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.).

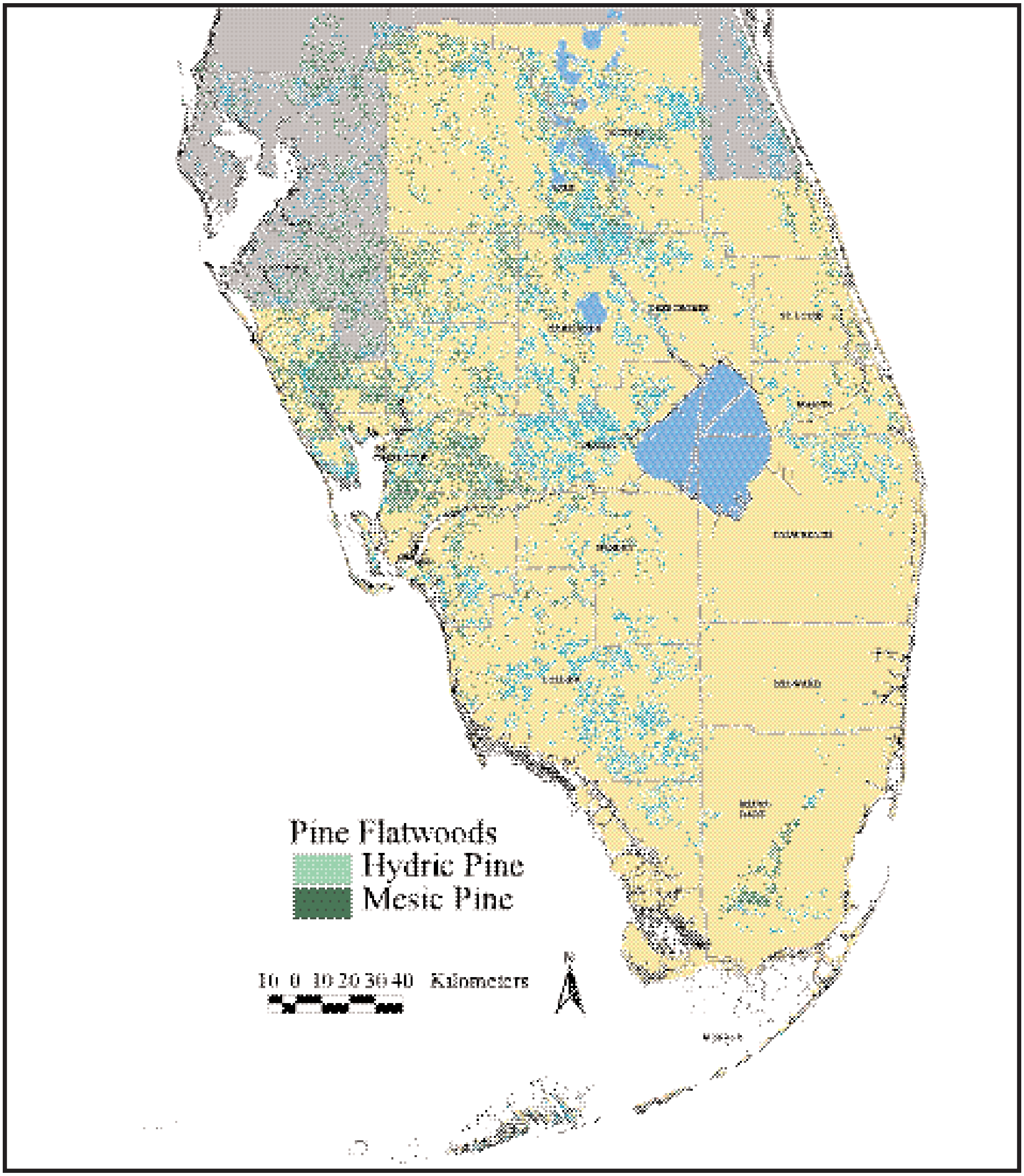

Figure 1. The distribution of hydric and mesic pine flatwoods in South Florida (data from USGS-BRD 1996).

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.