to sea turtles, fishes and invertebrate species, particularly during sensitive juvenile life stages or during reproduction, is needed. Basic information on the population densities of valued species on natural reefs is also desired to assist in determining the effects of reef loss on their populations.

5.3. **Incorporate monitoring and annual reporting to the COE and resource agencies on the effectiveness of the mitigation as a project feature.** After a project is constructed and artificial reef is deployed, a research opportunity is created. Monitoring should include qualitative measurement of the macroepibenthos per square meter. Comparisons should be made between total biomass, macroepifloral biomass and macroepifaunal biomass at the designed reef and at the natural reefs prior to burial. Fin fish communities at both reef types should be censused and compared in number, species and biomass (estimated). Fish community structure

should also be compared at both reef types using multivariate analyses: classification and ordination. Sampling should take place once in each season for 3 years or until it is clear that population densities and community structure has stabilized. Similarity indices between the natural reef data and the artificial reef data should be calculated to determine whether or not the target species are benefiting from the mitigation. The foregoing research should be done with a view toward promoting a better understanding of design effects on reef communities and to facilitate the development of an increasingly effective artificial reef strategy and better informed decision making for future civil works projects.

6. **Inform the public about the value of Florida's reefs.** Each artificial reef area should be placed near a public beach, if possible. A sign or display explaining why the reef was built along with a brief discussion of the ecological value of nearshore substrate and Florida's reefs in general should be included. Pictures of abundant reef inhabitants would enable the public to identify what they observe while snorkeling.