# Tropical Hardwood Hammock

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

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

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

## Synonymy

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

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

## Distribution

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

## Description

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

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

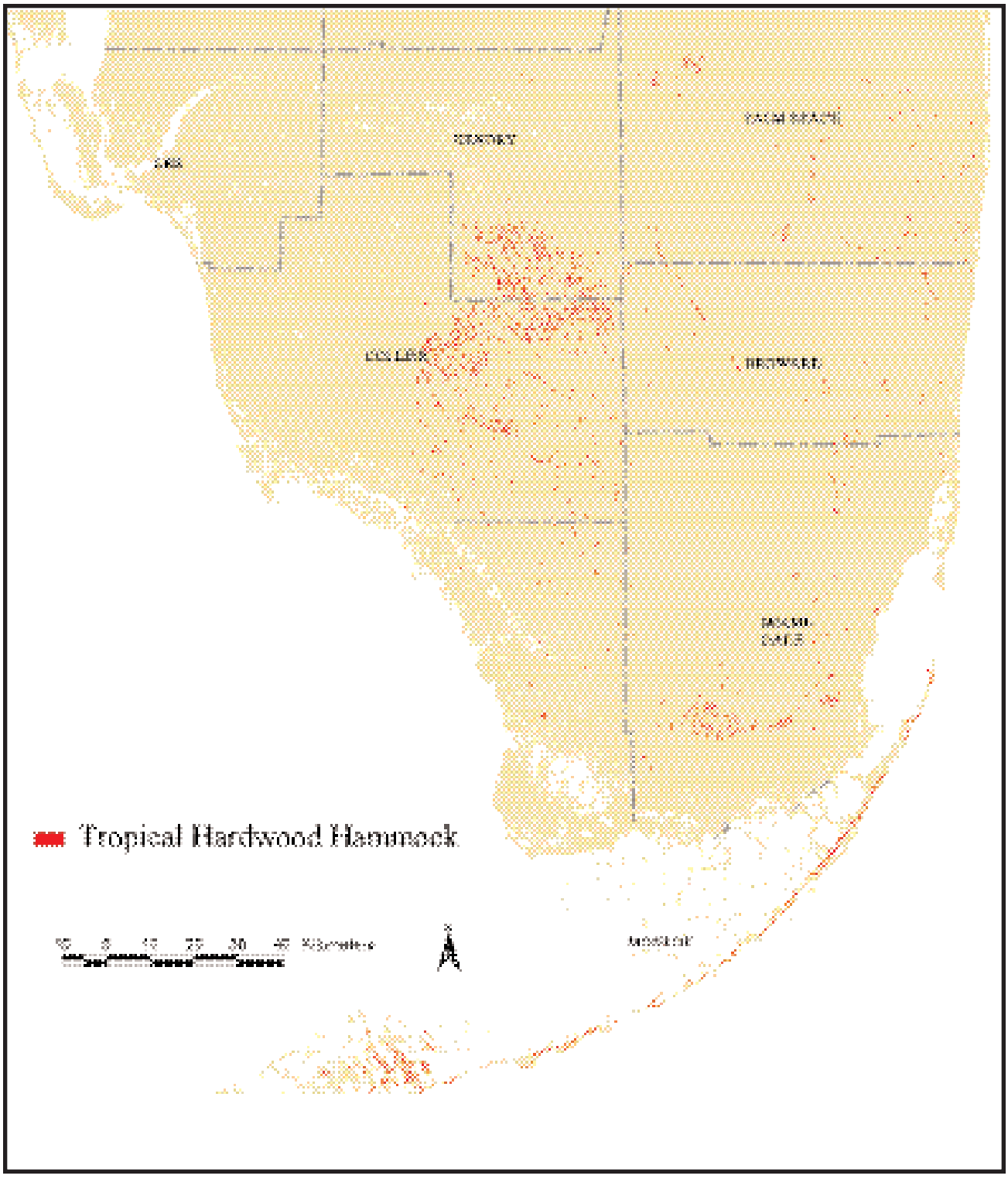


**Figure 1. The distribution of tropical hardwood hammocks in South Florida (adapted from USGS-BRD 1996).**

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

### Vegetative Structure and Composition

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

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

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

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

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

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

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

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

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

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

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

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

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

## Soils, Hydrology, and Climate

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

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

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

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

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

### Wildlife Diversity

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

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

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

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

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

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

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

## Wildlife Species of Concern

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

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

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

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

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

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

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

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

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

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

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

## Plant Species of Concern

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

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

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

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

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

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

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

## Ecology

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

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

## Status and Trends

The majority of the remaining tropical hardwood hammocks outside of the Florida Keys have now been acquired and are no longer threatened by development. Large areas of tropical hardwood hammocks are protected in Everglades NP, Big Cypress National Preserve, and Biscayne NP. Other areas with tropical hardwood hammocks on the mainland include several conservation areas on the Miami Rock Ridge which are managed by Miami-Dade County Park and Recreation Department, and the Miami-Dade County Environmentally Endangered Lands Program. Small hammock remnants also exist from Broward to Martin County along the eastern coast of Florida.

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

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

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

Although tropical hardwood hammocks tend to be located in patches across the landscape, they compose part of a complex mosaic of communities including mangroves, coastal marshes and prairies, freshwater swamps, and pinelands. Fragmentation of tropical hardwood hammocks and their artificial separation from other communities has had very serious effects on both the hammocks and the wildlife that utilize them. For instance, the physical separation of Key Largo woodrats caused by hammock fragmentation makes it more difficult for them to locate a mate. Fragmentation may also make it difficult for certain migratory bird species to survive in the developed landscape.

In addition to outright habitat loss and its associated fragmentation effects, the process of urbanization and rural development itself has caused significant negative effects on tropical hardwood hammocks. The development of roads, among other things, has increased access to natural areas, including hammocks, to collectors of orchids, bromeliads, ferns, butterflies, and *Liguus* tree snails. Collecting pressure has been particularly well documented for orchids by Luer (1972), and several species of orchids have been extirpated from South Florida primarily due to collecting. Collecting pressure is also one of the principal threats to the Stock Island tree snail and the semaphore cactus (*Opuntia corallicola*). Roads also lead to wildlife mortality from automobile traffic, including that of the Florida panther.

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

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

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

Exotic animals have also impacted tropical hardwood hammocks. Introduced species that occur in South Florida rocklands include seven mammals, about 30 birds, four amphibians, and 25 reptiles (Snyder *et al*. 1990). Armadillo (*Dasypus novemcinctus*), black rat (*Rattus rattus*), fire ant (*Solenopsis invicta*), and hog (*Sus scrofa*) as well as the domestic cat (*Felis domesticus*), have all been found in South Florida hammocks. Black rats and fire ants both prey on the endangered Stock Island tree snail, and fire ants may increase the mortality of the Key Largo woodrat. Feral and domestic cats prey on both the endangered Key Largo woodrat and resident and migratory land birds. The 15 species of parrots, parakeets, and other psittacines which have been recorded as nesting in the wild in South Florida (Snyder *et al.* 1990), are most certainly dispersing seeds of exotic plants.

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

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

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

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

## Management

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

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

In both Miami-Dade County and the Florida Keys, cooperation with landowners of tropical hardwood hammocks is essential to the long-term protection of this natural community. In 1979, Miami-Dade County enacted the Environmentally Endangered Lands Covenant Program which reduces taxes for owners of tropical hardwood hammocks and pine rocklands who agree not to develop these systems and to manage them for a period of 10 years. This program is still ongoing and protects many tropical hardwood hammock sites. Unfortunately, no similar system exists in Monroe County, where a significant amount of tropical hardwood hammock is still in private ownership, and much is

subdivided into small parcels. Monroe County should be encouraged to adopt a program similar to the Environmentally Endangered Lands Covenant Program to help prevent the destruction and/or deterioration of privately held hammocks. In addition to the Environmentally Endangered Lands Covenant program, Miami-Dade County also has the Forest Resources Program within DERM which provides private and public owners of tropical hardwood hammocks and pine rocklands with technical assistance including the preparation of management plans, herbicide training, prescribed fire coordination, plant identification workshops, and site-specific consultations (J. Klein, Miami-Dade DERM, personal communication 1998). The Forest Resources Program is also collaborating with the Boy Scouts of America to link private sites with Eagle Scout projects, and is exploring several mechanisms to provide monetary support for management on private lands. This kind of program should also be encouraged in the Florida Keys.

The Miami-Dade DERM Forest Resources Program also has regulatory authority over tropical hardwood hammocks and pine rocklands, and is charged with enforcing regulations which provide partial protection for tropical hardwood hammocks on the Miami Rock Ridge. This includes authority over all natural forest communities in Miami-Dade County, including county-and city-owned parcels. In the Florida Keys, most regulatory authority is found in the local comprehensive plan requirements which are administered by Monroe County with oversight by the Florida Department of Community Affairs (DCA) due to the Keys' designation as an Area of Critical State Concern (C.R. Kruer, Florida Audubon Society, personal communication 1998). Property owners now compete for permits through a Rate of Growth Ordinance that assigns positive and negative points for many factors, including presence of natural areas and endangered species (C.R. Kruer, Florida Audubon Society, personal communication, 1998). Neither regulatory program totally precludes development of hammocks.

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

Following public acquisition and the prevention of further disturbance, the most important step in recovery is to restore existing degraded tropical hardwood hammocks through active management, and, with a few exceptions, this process is still in its formative stages. Where possible, connections between tropical hardwood hammocks and surrounding natural communities such as pine rocklands and freshwater wetlands should be re-established. Roads and fire breaks which separate hammock edges from surrounding communities should be

removed, and prescribed fire should be used as a tool to re-establish historic hammock edges. Roads which dissect and fragment tropical hardwood hammocks should be removed and restored. Where possible, the water table should also be restored to approximate its historic condition. This includes raising the water table on the Miami Rock Ridge (which is essential to the survival of many epipetric ferns), and reducing the water level within the Water Management Areas where hammocks are being flooded out by artificially high water levels. Exotic plant species must be controlled with the ultimate goal of extirpating as many invasive exotic taxa as possible, and restoring historic hammock structure and composition. When possible, outlying populations of exotic plant species should be treated as a way of limiting expansion (Moody and Mack 1988). Exotic animals must be removed from natural areas, and domestic pets prevented from entering tropical hardwood hammocks. Animal removal must be sensitive to the needs of indigenous wildlife, such as Key Largo woodrats, which might be affected by certain chemical control methods. Efforts should also be made to control unauthorized use, including off-trail hiking which can cause damage to the humus litter in hammocks (which is essential to some organisms such as the Stock Island tree snail which uses it for egg laying). Land managers must also be vigilant against contamination of sites from mosquito spraying, and pesticide drift from commercial and agricultural operations. Finally, special emphasis should be placed on the reintroduction of extirpated species within their historic ranges.

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

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

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

Once tropical hardwood hammocks are restored, they must be maintained in perpetuity. In hammocks within the developed area, the effect of fragmentation will continue to be felt *ad infinitum*, including species extirpations due to small population sizes. In preserves of all sizes seed rain from exotic plant species, and invasions by exotic animal species (including feral and domestic pets) will continue. Natural fire will be dysfunctional, and prescribed fire will have to be used to maintain hammock edges. The water table must be monitored to insure that hammocks are not dewatered or flooded. Contaminants, including pesticides, must be continuously monitored. These negative trends must be countered through active management: species, populations must be monitored and augmented if necessary; prescribed fire must be used as a management tool; preserves must be monitored for re-establishment of known exotic species and the establishment of new species, and these plants and animals must be removed before they can become well established; water management agencies must be encouraged to continue providing the proper quantity of water; and, preserves must be protected from pesticides and other contaminants.

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

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

On the bright side, a multiplicity of opportunities do exist to create tropical hardwood hammocks within the urban/rural matrix of South Florida, and tropical hardwood hammocks are one of the easiest communities to replicate. Native plant enthusiasts have been promoting the use of native plants and the restoration of native plant communities in South Florida since the early 1970s, and tropical hardwood hammocks are one of the first natural communities which people attempted to create from scratch. Efforts to create tropical hardwood hammocks began as early as 1965 (Gann 1979). While most hammocks have been created by homeowners and schools, government agencies and commercial property owners have also created hammocks. One well-known example of a hammock creation is at Kenwoods Elementary School, which began construction of its nationally recognized award-winning outdoor learning center in 1985. For more than 10 years, hammocks have been created on spoil mounds in Biscayne Bay, and as part of the compensatory mitigation and land management process in the Florida Keys. Newly acquired land parcels on North Key Largo are being allowed to succeed to hammock through planting of hardwoods and control of exotics. Tropical hardwood hammocks can be created almost anywhere in the built environment, from residential yards, to small spaces between condominium buildings, to roadside swales. Tropical hardwood hammocks can also be created on abandoned fill pads in the Everglades marsh, in the Big Cypress swamp, and on spoil islands throughout South Florida. If done properly, this type of restoration could make a significant contribution to the recovery of the tropical hardwood hammocks community.

Guidelines for the creation of “hammocks” were first published in the late 1970s (Gann 1979). This article included an extensive table of native trees and shrubs which could be used to create hammocks, including growth patterns, soils, cultural tolerances, uses, special attractions, and drawbacks. Unfortunately, concepts of natural communities, species nativity and natural ranges were not well developed at the time, and this publication has limitations. In the early 1990s, The Association of Florida Native Nurseries published a “common-sense” guide to xeric landscaping with Florida native plants which included a preliminary list of recommended species for rockland hammock creation (Jameson and Moyroud 1991). More recently G. Gann (1995) created guidelines for the creation of rockland hammocks in Miami-Dade County, including a list of recommended species, planting techniques, watering requirements, and long-term maintenance. Miami-Dade County has recently published “The Landscape Manual” (Dade County Department of Planning, Development, and Regulation 1996), which includes a brief community description, a list of recommended plants for rockland hammock creation, and a table including cultural requirements and tolerances. These types of guidelines should be expanded to include tropical hardwood hammock creation

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

One of the downsides of the trend in landscaping with native plants is that some species are being distributed outside of their historic range, where they can become established and, potentially, invasive. For example, the pitch-apple (*Clusia rosea*), which is perhaps native to the lower Florida Keys, has been widely distributed in cultivation throughout southeastern Florida. It now has begun to naturalize throughout southeastern Florida and poses a threat to several natural communities, including tropical hardwood hammocks (Gann and Bradley 1996). Other native hammock species naturalizing outside of their historic range include bitterbush (Avery and Loope 1980), butterfly bush (*Cordia globosa*), coffee colubrina (*Colubrina arborescens*), redberry stopper (Avery and Loope 1980), and West Indian mahogany. In South Florida, native species have very specific natural ranges, and these ranges must be respected within the restoration planning context.

Research is also a critical component of tropical hardwood hammock recovery, especially applied research that pertains to the recovery of the ecosystem. Although much research on tropical hardwood hammocks and their management had been conducted earlier (*e.g.*, Olmsted *et al.* 1983), a significant amount of research has been conducted following Hurricane Andrew (1992). Recent research on tropical hardwood hammocks has been conducted by C. Horvitz (Horvitz 1994, Horvitz *et al.* 1995, Horvitz *et al.* in press), M. Ross *et al.* (1998), and H.H. Slater *et al*. (1995). This research primarily investigates hammock recovery following hurricane disturbance, and exotic plant species responses and management following Hurricane Andrew. Research has also been completed on the role of the hammock seed bank (L. Flynn, The Nature Conservancy, personal communication 1998).

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

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

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

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

## Table 1. Vertebrates of tropical hardwood hammocks

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

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

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

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

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

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

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

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

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

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

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

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

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

* = naturalized exotic (non-native) species Table Prepared by Roger L. Hammer and Keith Bradley

## Literature Cited

Alexander, T.R. 1967. A tropical hammock in the Miami (Florida) limestone: a twenty-five year study. Ecology 48: 863-867.

Avery, G.N., and L.L. Loope. 1980. Plants of Everglades National Park. Report T-574, South Florida Research Center, Everglades National Park; Homestead, Florida.

Bancroft, G. T. 1996. White-crowned pigeon. Pages 258-266 *in* Rodgers, J. A. Jr., H. W. Kale II, and H. T. Smith, eds. Rare and endangered biota of Florida. Vol. V. Birds. University Presses of Florida; Gainesville, Florida.

Bancroft, G. T., R. Bowman, R. J. Sawicki, and A. M. Strong. In press. Relationship between the reproductive ecology of the white-crowned pigeon and the fruiting phenology of tropical hardwood hammock trees. Florida Game and Freshwater Fish Commission. Nongame wildlife technical report; Tallahasse, Florida.

Correll, D.S, and H.B. Correll. 1982. Flora of the Bahama archipelago. Lubrecht and Cramer; Forestburgh, New York.

Craighead, F.C., Sr. 1971. The trees of south Florida., vol. 1: the natural environments and their succession. University of Miami Press; Coral Gables, Florida.

Craighead, F.C., Sr. 1974. Hammocks of south Florida. Pages 191-198 *in* P.J. Gleason, ed. Environments of south Florida, past and present II. Miami Geological Society; Coral Gables, Florida.

Dade County Department of Environmental Resources Management [DERM]. 1995. Restoration plan for Dade County's pine rockland forests following Hurricane Andrew. Dade County Department of Environmental Resources Management; Miami, Florida.

Dade County Department of Planning, Development, and Regulation. 1996. The landscape manual. Dade County Department of Planning, Development, and Regulation; Miami, Florida.

Dade County Park and Recreation Department, The Nature Conservancy, and Fairchild Tropical Garden. 1991a. Castellow Hammock Nature Center natural areas protection plan, October 14, 1991. Dade County Park and Recreation Department; Miami, Florida.

Dade County Park and Recreation Department, The Nature Conservancy, and Fairchild Tropical Garden. 1991b. Matheson Hammock Park natural areas protection plan, October 15, 1991. Dade County Park and Recreation Department; Miami, Florida.

Dade County Park and Recreation Department. 1993. Charles Deering Estate Management Plan. Dade County Park and Recreation Department; Miami, Florida.

Dade County Park and Recreation Department. 1994. R. Hardy Matheson Preserve Management Plan (a.k.a. ITT-Snapper Creek). Dade County Park and Recreation Department; Miami, Florida.

Dalrymple, G.H. 1988. The herpetofauna of Long Pine Key, Everglades National Park in relation to vegetation and hydrology. Pages 72-86 *in* R.C. Szaro, K.E. Severson, and D.R. Patton, technical coordinators. Management of amphibians, reptiles, and small mammals in North America. USDA Forest Service general technical report RM-166.

Davis, J.H. 1943. The natural features of south Florida. Florida Geological Survey Bulletin 25: 311.

Deisler-Seno, J.E. 1994. Florida tree snail. Pages 134-140 *in* M. Deyrup and R. Franz, eds. Rare and endangered biota of Florida. Volume IV. Invertebrates. University presses of Florida; Gainesville, Florida.

Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.A. Alexander, R.F. Myers, and D.P. Sprangler. 1979. Resource inventory and analysis of the Big Cypress National Preserve. Center for Wetlands, University of Florida; Gainesville, Florida.

Fisher, J. 1998. Telephone communication. April 14, 1998.

Florida Game and Fresh Water Fish Commission. 1991. Living treasures of Florida's tropical hardwood hammocks. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Florida Department of Administration [DOA]. 1976. Florida land use and cover classification system: a technical report. Florida Department of Administration, Division of State Planning, Bureau of Comprehensive Planning; Tallahassee, Florida.

Florida Natural Areas Inventory and Florida Department of Natural Resources [FNAI and FDNR]. 1990. Guide to the natural communities of Florida. Florida Natural Areas Inventory and Florida Department of Environmental Resources Management; Tallahassee, Florida.

Flynn, L. 1998. Telephone communication. April 13, 1998.

Franz, R. 1982. Rare and endangered biota of Florida, Volume VI: invertebrates. University Presses of Florida; Orlando, Florida.

Gann, G. 1995. Guidelines for rockland hammock creation in Dade County. Tillandsia, June, 1995; 2-3.

Gann, G., and K. Bradley. 1996. *Clusia rosea* escapes from cultivation in southeastern Florida. Tillandsia, September, 1996; 3.

Gann, J. 1979. Everything you always wanted to know about planting a hammock. Fairchild Tropical Garden Bulletin, April, 1979; 15-26.

Hammer, R. 1996. Porterweeds: the sequel. Tillandsia, June, 1996; 2-3.

Hammer, R. 1997. Have we lost the young palm orchid? The Palmetto, Spring 1997; 8-9.

Harshberger, J.W. 1914. The vegetation of south Florida. Transactions of the Wagner Free Institute of Science, Philadelphia, Pennsylvania.

Horvitz, C.C. 1994. Hammocks and hurricanes: a surprisingly diverse array of non-indigenous plants threaten the natural regeneration of hardwood hammocks after hurricanes. Box 3.7a *in* D.C. Schmitz and T.C. Brown, eds., An assessment of invasive non-indigenous species in Florida's Public Lands. Technical report no. TSS-94-100, Florida Department of Environmental Protection; Tallahassee, Florida.

Horvitz, C.C., S. McMann and A. Freedman. 1995. Exotics and hurricane damage in three hardwood hammocks in Dade County Parks, Florida. Journal of Coastal Research (Special Hurricane Andrew Issue) 18: 145-158.

Horvitz, C.C. 1996. Effects of an exotic removal restoration program on post-hurricane regeneration in subtropical hardwood hammock preserves. Final unpublished report prepared for Dade County Tree Trust Fund and U.S. Fish and Wildlife Service; Miami, Florida.

Horvitz, C.C., J.B. Pascarella, S. McMann, A. Freedman, and R.H. Hofstetter. In Press. Functional roles of invasive non-indigenous plants in hurricane-affected subtropical forests. Ecological Applications.

Horvitz, C.C. 1998. Telephone communication. April 14, 1998.

Humphrey, S.R., 1992. Florida mastiff bat. Pages 216-223 *in* R.S. Humphrey, ed. Rare and endangered biota of Florida. Volume I. Mammals. University Presses of Florida; Gainesville, Florida.

Jameson, M., and R. Moyroud, eds. 1991. Xeric landscaping with Florida native plants. Association of Florida Native Nurseries, Inc.; San Antonio, Florida.

Jones, A.L., Erwin C. Winte, O.L. Bass. 1981. The Status of Florida Tree Snails (Liguus fasciatus), introduced to Everglades National Park. South Florida Research Center report T-622. Everglades National Park.

Klein, J. 1998. Telephone communication. April 7, 1998.

Koptur, S. 1998. Telephone communication. April 13, 1998.

Kruer, C.R. 1992. An assessment of Florida's remaining coastal upland natural communities: Florida Keys. Unpublished report prepared for Florida Natural Areas Inventory; Tallahassee, Florida.

Kruer, C.R. 1998. E-mail communication. March 12, 1998.

Kruer, C.R., T. Armstrong, and P. Braisted. 1998. Invasive exotic vegetation mapping in the Florida Keys. Report and 122-MB CD prepared by the Florida Keys Environmental Restoration Trust Fund for the Florida Keys Invasive Exotics Task Force; Summerlin Key, Florida.

Loope, L.L., and N.H. Urban. 1980. A survey of fire history and impact in tropical hardwood hammocks in the East Everglades and adjacent portions of Everglades National Park. Report T-592, South Florida Research Center, Everglades National Park; Homestead, Florida.

Loope, L.L. and V.L. Dunevitz. 1981. Impact of fire exclusion and invasion of *Schinus terebinthifolius* on limestone rockland pine forests of southeastern Florida. Report T-645, South Florida Research Center, Everglades National Park; Homestead, Florida.

Luer, C.A. 1972. The native orchids of Florida. The New York Botanical Garden; New York.

McCartney, C. 1998. Telephone communication. February 26, 1998.

McNeese, P. 1996. Florida Keys Forest Canopy Inventory Project. Final report for Monroe County Environmental Resources Department.

Moler, P.E. 1992. Rim rock crowned snake. Pages 158-161 *in* P.A. Moler, ed. Rare and endangered biota of Florida. Volume III. Amphibians and reptiles. University Presses of Florida; Gainesville, Florida.

Moody, M.E. and R.N. Mack. 1988. Controlling the spread of plant invasions: the importance of nascent foci. Journal of Applied Ecology 25: 1009-1021.

Nauman, C. 1986. Increasing rarity of Florida's ferns. The Florida Naturalist 59(4): 2-4.

Olmsted, I.C., L.L. Loope, R.P. Russell. 1981. Vegetation of the southern coastal region of Everglades National Park between Flamingo and Joe Bay. Report T-620, South Florida Research Center, Everglades National Park; Homestead, Florida.

Olmsted, I, W.B. Robertson, Jr., J. Johnson, and O.L. Bass, Jr. 1983. The vegetation of Long Pine Key, Everglades National Park. Report SFRC-83/05, South Florida Research Center, Everglades National Park; Homestead, Florida.

Robertson, W.B, Jr. 1955. An analysis of the breeding-bird populations of tropical Florida in relation to the vegetation. Ph.D. dissertation, University of Illinois; Urbana, Illinois.

Robertson, W.B., Jr., and J. Kushlan. 1984. The south Florida avifauna. Pages 219-257 *in* P.J. Gleason, ed. Environments of South Florida, past and present II. Miami Geological Society; Coral Gables, Florida.

Robertson, W.B., Jr., and G.E. Woolfenden. 1992. Florida bird species. Florida Ornithological Society, special publication number 6; Gainesville, Florida.

Ross, M.S., J.J. O'Brien, and L.J. Flynn. 1992. Ecological site classification of Florida Keys terrestrial hbitats. Biotropica 24(4): 48-502.

Ross, M.S., G. Telesniki, P.L. Ruiz, and L.J. Flynn. 1998. Hurricane Andrew and upland forest succession in Biscayne National Park. Unpublished report to the National Park Service. Southeast Environmental Research Program, Florida International University; Miami, Florida.

Ross, M.S. Telephone communication. April 13,1998.

Sanders, R.W. 1987. Identity of *Lantana depressa* and *L. ovatifolia* (Verbenaceae) of Florida and the Bahamas. Systematic Botany 12(1): 44-60.

Slater, H.H., W.J. Platt, D.B. Baker, and H.A. Johnson. 1995. Effects of Hurricane Andrew on damage and mortality of trees in subtropical hardwood hammocks of Long Pine Key, Everglades National Park, Florida. Journal of Coastal Research (Special Hurricane Andrew issue) 18: 197-207.

Small, J.K. 1913. Flora of the Florida Keys. John K. Small; New York.

Small, J.K. 1929. From Eden to Sahara. The Science Press Printing Company; Lancaster, Pennsylvania.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina; Chapel Hill.

Snyder, J.R., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida rocklands. Pages 230-277 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Soil and Water Conservation Service [SWCS]. 1989. Twenty-six ecological communities of Florida. Florida Chapter of Soil and Water Conservation Society; Gainesville, Florida.

U.S. Department of Agriculture, Soil Conservation Service. 1947. Soil Survey: Dade County, Florida.

U.S. Geological Survey, Biological Resources Division [USGS/BRD]. 1996. Classification of 1993/94 Landsat TM Imagery. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Vardaman, S. 1998. Telephone conversation. April 13, 1998.

Wade, E., J. Ewel, and R. Hofstetter. 1980. Fire in South Florida Ecosystems. U.S. Forest Service technical report SE-1, Southeastern Forest Research Station; Asheville, North Carolina.

Ward, D.B. 1979. Rare and endangered biota of Florida. Volume V. Plants. University Presses of Florida; Orlando, Florida.

Wells, S.V., and D. Hazelton 1997. Dade County Florida's post-hurricane rockland hammock restoration program, a multi-species exotic plant control strategy. Abstract in program, Society for Ecological Restoration, 9th annual international conference. Society for Ecological Restoration; Madison, Wisconsin.

# Restoration of Tropical Hardwood Hammock

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

## Restoration Criteria

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

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

### Community-level Restoration Actions

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

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

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

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

1.4. **Prevent degradation of existing preserves containing tropical hardwood hammocks.** Work with Federal, State, county, and municipal agencies and non-governmental organizations to prevent further degradation of existing preserves from exotic plant and animal species (including feral and domesticated pets), anthropogenic fires, unauthorized site uses, illegal dumping, improper siting of facilities (including interpretive trails), poaching of animals, collecting of plants, hydrologic modifications including drainage, flooding, and salt water intrusion, and damage from pesticides and other contaminants. Protect shell mounds from artifact-seekers and archeological excavations. Encourage the use of prescribed fire in pine rocklands to protect hammock edges from effects of fire exclusion.

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

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

2.2. **Restore natural fire regimes.** Develop prescribed fire programs that allow fires from surrounding pine rocklands, prairies and other communities to burn freely into hammock edges when conducted during the proper fire season and with adequate moisture to protect the hammock interior. Control unauthorized anthropogenic fires.

2.3. **Where possible, restore the water table to its historic levels**. Rehydrate hammocks which have been dewatered by drainage in order to provide habitat for rare ferns and other sinkhole species. Reduce water levels in the Water Management Areas to historic levels to restore tropical hardwood hammocks that have been degraded due to unnaturally high water levels. Fill or plug problematic mosquito ditches in lower Keys hammocks without causing negative hydrologic impacts.

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

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

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

2.7. **Reintroduce species which have been extirpated within their historic ranges.** Develop plans to reintroduce plant and animal species which have been extirpated from South Florida where appropriate and only within historic ranges. Augment populations and establish new populations of rare species which have been impacted by habitat loss, poaching, collecting pressure, etc., to ensure the long-term persistence of the species in South Florida. If federally listed species are used for reintroduction purposes, appropriate FWS protocols must be followed.

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

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

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

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

   3.4. **Continue to monitor for and control exotic plant and animal species**, especially outlying populations before they become established.

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

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

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

4. **Recreate tropical hardwood hammocks where they have been destroyed by human activities.**

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

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

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

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

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

   5.3. **Discourage the use of tropical hardwood hammocks species outside of their historic ranges.** Many tropical hardwood hammock species have been promoted for landscape use within South Florida. Unfortunately, many of there species have been

and are being planted outside of their historic ranges; some are now escaping from cultivation and invading natural areas outside of their historic range. The use of native species only within their natural ranges should be encouraged.

6. **Connect existing tropical hardwood hammocks by acquiring lands for conservation between them.** Land acquisition, landowner agreements or conservation easements should be used to prevent development of lands between existing conservation areas and to restore lands where possible. Lands acquired as connectors between conservation areas containing tropical hardwood hammocks need not include tropical hardwood hammocks. Historically, tropical hardwood hammocks existed as "islands" in a matrix of other community types, and this pattern should be maintained as much as possible. Opportunities to use landscapes such as canal banks and roadsides as greenways dominated by native vegetation should be explored.

7. **Encourage community-level research.** More research is needed on wildlife habitat needs in terms of tropical hardwood hammock functions and biodiversity, the long-term role of fire and hurricanes in maintaining hammock structure and biodiversity, and the potential effect of oxidation of soil humus due to the lowering of the water table in southeastern Florida. Once exotic plants are initially removed, routine monitoring/inspections need to be performed.

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

9. **Increase public awareness.** Public understanding and approval are required for any conservation effort to be successful. Public announcements should highlight land acquisition projects such as Florida's Conservation and Recreational Lands (CARL) program and Preservation-2000. Inform local land owners on the importance and uniqueness of the tropical hardwood hammock ecological community. Environmental education programs in South Florida should be encouraged to distribute materials or develop lesson plans on tropical hardwood hammock habitats, tropical hardwood hammock species and the importance of maintaining natural biodiversity.