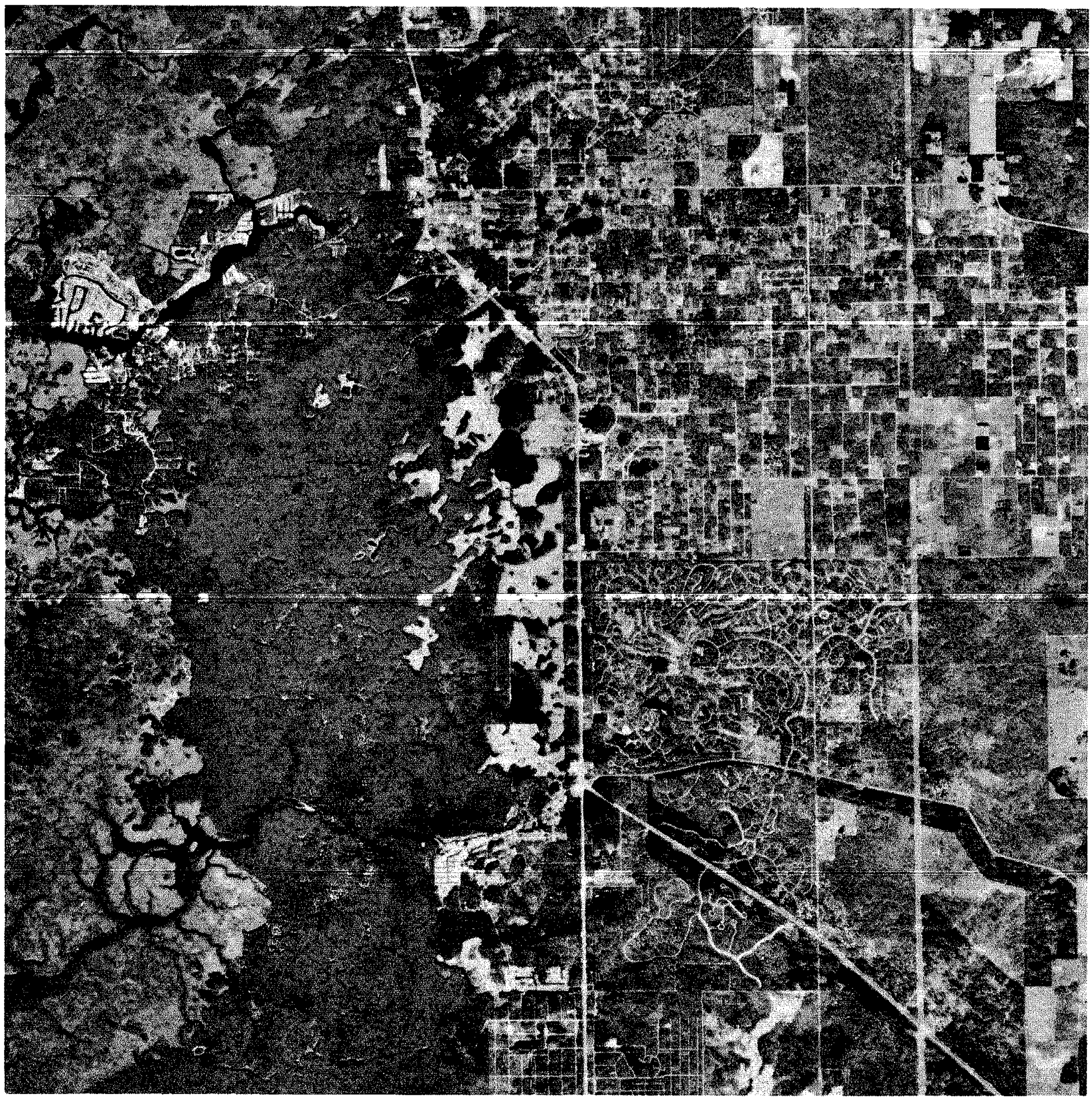
Biological Report 85(7.26 Supplement)
September 1989

# HYDRIC HAMMOCKS: A GUIDE TO MANAGEMENT





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**Cover: 1984 aerial photograph of coastal Citrus County, Florida. Dark, vertical band of vegetation is Chassahowitzka Swamp, a large hydric hammock. To the left of hydrick hammock is salt marsh; to the right is slash pine flatwoods and then longleaf pine sandhill. Hydric hammock is being developed as subdivisions in the vicinity of Homosassa Springs. For detail, see Figure 9.**

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# HYDRIC HAMMOCKS: A GUIDE TO MANAGEMENT

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# PREFACE

The emphasis of this guide is on hydric hammock, a distinctive type of forested wetland occurring at low elevations along the gulf coast of Florida from Aripeka to St. Marks and at various inland sites in Florida. This is a companion volume to a descriptive profile of the same community (U.S. Fish and Wildlife Service Biological Report 85(7.26)).

Relatively little research has been conducted on hydric hammock. It has not been adequately defined and described, and no thorough body of information on its management has been accumulated. Consequently, no systematic way of defining management options or judging their efficacy has been available. The purpose of this guide is to explain how the nature and functioning of the hydric-hammock community determines its best management. Information for the guide was gathered from published and unpublished literature, from personal communication with many technical experts, and from our own field experience. Because little has been published about hydric hammocks, much of this report is based on subjective opinions of ecologists, foresters, and land managers, including the authors, who have worked with and studied this habitat, and on extrapolation of information from other, similar habitats.

It is hoped that the content and format of this report will be useful to a broad spectrum of users, including other scientists, students, resource managers and planners, teachers, and interested citizens. The document includes a brief description of the community, a history of its use, its present functions and alterations, and the available management techniques and options.

## CONVERSION TABLE

### Metric to U.S. Customary

| *Multiply* | *By* | *To Obtain* |
|---|---|---|
| millimeters (mm) | 0.03937 | inches |
| centimeters (cm) | 0.3937 | inches |
| meters (m) | 3.281 | feet |
| meters | 0.5468 | fathoms |
| kilometers (km) | 0.6214 | statute miles |
| kilometers | 0.5396 | nautical miles |
| square meters ($m^2$) | 10.76 | square feet |
| square kilometers ($km^2$) | 0.3861 | square miles |
| hectares (ha) | 2.471 | acres |
| liters (l) | 0.2642 | gallons |
| cubic meters ($m^3$) | 35.31 | cubic feet |
| cubic meters | 0.0008110 | acre-feet |
| milligrams (mg) | 0.00003527 | ounces |
| grams (g) | 0.03527 | ounces |
| kilograms (kg) | 2.205 | pounds |
| metric tons (t) | 2205.0 | pounds |
| metric tons | 1.102 | short tons |
| kilocalories (kcal) | 3.968 | British thermal units |
| Celsius degrees (° C) | 1.8 (° C) + 32 | Fahrenheit degrees |

### U.S. Customary to Metric

| *Multiply* | *By* | *To Obtain* |
|---|---|---|
| inches | 25.40 | millimeters |
| inches | 2.54 | centimeters |
| feet (ft) | 0.3048 | meters |
| fathoms | 1.829 | meters |
| statute miles (mi) | 1.609 | kilometers |
| nautical miles (nmi) | 1.852 | kilometers |
| square feet ($ft^2$) | 0.0929 | square meters |
| square miles ($mi^2$) | 2.590 | square kilometers |
| acres | 0.4047 | hectares |
| gallons (gal) | 3.785 | liters |
| cubic feet ($ft^3$) | 0.02831 | cubic meters |
| acre-feet | 1233.0 | cubic meters |
| ounces (oz) | 28350.0 | milligrams |
| ounces | 28.35 | grams |
| pounds (lb) | 0.4536 | kilograms |
| pounds | 0.00045 | metric tons |
| short tons (ton) | 0.9072 | metric tons |
| British thermal units (Btu) | 0.2520 | kilocalories |
| Fahrenheit degrees (° F) | 0.5556 (° F - 32) | Celsius degrees |

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# FIGURES

# TABLES

## ACKNOWLEDGMENTS

We are grateful to Karla Brandt, Robert Dye, Judy Hancock, Paul E. Moler, Erika Simons, and Andy Vince for helping with field work with enthusiasm and without compensation. We are also grateful to the individuals cited in the text for unselfishly sharing their expertise during what often were lengthy conversations. We thank many staff members of the Florida Department of Natural Resources, Florida Game and Fresh Water Fish Commission, and St. Johns Water Management District for providing access to many areas, allowing personnel to spend time helping us, and in Wekiwa Springs State Park, for coming to our rescue. We thank David Hall of the University of Florida Herbarium for identifying many specimens and both he and Paul E. Moler for suggesting improvements to parts of the manuscript.

Finally, the senior author is forever grateful to many people for the knowledge and insights gained during this project and the many years preceding it: James Beauchamp, Jim Buckner, Archie Carr, Steve Christman, John and Katherine Ewel, Robert Godfrey, Dana Griffin, David Hall, Judy Hancock, Ellison Hardee, Larry D. Harris, Helen Hood, Charles Houder, Walter Judd, David Maehr, Paul E. Moler, Tom Morris, Reed Noss, Buford Pruitt, Daniel Ward, Donald Younker, and others.

# CHAPTER 1. INTRODUCTION

The naturalist William Bartram travelled widely in north Florida in the mid-1700's. In describing the country along the old Spanish highway between Paynes Prairie and St. Marks, he wrote: "Next morning we arose early, and proceeding, gradually descending again, and continued many miles along a flat, level country, over delightful green savannas, decorated with hommocks or islets of dark groves, consisting of Magnolia grandiflora, Morus tilia, Zanthoxylon, Laurus Borbonia, Sideroxylon, Quercus sempervirens, Halesia diptera, Callicarpa, Corypha palma, &c. There are always groups of whitish testaceous rocks and sinks where these hommocks are." Other hammocks contained "Live Oak, Mulberry, Magnolia, Palm, Zanthoxylon, &c" (Bartram 1791, p. 189).

Twentieth century ecologists (e.g., Harper 1914; Laessle 1942; Davis 1943) use the term hammock, just as Bartram used the term hommock, to denote islands of dense hardwood forests in the vast sea of Florida's pine forests, swamps, and savannas. The hammocks invariably contain oak trees and are often dominated by them. Another type of dense hardwood forest devoid of oak trees and dominated by bay trees (*Gordonia lasianthus*, *Magnolia virginiana*, and *Persea palustris*) is referred to as bayhead, baygall, and bay swamp. The term hammock is also commonly used by the people of Florida, and topographic maps (U.S. Geological Survey) of the Florida peninsula show the names and locations of hundreds of hammocks. Gulf Hammock is the largest, in excess of 100,000 acres. Two or three hammocks are about 20,000 acres in extent, and the rest are under 10,000 acres. Many are just a few acres associated with a limerock outcrop, a small depression, or the shore of a stream or lake. The term hydric hammock applies to those hammocks or parts of hammocks whose species composition is restricted or modified by occasional flooding.

Hydric hammocks are widely scattered throughout Florida from St. Marks (Wakulla County) east and south to just north of Lake Okeechobee (Figure 1). The largest contiguous tracts occur along the gulf coast and the St. Johns River. St. Marks National Wildlife Refuge contains the westernmost large area, and Myakka River State Park the southernmost. Hammocks south of Lake Okeechobee are subtropical and are quite different in character and species composition. Some of the larger and better-known areas of hydric hammock are listed in Table 1. Numerous other hydric hammocks exist. For example, ten other hydric hammocks ranging from 200 to 1,000 acres in area were identified in an inventory of habitats of Alachua County, FL (Duever 1987). Hydric hammocks also may extend north of Florida along the Atlantic coast, but if so, their extent and nature are undocumented.

Hydric hammock probably occupied about a half million acres of land when Columbus landed in the New World. Clearing for real estate development (Palm Coast), pine plantations (Gulf

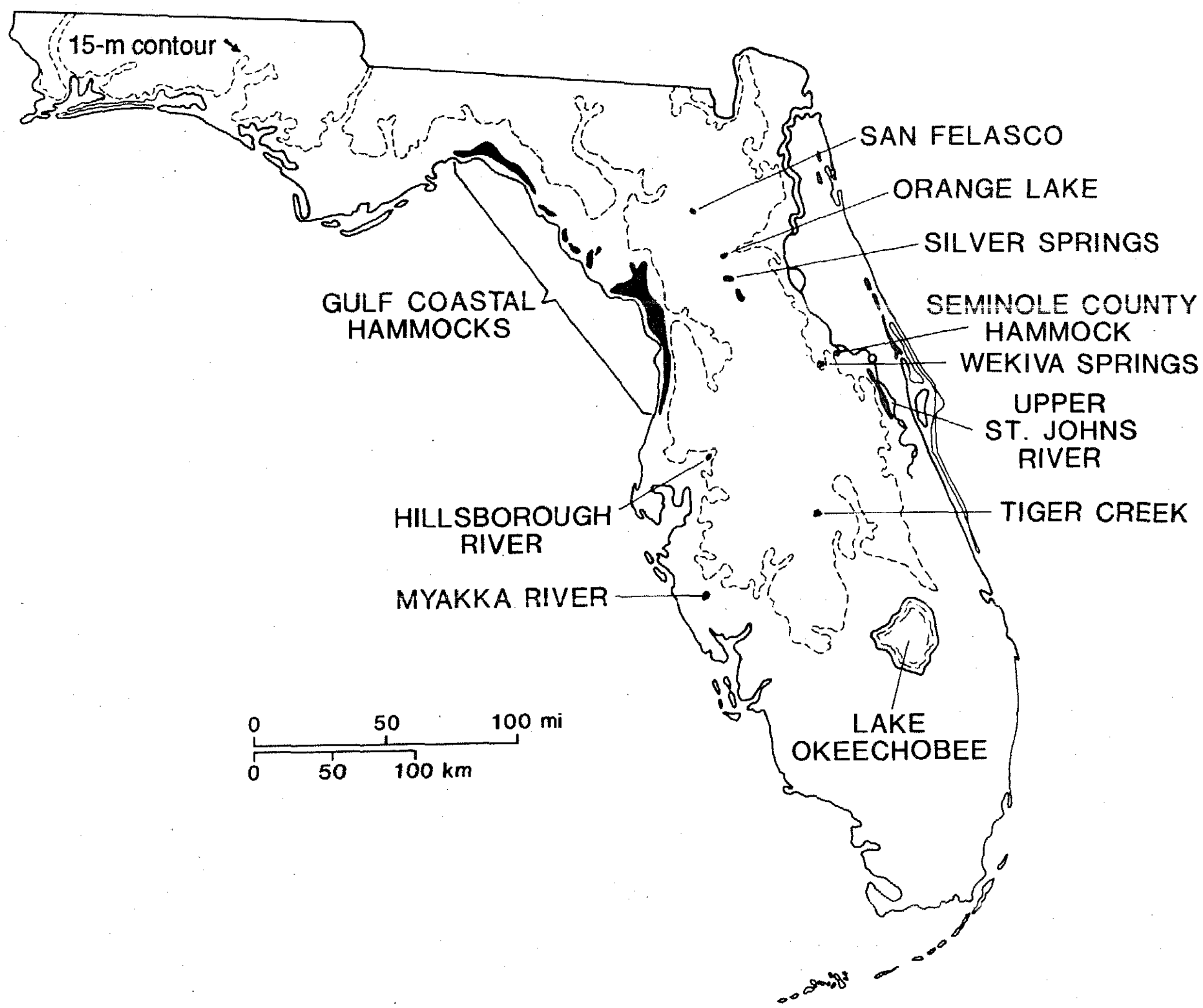



**Figure 1. Distribution of hydric hammocks in Florida. Many hydric hammocks too small to be delineated at this scale are scattered throughout peninsular Florida north of Lake Okeechobee.**

Hammock), and agriculture have decreased the original acreage considerably. In a few areas, for example Tosohatchee State Reserve and Myakka River State Park, hydric hammock has expanded slightly due to fire suppression. A rough guess is that about half of the original area of hydric hammock has been lost.

Some of these losses are permanent. Hammocks cleared for real estate development, improved pasture, or row crops are unlikely to be hammock ever again--these or more intensive uses are unlikely to be abandoned. However, areas cleared for pine plantations reseed with hammock trees beneath the pines within 20 years and, with no intervention, eventually revert to hammock.

The long-term prospects for hydric hammock are poor because of Florida's rapidly expanding human population. The only hammocks likely to remain in

Table 1. Approximate acreages of hydric hammock in some areas of Florida.

| Site | Florida county | Area (acres) |
|---|---|---|
| Gulf Hammock | Levy | 100,000 |
| Big Bend Coast Project | Dixie and Taylor | 35,000 |
| Loblolly Pine Hammock | Marion | 20,000 |
| St. Marks National Wildlife Refuge | Wakulla and Jefferson | 5,000 |
| Ten Mile Swamp | St. Johns | 4,000 |
| Withlacoochee State Forest | Citrus, Hernando, and Sumter | 4,000 |
| Devil's Hammock | Levy | 2,000 |
| Marshall Swamp | Marion | 2,000 |
| Tosohatchee State Reserve | Orange | 2,000 |
| San Felasco Hammock | Alachua | 1,000 |
| Cabbage Swamp | St. Johns | 1,000 |
| Myakka River State Park | Sarasota and Manatee | 1,000 |

a few decades are those that are protected in State or National parks, forests, and refuges. Another ominous threat is the projected rise in sea level resulting from the greenhouse effect. Most hydric hammock occurs in low-lying coastal areas (Figure 1). The ocean is projected to rise 144-217 cm by the year 2100, and there is no indication that people will reduce fossil fuel consumption sufficiently to alter this outcome (Hoffman 1984).

Large-scale loss of hydric hammock should be cause for concern, since this community benefits the public in many ways. The mixture of cabbage palm, live oak, and red cedar makes a visually interesting and beautiful forest. The mosaic of hydric hammock and salt marsh along the gulf coast forms one of the most scenic vistas in Florida. In a State where outdoor-oriented tourism is the number one industry, aesthetics must have considerable economic value, even though it is impossible to accurately quantify.

Hydric hammocks support a diverse and abundant animal community of value to tourists and Florida residents alike. Hydric hammocks often occur as strips and patches interspersed with other habitats and often produce mast in large quantity at times when the other habitats do not (Vince *et al.* 1989). Consequently, hydric hammocks are particularly important habitat for white-tailed deer, wild turkey, wild hog, and black bear, all of which are greatly valued as game animals, and are the sort of animals that outdoor recreationists like to see (Shaw and Mangun 1984). Hydric hammocks are also quite valuable as required winter habitat for many passerine birds that migrate from breeding grounds in eastern North America. In addition, many hydric hammocks support domestic animals by providing high quality winter range for cattle and year-round habitat for domestic hogs.

Some hydric hammocks produce high quality loblolly pine, red cedar, or sweetgum timber, with values reaching as high as $3,700 per acre in mature stands (Johnson 1978). The value of the annual growth in such stands averages roughly $50 per acre per year. Swamp laurel oak, water oak, swamp chestnut oak, persimmon, swamp tupelo, red maple, Florida elm, and other species often add to the timber value, although they are generally less valuable per unit volume. The value of timber production to the regional economy is much higher than the above stumpage values, because timber is the basic resource of a large industry. To calculate the total value to the economy of a given value of timber, the values of industrial processes must be added. For $1 worth of timber harvested in Florida the following estimated values should be added (Florida Department of Agriculture and Consumer Services 1986): logging, $0.70; transportation and marketing, $13.07; primary manufacturing, $7.57; and secondary manufacturing, $14.82. Thus each dollar of raw timber is worth, on average, $37 to the regional economy when all the activities take place in the region.

Hydric hammocks play an important role in regional hydrology. Water enters these forests via rainfall, groundwater discharge, and surface flows. Low topography and dense vegetation slow the sheet flow of water over the forest floor, increasing the time of contact between water and soil. Detention of water in hydric hammocks enhances the potential for water purification and recharge of surficial ground water. Pulses in freshwater runoff are attenuated; water is made available to the forest flora for longer periods; and water is released more evenly to downslope communities, such as estuaries. Estuaries may also benefit from the addition to their food chain of detritus flushed out of coastal hydric hammocks by occasional severe floods.

Coastal hydric hammocks provide some protection from hurricanes by damping the winds and storm tides and holding the soil. Live oak is particularly valuable in this regard because it can remain standing longer than other trees due to its low profile, strong root system, strong wood, and ability to shed branches.

In urban areas, strips and patches of hydric hammock are high-quality green spaces that filter surface water runoff, abate air pollution and noise, provide aesthetically pleasing scenery, and furnish birds and other wildlife a place to live. As Florida's population grows, hydric hammocks near metropolitan areas will increasingly be examined as possible sites for disposal of treated sewage effluent, storm water, and industrial discharges of water.

Many of the values and functions of hydric hammocks are shared by other wetlands (Greeson *et al.* 1979). During the past two decades, documentation of these values resulted in increased public awareness of the importance of wetlands. In response, laws have been passed to protect many types of marshes and swamps. A major purpose of this document and the hydric hammock community profile (Vince *et al.* 1989) is to detail these values and functions so that they can be protected. An ecological description is provided to elucidate the nature and functions of a hydric hammock. Numerous activities and their impacts on hydric hammocks are described in this report. Finally, various management strategies are outlined as the basis for rational decisions that will protect the inherent values of hydric hammock while at the same time provide for human use of this community.

# CHAPTER 2. ECOLOGY

## 2.1 PHYSICAL ENVIRONMENT

Most hydric hammocks occur on thin soils of sand and loam over limestone bedrock. Typically limestone is found in the root zone, and surface outcrops of bedrock are common. Some hydric hammocks are found in places without limestone, where calcium is supplied by artesian springs or shell and limestone fragments in the soil. Hydric-hammock soils are nearly level, relatively poorly drained, slightly acidic to slightly alkaline in pH, and lack the alluvial sediment in which bottomland hardwoods flourish.

The hydrology of hydric hammocks has not been thoroughly investigated; the following discussion is based on the description by Vince *et al.* (1989). Probably all hydric hammocks flood occasionally, but the hydroperiod is short relative to that of swamps. During especially wet years, the local water affecting hydric hammocks can become a substantial overland flow. The major source of water is local rainfall. Additional sources include stream floodwaters, seepage from adjacent uplands, and discharge from deep aquifers. However, stream floodwaters and seepage from adjacent uplands are more characteristic of bottomland hardwood and bayhead communities, respectively, than of hydric hammock. Ground-water levels are not nearly as constant as in bayheads, fluctuating seasonally, perhaps even dropping below the root zone for brief periods once or twice a year.

Both fire and salinity strongly affect the composition of some hydric hammocks (Vince *et al.* 1989). Hammocks are protected from fire by moist soil conditions, by high humidity and low wind velocity sustained by the dense forest canopy, by low amounts of flammable vegetation, and by adjacent wetlands or bodies of water (Harper 1911; Harper 1915; Laessle 1942; Wells 1942). Nonetheless, infrequent fires occur in hydric hammocks, particularly in those adjacent to fire-adapted communities like pine flatwoods and freshwater marsh. Such fires reduce and sometimes eliminate fire-sensitive species. The effects of salinity on hydric hammocks adjacent to salt marsh and along the St. Johns River is even more dramatic, often eliminating all but a very few salt-tolerant species of plants.

## 2.2 FLORA AND FAUNA

The species composition of hydric hammocks is diverse and varies considerably from hammock to hammock, from one type of hydric hammock to another, and from north to south Florida. Although particular stands may be difficult to categorize, four types of hydric hammock can be distinguished on the basis of relative abundance of species, hydrological regime, and physiographic setting; these types are described in the next section. Details of the variations and of the factors responsible are given by Vince *et al.* (1989). Many species of plants important to hydric hammocks have temperate-zone distributions that terminate in northern Florida, whereas others are confined to the southern part of the State, so different suites of species are available regionally. In Table 2 and the paragraphs that follow, those species occurring only in the northern hammocks are followed by an N in parenthesis, and those found only in the southern hammocks are followed by an (S). The remaining species are present in most of the range of hydric hammock. The species lists were derived by R. W. Simons

**Table 2. Plants occurring in hydric hammocks. Hammock types are inland (I), seepage (S), coastal (C), and loblolly pine (L). These types are described in detail in Chapter 2.3. For each plant species, hammock types are listed in decreasing order of that species' abundance, and hammock types in parentheses contain a markedly lower abundance. Abundance classes are abundant (A), common (C), occasional (O), and rare (R) and refer to the type of hammock in which the species is most commonly found.**

| Scientific name | Common name | Type | Abundance |
|---|---|---|---|
| | Woody plants: | | |
| *Acer barbatum* (N) | Florida maple | I, C | O |
| *Acer negundo* (N) | box-elder | I, L | R |
| *Acer rubrum* | red maple | S, I (C) | A |
| *Aesculus pavia* (N) | red buckeye | I, S | O |
| *Ampelopsis arborea* | pepper vine | I, (S, L, C) | C |
| *Baccharis halimifolia* | groundsel | C, L, I, S | C |
| *Berchemia scandens* | rattan vine | I, S | O |
| *Bignonia capreolata* | cross vine | L, I, S | O |
| *Bumelia reclinata* (N) | buckthorn | I | O |
| *Callicarpa americana* | beautyberry | L, (I, S, C) | C |
| *Campsis radicans* | trumpet creeper | I, (L, C, S) | A |
| *Carpinus caroliniana* | hornbeam | I, S | A |
| *Carya aquatica* | water hickory | I | R |
| *Carya glabra* | pignut hickory | I, L | R |
| *Celtis laevigata* | sugarberry | I, (C) | O |
| *Cercis canadensis* | redbud | I | R |
| *Cornus foemina* | swamp dogwood | I | C |
| *Crataegus marshallii* | parsley haw | I | O |
| *Crataegus viridis* (N) | green haw | I | O |
| *Decumaria barbara* | climbing hydrangea | S, I | C |
| *Diospyros virginiana* | persimmon | I, L | C |
| *Eugenia axillaris* (S) | white stopper | C | O |
| *Forestiera ligustrina* | privet | I | O |
| *Fraxinus caroliniana* | pop ash | I, C | O |
| *Fraxinus pauciflora* | swamp ash | I, C | O |
| *Fraxinus pennsylvanica* (N) | green ash | S (I) | C |
| *Gelsemium sempervirens* | yellow jessamine | I, L | A |

(Continued)

Table 2. (Continued).

| Scientific name | Common name | Type | Abundance |
|---|---|---|---|
| *Gleditsia aquatica* | water locust | I, C | R |
| *Gordonia lasianthus* | loblolly-bay | S | R |
| *Hypericum hypericoides* | St. Andrew's-cross | I, L | O |
| *Ilex cassine* | dahoon | S, (I) | O |
| *Ilex coriacea* | big gallberry | S | O |
| *Ilex decidua* | possum-haw | I | O |
| *Ilex glabra* | gallberry | L, S | C |
| *Ilex opaca* | American holly | I | O |
| *Ilex vomitoria* | yaupon | C (L, I) | C |
| *Illicium parviflorum* | yellow anise | S | R |
| *Itea virginica* | Virginia-willow | S | O |
| *Juniperus silicicola* | southern red-cedar | C, (I) | A |
| *Liquidambar styraciflua* | sweetgum | I, L, (C, S) | A |
| *Liriodendron tulipifera* | tulip tree | S | O |
| *Lyonia lucida* | fetterbush | S, I | O |
| *Magnolia virginiana* | sweetbay | S, (C, I) | A |
| *Morus rubra* | red mulberry | I, C, S, L | O |
| *Myrica cerifera* | wax-myrtle | S, I, C, L | A |
| *Nyssa sylvatica* var. *biflora* | swamp tupelo | S, I, L | C |
| *Parthenocissus quinquefolia* | Virginia creeper | I, S, L, C | O |
| *Persea palustris* | swampbay | S, (C, L, I) | C |
| *Pinus elliottii* | slash pine | C, S, I, L | O |
| *Pinus serotina* | pond pine | S, L | R |
| *Pinus taeda* (N) | loblolly pine | L, (C, I, S) | A |
| *Quercus laurifolia* | swamp laurel oak | I, S, (C, L) | A |
| *Quercus michauxii* (N) | swamp chestnut oak | L, I | O |
| *Quercus nigra* | water oak | L, (S, I) | A |
| *Quercus shumardii* (N) | shumard oak | L, I | R |
| *Quercus virginiana* | live oak | C, I, L | A |
| *Rhapidophyllum hystrix* | needle palm | S | C |
| *Rubus argutus* | highbush blackberry | S, L, I | O |
| *Sabal palmetto* | cabbage palm | C, L, S, (I) | A |
| *Sabal minor* | bluestem palmetto | L, (I) | A |
| *Sageretia minutiflora* | climbing buckthorn | C (I) | O |
| *Sambucus canadensis* | elderberry | S | O |
| *Sebastiana fruticosa* | sebastian-bush | I | O |
| *Serenoa repens* | saw palmetto | L, I | O |
| *Smilax* spp. | greenbriar | I, S, L, (C) | A |
| *Tilia caroliniana* (N) | basswood | I | O |
| *Toxicodendron radicans* | poison ivy | I, S, L, C | C |
| *Ulmus alata* (N) | winged elm | I, L, C | R |
| *Ulmus americana* var. *floridana* | Florida elm | I, S, (L, C) | C |
| *Ulmus crassifolia* (N) | cedar elm | C, I, L | R |
| *Vaccinium elliottii* | mayberry | I, S, L | O |

(Continued)

Table 2. (Continued).

| Scientific name | Common name | Type | Abundance |
|---|---|---|---|
| *Vaccinium fuscatum* | swamp blueberry | I, S, L | O |
| *Viburnum obovatum* | walter viburnum | I | C |
| *Viburnum dentatum* var. *scabrellum* | southern arrow-wood | I | O |
| *Vitis aestivalis* | summer grape | I, S, L, C | A |
| *Vitis rotundifolia* | bullace grape | I, S, L, C | C |
| | Herbaceous plants: | | |
| *Arisaema triphyllum* | jack-in-the-pulpit | S | O |
| *Arnoglossum diversifolium* (N) | indian-plantain | I | O |
| *Arundinaria gigantea* (N) | switch cane | I, S | O |
| *Aster* spp. | aster | I, L, C, S | O |
| *Azolla caroliniana* | mosquito fern | I | O |
| *Boehmeria cylindrica* | false nettle | I, S, L | O |
| *Botrychium* spp. | grape fern | I | O |
| *Cacalia suaveolens* | indian-plantain | I | R |
| *Carex* spp. | sedges | I, L, (C, S) | A |
| *Chasmanthium* spp. | spikegrasses | L, I, C, S | A |
| *Cirsium* spp. | thistles | I, L, S, C | O |
| *Cladium jamaicense* | sawgrass | C, I, S | O |
| *Clematis crispa* | leather-flower | I, L | O |
| *Conyza canadensis* | horseweed | L | C |
| *Cyperus* sp. | flat sedge | L, (I, S) | C |
| *Desmodium* spp. | beggarweed | L | O |
| *Dicondra caroliniensis* | pony-foot | I, S, L | O |
| *Dryopteris ludoviciana* | Florida shield fern | S, I | O |
| *Elephantopus nudatus* | purple elephant's-foot | I, L, C | C |
| *Elytraria carolinensis* | scale-stem | I, L, C | C |
| *Epidendrum conopseum* | green-fly orchid | I, S, C, L | C |
| *Erechtites hieracifolia* | fireweed | L, (I, C) | O |
| *Eupatorium capillifolium* | dog-fennel | I, L, C | O |
| *Eupatorium jacundum* | ageratina | L, (I) | C |
| *Galactia* spp. | milk pea | L | C |
| *Galium* spp. | bedstraw | L | O |
| *Hydrocotyle* spp. | penny-wort | I, S, L | O |
| *Hypoxis leptocarpa* | swamp (yellow) star-grass | L, I | O |
| *Hyptis alata* | musky mint | L, (I) | C |
| *Imperata* sp. | cogon grass | L | O |
| *Juncus* spp. | rush | L, I | O |
| *Leersia hexandra* | southern cut grass | I, L | O |
| *Lemna* spp. | duckweed | I | A |
| *Lorinseria areolata* | chain fern | S, I | O |
| *Melothria pendula* | creeping-cucumber | L, I | O |
| *Mikania scandens* | climbing hempweed | I, L, S | O |

(Continued)

Table 2. (Concluded).

| Scientific name | Common name | Type | Abundance |
|---|---|---|---|
| *Mitchella repens* | partridge berry | I, L | O |
| *Muhlenbergia schreberi* | nimbleweed | L | C |
| *Oplismenus setarius* | woods grass | L, I | C |
| *Osmunda cinnamomea* | cinnamon fern | S | C |
| *Panicum commutatum* | variable panicum | L, I, S, C | C |
| *Panicum rigidulum* | red-top panicum | I | C |
| *Panicum* spp. | panic grass | L, I | C |
| *Paspalum floridanum* | Florida paspalum | L, (I) | C |
| *Paspalum* spp. | paspalum | L, I | O |
| *Phlebodium aureum* (S) | goldfoot fern | L, C, S, I | C |
| *Phyllanthus liebmannianus* | pine-wood dainties | C, I | R |
| *Polygonum hydropiperoides* | mild water-pepper | I, L | C |
| *Polypodium polypodioides* | resurrection fern | I, S, C, L | A |
| *Ponthieva racemosa* | shadow-witch | I | O |
| *Psychotria undata* | wild coffee | C, S | R |
| *Rhynchospora* spp. | beak rush | L, I, S | O |
| *Ruellia caroliniensis* | wild petunia | I, L | O |
| *Salvia lyrata* | lyre-leaf sage | L, I, C | O |
| *Salvinia rotundifolia* | water spangles | I | C |
| *Sanicula canadensis* | snakeroot | L, I | O |
| *Scleria triglomerata* | tall nut-grass | I | O |
| *Senecio glabellus* | butterweed | I | O |
| *Sisyrinchium atlanticum* | blue-eyed-grass | L, (I) | C |
| *Spigelia loganioides* (N) | pink-root | I, L, C | R |
| *Spiranthes longilabris* | long-lip ladies'-tresses | I, S | O |
| *Spirodela* spp. | duckweed | I | A |
| *Stenotaphrum secundatum* | St. Augustine grass | C, (L) | C |
| *Thelypteris* spp. | wood fern | I, S | C |
| *Tillandsia bartramii* (N) | needle-leaf airplant | I, S, C, L | C |
| *Tillandsia recurvata* | ball moss | I, S, C, L | A |
| *Tillandsia setacea* (S) | needle-leaf airplant | I, S, C | C |
| *Tillandsia usneoides* | Spanish moss | I, S, C, L | C |
| *Trichostema dichotomum* | blue curls | L | C |
| *Urena lobata* | caesar weed | L, I | C |
| *Verbesina virginica* | frostweed | I, L | O |
| *Vernonia* spp. | ironweed | I, L | O |
| *Viola affinis* | Florida violet | I, L, S | C |
| *Vittaria lineata* (S) | shoestring fern | I, S, C | O |
| *Woodwardia virginica* | chain fern | L | O |

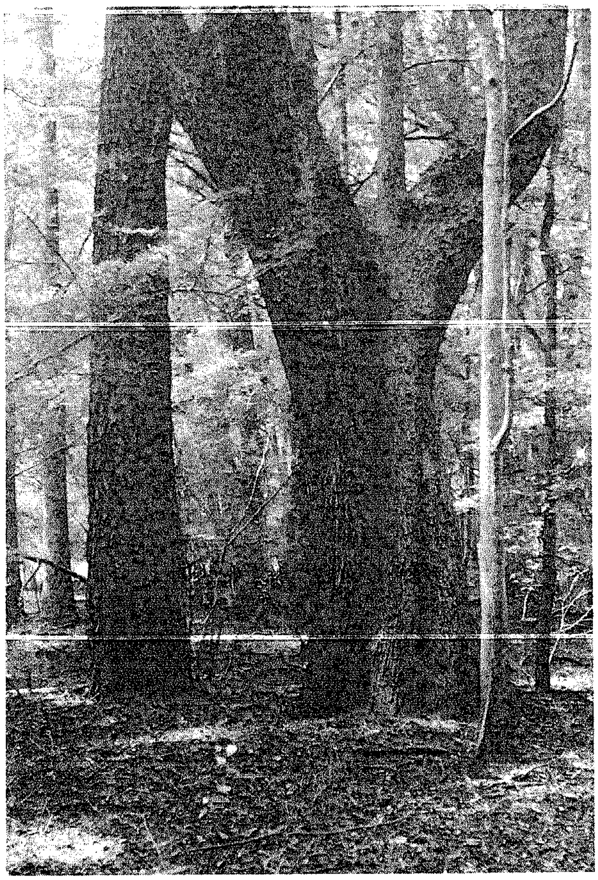
from numerous field trips and consultations with David W. Hall (University of Florida Herbarium), Daniel B. Ward (Department of Botany, University of Florida), Walter S. Judd (Department of Botany, University of Florida), Robert K. Godfrey (Department of Biological Sciences, Florida State University), Donald K. Younker (Florida Department of Natural Resources), Paul E. Moler (Florida Game and Fresh Water Fish Commission), Stephen A. Nesbitt (Florida Game and Fresh Water Fish Commission), Archie F. Carr, Jr. (Department of Zoology, University of Florida), and others; from a review of site surveys done for the Florida Natural Areas Inventory; and from a review of the literature (Nash 1895; Harper 1914; Laessle 1942; Pearson 1954; Florida Game and Fresh Water Fish Commission 1976; Simons and Hintermister 1984; Simons *et al.* 1984; Humphrey and Nesbitt [1988]; Vince *et al.* 1989).

The dominant trees of hydric hammocks are cabbage palm, live oak, swamp laurel oak (considered by most experts to be a separate species from the upland form of laurel oak, which often is called diamond-leaf oak (*Quercus hemisphaerica*)), sweetgum, red maple, southern red-cedar, and loblolly pine (N) (Figure 2). Florida elm is common in hydric hammocks and uncommon elsewhere. Hornbeam often dominates the understory. The shrub layer may be non-existent or it may be a dense tangle of greenbriar, a thicket of bluestem palmetto, or a mixture of shrubs and tree saplings. The ground cover is often a carpet of leaves with little else, but it may be a dense growth of greenbriar, yellow jessamine, ferns, sedges, or grasses. A frequent epiphyte in the "boots" under the crowns of cabbage palms is goldfoot fern, and the upper surface of the stout, horizontal limbs of live oak is often covered with a carpet of resurrection fern. Typical vines are trumpet creeper, pepper vine, poison ivy, and wild grape.

Only a few species of plants in hydric hammocks are considered endangered or threatened (Table 3). Most of these are not truly in danger of becoming extinct; instead, groups of plants such as ferns, bromeliads, and orchids are listed under Florida law to protect salable plants as a property right of the landowner.

The fauna of hydric hammock is generally similar to that of other hardwood forests of the region. The most distinctive aspect of the vertebrate fauna of hydric hammock is its high diversity and the high abundance of certain species. Relatively few endangered or threatened species of animals occur in hydric hammock (Table 4), but several are already extinct or extirpated. Virtually nothing has been published about invertebrates inhabiting hydric hammock. Several species of butterflies depend wholly or partly on sugarberry as a host plant. The burrowing crayfish *Procambarus geodytes* appears to have an endemic distribution in the hydric hammock along Silver River and in other forested wetlands of the Oklawaha River watershed (Franz 1976).

Thirty-one species of mammals are known to inhabit hydric hammock. Most common are the Virginia opossum (*Didelphis marsupialis*), short-tailed shrew (*Blarina carolinensis*), nine-banded armadillo (*Dasypus novemcinctus*), gray squirrel (*Sciurus carolinensis*), southern flying squirrel (*Glaucomys volans*), cotton mouse (*Peromyscus gossypinus*), raccoon (*Procyon lotor*), feral hog (*Sus scrofa*), and white-tailed deer (*Odocoileus virginianus*). Two endangered species, the Florida red wolf (*Canis rufus floridanus*) and Florida panther (*Felis concolor coryi*), have been extirpated from hydric hammock.



**Inland hydric hammock**

**Coastal hydric hammock**

**Figure 2. Typical hydric hammocks. The inland type, at Sanchez Prairie, Alachua County, has a canopy dominated by live and laurel oaks, loblolly pine, and sweetgum; the understory is composed mainly of hornbeam, and the shrub and ground layers are sparsely vegetated. The coastal type, on the north bank of the Econlockhatchee River, Seminole County, has multistratal forest composed almost solely of southern red-cedar, live oak, and cabbage palm.**

A threatened species, the Florida black bear (*Ursus americanus floridanus*), formerly was common but now is rare in this habitat. The Homosassa shrew (*Sorex longirostris eionis*) was described as endemic to the hydric hammock around Homosassa Springs, but both its taxonomic and distributional status are uncertain (Humphrey *et al.* 1986).

The avifauna of hydric hammock, at least 71 species, is more diverse than in most other forested communities of the northern peninsula of Florida (Humphrey and Nesbitt 1988). This habitat is linked with much of eastern North America by its support of very large populations of overwintering passerines. Several species that once were present are now extinct: ivory-

**Table 3. Endangered or threatened species of plants occurring in hydric hammock.**

| Species | Authority | |
|---|---|---|
| | FGFWFC 1989[a] | USFWS 1989 |
| Florida corkwood (*Leitneria floridana*)[b] | Threatened | Under review |
| Yellow anise (*Illicium parviflorum*) | Threatened | Under review |
| Needle palm (*Rhapidophyllum hystrix*) | Commercially exploited | |
| Bluestem palmetto (*Sabal minor*) | Threatened | |
| Grape fern (*Botrychium* spp.) | Threatened | |
| Florida shield fern (*Dryopteris ludoviciana*) | Threatened | |
| Green-fly orchid (*Epidendrum conopseum*) | Threatened | |
| Goldfoot fern (*Phlebodium aureum*) | Threatened | |
| Pine-wood dainties (*Phyllanthus liebmannianus*) | Threatened | |
| Shadow witch (*Ponthievia racemosa*) | Threatened | |
| Pink-root (*Spigelia loganioides*) | Endangered | Under review |
| Long-lip ladies'-tresses (*Spiranthes longilabris*) | Threatened | |
| Wood fern (*Thelypteris* spp.) | Threatened | |
| Needle-leaf airplant (*Tillandsia bartramii*) | Threatened | |
| Needle-leaf airplant (*Tillandsia setacea*) | Threatened | |
| Shoestring fern (*Vittaria lineata*) | Threatened | |

[a] Regulated by the Florida Department of Agriculture and Consumer Services; official list published in Preservation of Native Flora of Florida Act, Section 581.185-187, Florida Statutes.

[b] Occurs only in ponds within the hammocks.

billed woodpecker (*Campephilus principalis*), Carolina parakeet (*Conuropsis carolinensis*) and passenger pigeon (*Ectopistes migratorius*). Common birds year-round include turkey vulture (*Cathartes aura*), black vulture (*Coragyps atratus*), wild turkey (*Meleagris gallopavo*), red-shouldered hawk (*Buteo lineatus*), barred owl (*Strix varia*), red-bellied woodpecker (*Melanerpes carolinus*), pileated woodpecker (*Dryocopus pileatus*), northern flicker (*Colaptes auratus*), American crow (*Corvus brachyrhynchos*), fish crow (*Corvus ossifragus*), blue jay (*Cyanocitta cristata*), tufted titmouse (*Parus bicolor*), Carolina chickadee (*Parus carolinensis*), Carolina wren (*Thryothorus ludovicianus*), white-eyed vireo (*Vireo griseus*), blue-gray gnatcatcher (*Polioptila caerulea*), and northern cardinal (*Cardinalis cardinalis*). Common summer residents include yellow-billed cuckoo (*Coccyzus americanus*), great crested flycatcher (*Myiarchus crinitus*), Acadian flycatcher (*Empidonax virescens*), red-eyed vireo (*Vireo olivaceus*), northern

Table 4. Endangered or threatened species of animals occurring in hydric hammock.

| Species | Authority: FGFWFC 1989[a] | Authority: USFWS 1989 |
|---|---|---|
| Eastern indigo snake (*Drymarchon corais couperi*) | Threatened | Threatened |
| Gulf Hammock dwarf siren (*Pseudobranchus striatus lustricolus*) | | Under review |
| Wood stork (*Mycteria americana*) | Endangered | Endangered |
| Limpkin (*Aramus guarauna*) | Special concern | |
| Ivory-billed woodpecker (*Campephilus principalis*) | Endangered | Endangered |
| Bachman's sparrow (*Aimophila aestivalis*) | | Under review |
| Homosassa shrew (*Sorex longirostris eionis*) | Special concern | Under review |
| Southeastern brown bat (*Myotis austroriparius*) | | Under review |
| Southeastern big-eared bat (*Plecotus rafinesquii*) | | Under review |
| Florida black bear (*Ursus americanus floridanus*) | Threatened[b] | Under review |
| Florida long-tailed weasel (*Mustela frenata peninsulae*) | | Under review |
| Florida panther (*Felis concolor coryi*) | Endangered | Endangered |

[a] Official list published in Section 39-27.003-005, Florida Administrative Code.

[b] Not applicable in Baker and Columbia counties and Apalachicola National Forest, where hunting is allowed.

parula warbler (*Parula americana*), and summer tanager (*Piranga rubra*). Migratory birds overwintering in large numbers in hydric hammocks include yellow-bellied sapsucker (*Sphyrapicus varius*), eastern phoebe (*Sayornis phoebe*), American robin (*Turdus migratorius*), house wren (*Troglodytes aedon*), ruby-crowned kinglet (*Regulus calendula*), cedar waxwing (*Bombycilla cedrorum*), yellow-rumped warbler (*Dendroica coronata*), black-and-white warbler (*Mniotilta varia*), and American goldfinch (*Carduelis tristis*). Tree swallows (*Iridoprocne bicolor*) may be very abundant in winter in hydric hammocks adjacent to large areas of marsh. Red-headed woodpeckers (*Melanerpes erythrocephalus*) are sometimes attracted to hydric hammocks by a good crop of live oak acorns. Hydric hammocks dominated by loblolly pine support populations of hairy woodpecker (*Picoides villosus*) (N), eastern wood pewee (*Contopus virens*) (N), brown-headed nuthatch (*Sitta pusilla*), yellow-throated vireo (*Vireo flavifrons*), yellow-throated warbler (*Dendroica dominica*), pine warbler (*Dendroica pinus*), and summer tanager. Swallow-tailed kites (*Elanoides forficatus*) are common in some of the coastal hammocks in summer. The salt marsh edge of the hammocks on the gulf coast is particularly important for many migrating song birds and is occasional breeding habitat for the gray kingbird (*Tyrannus dominicensis*), prairie warbler (*Dendroica discolor*) and black-whiskered vireo (*Vireo altiloquus*) (S) (Oldenburg [1986]). The ecotone between hydric hammock and inland prairie is often very good habitat for the eastern bluebird (*Sialia sialis*).

The herpetofauna of hydric hammock is very large, including at least 64 species. Reptiles common in the hydric hammocks of Florida are the southern black racer (*Coluber constrictor priapus*), eastern indigo snake (*Drymarchon corais couperi*), yellow rat snake (*Elaphe obsoleta quadrivittata*), eastern coral snake (*Micrurus fulvius fulvius*), eastern diamondback rattlesnake (*Crotalus adamanteus*), Florida box turtle (*Terrapene carolina bauri*), green anole (*Anolis carolinensis carolinensis*), ground skink (*Scincella laterale*), and broad-headed skink (*Eumeces laticeps*) (N). Common amphibians include the southern toad (*Bufo terrestris*), green treefrog (*Hyla cinerea*), Cope's gray treefrog (*Hyla chrysoscelis*) (N), squirrel treefrog (*Hyla squirella*), spring peeper (*Hyla crucifer*) (N), and eastern narrowmouth toad (*Gastrophyrne carolinensis*). In the gulf coast hammocks, the gulf hammock rat snake (*Elaphe obsoleta quadrivittata x E. o. spiloides*), blue-striped garter snake (*Thamnophis sirtalis similis*), and blue striped ribbon snake (*Thamnophis sauritus nitae*) are common (these subspecies replace the yellow rat snake, eastern garter snake (*T. sirtalis sirtalis*) and southern ribbon snake (*T. sauritus sackeni*), respectively, in this area), and the rare one-toed amphiuma (*Amphiuma pholeter*) (N) occurs in some small springs and seeps. In hammocks with abundant loblolly pine, the scarlet kingsnake (*Lampropeltis triangulum elapsoides*), pinewoods snake (*Rhadinaea flavilata*) and pinewoods treefrog (*Hyla femoralis*) are very common (Florida Game and Fresh Water Fish Commission 1976).

## 2.3 TYPES, TRANSITIONS, AND ADJACENT COMMUNITIES

Four types of hydric hammock may be distinguished on the basis of relative abundance of species, hydrological regime, and physiographic setting. However, there is so much variation in composition that some stands defy classification into one of these types. The most common is the coastal or live oak/cabbage palm/southern redcedar hammock. The second type is the inland hydric hammock commonly composed of live oak, water oak, swamp laurel oak, and sweetgum. Loblolly pine dominates the third type in association with cabbage palm, live oak, water oak, and sweetgum. The fourth, seepage type, is dominated by cabbage palm, sweetbay, red maple, and swamp laurel oak, and often has an abundance of needle palm as a shrub layer.

The live oak/cabbage palm/red-cedar community is the most distinctive type of hydric hammock (Vince *et al*. 1989). It occurs on either sandy-loam or sandy-clay soils with limerock or shell near the surface. This forest is extensive along the Atlantic coast and, especially, along the gulf coast of Florida. Also common along the St. Johns and Myakka Rivers, around the low edges of some lakes, and around wet prairies and marshes, this type of hydric hammock usually is bordered on the downhill side by marsh or prairie vegetation. The uphill side may be bordered by almost any upland community, but often it grades into pine flatwoods or mesic hammock (hardwood forest on soils with moderate fertility and water-retention capacity that do not flood). All hydric hammocks are subject to flooding, but the frequency and duration vary. Those bordering streams and lakes may flood once for a month or so in most years; those bordering salt marsh may flood for only a few days at a time during severe storms or spring and fall high tides; those bordering karst prairies may flood only once every few decades, but may then remain flooded for several months. Other factors that shape this type of hydric hammock are wind, fire, and salt exposure. Forests adjacent to the ocean, large lakes, or prairies are exposed to much stronger winds than inland forests, and those beside marsh or prairie vegetation are subject to occasional severe fire. Of course, hydric hammocks close to the ocean receive salt spray and occasional flooding by saltwater.

The inland form of hydric hammock may be dominated by a nearly pure stand of live oak or, more commonly, by a mixture of live oak, swamp laurel oak, sweetgum, loblolly pine, cabbage palm, Florida elm, sugarberry, and red maple. The understory usually contains hornbeam and sometimes walter viburnum and green haw. Bluestem palmetto is sometimes an abundant shrub. When the hammock is flooded, duckweed and the floating ferns *Salvinia rotundifolia* and *Azolla caroliniana* may completely cover the surface of the water. Inland hydric hammock is most similar to some of the bottomland hardwood forests of the southeastern United States coastal plain as described by Wharton *et al*. (1982). It occurs on either sandy-loam or sandy-clay soils, usually with limerock near the surface. Generally, the inland type of hydric hammock is bordered by swamp rather than prairie or marsh.

Stands dominated by loblolly pine exist within many of the larger hydric hammocks. However, along both sides of the Oklawaha River in Marion County, Florida, hammock dominated by loblolly pine covers (or used to cover) thousands of acres. This type of hydric hammock is most similar to pine flatwoods, and, indeed, in some places it grades into typical pine flatwoods forest. In other spots it grades into the inland form of hydric hammock or, with improved drainage, into mesic hammock. Loblolly pine hammock usually occurs on sandy-clay soil (Harper 1915). The topography is flat, and the forest is usually flooded for several months in the summer or winter or both. The common associates are cabbage palm, live oak, water oak, and sweetgum, with some swamp laurel oak, swamp chestnut oak, winged elm, and cedar elm. Bluestem palmetto is often abundant in the shrub layer. and the ground cover often contains a great variety and density of grasses and herbs.

The fourth type of hydric hammock is quite different from the others. It occurs along spring runs, such as Alexander Springs Run in the Ocala National Forest and the Wekiva River north of Orlando. This hammock rarely floods, instead receiving a constant supply of water high in calcium and neutral in pH. The soil is often a deep organic muck. The dominant trees are cabbage palm, red maple, sweetbay, and swamp laurel oak. Other common trees are swampbay, swamp tupelo, Florida elm, and green ash. Loblollybay is usually present, but live oak and southern red-cedar are notably absent. The shrub layer is often a dense stand of needle palm. These forests are intermediate in species composition between hydric hammock and bayhead forest, and they contain some swamp species in addition. Their soils and hydrology are typical of bayhead except for the influence of calcium. Since these forests are usually called hydric hammock, they are included here as the seepage type.

Other forests intermediate between bayhead and hydric hammock are found along creeks in flatwoods and sandhills areas, such as along Tiger Creek in Polk County. These forests lack the lime influence typical of most hydric hammocks, grow on sandy soil, often have some organic muck accumulation, and have some lateral seepage. They typically have a mixture of cabbage palm, sweetgum, red maple, swamp laurel oak, swampbay, swamp tupelo, sweetbay, wax-myrtle, and dahoon.

The transition from hydric hammock to adjacent communities takes many forms (Vince *et al.* 1989). When the adjacent community is quite distinct (e.g., sandhill forest, pine flatwoods, marsh, or prairie) the transition is usually abrupt and obvious, but the transition to the more similar forest types of bayhead, swamp, and mesic hammock may be more difficult to recognize. Usually subject to extremes of flooding and drought, hydric hammock differs from bayhead forest, which has the most stable supply of moisture of any inland forest type and soils with low pH and high organic content. The species composition of these two forest types is also quite different in most cases (Table 5). Hydric hammocks also differ from swamps, which flood more frequently and for longer duration, and from upland hardwood and mixed pine/hardwood forests (including mesic hammocks), which flood less frequently. Each type has a distinct composition of plant species.

The following species do not occur in hydric hammocks except for an occasional individual: mockernut hickory (*Carya tomentosa*), pignut hickory (*Carya glabra*), southern red oak (*Quercus falcata*), southern magnolia (*Magnolia grandiflora*), white ash (*Fraxinus americana*), hop-hornbeam (*Ostrya virginiana*), redbay (*Persea borbonia*), winged elm (*Ulmus alata*), wild cherries and plums (*Prunus* spp.), dogwood (*Cornus florida*), hercules-club (*Zanthoxylum clavaherculis*), and crooked-wood (*Lyonia ferruginea*). Coastal xeric, mesic, and hydric hammocks all contain live oak. However, the live oak of the xeric hammocks is sand live oak (*Quercus geminata*), rather than the *Q. virginiana* of hydric hammock, and both xeric and mesic hammocks contain significant numbers of upland species such as pignut hickory, magnolia, redbay, hop-hornbeam, or crooked-wood, which are uncommon in hydric hammock.

The community most similar ecologically to hydric hammock is bottomland

**Table 5. Tree species typical of hydric hammock, bayhead, and swamp forests in northern and central Florida, listed in decreasing order of their average abundance in the community (adapted from Monk 1966; Simons *et al.* 1984; and Vince *et al.* 1989).**

| Hydric hammock | Bayhead | Swamps |
|---|---|---|
| cabbage palm | loblolly-bay | bald and pond cypress |
| live oak | sweetbay | tupelo species |
| sweetgum | swamp tupelo | green, pumpkin, and pop ash |
| swamp laurel oak | swampbay | red maple |
| southern red-cedar | | cabbage palm |
| hornbeam | | coastal plain willow |

hardwood forest (Wharton *et al.* 1982), which occupies the lowlands along rivers in the southeastern United States, typically on alluvial floodplains (Mitsch and Gosselink 1986). Florida has few alluvial rivers, and they are restricted to the panhandle. Perhaps the best example of a bottomland hardwood forest in Florida is on the floodplain of the Apalachicola River. The trees that distinguish hydric hammock from bottomland hardwood forest are live oak, cabbage palm, and southern red-cedar. Some trees that commonly are found in bottomland hardwood forest but rarely in hydric hammock are overcup oak (*Quercus lyrata*), cherrybark oak (*Q. falcata* var. *pagodaefolia*), water hickory, bitternut hickory (*Carya cordiformis*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), river birch (*Betula nigra*), cottonwood (*Populus deltoides*), swamp cottonwood (*P. heterophylla*), and black willow (*Salix nigra*).

# CHAPTER 3. HISTORY OF USE

## 3.1 PRE-COLUMBIAN HUNTING AND GATHERING

In his *Travels*, William Bartram observed that North Florida "being such a swampy, hommocky country, furnishes such a plentiful and variety of supplies for the nurishment of varieties of animals, that I can venture to assert, that no part of the globe so abounds with wild game or creatures fit for the food of man" (Bartram 1791, p. 182). Bartram perceived that the interspersion of hammocks and swamps in the pinelands of Florida were of great value in the production of animals fit for human consumption. The land animal most commonly used for food by the Indians of pre-Columbian north Florida was deer, followed by raccoon (Larson 1980). Hydric hammock is excellent habitat for both species. However, acorns and hickory nuts were considerably more important than meat to the diets of the Indians (Larson 1980). Live oak acorns, as well as laurel or water oak acorns, were among the most conspicuous plant remains from an Indian site at Hontoon Island on the St. Johns River (Newsom 1986). While living with the Seminoles in 1773, William Bartram observed "The Indians obtained from it [the acorn of the live oak] a sweet oil, which they use in the cooking of hommony [sic], rice, etc.; and they also roast it in hot embers, eating it as we do chestnuts" (Bartram 1791, p. 90). The cabbage palm, another hydric hammock tree, was used for food, thatch, and tinder by the Indians (Clausen 1971); after acorn and hickory, it was the most abundant wild plant resource recovered at Hontoon Island (Newsom 1986). Other hydric hammock species used for food included black bear, squirrel, turkey, opossum, box turtle, snakes, wild grape, persimmon, red mulberry, swamp tupelo, sugarberry, hawthorns, greenbriar, switch cane, and mushrooms (Clausen 1971; Larson 1980; Newsom 1986).

The Timucuans, the Indians of northeastern Florida at the time of European contact in the 1500's, cultivated crops, hunted, gathered, and fished (Spellman 1948). Early explorers observed fields of maize, beans, millet, squash, and pumpkins. Granaries were used to store the harvest, but Timucuans along the St. Johns River grew and stored food sufficient for only half the year (Laudonniere 16th century). During the winter these Indians moved into the woods (presumably hammocks) where they constructed palm-thatch homes and ate mast, fish, deer, and turkey (Laudonniere 16th century).

## 3.2 CATTLE AND HOG RANCHING

Cattle and hogs were introduced into Florida by Spanish explorers in the sixteenth century (Spellman 1948; Arnade 1961). Some of the hogs escaped, and wild hogs have roamed Florida ever since. Both the Spaniards and the Indians tended cattle and hogs on open range, a practice continued by the early white settlers and their descendants through the first half of the twentieth century.

Cattle were best adapted to the maidencane prairies such as Paynes Prairie in Alachua County, Florida. Bartram reported seeing in 1774 "innumerable droves of cattle" (Bartram 1791, p. 165) tended by the Seminole Indians on Paynes Prairie. Most prairies were partially ringed by hydric hammock, which provided the cattle with shade in summer, a palatable acorn crop in the fall, and green forage in winter when the prairies turned brown. In the days of open range, fires were set annually. Occasionally these burned into the hydric hammocks (Vince *et al.* 1989), opening them and clearing the forest litter enough to stimulate a good growth of grasses and sedges. Even in extensive hydric hammocks not adjacent to prairies, such as Gulf Hammock, cattle were ranched successfully, and this practice has continued to the present (Figure 3).

Hogs, even more than cattle, do best where they can make use of several different habitats. The most important habitat for cattle is open grassland, but hydric hammock is probably the best single habitat for hogs. Even as late as the 1950's, a number of families made their livelihoods by hog ranching in the gulf coastal hammocks (Varney 1963). Most had hog claims on other people's land; the hogs were marked (by notching the ears) and turned loose to forage. The owners gathered their hogs using dogs or baited pen-traps (Figure 4). Then they selected some to fatten for market or for the owners' use, castrated

**Figure 3. Cattle pen in coastal hydric hammock, Gulf Hammock.**

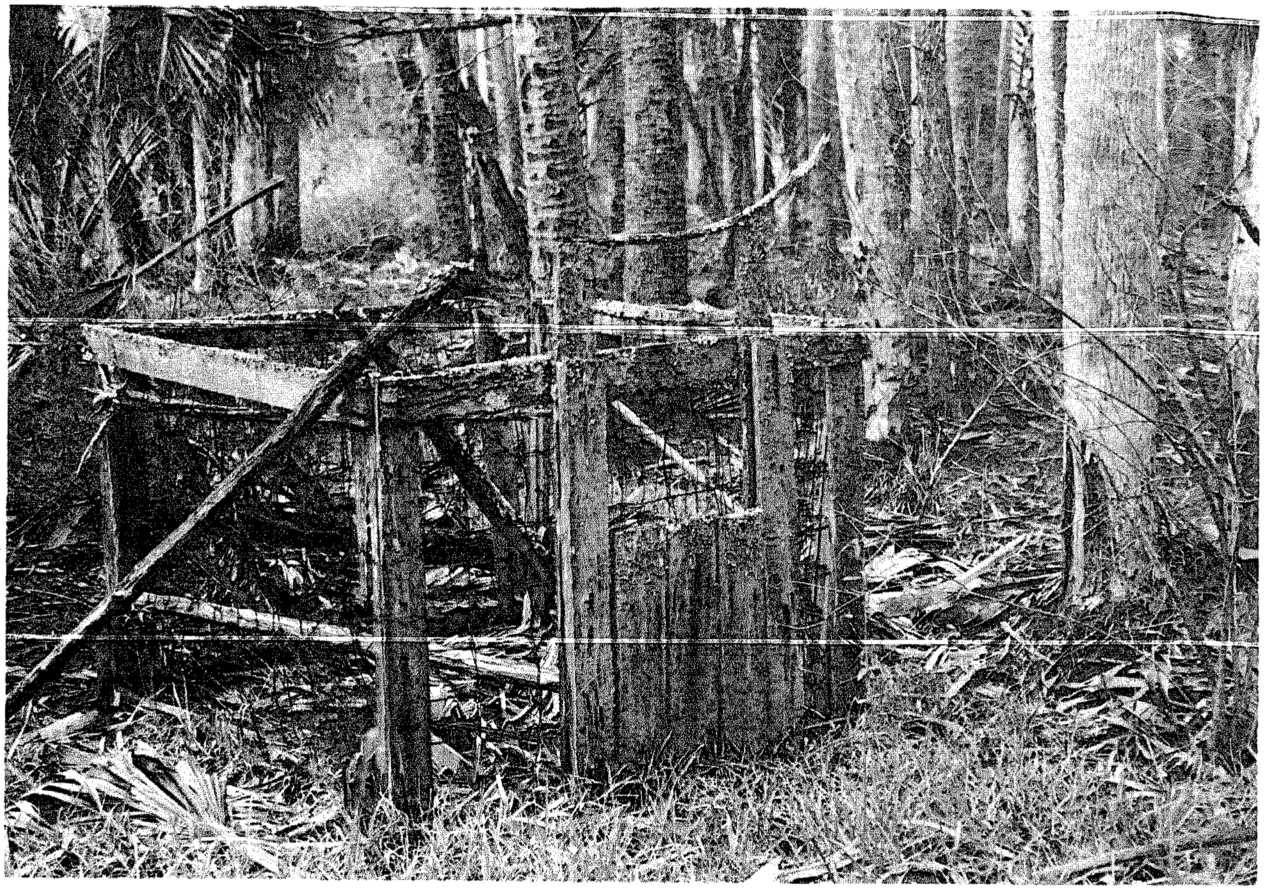


**Figure 4. Hog pen in coastal hydric hammock, Gulf Hammock.**

some of the remaining males, marked any unmarked hogs, and released the herd back to the wild (Varney 1963). The running of hogs in the wild was already declining when, in 1963, hog claims were terminated by the Florida Legislature. However, wild hogs are still abundant, particularly in areas containing hydric hammock. Many are shot for food by hunters each year, and, on many private lands, wild hogs are still trapped or caught by dogs in the traditional manner.

### 3.3 EARLY FOREST PRODUCTS

In the era of "wooden ships and iron men", the live oak was the most valued wood in the New World, with the possible exceptions of white pine in the Northeast and mahogany in the tropics. The keels, knees, and frames of the great sailing ships required great strength and durability, and, for this purpose, live oak had no equal (Figure 5). Over the centuries, the white oaks of Europe had provided the best timber for shipbuilding, but in the New World, live oak was quickly discovered to be superior. The wood of live oak has an oven-dry specific gravity of 0.98, and is exceedingly hard, strong in bending, strong in endwise compression, stiff, and high in shock resistance (Brown *et al.* 1949), making it the densest and strongest commercial wood in the United States--20% to 30% denser and

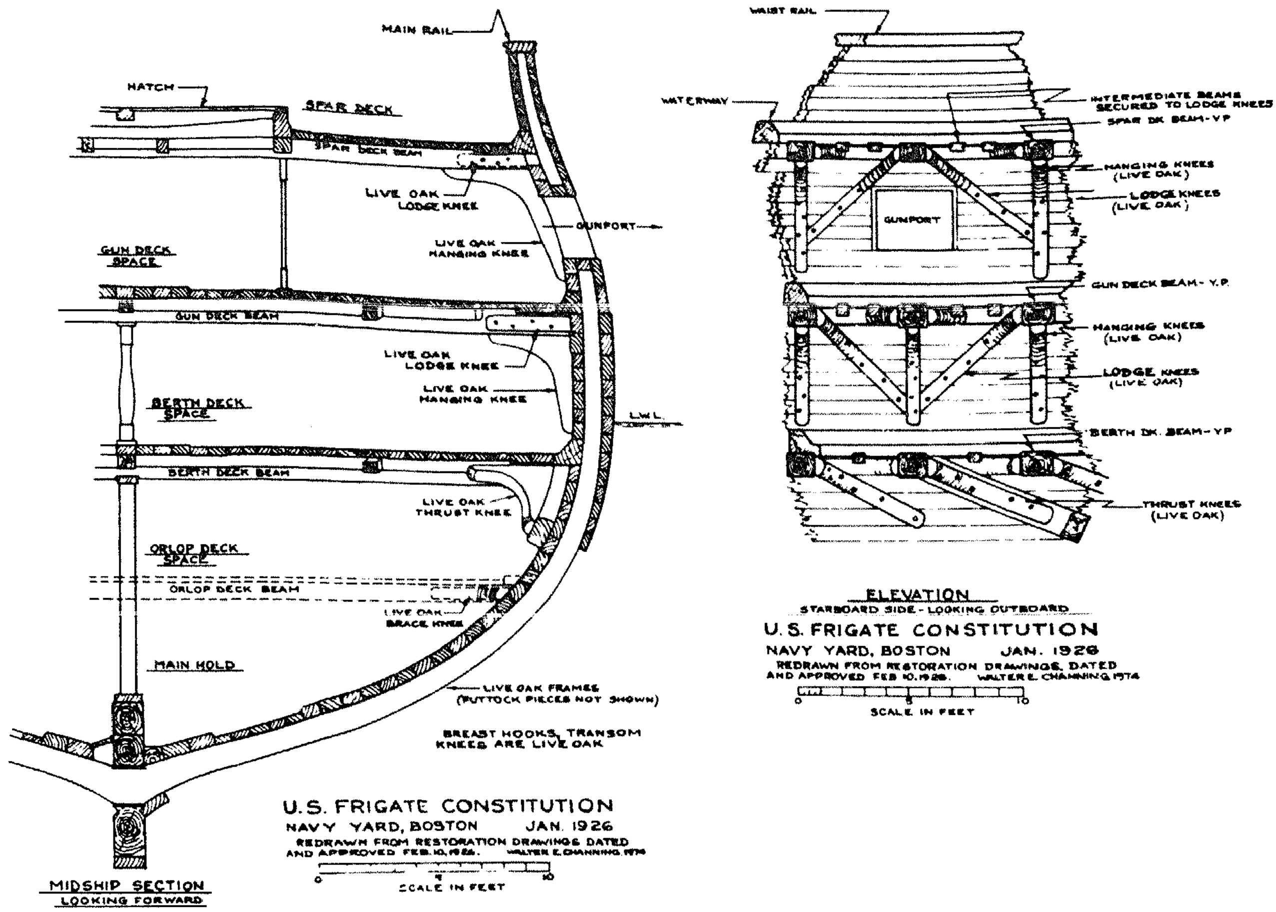



**Figure 5. Use of live oak in the construction of the *U.S.S. Constitution* (from Wood 1981). The live oak frames were spaced an inch and a quarter apart for ballistic purposes. The ship was nicknamed "Old Ironsides" during the War of 1812, when a Yankee sailor observed British shot bouncing off the *Constitution's* hull and exclaimed "Huzza! Her sides are made of iron!"**

stronger than white oak. The heartwood is also very rot-resistant. The short trunks and great, arching branches which, today, make live oak nearly worthless as timber, were perfectly suited for the ship-building industry of that period, when men would go to the forest to select each curved knee, rib, or keel from a branch or trunk of just the right shape and dimension.

Throughout the 18th century and into the 19th, the shape and strength of oak timbers limited the size of warships. Numbers of ships, therefore, were decisive in war, and supplies of oak timbers were essential natural resources (McNeill 1982). In the early 1800's, the great naval rivalry among Great Britain, France, and the United States increased demand for live oak so much that the Federal Government took steps to protect naval-timber resources (Wood 1981). Live oak forests were purchased and reserved as public lands, trespass laws were passed to prevent poaching, and agents were appointed to provide surveillance. In spite of these actions, public lands were heavily looted, and most of the live oak was sold at a high price to the U.S. Navy. Wholesale disappearance of live oak in Florida began soon after Spain ceded the land to the United States in 1821 (Figure 6). Two patrolling schooners, one on the Atlantic coast and one on the gulf coast, each with only one gun, had negligible effect on "oak running" (Wood 1981). By 1842 the public lands along the St. Johns River and its tributaries were stripped of both live oak and southern red-cedar (Kendrick 1967). A live oak nursery was established near Pensacola (Wood 1981) to restore naval-timber resources. President John Quincy Adams, an amateur horticulturist, championed this effort. However, the thousands of live oak saplings fell prey to politics; Adams' successor did not share his interests. Fortunately for Florida's forests, demand for live oak timber ended in the 1880's when Congress mandated the construction of steel ships for the navy.

Another hydric hammock tree, southern red-cedar, dominated a wood-using industry for several decades in the late 1800's. Beginning about 1875 (Jennings 1951), hundreds of men, known as cedar getters, cut the trees in Gulf Hammock and hauled them on ox wagons to the nearest creek or river (Yearty 1959). Rafts made of cabbage palm logs carried the cedar to the Faber and the Eagle Pencil mills at Cedar Key. In 1872, one million cubic

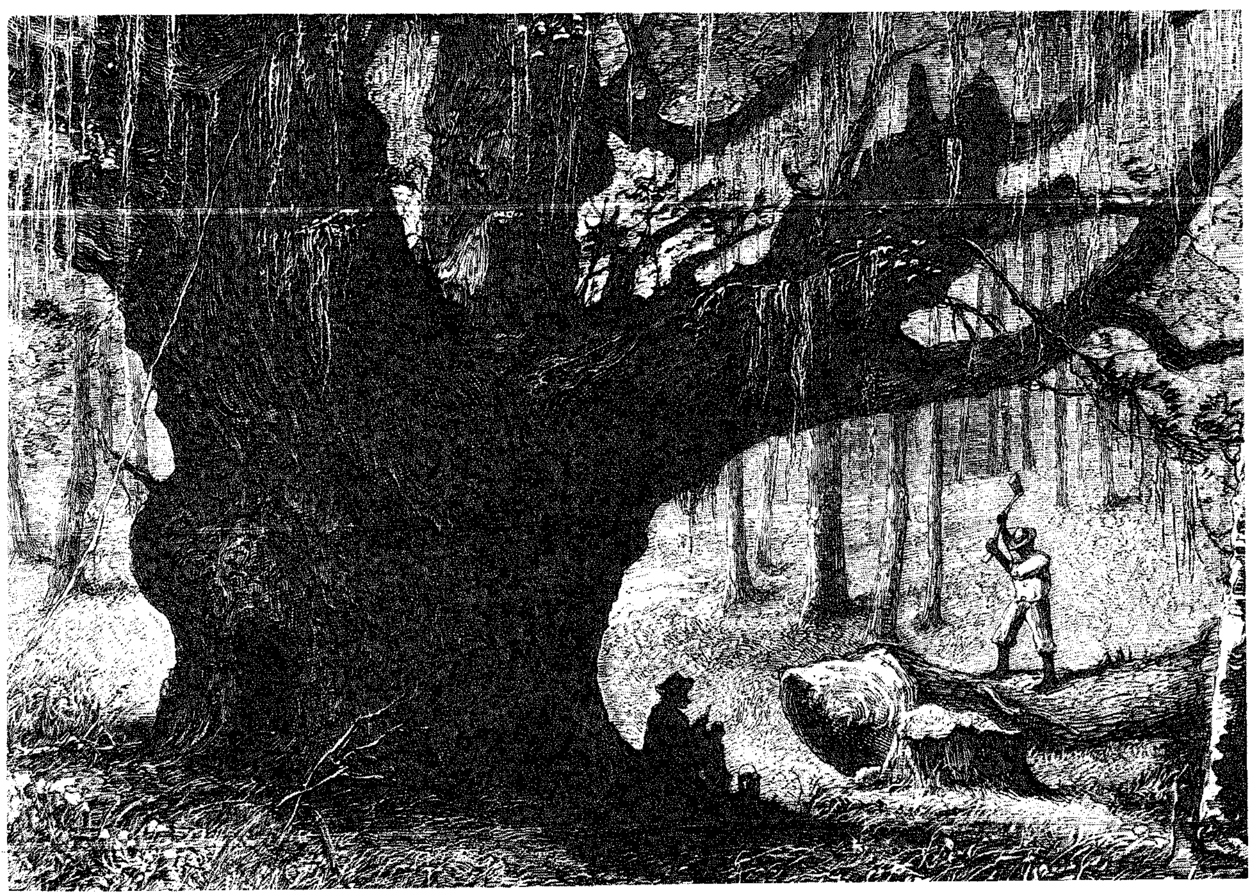


**Figure 6. Live oak cutting in Florida, 1859 (from Bryant 1872).**

feet of trimmed red-cedar slats, ready to be made into pencils, were shipped from Cedar Key (Cedar Key State Museum exhibit). In this era of "cut out and get out" timbering, there was no thought of using the cedar supply on a sustained-yield basis. When, in 1896, all the profitable red-cedar in the area was gone and a hurricane destroyed the cedar mills (Burtchaell 1949), the industry moved to the Pacific coast and turned to incense cedar (Panshin *et al*. 1962). Fortunately, unlike the lake states pine forests and some other areas that were severely damaged by this sort of exploitation, the forest of Gulf Hammock was not greatly altered by the logging. The cedars grew back and were subsequently used for fence posts, for which their rot-resistant heartwood made them well suited, and, if large timber could be found, it was used for making cedar paneling, cedar chests, and various specialty items (Brown *et al*. 1949).

Cabbage palm has also been used commercially, although to a lesser extent than live oak and red-cedar. Harvest began about 1900 and was most extensive in coastal hydric hammock (Jennings 1951). Buds were cut from young palms from about 3 to 8 feet in height. An area produced a crop about every 5 years, and most coastal hammock was cut over several times. A factory at Cedar Key made hat brushes, clothes brushes, table brushes, and brooms from cabbage palm fibers (Burtchaell 1949). Between 1910 and 1942 and from 1945 to 1950 (when it was destroyed by a hurricane), the factory required a minimum of 600 palm buds (trees) each day (Burtchaell 1949). Twenty workers harvested the buds from Gulf Hammock. The cabbage palms were used for food as well as fiber. Heart-of-palm salad has long been a specialty at the Island Hotel in Cedar Key and is now popular at many North Florida restaurants. It is also popular with many local people, and poaching of palm hearts for this purpose has been and still is common. Finally, whole cabbage palms were dug out of the forest and sold for ornamentals, and this practice continues at an increasing pace today.

Other trees of the hydric hammocks were also extensively cut for sawtimber. Loblolly pine and sweetgum were selectively logged from these forests beginning around the turn of the century. The pine was used mostly for construction lumber, while some sweetgum was used for furniture stock (Kendrick 1967). Although sweetgum is particularly well suited for turned table and chair legs, rungs, etc. (Koch 1985), most of the wood was used as veneer stock or for making packing crates to ship Florida's citrus and vegetable crops. Red maple, sweetbay, blackgum, and other soft hardwoods occasionally found in hydric hammocks were used for the same purpose, and this practice continues today.

All of this early timbering was selective. One or several species were heavily cut while the other species remained. Generally, only the best trees of the selected species were harvested, leaving the crooked, hollow, and small trees. Because the logging was not intense and species preference changed with time, with all the overstory tree species being selected at one time or another, these early logging operations did not greatly alter the forests. The average size and timber quality of the trees were significantly reduced, but the biological community remained largely intact.

# CHAPTER 4. PRESENT USES AND ALTERATIONS

## 4.1 OWNERSHIP

The hydric hammocks of Florida are currently being used more intensively and altered more rapidly and more drastically than ever before. On the other hand, more hydric hammock is now protected by public ownership from alteration and destruction (Figure 7).

The first major public purchases of lands containing significant acreages of hydric hammock were St. Marks National Wildlife Refuge in 1931 and Myakka River State Park in 1936. Later State purchases included Waccasassa Bay State Preserve in 1971, San Felasco Hammock State Preserve in 1974, River Rise State Preserve in 1974, Tosohatchee State Reserve in 1977, and Silver River State Park in 1986. State purchase of 95,000 acres along Florida's gulf coast in the Big Bend region was approved in late 1986. Big Bend's 30,000 to 40,000 acres of hydric hammock more than doubles the total amount in public ownership. At present, about 20% of Florida's hydric hammock is publicly owned.

Perhaps 100,000 acres of hydric hammock belong to individuals. About twice that much, roughly 200,000 acres, is owned by forest-products corporations. The largest of these timber-industry tracts is the part of Gulf Hammock owned by Georgia Pacific. About half of the hydric hammock owned by timber companies has been converted to pine plantations.

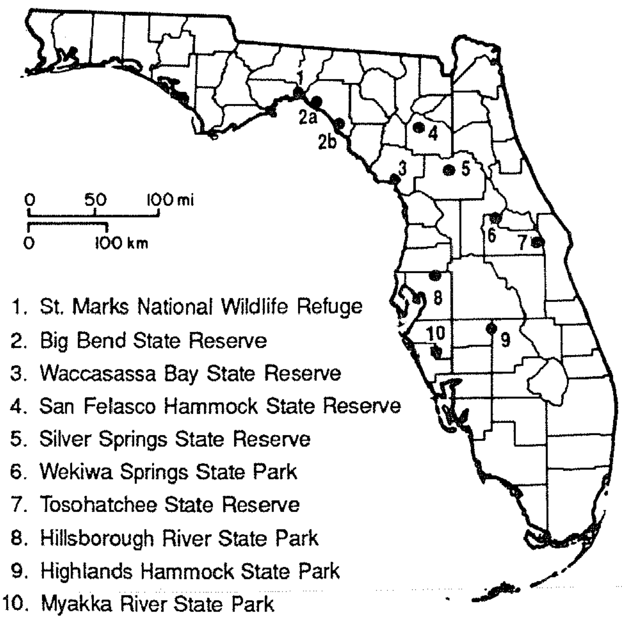



**Figure 7. Location of publicly owned hydric hammocks in Florida.**

Most of the large acreages of private land (industrial and individual) are leased for hunting and cattle grazing. These leases provide some money and, sometimes, some management aid to the landowner. Private hunting leases on hydric hammock range from $1.00 to $5.00 per acre per year. Although not able to pay as much as private hunting clubs, the Florida Game and Fresh Water Fish Commission leases some hydric hammock land (at least 50,000 acres) for public hunting within its Wildlife Management Area program, which encompasses a total of about six million acres (Frank H. Smith, Jr., Florida Game and Fresh Water Fish Commission; pers. comm.). Cattle leases range between $0.25 and $0.50 per acre per year.

## 4.2 LAND CONVERSION

The total area of hydric hammock is continually being reduced by permanent conversions to other uses. A very rough estimate of the amount of hydric hammock that has been converted by 1986 to such uses as real estate developments, improved pasture, intensive agriculture, mining, and other uses that completely and permanently remove the natural community is about 200,000 acres. About another 100,000 acres of the original half million has been cleared and converted to pine plantations. Unfortunately, exact changes in the extent of hydric hammock cannot be determined, because the boundaries of this community are difficult to delineate on maps and aerial photographs.

The oldest and probably the most extensive clearing of hydric hammocks was done to create improved pasture for beef cattle and, more recently, for horses and dairy cattle. The early clearing was mostly done with fire, along with logging, tree girdling, and bulldozing. Today, the primary methods of clearing are bulldozing and broadcast herbiciding, although fire is still used extensively to maintain established pasture. Hydric hammocks generally occur on fertile, moist soil with limerock or shell near the surface, which makes the land well suited for pasture. Occasional flooding causes only minor problems for livestock grazing and is an asset where maidencane grows in the more flood-prone areas.

Intensive agriculture has replaced hydric hammock to a lesser extent than has pasture, because occasional flooding is too detrimental and too expensive to control by drainage and diking. However, if irrigation also is provided for by the water control structures, then it sometimes becomes economical to clear and farm this type of land. Some of the irrigated and intensively cultivated land now producing cabbage and potatoes in western St. Johns County was hydric hammock.

Mining alters hydric hammock land more than any other use. Some of the land that is strip-mined for phosphate in central Florida and, to a lesser extent, in northern Florida, is hydric hammock (Simons *et al.* 1984; Simons and Hintermister 1984). Reclamation is required by state law, but most of the mined hammocks will never be returned to their original state. Attempts to recreate hardwood-dominated wetlands are few and still experimental (Robertson 1986); successful reclamation of these complex communities has yet to be demonstrated. Most hydric hammocks are underlain by limerock, and limerock mines have replaced hydric hammock in scattered locations throughout most of its range. For instance, several mines are active now in Gulf Hammock (Figure 8). Most of the limerock is used for local road beds.

Real estate developments such as home construction, apartment complexes, golf courses, commercial development, roads, and power lines are the ultimate fate of much of Florida's forested land. Although hydric hammocks flood occasionally, they also are developed extensively, as at Homosassa Springs (Figure 9). Here a major tourist attraction at the spring has altered the hammock only slightly, but housing and associated canals have been built in former hammock along the spring run. The town of Homosassa Springs also has expanded into hydric hammock, and drainage canals from the town through the hammock have been extended or rerouted. Drainage protects parts of the hammock from flooding, but other parts are certain to flood in the future. For some uses, such as golf courses, some roads, and power

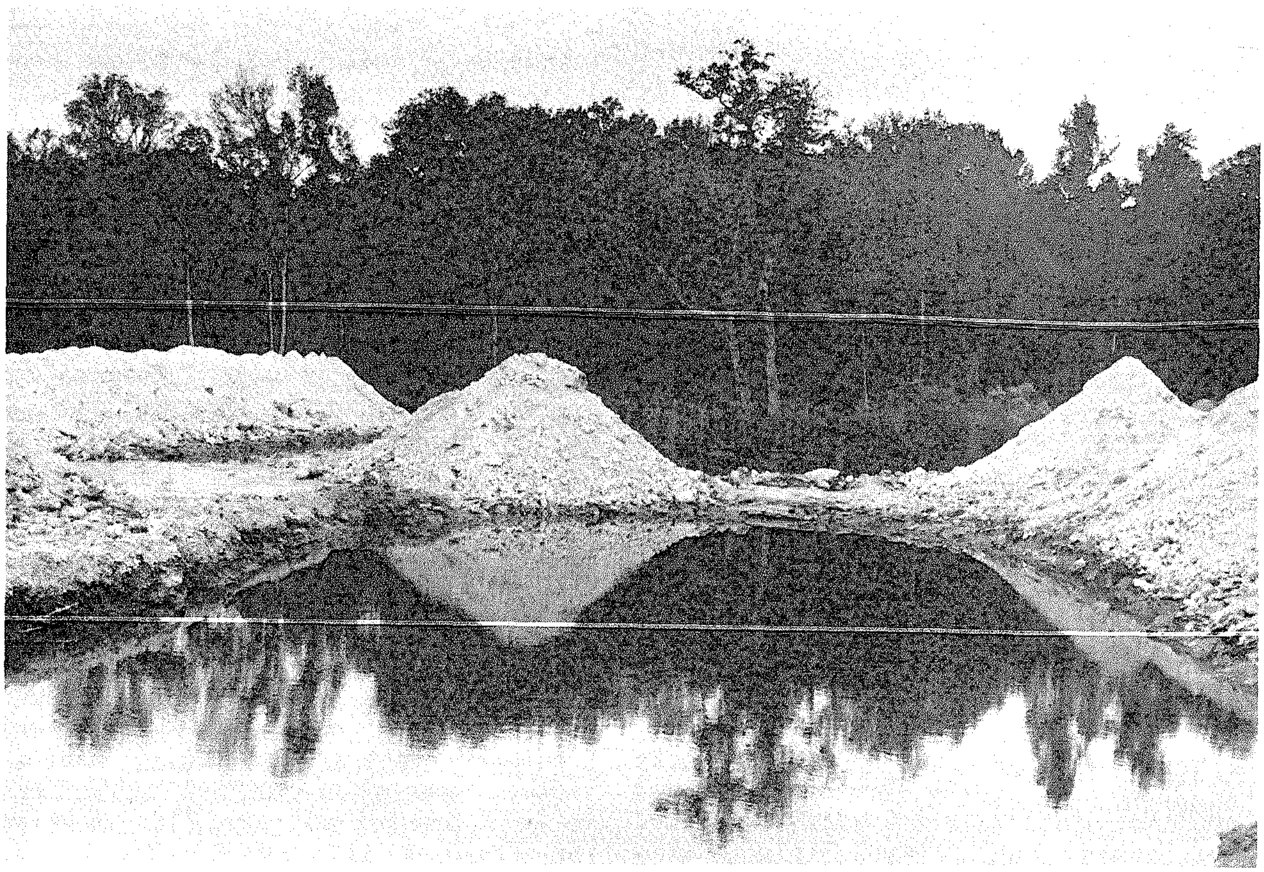


**Figure 8. Limerock pit in inland hydric hammock, Gulf Hammock.**

lines, flooding is not a great problem. However, it creates serious problems for residential and commercial developments. Unfortunately, some developers subdivide these areas and sell to unsuspecting buyers. Pressure is then put on local governments to provide flood control, with the cost paid by all taxpayers and often with impacts on adjacent areas of hydric hammock and other wetland communities.

The history and consequences of development in the Old Town Hammock, a mixture of mesic and hydric hammock between Cross City and the Suwannee River, in Dixie County, Florida, are well-documented by newspaper coverage. Subdivision of this hammock for residential homesites began in about 1981. Heavy rains in the fall and winter of 1986-87 flooded Old Town Hammock, along with many of its recently built roads and houses. About 75 families were forced out of their homes (*Gainesville Sun*, 24 April 1987), and about 125 homes and businesses were damaged (55 of these were uninsured) (*Dixie County Advocate*, 30 April 1987). Total damage to public roads was estimated at $940,585 (*Dixie County Advocate*, 30 April 1987).

Today, local, regional, and state regulations prevent the construction of most large or intensive types of development in flood-prone areas. However, rural "ranchette" development, such as at Old Town Hammock,

1944

1974

Figure 9. Real estate development from 1944 to 1974 in hydric hammock, Homosassa Springs, Citrus County, Florida. The major habitats shown are slash pine flatwoods on the right, hydric hammock on the left, and salt marsh in the upper left corner.

still proceeds in these areas and currently invades hydric hammocks at a rapid pace. A house may be built provided the floor is elevated to above anticipated flood levels, and the rest of the property may be cleared for lawns, work space, pasture, and so on.

The amount of hydric hammock protected from destruction caused by real estate development is only slightly greater than the amount in public ownership. The Florida Legislature passed the Warren S. Henderson Wetlands Protection Act of 1984, but its jurisdiction is determined by a vegetation list that categorizes most hydric hammock species as either transitional or upland. According to this list, only the bayhead-like seepage hammocks and a few inland type hydric hammocks qualify for protection from development. Furthermore, this law exempts clearing for agricultural purposes as a proper use of wetlands.

## 4.3 TIMBER PRODUCTION

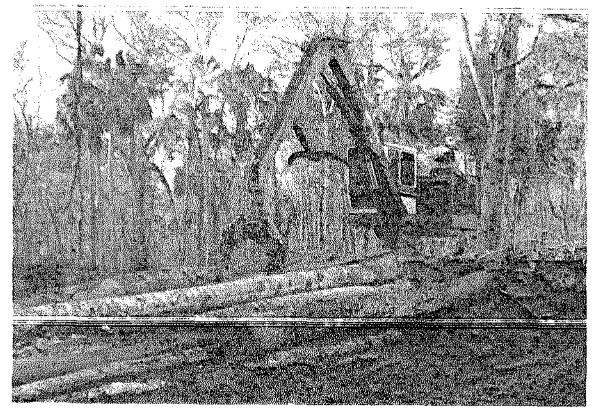
With the exception of State parks and preserves, practically all hydric hammocks not within city limits are used to some extent for timber production. The amount and value of timber production varies widely among hammocks, however, depending on the species composition, site quality, past history of the forest, ease of harvest, and management decisions of the owner. A forest of live oak and cabbage palm has little timber value, although a small market exists for live oak timber with straight, sound trunks, and cabbage palms can sometimes be sold for ornamental planting. At the other extreme, the timber in a forest with a large volume of high-quality loblolly pine, sweetgum, or red-cedar sawtimber might be worth as much as $3,700 per acre (Johnson 1978). The value of the annual growth in such a forest might exceed $50 per acre if the site quality is high (site quality is a measure of how rapidly a tree species grows on a particular plot of land). An area of lower site quality might achieve the same eventual timber value, but at a slower rate, so that the annual increase in value might be $25 or less per acre. Past events such as logging, fire, storms, grazing, and drainage affect the timber age, volume, quality, species composition, and site quality. Decisions that determine timber production are how much of the forest is used to produce timber, how intensively the timber is managed and harvested, and how frequently the timber is harvested. These decisions usually are based on a combination of multiple-use and financial considerations.

### 4.3.1 Techniques

Today, most logging in hydric hammocks is done with rubber tire skidders, which haul logs to a staging area (log deck) where they are loaded onto trucks (Figure 10). Though the equipment used and the construction of logging roads vary among sites, the factor most affecting the forest is the silvicultural method of logging.

Highgrading is the cutting of the most valuable trees, leaving the small, crooked, rotten, and hollow trees and the species of low or no value such as live oak, hornbeam, and cabbage palm. This method yields a high financial return but poor prospects for future timber growth. Highgrading was the dominant method of harvest until a decade or two ago, and it still occurs to some extent, particularly on small tracts. A rarely practiced way to maximize future timber values is selective harvesting of low-value species and individuals along with high-value mature trees, leaving the best small-to-medium-sized trees to grow and produce the next crop. The method usually recommended

Rubber-tire skidder



Loader at a log deck

Figure 10. A modern logging operation in hydric hammock, Gulf Hammock.

by foresters and used today is clearcutting, because many of the wetland hardwood forests have been so severely degraded by highgrading that only replacement of the existing stand by natural regeneration or high-value plantation will improve timber quality and production (Hudson 1983; Kellison 1983; Windsor 1983). This method still leaves some unusable trees that must be felled or killed to produce a true clearcut, and sometimes it yields less money to the landowner than highgrading, because cutting and transporting the additional trees can cost more than they are worth. Complete harvest cuts have become increasingly common in hydric hammocks, particularly those owned by forest industry (Figure 11). Since 1970, about 80% of the hydric hammock in Gulf Hammock has been clearcut (Figure 12), mostly for conversion to loblolly pine plantation.

Following the selective types of harvest, regeneration is obtained from natural reseeding, sprouting, and growth of seedlings and saplings already established in the understory. Clearcuts in wetland hardwood forests will also regenerate naturally, but the landowner has little control over the rate of growth, composition, and spatial distribution of the resulting stands (Gresham 1985). The alternative, artificial regeneration, costs more--perhaps $100 to $200 per acre to prepare the site and $50 per acre to obtain and plant seedlings. The advantage is that by selecting rapidly growing and valuable tree species, the landowner may realize an earlier and greater return on investment. Loblolly pine is the species most commonly replanted on hydric hammock clearcuts (Hudson 1983; Gresham 1985), because its timber is highly valued, the market is more stable for pine than for hardwood, it grows rapidly on appropriate sites, and it is superior to other southern pine species in its ability to compete and grow on hydric hammock sites.

Establishment of loblolly pine stands on hydric hammock sites may involve intensive site preparation (Hudson 1983). Objectives are to reduce logging slash and residual vegetation, to facilitate planting, and to enhance the survival and growth of the planted pines by reducing competition and, sometimes, by providing elevated planting beds. After the marketable

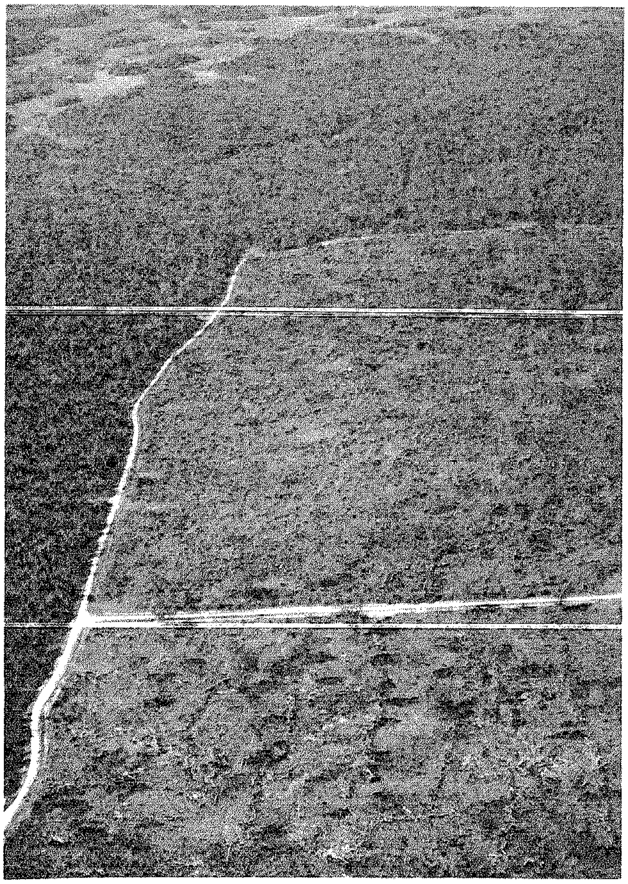


**Figure 11. An extensive clearcut of hydric hammock on timber-company land, Gulf Hammock. Standing dead live oaks from the original canopy cast large shadows. The clear-cut land was converted to pine plantation. The uncut hammock beyond the section lines subsequently was sold to the State of Florida as part of Waccasassa Bay State Preserve. Salt marsh is visible in the distance, beyond the coastal hydric hammock.**

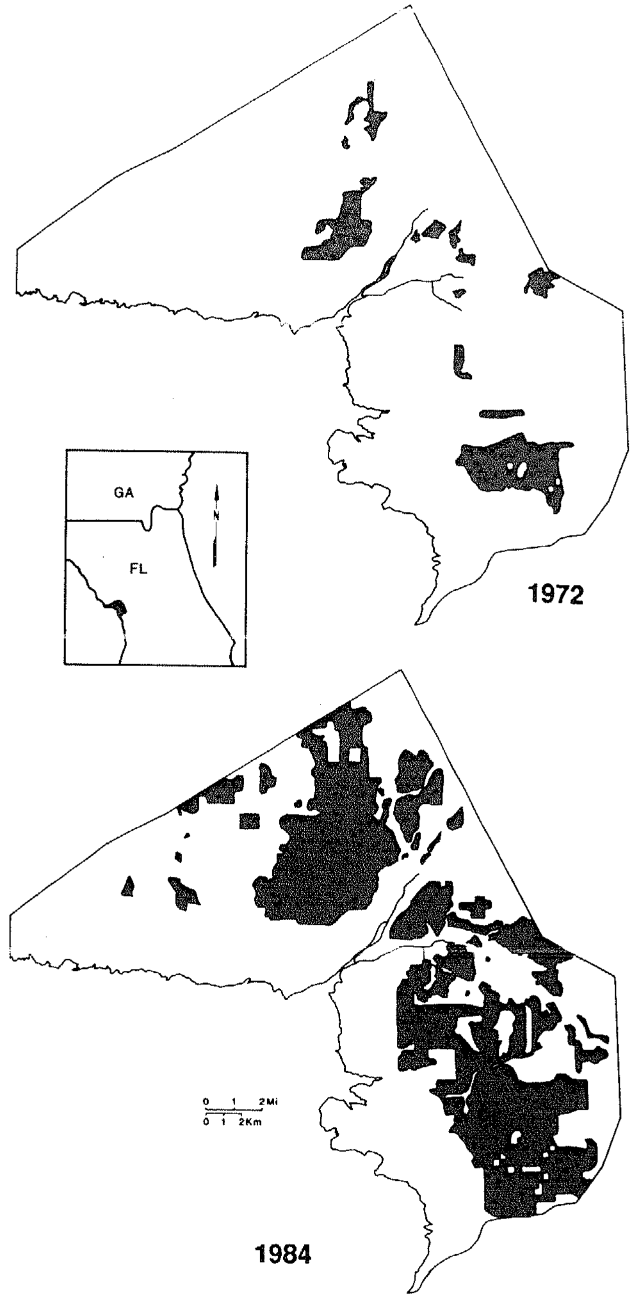



**Figure 12. Extent of clearcuts in Gulf Hammock in 1972 and 1984.**

hardwoods are cut, most of the residual trees are felled by crushing or shearing with a bulldozer KG blade to a height of less than 30 cm (Figure 13). Cabbage palms may be uprooted and sold as ornamentals, while live oaks are girdled manually or injected with herbicide. Heavy drum choppers are pulled over the site to break up the severed vegetation. Following a drying period, the plant debris may be burned. If surface material still hinders tree planting, then tractors push the debris into piles or windrows. Less intensive site preparation, practiced on some Gulf Hammock sites, requires fewer passes by heavy

Figure 13. Ground view of a clearcut in hydric hammock, Gulf Hammock.

equipment. Residual trees are controlled by herbicide injection rather than shearing (E. Jokela, School of Forest Resources and Conservation, University of Florida; pers. comm.). Loblolly pine seedlings are planted, often on raised beds, at a density of about 1,110 per hectare (Hudson 1983). A standard site preparation technique is to use a bedding plow to produce a series of ridges elevated a foot or two above the original surface (Figure 14). These beds are better aerated and farther above the water table than the surrounding land (McKee and Shoulders 1970). On poorly drained sites, pine seedlings planted on top of these ridges usually experience increased growth for at least several years compared to those on non-bedded areas (Terry and Hughes 1975; McKee and Wilhite 1986).

### 4.3.2 Impacts

Impacts on species composition of the forest by the various logging and site preparation options are quite variable and not always predictable. In general, the more complete the harvest and the more severe the site preparation, the more drastic and longlasting are changes in the vegetation. Rapidly-growing pioneer species like loblolly pine and sweetgum, which require large openings in the canopy and mineral soil for good seed germination, benefit the most from intensive disturbance (Putnam *et al.* 1960;

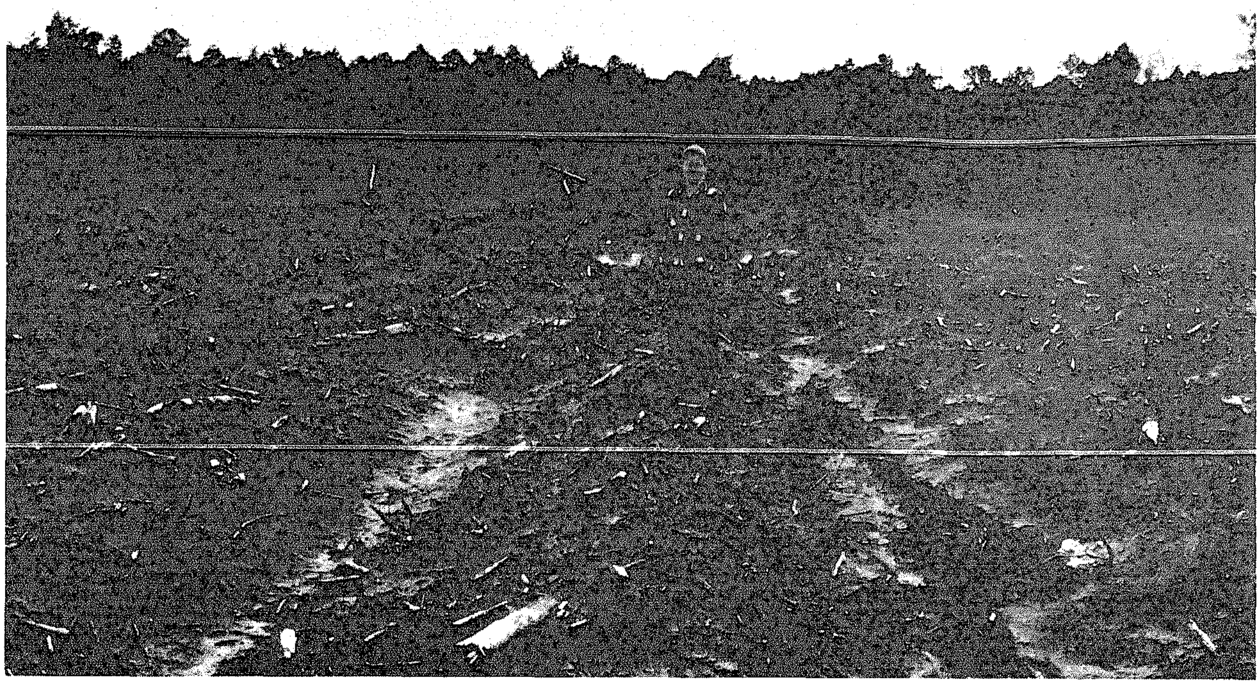


**Figure 14. Bedding rows for pine seedlings in hydric hammock.**

Fowells 1965). Sweetgum sprouts vigorously from the stump and roots, giving it an early competitive advantage on clearcut sites and often resulting in stands dominated by trees of root-sprout origin (Fowells 1965). Even chopped residuals left on the surface of a clearcut in wetland hardwood forest hinder loblolly pine recruitment (Windsor 1983). Other trees, such as cabbage palm, southern red-cedar, hornbeam, oaks, elms, and maples will decline in abundance with increasing intensity of harvest and site preparation. On the ground, weedy herbaceous plants like dog-fennel will be favored over shade-tolerant plants like spikegrasses, violets, and ferns. Cattle grazing greatly accentuates the changes in herbaceous vegetation on logged and prepared sites. In the absence of fire, cattle, and herbicides, a dense thicket of tree, shrub, and vine sprouts and seedlings will grow up on a heavily logged site (Figure 15). The open, park-like character of the mature hydric hammock begins to reappear only after several decades.

The extreme disturbances of clearcutting and site preparation result in large effects on wildlife, grazing, aesthetics, and recreation (Figure 16). Clearcutting and site preparation eliminate most mast production and most or all den trees and nest sites for cavity nesters. Some species, like gray squirrel, southern flying squirrel, barred owl, all of the woodpeckers, blue-gray gnatcatcher, red-eyed vireo, northern parula warbler, Acadian flycatcher,

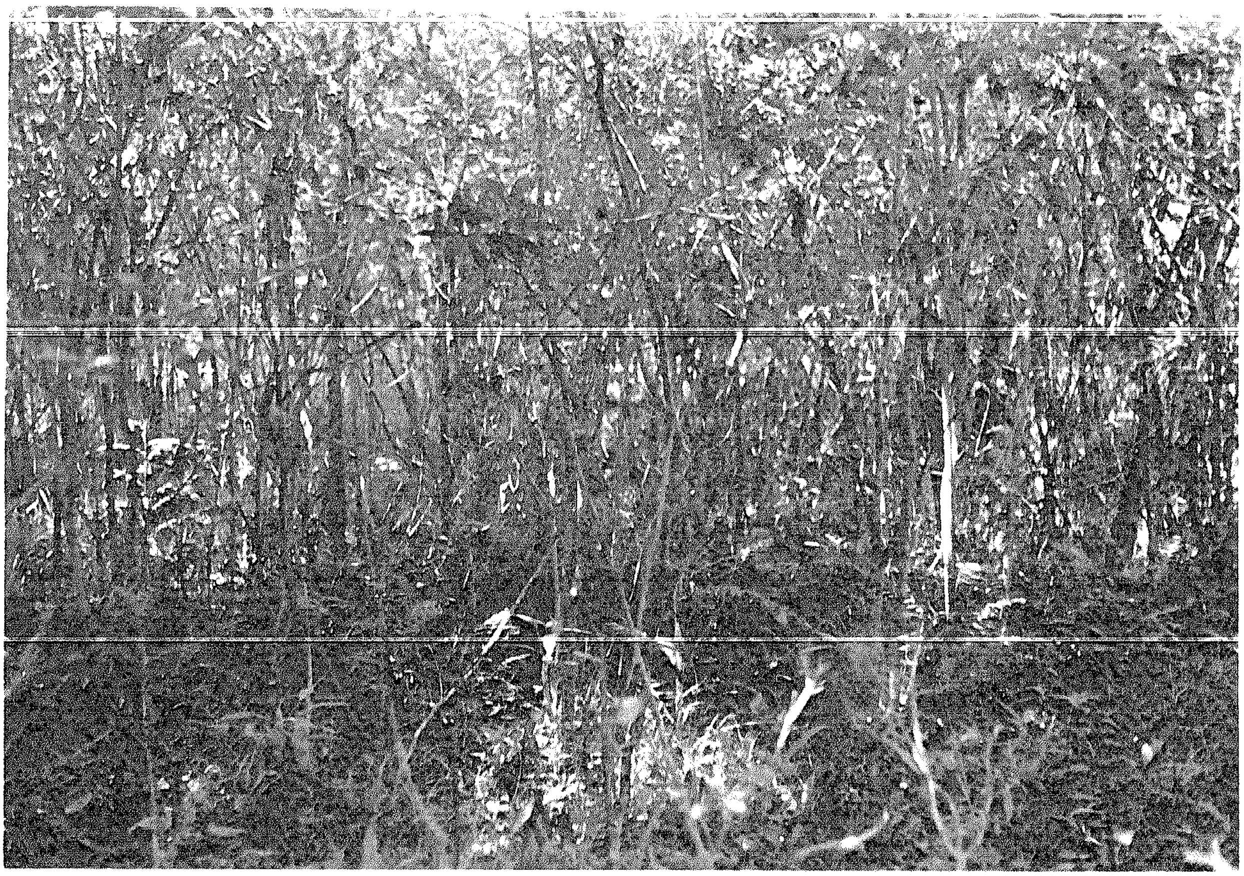


**Figure 15. Dense thicket of trees, shrubs, and vines on a hydrick-hammock site about 10 years after clearcutting.**

yellow-billed cuckoo, broad-headed skink, and the tree frogs are eliminated from clearcut areas. Other species, like cottontail rabbit (*Sylvilagus floridanus*), cotton rat (*Sigmodon hispidus*), great-horned owl (*Bubo virginianus*), red-tailed hawk (*Buteo jamaicensis*), northern bobwhite (*Colinus virginianus*), eastern meadowlark (*Sturnella magna*), sparrows, eastern diamondback rattlesnake, and southern black racer greatly benefit during the first years after a clearcut. Summer range for cattle is greatly improved, although at the expense of winter range value. Open, grassy areas like those produced by intensive site preparation coupled with cattle grazing are essential feeding habitat for young turkeys (Swindell 1949). Under natural conditions, this grassy habitat was supplied by adjacent sandhill, flatwoods, or prairie communities kept open by frequent fire and by the spikegrass, panic grass, sedge, fern ground-cover of some mature, ungrazed hammocks. Logging of any intensity, and especially clearcutting, temporarily stimulates browse production for deer, cattle, turkey, and rabbits. When mixed hardwood sites are clearcut and converted to loblolly pine stands, new forage plants replace the mast lost to white-tailed deer (Felix *et al*. 1986). However, deer browse decreases rapidly following closure of the pine canopy at about 10 years, and suitable foods

**Figure 16. Two-year-old loblolly pine plantation in Gulf Hammock. Dead live oaks from the former stand of hydric hammock were girdled rather than cut, because of their size and current lack of economic value.**

for turkey decline much earlier in the life of the pine stand (Felix *et al.* 1986). During the latter half of the first decade, thicket-loving species like golden mouse (*Ochrotomys nuttalli*), brown thrasher (*Toxostoma rufum*), hooded warbler (*Wilsonia citrina*), white-eyed vireo, and rufous-sided towhee (*Pipilo erythrophthalmus*) may do quite well. Following the first decade, however, there is a long period of several decades in which the pioneer species are gone and the mature hammock species have not yet returned in abundance. During this period, the range value is very low, and even the very adaptable species like deer, raccoon, and wild turkey make less use of the forest. Furthermore, this intermediate-aged, second-growth forest is more monotonous and less open visually than either a very young (first decade) or a mature forest. Unless a cleared path is provided, hydric hammocks become impenetrable to most recreationists two or three years following a clearcut and do not open up enough for much use for several decades.

Impacts on soils, hydrology, and water and site quality can be caused by the heavy equipment used in logging and site preparation. Skidders can leave ruts 0.6 m wide and 1 m deep if the ground is soft. If the same route is repeatedly followed, a 3 m wide canal may be created that becomes a permanent feature of the property. Soils may be compacted and ponded by repeated passes of heavy equipment on log decks and skid trails (Table 6). These logging disturbances may occupy a large proportion of the harvested area--34% on average in logged loblolly pine forests (Hatchell *et al.* 1970). The disturbed soils are slow to recover and productivity is reduced, particularly where compaction is combined with high soil moisture. If deep tracks go up and down slope, following the water flow direction, considerable erosion may occur, in which increased sediment loads are carried to streams, swamps, ponds, or lakes. Ruts can channelize the flow where previous drainage was sheet flow over the surface, accelerating runoff and reducing the water retention and filtering capacity of the wetland.

The influences of forestry practices on the water quality of blackwater rivers and estuaries are of particular concern in the southeastern United States (Netter and Gregory 1985). Because blackwater rivers usually contain low levels of nutrients (Wharton *et al.* 1982), even small increases in nutrient loading may significantly alter these systems. Elevated flows of freshwater to estuaries, especially in late spring and early summer, may reduce salinity to levels below those tolerated by invertebrate and fish species that use the estuaries as breeding and nursery areas. Fortunately, due to the flat terrain of hydric hammocks and the generally low erodibility of forested wetland soils in Florida (Riekerk 1983), erosion and sediment loss are probably not major consequences of timber harvesting in these wetlands. Increased sediment, nutrient, and water exports are probably temporary, lasting one year or less after the work is completed. In the southeastern coastal plain, nutrient and sediment losses associated with erosion, leaching, and runoff from cleared wetland forests are small and short-term (Table 7). Of the steps involved in converting a hardwood wetland forest into a loblolly pine plantation, drainage has by far the most deleterious effect on water quality (Askew and Williams 1984; 1986). In slash pine dominated wetlands, most nutrient concentrations in runoff return to control levels during the second year after harvest and site

**Table 6. Effects of logging on physical properties of coastal plain soils supporting loblolly pine stands (from Hatchell *et al.* 1970). Infiltration rate is a measure of soil drainage. Air space is negatively correlated with soil-water content.**

| Location of soil sample | Bulk density ($g/m^3$) | Infiltration rate of water (cm/hr) | Air space (% by volume) |
|---|---|---|---|
| Log deck | 1.14 | 6.6 | 26.2 |
| Skid trail | 1.08 | 6.9 | 23.1 |
| Undisturbed forest | 0.75 | 64.8 | 38.5 |

Table 7. **Nutrient and sediment export in runoff from forested and clearcut wetlands in the southeastern coastal plain.**

| Forest description (dominant trees) | Year of sampling | Treatment | Concentration, mg/l | | | | | | | Flux, kg/ha/year | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $NO_3$ | $NH_4$ | P | K | Ca | Mg | Ss* | $NO_3$ | $NH_4$ | P | K | Ca | Mg | Ss* |
| | | | | | - | | | | | - | - | - | - | - | - | - |
| **Mixed hardwood swamp**[a] (bald cypress, tupelo, sweetgum, red maple) | | Control | 0.47 | 0.047 | - | 0.80 | 5.5 | 2.7 | 2.5 | - | - | - | - | - | - | - |
| | | Drain | 0.94 | 0.074 | - | 0.87 | 10.8 | 3.5 | 50.0 | - | - | - | - | - | - | - |
| | | Drain, log, prepare | 0.20 | 0.026 | | 1.6 | 6.0 | 2.2 | 8.0 | | | | | | | |
| | | Drain, log, prepare, plant | 0.05 | 0.022 | | 2.0 | 5.3 | 2.3 | 14.0 | | | | | | | |
| | | | | | | - | - | - | | | | | - | - | - | |
| | | | | | | - | - | - | | | | | - | - | - | |
| **Wet savanna forest**[b] (slash pine) | 1 | Control | 0.01 | 0.02 | 0.03 | | | | 6.0 | 0.09 | 0.22 | 0.22 | | | | 44.0 |
| | 1 | Log, chop, burn, bed, plant | 0.05 | 0.43 | 0.28 | - | - | - | 137.0 | 0.20 | 1.75 | 0.81 | - | - | - | 550.0 |
| | 2 | Log, chop, burn, bed, plant | 0.02 | 0.07 | 0.03 | | | | 28.0 | 0.13 | 0.44 | 0.21 | | | | 178.0 |
| **Poorly drained flatwoods**[c] (slash pine) | 1 | Control | 0.04 | 0.22 | 0.02 | 0.18 | 0.26 | 0.98 | 2.7 | 0.04 | 0.23 | 0.02 | 0.19 | 0.28 | 1.06 | 2.8 |
| | 1 | Minimum site preparation | 0.03 | 0.05 | 0.02 | 0.55 | 0.37 | 1.13 | 5.0 | 0.05 | 0.07 | 0.03 | 0.78 | 0.53 | 1.60 | 7.1 |
| | 1 | Maximum site preparation | 0.07 | 0.12 | 0.02 | 0.90 | 0.94 | 1.05 | 14.4 | 0.17 | 0.30 | 0.04 | 2.25 | 2.53 | 2.64 | 36.0 |
| | 2 | Control | 0.02 | 0.07 | 0.02 | 0.05 | 0.37 | 0.53 | 2.7 | 0.03 | 0.08 | 0.03 | 0.06 | 0.44 | 0.62 | 3.1 |
| | 2 | Minimum site preparation | 0.04 | 0.06 | 0.05 | 0.25 | 0.38 | 0.77 | 3.7 | 0.04 | 0.06 | 0.05 | 0.26 | 0.40 | 0.82 | 3.9 |
| | 2 | Maximum site preparation | 0.03 | 0.08 | 0.02 | 0.45 | 0.89 | 0.66 | 11.4 | 0.02 | 0.04 | 0.01 | 0.25 | 0.49 | 0.37 | 6.4 |

*Suspended sediment.

[a]Askew and Williams (1984; 1986). Water quality of all treatment sites was measured over the same period, but the sites were of different ages. Sites were logged and prepared two years after drainage. Loblolly pine was planted one year later.

[b]Hollis *et al.* (1978).

[c]Riekerk (1982). Minimum site preparation consisted of manually harvesting, chopping, bedding, and planting. Maximum site preparation was mechanized logging, stumping, burning, windrowing, discing, bedding, and planting.

preparation. The magnitude of nutrient and sediment loss is positively correlated with the intensity of site preparation (Riekerk 1982).

Only suspended sediment and potassium levels in runoff were consistently elevated by harvesting and site preparation in coastal plain wetlands (Table 7). Concentrations of phosphate in water draining undisturbed and logged hardwood wetland forests were too low to be measured (Askew and Williams 1986). Neither phosphate nor total-phosphorus levels were increased by harvesting or site preparation in flatwoods. Concentrations of nitrogen compounds, also of concern to downstream water quality, were significantly raised only by drainage of forested wetlands (Table 7). Like hydric hammocks, these forested wetlands occur on flat coastal soils and support rapid growth of planted pines. Maximum nutrient losses occur when the soil is bared, especially when mechanically disturbed, and before establishment of new vegetation. Ditch installation prior to harvesting, a common practice in swamps and pocosins (Ash *et al.* 1983), also releases nutrients, but drainage is generally not practiced in hydric hammocks. Harvesting systems that are less severe than clearcutting are likely to have little impact on nutrient loss from hydric hammocks.

A far greater drain on the essential nutrients of hydric hammocks is their direct removal in the products that are harvested and in the debris and top soil that is pushed into windrows. If removals are averaged over the rotation length, a loblolly pine plantation might produce 7.2 t/ha of stemwood annually and result in an annual removal of 6.5 kg/ha of nitrogen, 0.9 kg/ha of phosphorus, 5.0 kg/ha of potassium, and 6.4 kg/ha of calcium (Jorgensen and Wells 1986). When whole trees are harvested, such as biomass harvests for fuel, the biomass removal is increased by about 60%, and the nutrient removals are more than doubled (Jorgensen and Wells 1986). Displacement of nutrients into windrows can be more than double the amounts lost to stem harvest (Morris *et al.* 1983). The nutrient levels in hardwood timber are higher than in pine, so losses from clearcutting hardwood-dominated hydric hammocks are likely to be somewhat higher. Although hydric hammock soils are usually rather fertile, successive harvests of timber could lead to a decline in productivity.

A transient impact of clearcutting is the elevation of the water table due to reduced transpiration. The extent and duration of the rise depend on the size of the clearcut and the rate of revegetation, respectively. Increased water table height may alter the species composition of the regenerating forest (Riekerk 1983) and may also result in greater number and size of stormwater peaks (Williams 1979). While the increased runoff is likely to be transient, the potential impact on downstream water bodies is great since many hydric hammocks adjoin marsh or estuarine systems.

## 4.4 LIVESTOCK GRAZING

Cattle grazing of hydric hammocks is still a common practice, although not as extensive or as important as in the past. Beef cattle outnumber dairy cattle but are on the decline, whereas dairy cattle are generally on the increase in Florida. However, because of differences in grazing strategies, beef cattle are far more commonly grazed in hydric hammocks than dairy cattle (George W. Tanner, Department of Wildlife and Range Sciences, University of Florida; pers. comm.). Hydric hammocks usually supplement larger areas of other kinds of pasture such as pine flatwoods, prairie, or improved pasture, and, though sometimes grazed year-round, they are especially valuable for winter grazing (Camp 1932). The grasses, sedges, vines, and other browse in hydric hammocks stay green in winter, and some of the grasses and sedges remain actively growing. In the loblolly pine hammocks of Marion County, in the inland parts of Gulf Hammock, and in many other hammocks, grasses in the genus *Chasmanthium* (*C. laxum*, *C. nitidum*, and *C. sessiliflorum*) are particularly important for grazing because of their ability to grow in dense shade and stay green in winter (Wolters 1974). When used for only three or four months in winter, the carrying capacity for a hydric hammock with an abundance of forage is probably about one cow for every 10 to 30 acres (George W. Tanner, pers. comm.).

Hydric hammocks can be damaged easily by over-grazing (Lewis 1981), in part because their soils are easily compacted, and, in part, because soil aeration, which is reduced by compaction, can be a limiting factor for plant growth. Water infiltration into the soil is also reduced by compaction, affecting surface runoff, erosion, soil moisture patterns, onsite water use, nutrient cycles, onsite productivity, and downstream water quality and sedimentation (Gifford and Haskins 1978). Because cattle consume large quantities of vegetation and deposit the resulting excrement on the soil surface, the increased runoff carries an enriched load of nutrients out of the forest. These nutrients usually enter an aquatic environment, lowering the fertility of the hammock and polluting the receiving waters. The reduction of ground-cover vegetation density that accompanies overgrazing enhances runoff and erosion (Lutz and Chandler 1946). Even moderate cattle grazing over long periods can affect the species composition of plants in hydric hammocks and greatly reduce browse available for white-tailed deer (Harlow 1959). Grazing often increases the abundance of dog-fennel, cabbage palm, bluestem palmetto, live oak, and persimmon; most other species are reduced and some may be eliminated.

Swine also make considerable use of hydric hammocks, mostly as feral animals. Population densities in hydric hammock may average as high as one adult animal per fifteen acres (Lovett Williams, Florida Game and Fresh Water Fish Commission, retired; pers. comm.; William B. Frankenberger, Florida Game and Fresh Water Fish Commission; pers. comm.). Feral hogs use the acorn crop to build up fat reserves that help them survive through the rest of the year; reproductive success is correlated with mast production (Matschke 1964; William B. Frankenberger, pers. comm.). Hogs also eat the fruits of cabbage palm, saw-palmetto, bluestem palmetto, persimmon, hawthorn, maple, wild grape, etc. and root for bulbs, tubers, roots, and small animals (particularly invertebrates) (Wood and Roark 1980). Wild hogs will travel a mile or more to take advantage of seasonal changes in food availability (Wood and Brenneman 1980). Domestic hogs are often given access to small hammocks scattered about in farming areas. The shade, moist soil conditions, and seasonal acorn crop make an area of hydric hammock well suited for inclusion in a hog pen, though the entire hog pen should not be located within a hydric hammock because of flooding. The other values of the hammock (timber, wildlife, watershed, etc.) are largely sacrificed when such intensive livestock use occurs.

Goats are the only other livestock making any significant use of hydric hammock. Although they have been grazed in hammocks in Florida for a long time, only recently have goats become more abundant. They thrive on a wider variety of plants than cattle or horses, range more evenly over the area they use, make more efficient use of the forage consumed, and therefore do less damage for the same level of production (Corbett 1978). The drawback is that, with mismanagement, goats may severely overgraze hydric hammock (Corbett 1978).

Finally, horses should be mentioned, because they have become quite popular and abundant in Florida. Horses can do quite well grazing in hydric hammocks at low densities, especially in winter. However, horses are usually raised in intensively-managed improved pastures where the only evidence of the original forest is an occasional tree left for shade.

## 4.5 HUNTING

Hunting is the main recreational use of hydric hammocks. The favored species in the fall and winter hunting season are white-tailed deer, gray squirrel, wild hog, and wild turkey. Squirrel hunting is most important in many small patches that do not have good populations of the larger game animals, and when deer season is closed. Other animals hunted in hydric hammocks include wood duck, crows, bobcat (*Lynx rufus*), raccoon, opossum, gray fox (*Urocyon cinereoargenteus*), and armadillo. Although hydric hammock is good black bear habitat, most hunting of this species occurs in other habitat types. For one month in the spring, the hunting of turkey gobblers dominates.

Hydric hammocks are particularly good habitat for white-tailed deer, wild hogs, wild turkeys, and gray squirrels, and most large tracts have good populations of these species. In the 1950's, Gulf Hammock (Florida's largest hydric hammock), had one of the highest combined population densities of deer, cattle, and hogs of any one area in Florida (Harlow 1959), as well as very good populations of wild turkeys and gray squirrels. Deer and hog populations in hydric hammock can be as high as one adult animal per fifteen acres; a good turkey population is one adult per 20-40 acres (Lovett Williams, pers. comm.). Density of gray squirrels ranges from two to five animals per acre (Jennings 1951; Wayne R. Marion, Department of Wildlife and Range Sciences, University of Florida; pers. comm.). Evidence from 15 years of hunting-success records in Gad's Bay, Levy County, Florida, and information supplied by Lovett Williams (pers. comm.) indicate that deer populations can be quite stable, whereas wild hog and squirrel populations fluctuate noticeably from year to year; wild turkey populations are quite variable over time.

Hydric hammocks are conducive to hunting for additional reasons. They generally produce a good acorn crop that matures and drops to the ground during the first half of the main hunting season, attracting maximum densities of bear, deer, hogs, and turkeys to these forests when hunting use is greatest. Hydric hammocks that have not been logged recently generally have an open understory, providing good visibility and an aesthetically pleasing place to hunt. Wild turkeys also prefer habitat with good visibility. The occasional flooding of hydric hammocks may limit access for some hunters, but it attracts wood ducks to feed on acorns, providing an opportunity to hunt another species.

Because live oak acorns are produced abundantly in hydric hammocks, and bears, raccoons, and squirrels seem to prefer these to the more bitter acorns of the red oak species (Figure 17), hydric hammocks are particularly attractive to these animals in the late

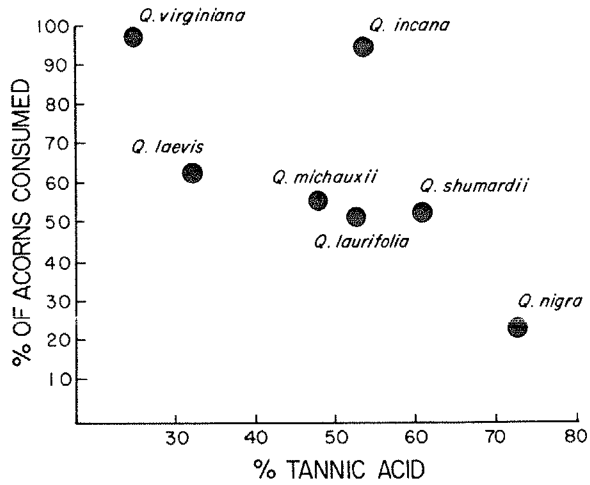



**Figure 17. Preference of gray squirrels for acorns of various species of oaks as a function of the tannic acid content of the acorns (from Harris and Skoog 1980).**

fall. While bear hunting is not allowed in most areas of Florida, raccoons may be hunted year-round, and hunting them at night with hounds is still a common activity in some areas (Klein 1986). Other furbearing animals occasionally taken in, or adjacent to, hydric hammocks are opossum, beaver, otter, mink, and bobcat.

### 4.6 DAMS AND DIVERSIONS

The hydroperiod and average groundwater level of many hydric hammocks have been altered by dams (both upstream and downstream), by upstream water diversions, and by aquifer drawdowns. Depending on the magnitude of change in the hydrological regime, consequences have ranged from slight shifts in species composition to complete destruction of the forest.

Although Florida has fewer dams than other southeastern states, some areas of hydric hammock have been flooded and killed by such projects. One example is the Rodman Dam on the Ocklawaha River (Florida Game and Fresh Water Fish Commission 1976). Three years after flooding, examination of the wetland forest fringing the reservoir revealed a strong correlation between average depth of flooding and tree mortality (Harms *et al.* 1980) (Figure 18). Tree species were not affected equally by flooding: bald cypress (*Taxodium distichum*), cabbage palm, and swamp tupelo were the most flood tolerant; red maple and the ashes were moderately tolerant; and Florida elm and the oak species were the least flood tolerant (Harms *et al.* 1980; Lugo and Brown 1984). These changes suggest that the deeply flooded areas of Lake Ocklawaha are likely to remain open water, while the

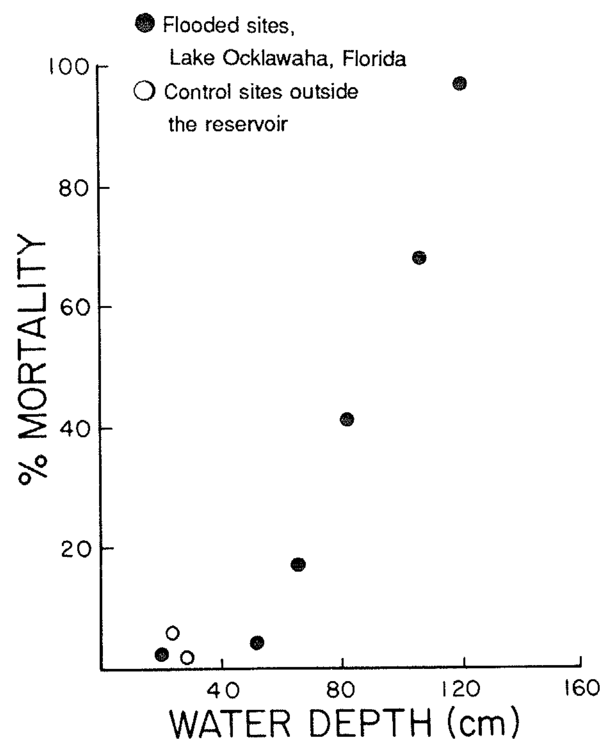



**Figure 18. Effect of water depth on mean mortality of wetland hardwood trees (all species). Water depth and tree mortality were measured in April 1972, three years after completion of the dam (adapted from Harms *et al.* 1980).**

shallower sections will slowly become swamp forest dominated by cypress, swamp tupelo, and cabbage palm. Even areas of hammock above the level obviously exposed to increased flooding may change over time due to higher ground-water levels.

Dams not only alter upstream forests that are in or near the flooded area, but, by altering the hydroperiod and water quality of the stream, they also affect the floodplain forests downstream. Both floods and low-flow periods are less frequent and less severe. Because hydric hammocks are adapted to and shaped by cycles of flooding and drying, these forests are affected by altered hydroperiod. Tracts high enough to be above flooding once the dam is built will succeed to mesic hammock. Hammocks on the lower ground that will remain flooded most of the time once the dam is built will succeed to swamp. Those in the middle ground will undergo a shift of some degree toward the species that do better under more stable water levels (i.e., swamp laurel oak, sweetgum, cabbage palm, red maple, swamp tupelo, and sweetbay).

Water is diverted from the upper parts of several of Florida's rivers for irrigation, municipal use, industrial use, and flood control, thereby decreasing all stages of river flow. Hydric hammocks in the St. Johns and Myakka River basins have expanded into areas that formerly were open marshland (Figure 19), in part because lowered levels of the rivers have reduced the hydroperiods of the marshes (Randall E. Hester, Florida Department of Natural Resources; pers. comm.; Robert Dye, Florida Department of Natural Resources; pers. comm.). In the past, fire also retarded invasion of the marsh by hammock and swamp trees, but human activities have decreased the frequency and intensity of fires. Lowered water levels probably also en-

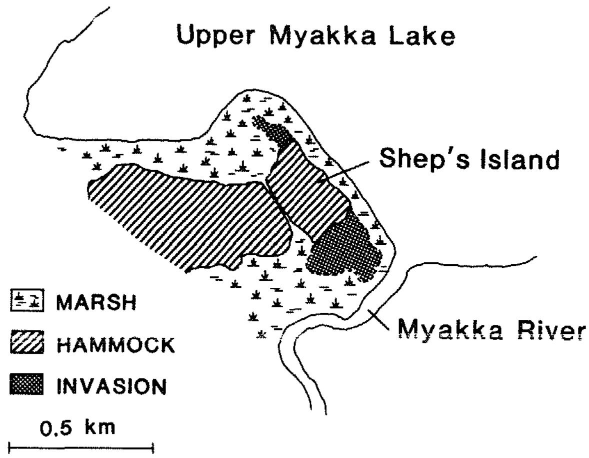



**Figure 19. Expansion of hydric hammock (Shep's Island) into freshwater marsh, Myakka River State Park, 1957-72.**

able some of the higher areas of hydric hammock to succeed to mesic hammock.

Aquifer drawdowns caused by pumping large volumes of water for municipal, industrial, and agricultural uses can have effects similar to upstream diversions. The decline in aquifer level tends to reduce or stop discharge, diminishing spring and river flows (Conover *et al.* 1984). This is one of the changes affecting the St. Johns River (Campbell *et al.* 1984). In areas of Florida where the aquifer is the ground-water table, lowering of the aquifer can affect even isolated wetlands.

## 4.7 WASTEWATER DISPOSAL

Hydric hammocks often are used as detention or retention areas for stormwater runoff from developments and urban areas. A detention area holds sufficient water to greatly slow the flow rate through it, reducing peak storm flow rates and allowing particulates to settle out of the water. A retention area is a much larger basin relative to the runoff volume and will hold all the runoff from all but the most extreme storm events. Both types of areas often act like ponds with leaky bottoms in that the basin goes dry, or nearly so, between storms. In addition, some areas of hydric hammock are used to dispose of water discharges from industrial plants, power plants, and agricultural operations. Finally, the use of wetlands for disposal and final treatment of sewage effluent is gaining importance in Florida, and there is considerable interest in using some hydric hammocks for this purpose.

### 4.7.1 Storm Water Runoff

Storm water runoff arriving from developed areas is by far the greatest wastewater use of hydric hammocks. Most of the hammocks are in depressions that received runoff from the area prior to development, and the drainage pattern often remains the same. However, the amount of storm runoff increases considerably after development; permeability of the developed area decreases because of the large areas covered by buildings and pavement and the compaction of peripheral areas by frequent vehicular and foot traffic. Often the pollution load is increased to the point that the first flush of storm runoff from densely populated areas is as polluted as raw domestic sewage (Richard P. Vogh, Florida Department of Environmental Regulation; pers. comm.). Sometimes storm sewage is intentionally routed to hydric hammock areas. Retention and detention areas are increasingly being required for new developments, and hydric hammocks often are the logical choice for this purpose. An example is the use of a 178 ha hydric hammock as a detention area for residential developments northwest of Gainesville, Florida, which are planned to encompass 355 ha (Figure 20). In other cases, retention or detention areas are created by building dams or digging holes. Some of these become new hydric hammocks, and many more would do so if natural succession were allowed to occur.

Hydric hammocks are well adapted to receive stormwater runoff. Flooding depth is increased, but the natural cycles of flooding and drying are maintained. The hammock is damaged significantly only when the dry periods are reduced or heavy siltation occurs. Even then, perhaps only the deeper areas are killed, and, subsequently, these may be replaced by swamp, prairie, or marsh vegetation. Whether damaged or not, many hydric hammocks are performing a valuable service by detaining, filtering, and storing stormwater. Water quality is improved and downstream flooding is reduced.

### 4.7.2 Power Plant Discharge

Power plants also may add water to hydric hammocks, but in a continuous rather than pulsed flow. The blowdown water that is discharged from cooling towers often contains high concentrations of sulfate or chloride ions, which are added to cooling tower water in the form of sulfuric acid or hydrochloric acid to maintain a neutral pH and reduce scale formation. In 1972, the Deerhaven Power Plant northwest of Gainesville, Florida, began releasing 2.3 million liters per day of sulfate-laden water into the watershed of Turkey Creek (Environmental Science and Engineering, Inc. 1974), changing an intermittent stream to a permanent one and roughly doubling the average flow rate downstream into the hardwood wetland forests of the 200-ha Sanchez Prairie basin in San Felasco Hammock State Preserve (Simons, unpubl.). The concentration of sulfate decreased from approximately 500 ppm at the power plant to about 120 ppm at Sanchez Prairie (Richardson *et al.* 1983). By 1976, 8 ha of water elm

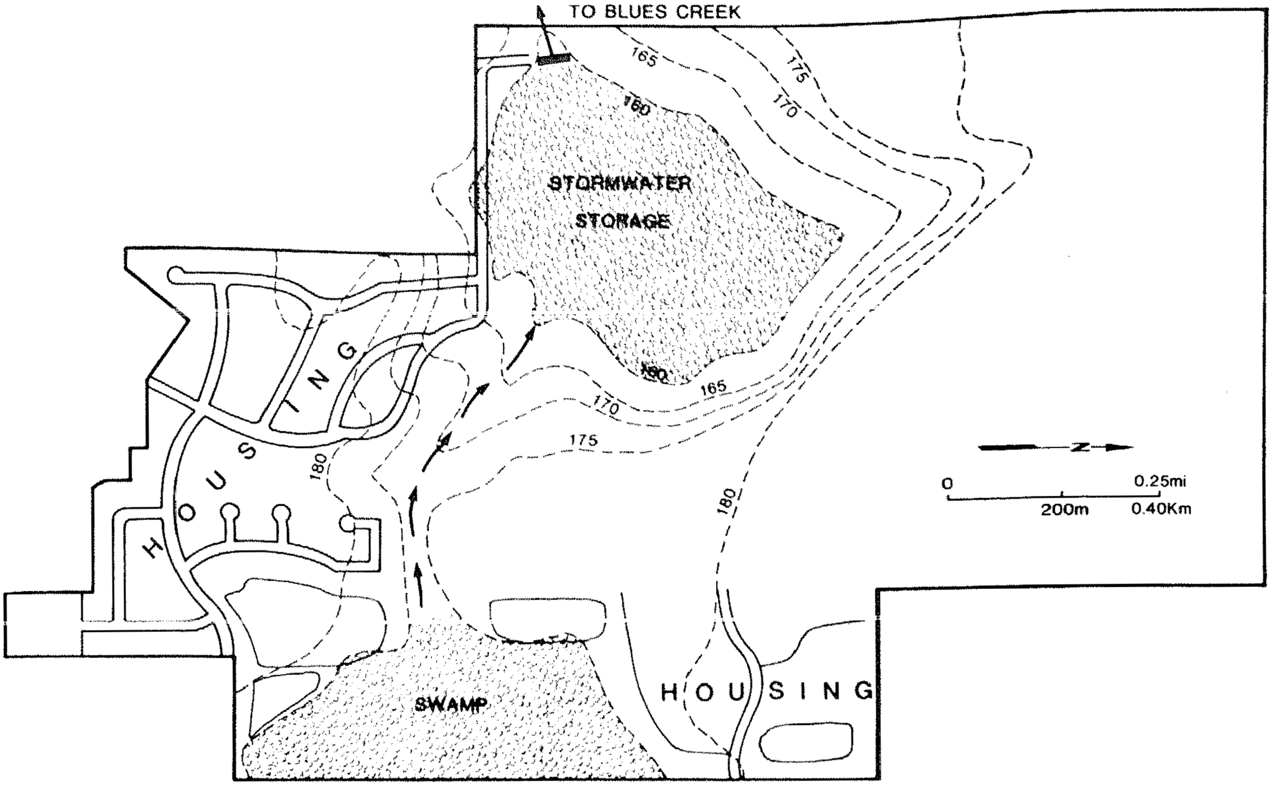



**Figure 20. Proposed stormwater management plan for San Felasco Villas, Deer Run Unit 3, Alachua County, Florida. Water naturally flows out of the mixed hardwood swamp (bottom of figure) into a creek that meanders through hydric hammock before discharging into Blues Creek. Development would increase the volume of stormwater, which would be stored in the hammock by a water-control structure (top of figure). No buildings would be allowed around the swamp below an elevation of 177 ft or around the stormwater detention area below 160 ft (adapted from Hasan 1980).**

(*Planera aquatica*) / pop ash (*Fraxinus caroliniana*) swamp and 16 ha of hydric hammock, composed of live oak, swamp laurel oak, loblolly pine, sweetgum, Florida elm, and red maple, were dead (Simons, unpubl.). The tree kills probably resulted from one or a combination of factors: increased hydroperiod, reduction of sulfate to toxic hydrogen sulfide, and buildup of organic muck that blocked former water channels and sealed the soil surface (H. T. Odum, Center for Wetlands, University of Florida, Gainesville; pers. comm.).

A short-term experiment tested the effects of extended hydroperiod, with and without sulfate addition, on a nearby wetland forest similar to that in Sanchez Prairie except for the absence of live oak (Richardson *et al.* 1983). Hydroperiod was increased on two plots by the addition of water; one of them received water containing about 150 ppm sulfate. Water was pumped to a depth of 20 cm during summer, fall, and the following spring. The natural flooding regime of a third plot, the control, was not altered. One year after the initiation of the experiment, seedling density was significantly reduced and the number of stressed trees was considerably increased on the sulfate plot (Table 8). Though the added-water plot remained similar to the control plot, increased hydroperiod resulted in greater transmission of sunlight to the forest floor in spring and fall, indicating some stress on the trees.

These results indicated that the main culprit in the tree kills on Sanchez Prairie was the high concentration of sulfate in the discharge water, but a contributing role of increased hydroperiod was not ruled out. Unlike the power plant discharge, the experiment was of short duration and included a short drydown period. Even so, increased hydroperiod without sulfate addition adversely affected foliage density. Increased sedimentation of fine organics on Sanchez Prairie probably also exacerbated the effects of sulfate addition by decreasing oxygen diffusion into the soil and so improving conditions for hydrogen sulfide production. In 1975, the Gainesville utility company proposed an expansion of facilities that would have tripled the blowdown discharge. This proposal was withdrawn and later the effluent discharges were stopped due to citizen protest and actions by State agencies.

4.7.3 Wastewater Treatment

Wastewater contains dissolved and particulate nutrients, organic matter, bacterial and viral pathogens, and other contaminants including heavy metals and other toxins. The purpose of discharging wastewater into wetlands is to obtain some additional removal of the nutrients and contaminants before the water reenters aquifers and surface flows. Wetlands may not be final sinks for heavy metals (Richardson and Nichols 1985), but they can effectively assimilate the nutrients and organic loads of wastewater (U.S. Environmental Protection Agency 1985). Uptake of added nitrogen and phosphorus has been demonstrated in several forested wetlands in Florida. A mixed hardwood swamp receiving secondarily treated wastewater reduced total nitrogen and phosphorus levels in the water to values equal to or less than those in a nearby unaffected swamp (Boyt *et al.* 1977). Reduction in concentrations of phosphorus and nitrogen to natural levels occurred in a cypress dome exposed to experimental additions of treated effluent (Dierberg and Bre-

**Table 8. Effects of increased hydroperiod and sulfate addition on hardwood wetland plots (from Richardson *et al.* 1983). Measurements were obtained in spring, one year after initiating the experiment. Tree stress was indicated by shriveling and browning of leaves.**

| Treatment | Number of seedlings per $m^2$ (std. error) | Number of stressed trees per 400 $m^2$ | % transmittance of sunlight to ground |
|---|---|---|---|
| Control | 23.4 (3.18) | 71 | 6% |
| Water | 22.4 (3.32) | 96 | 14% |
| Water + sulfate | 1.4 (0.81) | 596 | 17% |

zonik 1984). One sewage-enriched cypress strand lowered phosphorus levels to background levels (Nessel and Bayley 1984); another reduced nutrient concentrations between the inflow and the outflow, but, in the case of phosphorus, not to the levels observed in undisturbed cypress swamps (Tuschall *et al.* 1981).

In all cases, nutrient retention in sediments appeared to be the primary mechanism of removal. Whereas most nitrogen processing in wetland sediments is mediated biologically, phosphorus removal results from adsorption/precipitation reactions. Efficient immobilization of phosphorus depends on the duration of contact between the nutrient and the organic substrate (Kadlec and Tilton 1979). The forested wetlands studied thus far are characterized by slow or nonexistent water flow, and so the wastewater and "sorptive" organic surfaces have long residence times.

Some nutrients also appear to be retained in tree biomass. In most cases, tree growth (mainly cypress) increased in response to additions of secondarily treated wastewater (Boyt *et al.* 1977; Nessel *et al.* 1982; Lemlich and Ewel 1984), and detrimental effects on species composition of overstory and understory vegetation were not observed (Ewel 1984).

Ewel *et al.* (1982) discussed a number of criteria by which the suitability of an ecosystem for receiving wastewater inputs can be judged. The first is the ability to provide effective tertiary treatment, and another is the importance of the ecosystem (i.e., whether the ecosystem will be significantly altered, and, if so, whether it can be sacrificed). By these criteria, hydric hammocks appear to be far less suited than mixed hardwood and cypress-dominated swamps for receiving wastewater. Because of the absence of a thick organic layer, hydric hammocks generally have less potential than swamps for nutrient removal. Brown and Starnes (1983) concluded that discharge of wastewater is incompatible with the maintenance of biological and physical functions in these wetlands. Hydric hammocks are likely to be severely altered by wastewater inputs because they are characterized by short hydroperiods, and many species are not adapted to continuous inundation or anaerobic conditions (Richardson *et al.* 1983). Wastewater, whether from sewage treatment facilities, power plants, agriculture, or industry, has the potential to kill hydric hammock, particularly if applied continually during the growing season.

An example of a proposed use of hydric hammock for disposal of sewage effluent is a plan by the city of Ocala, Florida, to pump up to 32 million liters per day of secondarily treated effluent from Ocala to a 486-ha area of Marshall Swamp (City of Ocala 1986). The part of Marshall swamp to receive the effluent is a mixture of hydric hammock and cypress/hardwood swamp. The water would travel through Marshall Swamp by a combination of channeled flow and sheet flow to the Oklawaha River, a distance of about 5 km.

## 4.8 NONCONSUMPTIVE USES

In addition to those already mentioned, a number of uses of hydric hammocks are not consumptive and generally have less impact on the forest. These are sometimes referred to as passive uses, although some can be quite active. In this category are such uses as wildlife (both fauna and flora) conservation, urban open space, and various types of outdoor recreation such as hiking, jogging, bird watching, picknicking, camping, and canoeing (on adjacent rivers and in the interior of hydric hammocks during floods). These uses of hydric hammocks are generally compatible with most other uses.

Some hydric hammocks have been purchased, at least in part, for wildlife conservation. St. Marks National Wildlife Refuge, San Felasco Hammock State Preserve, Waccasassa Bay State Preserve, Big Bend Wildlife Management Area, and Tosohatchee State Reserve are examples. All of these areas have other biological communities and other uses, but wildlife conservation was one of the main reasons for purchase and is one of the primary management goals. Maintaining healthy examples of the hydric hammock community is an important conservation goal by itself. In addition, hydric hammock is significant to many animals (Table 9) and plants (Table 10), including threatened and endangered species.

Mature hydric hammocks are well suited for recreational use due to their open understories, scenic beauty, and diverse and abundant wildlife. Although use for hunting is substantial, the nonconsumptive recreational use of rural hydric hammocks has been small, due mainly to lack of easy access. However, this is beginning to change. The hydric hammocks at Myakka River State Park, for instance, are now heavily used for camping, hiking, and nature study; it is considered Florida's premier park for wildlife viewing and photography (Kenneth Alvarez, Florida Department of Natural Resources; pers. comm.). Such activities are becoming more popular in many hammocks. The bits and pieces of hydric hammock that remain in some urban areas are more readily available to people than remote tracts. The community uses these open spaces not only for recreation, but for noise and air pollution abatement,

**Table 9. Animals with at least 10% of their Florida populations in hydric hammock, for at least part of the year. For each species, the percent of Florida population occurring in hydric hammock was estimated by R.W. Simons in consultation with State wildlife biologists. Endangered status: T = threatened (Florida Game and Fresh Water Fish Commission 1986).**

| Common name | Scientific name | Percent | Status |
|---|---|---|---|
| Florida black bear | *Ursus americanus floridanus* | 30 | T |
| Barred owl | *Strix varia* | 10 | |
| Red-shouldered hawk | *Buteo lineatus* | 10 | |
| Ruby-crowned kinglet | *Regulus calendula* | 20 | |
| American robin | *Turdus migratorius* | 50 | |
| Tree swallow | *Iridoprocne bicolor* | 30 | |
| Cedar waxwing | *Bombycilla cedrorum* | 30 | |
| Swallow-tailed kite | *Elanoides forficatus* | 20 | |
| Florida box turtle | *Terrapene carolina bauri* | 10 | |
| Gulf hammock rat snake | *Elaphe obsoleta quadrivittata* x *E. o. spiloides* | 30 | |
| Eastern indigo snake | *Drymarchon corais couperi* | 10 | T |
| Blue-striped garter snake | *Thamnophis sirtalis similis* | 30 | |
| Blue-striped ribbon snake | *Thamnophis sauritus nitae* | 30 | |
| One-toed amphiuma | *Amphiuma pholeter* | 30 | |

Table 10. Plants having at least 30% of their populations in hydric hammocks. For each species, the percent of Florida populations occurring in hydric hammock was estimated by R.W. Simons in consultation with University of Florida botanists and others. Endangered status: E = endangered, T = threatened, C = commercially exploited (Florida Game and Fresh Water Fish Commission 1986).

| Common name | Scientific name | Percent | Status |
|---|---|---|---|
| Southern red-cedar | *Juniperus silicicola* | 70 | |
| Cabbage palm | *Sabal palmetto* | 50 | |
| Bluestem palmetto | *Sabal minor* | 50 | T |
| Needle palm | *Rhapidophyllum hystrix* | 50 | C |
| Live oak | *Quercus virginiana* | 30 | |
| Sweetgum | *Liquidambar styraciflua* | 30 | |
| Florida elm | *Ulmus americana floridana* | 80 | |
| Cedar elm | *Ulmus crassifolia* | 90 | |
| Hornbeam | *Carpinus caroliniana* | 50 | |
| Star (yellow) anise | *Illicium parviflorum* | 50 | T |
| Pine-wood dainties | *Phyllanthus liebmannianus* | 80 | T |
| Pink-root | *Spigelia loganioides* | 90 | E |
| Indian-plantain | *Arnoglossum diversifolium* | 50 | T |
| Indian-plantain | *Cacalia suaveoleus* | 100 | |
| Goldfoot fern | *Phlebodium aureum* | 50 | T |
| Shoestring fern | *Vittaria lineata* | 50 | T |

temperature moderation, and habitat for urban wildlife.

## 4.9 POTENTIAL ALTERATIONS

Some far-reaching but subtle changes in the general environment of hydric hammocks may be affecting them now or may do so in the future. The most threatening of these was already mentioned--sea-level rise due to the greenhouse effect. Some others are climate changes, air pollution, fire protection, invasion by exotics, and extinctions of individual species.

The gulf coast of Florida, where the largest concentration of hydric hammock occurs, is subsiding at a rate of about 1 mm per year (Holdahl and Morrison 1974). World-wide sea level is rising at about the same rate, 1.2 mm per year (Gornitz *et al.* 1982). So the net change on Florida's gulf coast, recorded by tidal gauges, has been a relative sea-level rise of about 2 mm per year over the past 70 years (Hicks *et al.* 1983) (Figure 21). The results are visible. Cabbage palm and red-cedar stumps in the salt marsh indicate areas that were once hydric hammock (Figure 22). Unfortunately, these changes are insignificant compared to what is projected for the next 100 years. The concentration of carbon dioxide in the earth's atmosphere has risen by about 20% in the last 100 years, due primarily to the burning of fossil fuels, and it is expected to at least double in the next 100 years (Titus and Barth 1984). Carbon dioxide allows the sun's radiation to enter the atmosphere but

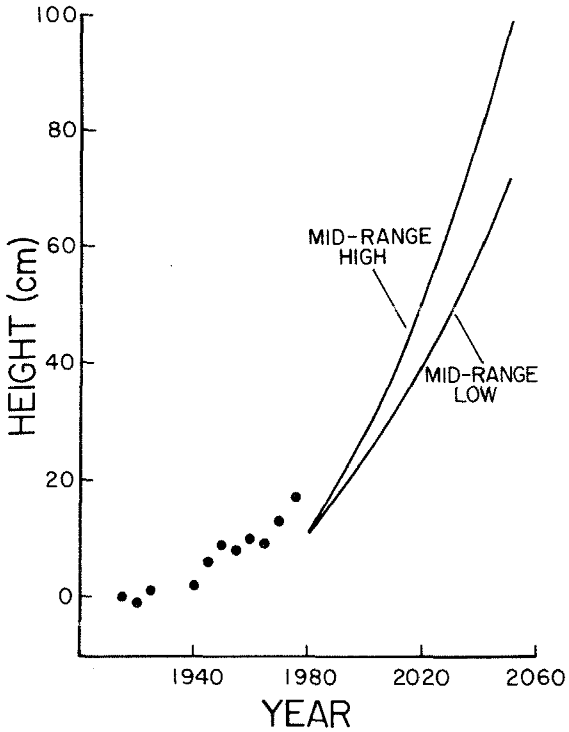



**Figure 21. Sea-level rise at Cedar Key, Florida, 1915-80, and projected rise to 2075 (from Hicks *et al.* 1983; Hoffman *et al.* 1983).**

blocks the escape of heat radiation. Other gases such as chlorofluorocarbons (e.g., freon), nitrous oxide, and methane have the same effect and also are increasing (Titus and Barth 1984). The result is that the earth is warming, causing the oceans to rise due to thermal expansion of sea water and the melting of glaciers (Hoffman 1984). Furthermore, the process is accelerating as the production of the "greenhouse gases" increases. While global sea level rose only 10-15 cm in the past century, the modal prediction for the next century is a rise of between 144 and 217 cm (Hoffman *et al.* 1983).

This amount of sea-level rise is likely to eliminate about half of the total amount of hydric hammock by marine inundation or replacement by salt marsh or both. The extent of coastline regression will depend upon the relative rates of ocean rise and sedimentation (Titus 1985). Salt marsh formation can keep pace with a low rate of sea-level rise through sediment trapping and peat production, but little riverine sediment is supplied to Florida's gulf coast. Therefore, as sea level rises, open water will replace salt marsh, salt marsh will migrate inland and replace coastal hydric hammock, and coastal hydric hammock will tend to replace inland hydric hammock and mesic hammock. However, the inland hydric hammock on the upland side of the extensive gulf coast hammocks cannot migrate because it is bordered by pine flatwoods and sandhills with soils unsuited for hammock invasion. This is evident by the proximity of flatwoods and sandhill communities to salt marsh where these soil types occur. If sea-level rise continues unabated, the hammocks will be squeezed between the advancing salt marsh on the west and the limits of suitable soil on the east. These hammocks are likely to face increased flooding due to high tides, storm surge, and larger waves (Hoffman *et al.* 1983). The plant composition may change to the extreme type of coastal hammock, dominated almost exclusively by the salt-tolerant species: live oak, cabbage palm, and southern redcedar (Kurz and Wagner 1957). The coastal hammock type will also be favored by another impact of sea-level rise: salt water intrusion into ground water and rivers (Titus 1985).

The greenhouse effect is projected to raise average world-wide temperature by $4^{0}$ C before the end of the next century and is predicted to alter rainfall patterns (Hansen *et al.* 1981). These changes might be sufficient to render many hydric hammock

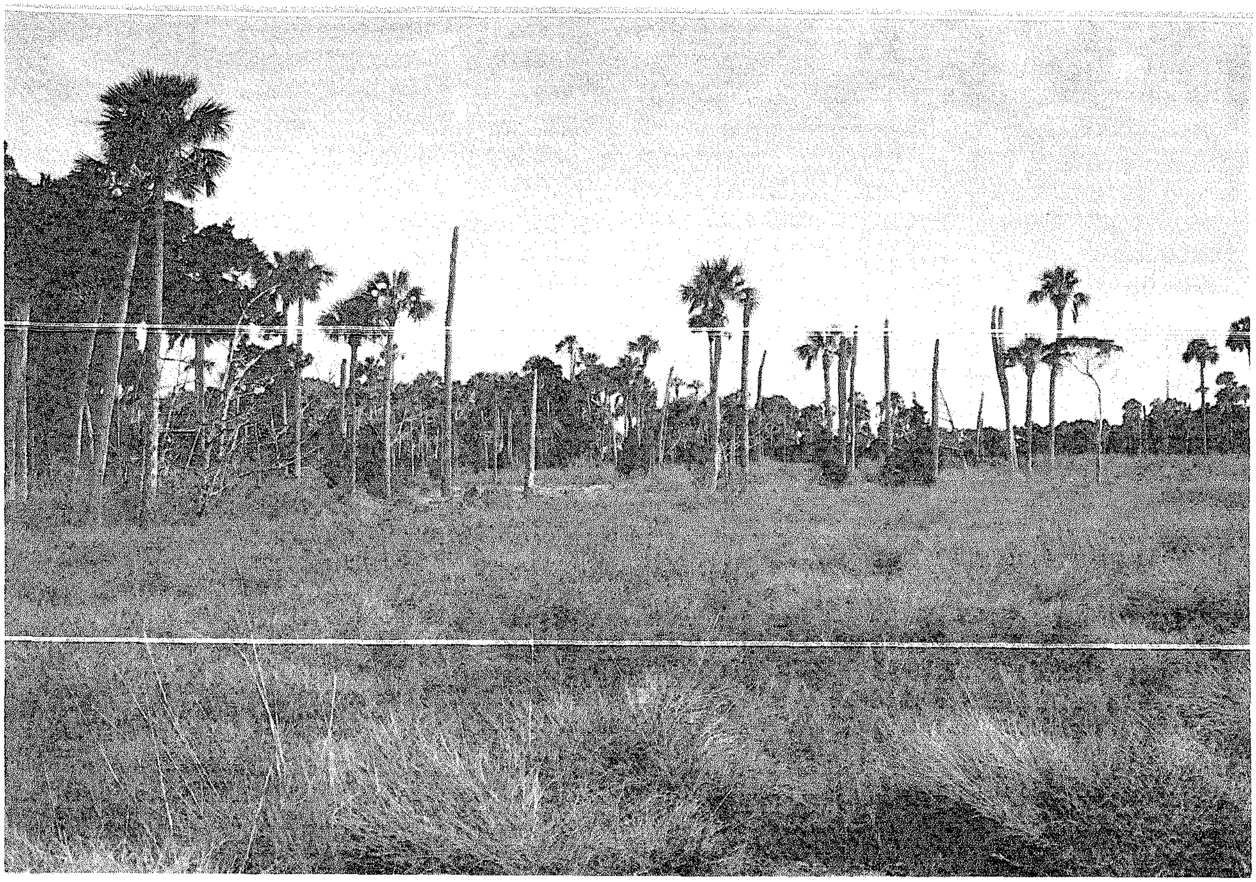


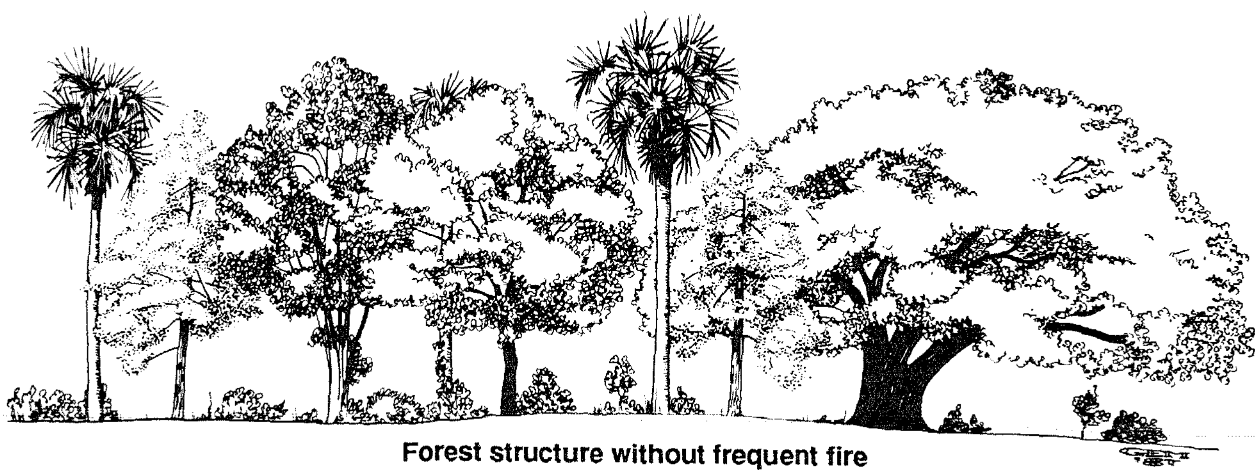
**Figure 22. Rising sea level is indicated by the presence of cabbage palm stumps in gulf coastal salt marsh.**

species poorly adapted to their current locations. It might also enable native and exotic tropical species to invade areas much farther north than they do currently.

Air pollution of other sorts is being blamed for the destruction of forests in North America and Europe (Smith 1985). Devastating effects of local pollutants, such as heavy metals from smelters, on tree growth and survival are well documented. Acid rain is strongly implicated in the decline of forests in western Europe, the northeastern United States, and at high elevations in the southern Appalachian Mountains. The acidity of rain in northern Florida increased ten-fold in a 25-year period, from pH values greater than 5.6 in the mid-1950's to average annual values below 4.7 in the late 1970's (Brezonik *et al.* 1980). The present degree of acidity in Florida rainfall is unlikely to be affecting hydric hammocks, except perhaps for the epiphytes, because these forests generally grow on soils with very large buffering capacities attributable to the presence of either limerock or shell. With Florida's rapid population growth and consequent increases in the use of motor vehicles and electric power, acid rain and other forms of air pollution may become a problem for hydric hammocks in the future.

In prehistoric times, periodic fires burned unchecked across much of the Florida landscape (Laessle 1942). Now, the many roads, towns, cleared fields, and other sorts of firebreaks, in combination with active fire suppression, have greatly reduced the frequency of wildfires. Continued suppression of fire is likely to affect the extent and composition of hydric hammocks (Vince *et al.* 1989). Marshes that were previously kept open, at least in part, by fire can now be invaded by hydric hammock. Fire suppression also may result in invasion of pine flatwoods and prairie by hydric hammock. Just as fire favored the more fire-tolerant species (cabbage palm and loblolly pine, followed by live oak), so fire protection favors the more fire-susceptible species (sweetgum, swamp laurel oak, southern red-cedar, Florida elm, sweetbay, swamp tupelo, hornbeam, and red maple) (Putnam *et al.* 1960; Laessle and Monk 1961; Hare 1965; Ewel and Mitsch 1978). Fire suppression reduces the density of the grasses, sedges, and small shrubs by allowing the overstory vegetation to become denser. With time, a three- or four-layered forest may replace the two-layered structure of most fire-modified hydric hammocks (Figure 23).

Forest structure with frequent fire



Forest structure without frequent fire

Figure 23. Effect of fire on hydric hammock forest structure.

The tree-species composition of hydric hammocks also is likely to be affected by the extinction of animals that are seed-dispersing mutualists. The black bear is either absent or greatly reduced in numbers in most areas of hydric hammock, so its role as a disperser of saw palmetto, cabbage palm, needle palm, swamp tupelo, gallberry, blueberry, and blackberry seeds is lost (Maehr and Brady 1984). Deer, livestock, raccoons, and smaller mammals and birds also disperse seeds, but their diets and seed-dispersing effects in hydric hammock are undocumented. Certainly the black bear was the primary disperser of needle palm fruits, and it shares only with livestock the range of movement over such a large daily activity area. Predators of seed-dispersers also are extinct or nearly so (red wolf and Florida panther). The severe reduction of large predators has apparently allowed deer and raccoons to overpopulate in areas where hunting has not compensated for the lost predators (Archie F. Carr, Jr., Department of Zoology, University of Florida; pers. comm.). The outlawing of leg-hold traps in Florida in 1973 has made humans much less effective predators on raccoons.

Two exotics, wild hogs and armadillos, have achieved much higher populations in this habitat than they would in the presence of normal wolf, panther, and black bear populations (Archie F. Carr, Jr., pers. comm.). These two animals have, in turn, altered the terrestrial flora and fauna of these hammocks. For instance, the populations of terrestrial snails, salamanders, and lizards have been greatly reduced (Archie F. Carr, Jr., pers. comm.). Other exotic animals that have taken hold in many hydric hammocks are cattle egrets, Cuban tree frogs, greenhouse frogs, coyotes, feral cats, and feral dogs.

St. Augustine grass is an abundant exotic plant in some hydric hammocks. The aggressive cogon grass (*Imperata*) is spreading throughout Florida and, at the moment, seems unstoppable. Growing well in some hydric hammocks, it may form a very dense stand that kills all competing ground-cover plants (Figure 24). Dense stands of this fire-adapted grass are very flammable, particularly after the leaves have died, and burn with much greater intensity than other hydric hammock fuels. A few of the many other introduced plants that are spreading in the wild and have the potential for altering hydric hammocks are camphor tree (*Cinnamomum camphora*), Brazilian pepper-tree (*Schinus terebinthefolius*), glossy privet (*Ligustrum lucidum*), white-flowered spiderwort (*Tradescantia flumensis*), skunkvine (*Paedevia faetida*), wisteria (*Wisteria sinensis*), and Japanese honeysuckle (*Lonicera japonica*).

Figure 24. Invasion of hydric hammock by cogon grass, Silver River.

# CHAPTER 5. MANAGEMENT TECHNIQUES AND OPTIONS

## 5.1 PLANNING

For a hydric hammock to be soundly managed, the main goals of management must be formulated, taking into account the specific uses the forest should support and the appropriate condition of the forest to maintain these uses. To obtain the desired results, a management plan can be drafted that selectively prescribes and controls the uses, or prevents the various impacts described in the preceding chapter.

The most important step in the management process, where the greatest mistakes often are made, is determination of the overall goal or goals. If goals are not carefully formulated and clearly stated, subsequent management may lack direction or may do considerable harm to some unspoken but strongly desired quality or potential use of the forest. Even if the owners of the hammock have little idea of what different actions, or lack thereof, might do to the forest, they should nevertheless formulate goals to direct consultants or managers toward desired results.

Consideration of the following questions, and ranking of the answers in order of importance, will help to formulate goals and specific objectives:

1. What is the main purpose for owning or managing the forest?

2. Is producing income from the forest important?

3. What amount of money can be spent on management and improvements and how important is this amount of expense in relation to the goals?

4. What rate of return on investment, if any, is expected?

5. Is the timing of income and/or expenses important and, if so, how?

6. Is the production of some product for reasons other than income important?

7. Is producing high populations of specific animals (like deer) important?

8. Is maintaining populations of specific animals or plants important and, if so, which ones and in what order of importance?

9. Is maintaining the entire, existing spectrum of fauna and flora of the biological community in a healthy state important?

10. Is maximizing wildlife diversity important, including existing and potentially-present species?

11. Is the appearance and character of the forest important?

12. Is a visually open and easily traversed understory important?

13. Are individual trees or other features important or special?

14. Is recreational use important and, if so, what kinds?

15. Is the abundance of pests like ticks, mosquitoes, poison ivy, etc. important?

16. Are watershed values important?

Other questions relevant to local conditions should be included.

After writing down goals and setting priorities, the next step is to determine specific uses for the forest and what state or condition of the forest will best suit these. Some examples of specific uses are: sustained yield production of sweetgum veneer logs, wild turkey hunting, enhancing habitat for and reintroduction of black bears, camping and hiking, protecting a particular archaeological site, etc. The desired condition of the forest may include such factors as species composition of timber-producing stands, habitat quality for particular wildlife species, desired range of water quality parameters, visual and biological condition of areas used for recreation, and level of forage production for livestock. Once step two is completed, the actual management plan can be drafted. The management plan is only as good as the knowledge, effort, and direction that go into it. The people who prepare the management plan should have knowledge that covers the spectrum of the goals and uses that have been determined. In many cases, this means having a team of people to work on the plan. Examples of fields of knowledge that might be needed are ecology, zoology, botany, hydrology, forestry, range management, game management, and outdoor recreation.

The management plan should include the goals and priorities, the specific uses, and descriptions of the current and desired states of the forest. It should contain a legal description of the property, a topographic map, an ownership map, a road and firebreak map, a vegetation map, and perhaps several other types of maps of the forest and surrounding properties. A case-by-case and area-by-area plan and timetable should detail how to accomplish the goals, how to set up and control the uses, and how to bring about and maintain the proper condition of the forest. Various management options and techniques that are available make up the rest of this guide.

## 5.2 TIMBER MANAGEMENT

Timber management is a very powerful tool in the management of forest land for wildlife, recreation, watershed, grazing, and other uses, as well as for timber production. It can greatly alter the forest in a variety of ways, and it often produces considerable financial profit. However, like any powerful tool, timber management must be used wisely and carefully if damage is to be minimized or avoided; its use is not always compatible with all management goals. Timber management practices in hydric hammocks are similar to those used in bottomland hardwood forests; the latter are described by Putnam *et al.* (1960), McKnight and Johnson (1980), and Johnson and Shropshire (1983).

### 5.2.1 Timber Harvesting

Because of its potential for making money, the timber management technique that usually comes to mind first is timber harvesting, but harvesting also is a way to moderately or greatly alter the forest (Figure 25). Selective logging is the cutting of individually selected single trees or small groups of trees (less than 0.2 ha) throughout the forest. While it is the most precise and versatile harvesting technique, selective logging is the most

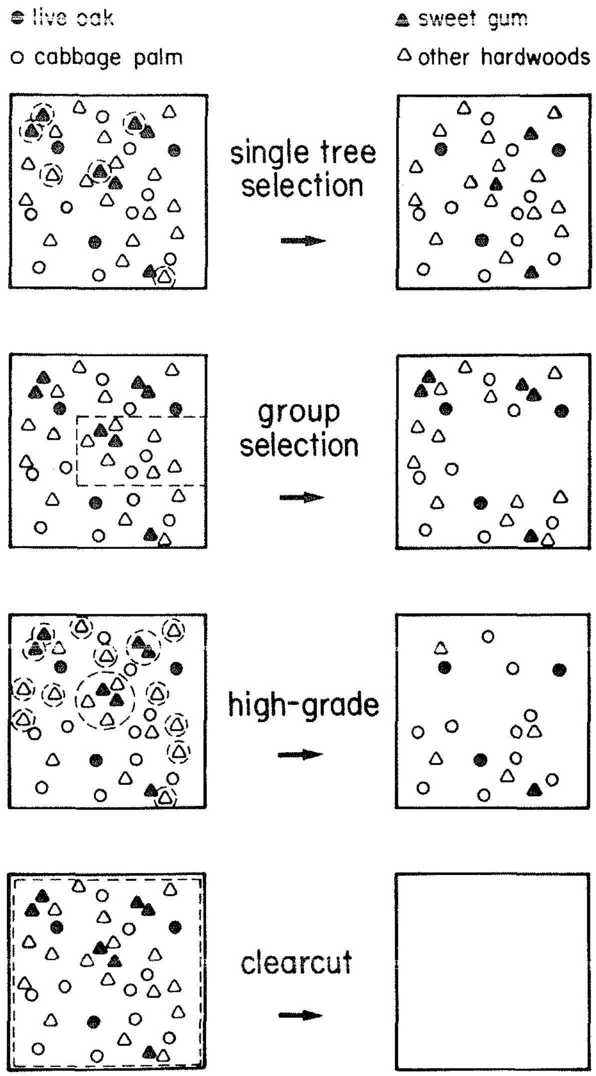



**Figure 25. Impacts on species composition of common timber harvesting schemes in hydric hammocks.**

expensive. Trees may have to be individually marked (usually by a forester), volume per acre may be low, and negotiating around and protecting the remaining trees may be difficult. Selective logging usually is done to increase the quality of the remaining growing stock, by cutting mature trees, crooked and diseased trees, and small and medium-sized trees of low-value species. This leaves the small and medium-sized, straight, healthy trees of valuable species to grow and produce the next timber crop. The main drawbacks of using single-species selective logging to produce timber of better quality are the high cost, the damage to the remaining timber, and the uncertainty of relative market values of different species and qualities of logs in the future.

Selective logging of hydric hammock may be used to change the composition of tree species, increase the diversity of wildlife habitats, and open the forest to stimulate growth in the understory and ground cover for the benefit of wildlife, livestock, and tree regeneration. For instance, if an increase in acorn production is desired in a hydric hammock dominated by sweetgum, selective logging of sweetgum would be a logical prescription, because oaks and other hydric-hammock species reproduce better than sweetgum in small openings. This could be done in varying degrees of intensity. Only those sweetgums adjacent to or overtopping oak trees might be marked and then removed, or some percentage of the remaining sweetgums might be cut in addition; or, to further increase profit by avoiding the expense of marking and by producing more timber per acre, all marketable sweetgums could be harvested. Though less effective, the same purpose could be achieved by group selection, logging the small areas most strongly dominated by sweetgum. Diversity is increased when the dominant species is reduced, reproduction of trees and growth of seedlings and saplings already present are stimulated, and growth of the understory and ground cover increases the habitat value for browsers and grazers like deer, cattle, and rabbits.

Thinning is selective logging in immature, usually even-aged, stands such as those growing on old clearcuts. Selections may be based on species, trunk size, crown size, position in the canopy, health, and straightness, or parallel strips may be cut through the forest in which no individual tree selection is done. Although it can produce some income and is a good way to stimulate browse production and use (Harlow 1976), thinning most commonly is done to enable the remaining trees to grow faster. Timber production, wildlife, and aesthetics benefit from the faster growth of selected valuable trees. Fewer, larger trees are more valuable as timber than more, but smaller, trees. Vigorously growing, large trees produce much more mast than crowded, smaller trees, and they can become den trees much sooner. Finally, a more open forest of larger trees is generally more valuable aesthetically than a denser forest of smaller trees. Thinning allows the forest manager to influence the final species composition and diversity of the hydric hammock by removing or leaving some species in preference to others. Thinning is most profitable in second growth pure or mixed stands of loblolly pine and red-cedar, because there are good markets for the products. It also can be done in stands of other hydric hammock species but is not always profitable, because sale of the logged trees may not cover all the costs of marking and logging. Thinning in stands of live oak and cabbage palm may be very expensive, because markets may not be available for the products (see paragraph on timber stand improvement for alternatives).

Highgrading is the harvesting of some or all of the trees that can be logged and sold at a substantial profit, leaving behind trees that are economically less desirable or completely worthless. This type of logging is intermediate between selective logging and clearcutting in the intensity of disturbance produced (Figure 25) and is a common method of logging on private land, both corporate and individual, because it often produces the most income at the time of logging. Highgrading in hydric hammocks increases the percentage of crooked, hollow, and diseased trees and alters the species composition of the canopy. Future timber productivity and value of the forest often are greatly diminished because the crooked, damaged, and other low value trees continue to grow, taking up space that young trees of valuable species would otherwise occupy. Although in the past highgrading removed live oak from some hammocks and cabbage palm from at least parts of Gulf Hammock (see Chapter 3.3), today these are the two canopy species most commonly left behind by highgrading operations. In hydric hammocks where live oak, hornbeam, and cabbage palm are uncommon, highgrading may have little effect on the future economic value of the forest and serves to increase the vegetation diversity and wildlife habitat value. However, where cabbage palm, hornbeam, or live oak (or a combination) dominates the forest, highgrading enhances this domination to the detriment of wildlife habitat and future economic values. In hydric hammocks, highgrading generally is better for wildlife and aesthetics than clearcutting. Both methods greatly open the forest, increasing browse production, but highgrading leaves hollow trees and picturesque old live oaks and cabbage palms. The hollow trees and large live oaks often are den trees, and the live oaks and cabbage palms are good mast producers.

Clearcutting is used in preference to highgrading by most managers of hydric hammocks, because a new forest that is more valuable for timber production can be established either by natural regeneration or planting. Clearcutting is especially recommended by some foresters where stands have been repeatedly highgraded, resulting in an abundance of damaged and cull trees and species of low value (Kellison 1983). With natural regeneration, clearcutting produces a forest containing more pioneer species like loblolly pine and sweetgum, and provides them with better conditions for rapid growth. On areas to be planted (usually with pine), clearcutting facilitates site preparation and planting.

Clearcutting of patches between 0.2 ha and 0.8 ha in size has been termed group selection (Figure 25) and classified as a type of selective harvest by some foresters. Clearly, the impacts on wildlife, recreation, and watershed of this type of harvesting are quite different from those of 32 ha clearcuts. Single-tree selection also differs from group selection in its impacts on the forest since even a very large forest-grown oak, elm, sweetgum, or maple would seldom cover more than 0.04 ha with its crown. Group selection is a way of avoiding the high marking and logging costs of single-tree selection, avoiding the extreme wildlife and recreation impacts of larger clearcuts, and maximizing the beneficial edge and diversity effects of clearcutting. Small openings in large hardwood forests benefit deer (McCafferty and Creed 1969), turkeys (Stoddard 1936), and songbirds (Lay 1938). Small openings occur naturally in old-growth forests, but wildlife in the more uniform second-growth forests can benefit from clearings produced by periodic small clearcuts. However, some of the timber production benefits of clearcutting are lost, because the openings are not large enough to give loblolly pine and sweetgum the strong competitive advantage they get on large clearcuts, and because logging costs are still higher than on larger cuts. Finally, the flexibility and precision of individual tree selection is lost. A technique even more beneficial to wildlife, with aesthetic and recreational values, is to maintain small, scattered openings by mowing, burning, or growing food plots (Healy and Nenno 1983).

Ways of reducing the damage to wildlife, aesthetics, recreation, and other values by clearcutting or highgrading hydric hammock are to limit the size of individual cuts and to design their shape and location to maximize contrasting edges and the interspersion of habitats (Harris and Smith 1978). Most wildlife species do best in a diverse habitat, and most people prefer diverse scenery. Therefore, in large, uniform forests of hydric hammock, some clearcutting or highgrading in small, irregular patches is probably beneficial. Because few such tracts now exist, logging of mature hydric hammock is not beneficial or advisable if wildlife, aesthetics, recreation, and urban open space are the only considerations. The amount, size, and rotation length of well-placed, irregular clearcuts should be based on the priority of the uses being considered. Where timber or grazing is the primary use of the land, the size, shape, and other factors of logging operations are best determined by economic factors, sustained yield considerations, and Florida's *Best Management Practices* (Florida Division of Forestry 1980), which requires buffer strips along waterways and proper road, bridge, and culvert construction to minimize water pollution.

Rotation length (the time between harvests) is one factor to consider in the even-aged management that results from clearcutting and, to a large degree, from highgrading. Again, where timber production and grazing are the primary uses of the forest, rotation length can be determined on the basis of maximum return on investment, usually between 30 and 50 years in hydric hammocks. Pines generally are grown on shorter rotations than hardwoods, although there is considerable variation in both due to the many different products for which timber is grown. Longer rotations are desirable if multiple uses are being balanced and integrated. Following a clearcut in hydric hammock, browse is ample, but mast production is scanty and few cavities are available for wildlife dens and nests. From 10 years of age until age 20 or 30 years, the hammock is a dense stand of young trees with almost no ground cover, browse, mast, or cavity space. Subsequently, diversity and wildlife value of hydric hammock increase; the ground plants recover, some trees die, others develop cavities, and many mature to mast-producing age. Tree cavities that provide shelter and nest sites for many wildlife species will increase many fold during this process (McComb *et al*. 1986). The species composition of hydric hammock may influence the selection of rotation length, particularly if an old-growth condition is to be attained before the stand is cut. Swamp laurel oak reaches maturity in about 50 years (Fowells 1965), loblolly pine in about 150 years, and sweetgum in about 200 years (Harlow and Harrar 1958). Live oak, southern red-cedar, and cabbage palm are probably similar to or longer-lived than sweetgum, whereas hornbeam may be even shorter-lived than swamp laurel oak. The economic maturity of these species for timber production is much shorter than these values. Where to set the rotation age in a particular instance depends on the relative demands and priorities of the uses, and on the condition of the stand and the surrounding forest.

Wildlife, recreation, and aesthetic values of many hydric hammocks can be increased by identifying sites of particular significance for these purposes and keeping them in an old-growth condition. In the case of the private timber grower, the sites may be quite small and located around sinkholes, on steep slopes, along streams, or in other places that cause logging problems anyway. In hydric hammocks being managed for multiple uses, the sites should be much larger, and in hydric hammocks being managed specifically for uses other than timber and grazing, old growth might well be the optimal condition.

How logs are felled and removed from the forest is another factor that should be considered in timber management. Access or logging roads usually must be built or improved. A set of guidelines (*Best Management Practices*) detailing how to avoid siltation and other environmental problems associated with constructing logging roads and culverts is available (Florida Division of Forestry 1980). Even when these guidelines are followed, problems can occur when fill is used to construct roads across drainages and wetlands. Culverts need to be large and numerous enough to handle flood conditions and allow water circulation in wetlands. In general, the use of fill should be minimized, and, in some cases, the fill roads should be removed after logging is complete.

The logging itself usually involves heavy equipment like big skidders and hydraulic shears, which cause large ruts, soil compaction, and erosion if the soil is soft (Hatchell *et al*. 1970). This equipment can also cause a lot of damage to the trees remaining in a selective cut, unless the logger is careful and the logging is supervised closely. The best way to reduce the soil damage is to log only when the soil is dry. A timber contract can be written so that the landowner has the power to stop the logging when the ground is too wet. Requiring the large machines to take a different route through the woods on every trip prevents deepening ruts in the soil and distributes the impact evenly over the site. This practice is preferred (provided that the soil is not too soft or wet) for clearcuts where some additional site preparation from the logging operation is desired, but for selective cuts it is undesirable, because it maximizes damage to the remaining trees and to the understory, shrub, and ground-cover vegetation. Skidder ruts or trails can channelize water flow, increasing erosion and drainage and reducing the water storage and filtering function of the forest. This damage can be reduced by planning the logging so that most skidder routes go parallel with the contours of the land and across the direction of water flow. If the site is too difficult to log with skidders, or if the damage that would result is unacceptable, there are some alternatives. Small timber can be logged by chainsaws and medium-sized trucks. If the target is big and valuable sawlogs and ply logs, logging may be done by helicopter, though this is obviously much more expensive. A third possibility, seldom available, is the use of draft animals for skidding. Use of a portable winch to do some or all of the skidding can greatly reduce logging damage and may be the most economical method for small thinning operations (Post 1986).

### 5.2.2 Timber Stand Improvement

Timber stand improvement is the selective killing of unwanted trees or other vegetation. It is used for trees that are not salable or cannot be removed without excessive damage to the forest. Some small trees and most vines can be killed by cutting the stem. When trees are larger than about 10 cm in diameter and are not too numerous, they can be killed by girdling with an ax or machete and completely removing a belt of bark and cambium about 10 cm wide from around the trunk. Girdling is most effective and easiest in the spring when the cambium is actively growing. A more certain way of killing individual big trees is to inject them with herbicide. Several types of herbicides and injectors are available that work well (Haywood 1986). For killing small trees or shrubs, applying a systemic herbicide mixed with diesel, fuel oil, or kerosene to the basal bark or stem of the plant may be the most effective and efficient method (Haywood 1986). Hexazazinone, applied on the ground either as pellets or in liquid form, kills most woody plants, and, at the right dosage, can kill hardwoods without affecting associated pines and palms. Because oaks and many other hardwoods are particularly sensitive to this chemical, it cannot be applied near hardwoods that are to be saved.

Timber stand improvement is generally more precise and delicate than logging, and it can be applied in small and widely scattered locations. It is commonly used to release young, potentially valuable timber trees from competition with culls and unmerchantable species, but it is also ideally suited to releasing trees that have or will have high wildlife or aesthetic value. For instance, if a hydric hammock has very few live oaks, which are generally of high value for wildlife and aesthetics, these can be freed from competition. The old oaks will live longer and the young ones will grow faster and have a better chance of surviving to maturity. Diversity may be increased by releasing individuals of any uncommon component of the forest. Den trees and special nest trees could also be released. Killing a few trees each year improves habitat for woodpeckers by providing a continuous supply of feeding and nesting trees.

Not all trees benefit from competitive release. Killing trees around one already well situated in the canopy can hurt the tree by killing roots to which it is root-grafted, by opening the canopy enough to make it more subject to wind damage, or by triggering root-rot diseases or pest insect populations.

### 5.2.3 Regeneration

The regeneration of hydric hammocks involves another set of techniques that can be used to shape the forest to benefit various uses. There are two categories of regeneration: natural, in which the forest reproduces itself, and artificial, in which seed is applied or seedlings are planted (Smith 1962). Natural regeneration is almost always used in hydric hammock, except where a pine forest is the desired result. Hydric hammocks regenerate very easily and prolifically, and any sort of logging, fire, hurricane damage, or similar disturbance will be followed by abundant regeneration. The question for management is whether or not and how to influence the composition and condition of the reproduction. Factors affecting this decision are the composition of the original stand in terms of species that will root- or stump-sprout, composition of the suppressed seedlings and saplings that will respond to release, seed sources remaining after the disturbance (seeds in and on the ground and in seed trees), the timing (e.g., season) and severity of the disturbance (Johnson 1977), and subsequent events such as droughts, floods, browsing by livestock and deer, and fires. In general, the next stand will be dominated by the seedlings and saplings that remain plus sprouts from vigorous sprouters like sweetgum and persimmon. Oaks, elms, bays, redcedar, and cabbage palm generally have enough seedlings in the understory to regenerate the forest, so these species have the advantage if the forest is disturbed gently enough that most seedlings and saplings survive. More severe disturbance favors the sprouters and seeders, such as sweetgum, a common component of the forest and a prolific sprouter and seeder. The only tree more favored by severe disturbance is loblolly pine, which needs the competing vegetation set back heavily to enable it to start from seed and outgrow its competition. Natural loblolly pine reproduction is greatly benefited by burning in the spring or summer and logging in the late fall and winter, because the seeds fall on mineral soil and are covered during the logging disturbance at the proper time of year to get a good crop of seedlings (Haymond 1983). Burning and logging are disturbances that help to control competing vegetation; cattle grazing favors the regeneration of pine and cabbage palm.

Leaving seed trees is another way of obtaining pine or hardwood reproduction after logging. Alternative procedures are to leave 5 to 10 seed trees per acre (seed-tree cut) or to leave 20 to 40 seed trees per acre (shelterwood cut). The shelterwood method can work well for loblolly pine if an adequate thinning and prescribed burning program is done in the decade prior to harvest. It also may work well for regenerating oaks if there are adequate preliminary thinnings (McKnight and Johnson 1980). However, shelterwood and seed tree harvests often are less effective than winter clearcutting for obtaining loblolly pine reproduction in Florida hydric hammocks, because the seed falls after the disturbance and after the competing vegetation has begun to recover. Furthermore, many of the trees left to supply seed may die from the stress of logging damage to root systems, soil compaction, windthrow, and the increase in insect and disease populations following logging. This loss, combined with the cost of having to log the area again if the remaining seed or shelterwood trees are to be salvaged, can make this a very expensive way to regenerate the forest.

Establishing hydric hammock on old fields, pastures, and reclaimed surface mines that were originally hydric hammocks is best accomplished by first planting loblolly or slash pine. When the pines grow large enough to suppress the weeds and grasses and to provide perches for birds, many of the hydric-hammock species of trees and shrubs will become established under the pines if a seed source is nearby. If there is no seed source, or if a particular species composition is desired, some planting or seeding of the desired species can be done. This method closely imitates the old-field succession that occurs naturally on abandoned sites in Florida. When the pines are large enough to harvest, some or most could be cut and sold, but this would set back the development of the hammock by damaging the young hardwoods and by reducing soil fertility through nutrient removal and soil compaction.

**Figure 26. Fire scars on cabbage palm in hydric hammock, Seminole Ranch, in the upper basin of the St. Johns River.**

### 5.3 FIRE MANAGEMENT

Hydric hammock is not generally considered a fire-adapted community, and fire does not naturally occur there with nearly the frequency found in high pine or pine flatwoods (Harper 1915; Laessle 1942; Wells 1942). However, the authors found evidence of fire in at least parts of all the hydric hammocks we visited and throughout many of them (Figure 26). Certainly the edges of hydric hammocks adjacent to fire-adapted communities like pine flatwoods and prairie are subject to fire on occasion. Indeed, the location, structure, and species composition of the edge between the two communities is determined partially by fire (Vince *et al.* 1989). Clearly fire is a tool that can be used to keep hydric hammock from encroaching on other communities.

Fire also can be used to control the structure and species composition within some kinds of hammock. Both the forest floor beneath hammocks dominated by loblolly pine and the leaf litter beneath cabbage palm are highly flammable. Prescribed fire often is used in loblolly pine hammocks to reduce hardwood regeneration and to maintain the pine domination of the forest (Jerry L. Clutts, Ocala National Forest; pers. comm.). Hydric hammocks on ranches are burned occasionally to eliminate shrubs, small trees, and some larger trees, encouraging growth of grasses, sedges, and other herbaceous plants favored by cattle. Prescribed burns often are conducted in early spring to remove the tough, old grass and stimulate the production of tender, new grass for cattle grazing. These hammocks become very open beneath the canopy and usually consist of cabbage palm, live oak, and sometimes loblolly pine (Figure 23). Harlow (1959) attributed the maintenance of cabbage palm hammocks to frequent burns (every 2 to 3 years). One very severe fire was sufficient to eliminate all the trees except cabbage palm from a hydric hammock containing a mixture of cabbage palm, live oak, and southern red-cedar at Tosohatchee State Reserve (Randall E. Hester, Florida Department of Natural Resources; pers. comm.).

The use of controlled burning or the active protection from fire of a hydric hammock are forest management actions that should be considered based on the desired condition of the forest. When the management goal is a forest of merchantable hardwoods such as sweetgum, fires can be calamitous (Putnam *et al.* 1960). Even low-intensity fires that do not kill the hardwoods may wound the trees, leading to fungal attack (Kaufert 1933). Fire favors cabbage palm, loblolly pine, and live oak in the overstory; removes vines, shrubs, and understory trees; and increases grasses, sedges, and other herbs in the ground cover. Frequent, mild fires favor loblolly pine; severe, occasional fires strongly favor cabbage palm; and fire protection favors sweetgum, swamp laurel oak, elms, maples, mulberry, sweetbay, etc. in the overstory and hornbeam, wax myrtle, hollies, etc. in the understory. Southern red-cedar is very susceptible to fire but is salt-tolerant (Putnam *et al.* 1960); it cannot compete well in a dense forest of the fire-intolerant species. Along the coast, where these competing species are removed by salt stress, red-cedar benefits from fire protection.

Prescribed burning may be used as an aid in regenerating loblolly pine on hydric hammock sites. Annual burns for several years prior to logging enhance the probability of obtaining successful natural regeneration of loblolly pine (Haymond 1983). Summer fires are particularly effective in controlling the hardwood understory of loblolly pine stands (Lotti *et al.* 1960), and they are also much more effective than winter fires in preparing a good seed bed (Ferguson 1958). Hot fires are very helpful in preparing sites for planting pines because they control hardwoods and reduce logging slash and other debris that would hinder site preparation and planting operations.

## 5.4 WATER MANAGEMENT

The frequency, duration, depth, and time of year of flooding, as well as the depth of the water table and its fluctuations between floods, all influence the character and extent of hydric hammocks. Other factors such as soil characteristics and water quality may interact with flooding to affect plant growth and composition in these forests. Many of the relationships among water, soils, and hydric hammock plants are poorly understood. However, numerous studies in the laboratory and field have shown that wetland tree species differ in their tolerance to inundation (summarized in Gill 1970; Teskey and Hinckley 1977). These data and correlations of tree-species distribution and flood characteristics in southeastern floodplain forests (e.g., Bedinger 1978; Leitman *et al.* 1983) permit some general water management guidelines for hydric hammocks.

The main kind of water management problem in hydric hammocks is the mitigation of existing or proposed alterations to the natural hydrological regime. Regional water management plans increasingly call for the purchase of forested and other wetland areas to detain and store flood and stormwater flows. Impacts on the hydrology of hydric hammock reserves will depend upon the rate and nature of development in the watershed; as urbanization increases and water infiltration into the soil of upland areas decreases, hydric hammocks will receive more frequent and greater peak flows of runoff. Dams, upstream diversions, water table drawdowns, and discharges from power and wastewater treatment plants, industry, and agriculture influence the amount and quality of inflow to hydric hammocks. Logging and concomitant road-building in hydric hammocks have multiple effects on both on- and off-site hydrology (see section on Timber Production). The hydrological consequences of timber harvesting in hydric hammocks are mainly associated with removal of the canopy, use of heavy machinery, and road construction. The effects increase with the intensity of logging and site preparation, but generally are short-term. Similar but more severe and long-lasting impacts can be expected to result from land clearing for other purposes such as agriculture and real estate development, where the land is permanently cleared and greatly compacted.

### 5.4.1 Mitigation of Impacts of Timber Production

Silvicultural "best management practices" are designed to reduce nonpoint source pollution from forest lands and are implemented on a voluntary basis in Florida (Florida Division of Forestry 1980; Riekerk 1983). In forested wetlands occupying areas of low slope, the main recommendation is the retention of buffer strips along open waterways. These forested tracts decrease runoff velocity and, depending on the width of the strip and the volume and rate of flow, retain some of the nutrient and sediment load. The width necessary to achieve desirable water quality will vary with the slope, soil type, and extent of logging disturbance. Best management practices for roads include careful siting and construction so water drainage is not impeded. Culverts should be frequent and properly sized. Road construction should be minimal and carried out during the dry season. Log skidding and mechanical site preparation, which also require heavy machinery, should be restricted similarly. Good forest and water management requires that cleared areas are rapidly revegetated. Dense canopy will intercept rainfall and lessen soil erosion; plant uptake of water and nutrients will further decrease soil losses and return the water table to pre-disturbance levels. Sites with severely disturbed soils, such as log decks, may require seeding or planting. Clearcuts or other forest clearings (e.g., for agriculture or buildings) should be small and interspersed among undisturbed hammock stands.

### 5.4.2 Mitigation of Impacts of Wastewater Disposal

Stream diversions and aquifer drawdowns provide water to agriculture, industry, and Florida's rapidly expanding population. To moderate the impacts of water removal on a hydric hammock, either the drawdown must be reduced or an additional source of water must be found to substitute for the loss. Some possible sources are underlying aquifers, stormwater runoff from developed areas, and wastewater discharges from power plants and sewage treatment facilities.

Restoring stormwater and wastewater to a usable condition is a goal of regional water management. One approach is filtration through wetlands, which achieves tertiary treatment of sewage effluent while returning the water to the aquifer or surface flows. Impacts of wastewater additions on the hydroperiod of hydric hammocks and concerns about the filtering capacity of these wetlands have already been discussed (see Chapter 4.7).

Water management options for introducing wastewater into hydric hammocks include regulation of the water depth and flooding duration and frequency. Because virtually no data exist on which to base appropriate levels, the safest procedure is to develop an experimental plan that would allow assessment of several different scenarios (G. Ronnie Best, Center For Wetlands, University of Florida; pers. comm.). If possible, a small part of the hydric hammock should be treated with water regime alterations on an experimental basis for several years before applying the same techniques to a larger area. The first step is site selection. Hydric hammocks with an abundance of species that are tolerant, or moderately so, of flooding, such as cabbage palm and red maple, are most suitable since these would be least likely to be adversely affected by increased hydroperiod. Those hammocks with moderately high levels of organic matter in the soils probably have the greatest capacity for nutrient and contaminant retention. The requisite size of the site will depend upon the amount and rate of wastewater to be discharged; the hammock must be sufficiently large to ensure slow water velocity and a water retention time of at least several days. If the wastewater is held on the wetland for a period of less than 3-5 days, removal rates of nitrogen and biological oxygen demand (BOD) greatly decrease (Robert L. Knight, $CH_2M$ Hill, Inc., Gainesville, Florida; pers. comm.). Present hydraulic loading rates of wastewater into Florida wetlands are on the order of 2.5-13 cm per week, although one swamp receives 25 cm per week. The concentration of nutrients in the wastewater also must be considered when determining the size of hydric hammock required for adequate rates of removal. Retention of water in an impoundment prior to discharge into the wetlands may aid the effectiveness of nutrient removal by stabilizing flow rates. Wastewater should be allowed to spread in a shallow layer over the hammock. Harms *et al.* (1980) observed little mortality among mature wetland hardwood trees, including oaks and Florida elm, exposed to average water depths of 52 cm or less for seven years (see Figure 18), but at least two drydown periods occurred within that interval. Drydowns are a necessity in hydric hammocks because none of the woody plant species in this community can withstand continual inundation throughout the growing season (Gill 1970; Teskey and Hinckley 1977). However, the duration of flooding that can be tolerated, and the length of the following aeration period, can only be conjectured. A review of the flood tolerance of wetland tree species (Teskey and Hinckley 1977) suggests that mature hydric hammock trees remain healthy even when flooded for 17%-37% of the growing season. However, the seedlings are more sensitive to inundation: survival drops sharply after 10 days of flooding. Division of the hydric hammock into separate receiving cells would allow for the continuous discharge of wastewater into the wetland without exposure of any particular area to constant inundation. Duration of flooding and drydown periods could be varied among the cells, permitting an experimental evaluation of the effects of these variables on the plant community and on nutrient removal. Any program that adds wastewater to a hydric hammock should include careful, long-term monitoring that assesses both the health of the existing stand and its regeneration. Nutrient concentrations in the outflow must be measured to ensure that increased levels are not added to downstream waterbodies.

## 5.5 WILDLIFE MANAGEMENT

A broad range of wildlife management techniques is applicable to hydric hammocks. These involve management of habitat quantity and quality, and management and protection of wildlife populations.

### 5.5.1 Management of Habitat Quantity and Quality

Given the diverse and abundant wildlife occupying hydric hammock (Vince *et al.* 1989), conserving the maximum possible amount of this habitat is probably the single most important consideration for wildlife management. Hydric hammock is, on average, less valuable for timber production than many other types of forest. In times of economic recession, this habitat often is available for purchase from timber companies. Substantial portions of hydric hammock not converted to other uses has come under public ownership, including parts of Chassahowitska National Wildlife Refuge, Waccasassa Bay State Preserve, Big Bend Wildlife Management Area, Lower Suwannee River National Wildlife Refuge, St. Marks National Wildlife Refuge, San Felasco Hammock State Preserve, Silver River State Park, Seminole Ranch, Tosohatchee State Reserve, and Myakka River State Park. All these areas are or will be managed for conservation by public agencies. Additional acquisitions of hydric hammock for this purpose can be anticipated in the future.

Conversion of hydric hammock to other uses usually substitutes wildlife communities with less diversity and abundance of wildlife than normally supported by hydric hammock. How this affects the regional fauna depends on the configuration of management units. Because clearcut areas will support a different set of animal species than undisturbed hydric hammock, the overall diversity of wildlife across management units may increase if the new land-use pattern creates a more complex mosaic of habitats. On the other hand, regional diversity may decrease if clearcutting, livestock grazing on native pastures, or farming are common practices nearby, even if these other lands were not originally hydric hammock. The reason is that the set of wildlife benefited by clearcuts in hydric hammock is essentially the same as that benefited by fallow fields, native pastures, and clearcuts in most other forest types.

A related practice important to maintenance of the wildlife of hydric hammock is to maintain the existing interspersion of hydric hammock with upslope and downslope habitats. As documented for turkey, squirrel, and deer (Vince *et al.* 1989), some of the important wildlife species depend on movement among these habitats seasonally; loss or impoverishment of one of the habitats may diminish the carrying capacity for an overall population spanning several habitats. Probably the lumbering of cypress swamp had this effect on ivory-billed woodpeckers that also used hydric hammock. Perhaps the most important such negative effect on wildlife populations has been the large-scale conversion of mesic hammock to pine plantations, which has eliminated the best habitat available to deer during summer flooding. Where mesic hammock is lost, the adjacent hydric hammock can support only the resident gray squirrels; buds of elm and red maple that could also sustain temporary immigrants from mesic hammock during late winter become an underused resource. Loss of the mesic hammock upslope also has reduced mast-producing habitat for a long list of wildlife species, including many of the largest and most important game species such as turkey, squirrel, bear, deer, and feral hog. Data from other habitats in Florida (flatwoods and scrub) demonstrate that the body mass of deer is correlated with levels of mast production (Figure 27; Harlow and Tyson 1959; Harlow 1965). Because subsequent fecundity and survival of offspring are directly related to body condition, the amount of mast available appears to determine the productivity of deer populations. This implies that loss of the upslope mesic hammock should cause a reduction in the carrying capacity of the adjacent hydric hammock for deer.

The second important consideration for wildlife management in hydric hammock is habitat quality. Several inherent characteristics make hydric hammocks high-quality habitats for wildlife (adapted from Harris *et al.* 1979; Wharton *et al.* 1981; Harris and Mulholland 1983): the abundance of sites for nests and shelter at ground level (tree bases) and in the canopy (tree cavities); the ready supply of water in small ponds and streams; the abundance of broadleaf evergreen trees that provide cover and food in winter; high plant productivity; the diversity of mast, soft fruit, and browse that provides abundant food most of the year; and high diversity of plant species and structure, including a variety of tree ages, forms, and strata. Wildlife management should aim to maximize these features in each tract of hydric hammock.

Probably the single most influential management practice in hydric hammock is timber harvest and the consequent plant succession. Historical cutting of the original forest made changes on a massive scale. The major effects on wildlife were a loss of habitat quality to species adapted to the climax conditions and a gain of habitat quality for species adapted to early successional stages. Tanner (1942) showed that clear-cutting of hydric hammock and other types of forest was a major cause of the extinction of the ivory-billed woodpecker. Swindell

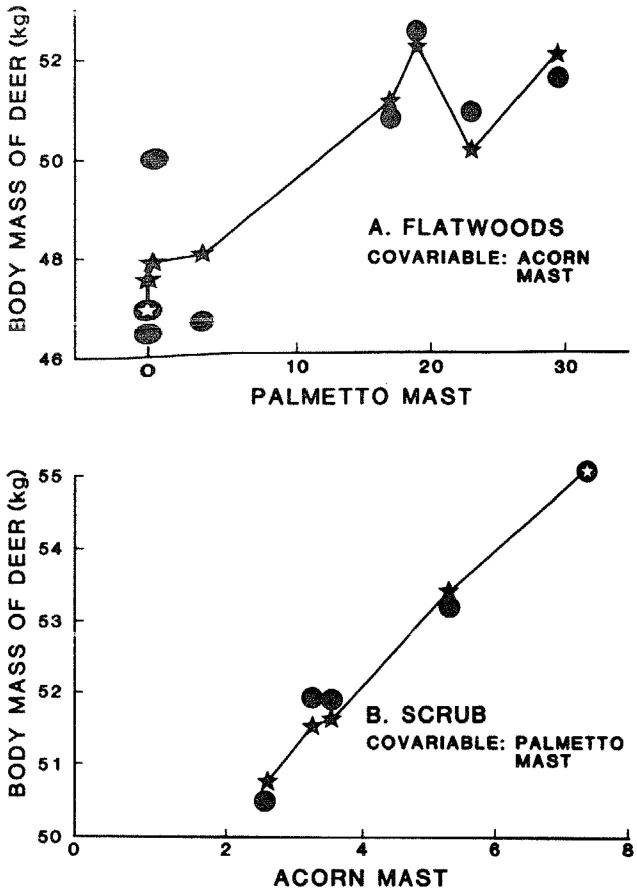



**Figure 27. Relationship of deer body mass to mast production in two Florida habitats (●). Lines connect predicted values (★) calculated by simple linear regressions (*P* <0.05) from data in Harlow (1965: pp. 100-101): (a) plot of 1.5- and 2.5-year-old deer mass vs. percent of palmetto plants bearing berries in flatwoods habitat, with the average number of scrub oak acorns per shrub treated as a covariable; (b) plot of 1.5-years and older deer mass vs. average number of scrub oak acorns per shrub in scrub habitat, with the average number of palmetto berries per plant treated as a covariable.**

(1949) reported that wild turkey and white-tailed deer first were favored when lumbering brought primary productivity down to ground level but then declined in numbers (probably below levels sustained in climax forest) as succession reestablished a dense, closed canopy of trees.

The major techniques used to manage hydric hammock habitat have already been discussed above under management of timber, fire, and water. Many of these can be used to promote wildlife use and production. Selective cuts that remove competing trees can favor the growth of mast-producing trees. An extreme example was the removal of southern red-cedar from coastal hydric hammock, which now includes live oak as a co-dominant species. Presumably the present-day coastal hammock is much more valuable to wildlife than 100 years ago (after logging of live oaks), because live oaks are again abundant there. Thinning of the canopy in hydric hammock increases food production in the understory and its use by white-tailed deer (Figure 28). Additionally, the dense, brushy vegetation in openings will satisfy the cover requirements of some wildlife species. By increasing the foliage layers beneath the canopy, thinning and selective harvests should result in greater bird density and diversity (Dickson 1978). Clearcutting can be compatible with wildlife management, provided that the cut areas are small enough, infrequent enough, and situated to maintain a high diversity of plant species and age classes (up to and including old-growth stands with cavity trees) in the hammock. Finally, if maintaining populations of squirrels, woodpeckers, barred owls, or canopy-dwelling songbirds is the primary management goal, then clearcutting reduces habitat quality.

The multistratal structure of hydric-hammock vegetation may be a key

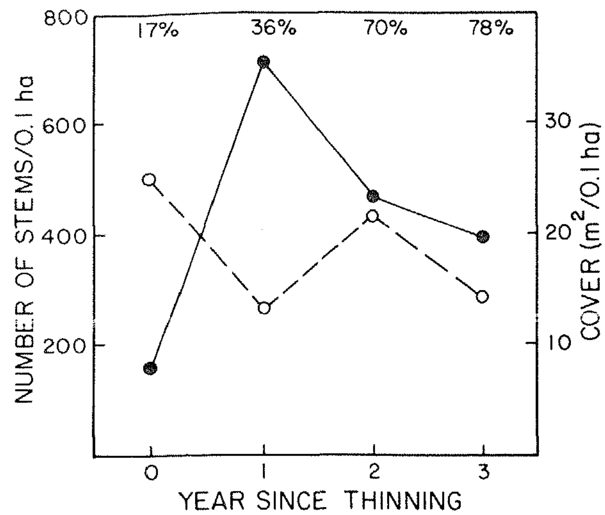



**Figure 28. Effects of forest thinning on the number of stems (●) and cover (○) of species browsed by deer. About 50% of the basal area of mature stems was removed from the cabbage palm-dominated hydric hammock. The percentages indicate the proportion of twigs browsed by white-tailed deer (adapted from Harlow 1976).**

to the high diversity of the bird community occupying this habitat. The diversity of niches available to forest birds is positively correlated with the structural heterogeneity of the vegetation (MacArthur and MacArthur 1961; Roth 1976). One possible implication is that the relatively high diversity of the bird community (Vince *et al*. 1989) actually has been depressed from presettlement levels by historical timbering. Such an effect would be felt to varying degrees throughout the period of recovery to old-growth condition.

In all systems of timber harvesting, some wildlife species can be aided by marking and saving trees with the capacity to provide dens. Black bear, bobcat, gray squirrel, flying squirrel, raccoon, opossum, woodrat, cotton mouse, bats, wood duck, woodpeckers, barred owl, flycatchers, tufted titmouse, Carolina wren, eastern indigo snake, and several other species of snakes, lizards, and treefrogs require or are benefited by den trees for nesting and brood-rearing, shelter, or seclusion from predators. Other specific habitat features that may be required for targeted wildlife species to be successfully managed include preferred nest sites, breeding ponds, bedding sites, stands of rare or special plant species, and grazing areas. Good management of these specific sites requires that they be identified and protected. Protecting important spots of habitat involves finding and recognizing them in the field, locating them on a map, remembering them when planning any action that might cause damage (such as logging, timber stand improvement, draining, surveying, road or trail construction, burning), teaching personnel how to recognize and protect them, marking them with flagging before beginning the activity, and then supervising the threatening activity. It is particularly important to avoid scraping off or building on the rare high spots in a hydric hammock (or in any other periodically flooded or poorly drained habitat), because these supply special habitat benefits for a variety of species. Periodic manipulation may be needed to maintain important spots of habitat. For instance, a large, grassy opening in a hydric hammock that is important feeding habitat for young turkeys probably would need to be burned or mowed periodically. Similarly, a combination of grazing, mowing, and burning might be needed to maintain good bluebird habitat on a hammock's prairie edge.

The population of wild turkeys in hydric hammocks could be increased substantially by creating small clearings throughout the hammock. These clearings provide important foraging habitat, especially for the mainly insectivorous poults. Probably the original forest had such clearings widely available as a result of treefall light-gaps, but secondary forest probably has a denser and more homogeneous canopy for at least a century after lumbering. Foraging habitat for poults also can be provided by frequent summer burning of pine forests adjacent to hydric hammocks.

Artificial enhancement of habitat, supplemental feeding, installation of nest boxes, and pond construction are supplemental ways of improving habitat for wildlife. Where food supplies are abundant, but natural nesting sites are rare, artificial nesting structures can be very successful in increasing wildlife populations (Yoakum *et al.* 1980). Cavity nesters such as barred owls, flycatchers, and flying squirrels can be aided by nest boxes placed in second growth hydric hammocks that lack the abundant natural cavities of mature hammocks. Many cavity-nesting species willingly accept artificial houses (McComb and Noble 1981) if the nesting boxes are properly designed and placed. Yoakum *et al.* (1980) give plans for making housing structures of benefit to a variety of wildlife species including wood ducks, woodpeckers, and squirrels. Hollow trees without openings (consult a timber cruiser) may be converted to den trees by creating openings.

Food plots on the hydric hammock edge or on clearings within can benefit populations of deer, turkeys, and other animals. Truby Lee (Florida Game and Fresh Water Fish Commission, pers. comm.) makes the following general recommendations for food plots in Florida hydric hammocks. Plots should be one to two acres in size. They should be fertilized with each crop, or at least annually, with a balanced fertilizer containing nitrogen, potassium, and phosphorus, and should be limed if needed (liming and fertilizer needs can best be determined using soil tests), because the main value of the food plots is the high nutritional value of the food due to fertilizing. The plots should be planted in early March with some combination of chufa, benne (sesame seed), millet (browntop, pearl, or proso), low-growing sorghum, corn, and field peas (iron clay or combine). The plots should be planted again in late September with some mixture of oats, wheat, winter rye, and gulf ryegrass. In addition, some plots can be maintained year-round in joint vetch or perennial peanut. Interplanting of nitrogen-fixing legumes in hammock land converted to pine plantations may be a way to improve both pine growth and herbaceous forage for wildlife.

Pits often are dug in hydric hammocks to obtain road building material. Proper location and design of these to create ponds can provide breeding sites for toads, tree frogs, and salamanders, and additional habitat for wood ducks, otters, indigo snakes, frogs, turtles, fish, alligators, wading birds, and kingfishers. The habitat value of the area can be increased further by using extra fill to create a small hill nearby, which would provide a bedding, dusting, nesting, burrowing, and high-water refuge for various animals.

Nesting and refuge cover can be provided for wildlife species by constructing brush piles from logging or land-clearing debris. These are especially effective when placed in clearings within hydric hammocks or on the forest edge. A small clearing and a brush pile can be created simultaneously by felling a group of low-value trees on top of one another in the center of the area that is to become the clearing. This is a beneficial technique in 10- to 40-year old second growth hammocks that have uniformly dense canopies and little terrestrial cover or structural diversity. Plant colonization of brush piles adds to their value by providing additional food and cover. Windrows and piles that result from clearcutting and site preparation (Figure 29) are particularly important and should not be burned, because frequently they provide the only remaining cover on the clearcut area. Species benefited by windrows and brush piles include bobcat, raccoon, opossum, cottontail rabbit, woodrat, cotton mouse, Carolina wren, brown thrasher, towhee, white-eyed vireo, eastern indigo snake, and several other species of snakes, lizards, and salamanders.

In addition to techniques that protect or enhance characteristics of the environment, steps can be taken to decrease the influence of features that negatively affect wildlife populations. Cattle grazing and browsing in hydric hammocks can greatly reduce the availability of forage for deer (Figure 30). Conversely, harvesting timber can benefit deer by increasing the amount of forage available, even when cattle are present. Fencing to exclude cattle is recommended when the hammock is small and management for white-tailed deer is a priority (Harlow 1959), because the two species compete for food. Invasion of hydric hammocks by exotic plants, like cogon grass, can adversely affect habitat quality for wildlife. If the forest is surveyed frequently, the initial entry of some exotics may be detected early enough for them to be eliminated before control becomes impossible. Once well established, the only hope for control of most undesirable exotic plants is the development of some means of biological control. On a regional basis, this is the most cost effective and permanent solution to exotic pest problems.

**Figure 29. Debris pile on a hydric hammock site two years after clearcutting.**

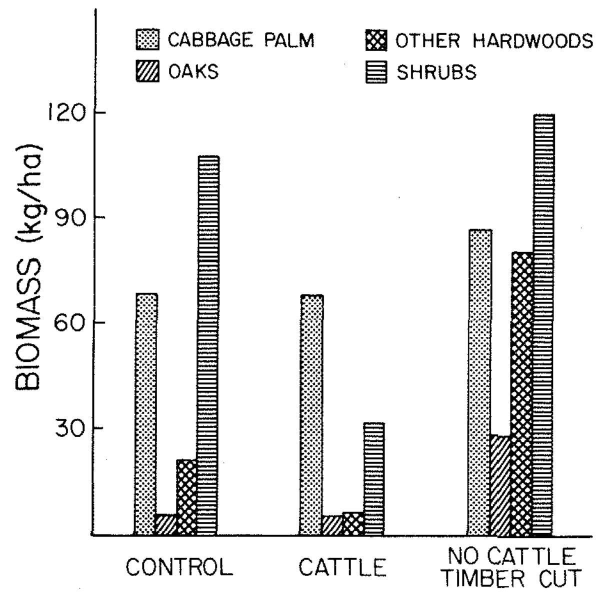



**Figure 30. Effects of cattle browsing and timber cutting on hydric-hammock vegetation (adapted from Harlow 1959).**

5.5.2 Management and Protection of Wildlife Populations

Elimination of poaching within refuges and in hydric hammocks elsewhere and regulation of hunting, where allowed, are primary concerns of wildlife management. Without adequate protection, many species of animals and some species of plants may be greatly reduced or eliminated. Some species that are vulnerable to or have been damaged by unrestrained exploitation in Florida's hydric hammocks include: panther, red wolf, black bear, white-tailed deer, wild turkey, swallow-tailed kite, indigo snake, and needle palm. Several management alternatives are available to deal with poaching. The owner or manager can fence, post, and patrol the land without outside help or with help from the Florida Game and Fresh Water Fish Commission. If the area is very large or is adjacent to a public game management area or a private hunting club area, it can be leased for hunting with the desired wildlife protection specified in the contract. This protection by lease often works well, particularly with private hunt clubs of local people, because the lease holders generally can provide better protection than the owner or manager can, except in the case of public lands where the managers have both the personnel and legal authority to do a good job. In fact, even the species that are hunted by the lessors will often become more abundant due to the protection from poaching provided by the hunt club.

Legal hunting in hydric hammocks and elsewhere in Florida is regulated by the Florida Game and Fresh Water Fish Commission. However, minor adjustments to address local problems or desires may be made by the land manager. For instance, if the local turkey population has declined, the winter turkey season could be closed or the shooting of hens could be banned for a year or two. If the local deer population is getting too large, the Game Commission usually will allow special doe hunting permits. Wild hogs on private property are not governed by the Florida Game and Fresh Water Fish Commission; the manager may determine harvest limits, methods, and season if the hogs are desired as game, may manage the hogs as domestic livestock, or may exterminate them if so desired.

Jennings (1951) concluded that in good habitat like hydric hammock, hunting is the primary factor determining the maximum density of gray squirrels. He further noted that hunter success is not determined by the density of squirrels but rather by the level of seed-storing activity. That is, during a good mast year the level of squirrel activity allowed a substantial harvest, whereas in a poor mast year, their inactivity prevented a good harvest even if squirrel numbers were high. The ideal time for a hunting season was considered to be from mid-October, after most young are weaned, to the end of December, before females become pregnant.

Although it has been argued that interest in the Florida black bear as a game species supports its conservation (Smith 1971), poaching, hunting, and road-kills have been significant factors in extirpating bears from large areas of Florida, leading to its listing as a threatened species in the State. Prior to listing, bears were not aided by active management. Since listing, their threatened status has been used to justify acquisition of habitat for conservation. Because bears are commonly hunted with dogs, populations survive only on areas with extensive escape cover (in Florida, mainly the Apalachicola and Osceola national forests) and on public lands where hunting is prohibited. Two of the three areas in Florida with healthy populations of black bears (the Osceola and Ocala National Forests) include hydric hammock among the habitats used by bears. A serious management problem is suggested by the possibility that the population in Osceola National Forest may not reproduce itself but instead may be sustained only by dispersal of subadults from the Okefenokee Swamp National Wildlife Refuge in Georgia (James Mykytka; Reynolds, Smith and Hills, Tampa; pers. comm.).

Bears' consumption of honey and honeybees creates considerable conflict with humans. Bears frequently damage apiaries and as a result are illegally shot or poisoned by beekeepers (Maehr and Brady 1982). Presently, most of this conflict is confined to apiaries located in national forests. Beekeepers on public land increasingly are being required to protect their apiaries with electric fences (Maehr

1982), which are an effective deterrent to bears (Brady and Maehr 1982). Bears that learn to penetrate electric fences become averse to beeyards after being captured, handled, and released at the capture site (Brady and Maehr 1982). Such protective measures that promote coexistence of bears and beekeeping seem necessary to maintain the components of a mutualistic system: the apiaries are placed in habitats occupied by bears partly because the flowers pollinated by honeybees (such as swamp tupelo) are of species supplying fruit to bears and regenerated in the stand partly through seed-dispersal by bears.

The presence of feral hogs in hydric hammock presents conflicting management issues. On the one hand, hogs are useful as game. On the other, they slow recovery of timbered hammock by destroying seedlings, and they compete seriously with numerous other game and nongame species of wildlife. Wild hogs directly compete for many foods, especially the fall mast crop, with native wildlife species such as wild turkey and white-tailed deer (Swindell 1949; Wood and Roark 1980). Wild hogs also may destroy wild turkey nests (Swindell 1949), and they may be significant predators on reptiles and amphibians (Archie Carr, pers. comm.). In practice, clear management decisions regarding feral hogs are seldom made on Florida hammock lands. In national forests, feral hogs are regarded as trespassing livestock. In State parks and preserves, where policy is to maintain the natural conditions of presettlement times, feral hogs are regarded as undesirable exotics. If a decision were to be made to eliminate feral hogs from an area, this could be accomplished routinely by concerted hunting with dogs. However, efforts to trap and shoot hogs have fallen far short of the exhaustive levels necessary, because of insufficient funds to pay to have the work done and insufficient will to withstand sentiment against hunting on public park and preserve land. On wildlife management areas, where policy is to maintain populations at sustained-yield levels, overhunting has been a chronic problem (Belden and Frankenberger 1977); the regulations devised have not been restrictive enough to prevent depletion of the populations. An effort has been made, with limited success, to reconcile the conflicting policies on preserves and hunting areas by trapping hogs on preserves and releasing them in hunting areas. Some new hog populations have been established in this way, but in other areas the relocation simply has provided some very expensive "put-and-take" hunting (Belden and Frankenberger 1977). Where hogs are hunted, hunting is the dominant limiting factor for all the major game species that depend on the mast crop (hogs, turkey, deer); all these populations are kept well below carrying capacity, and competition for food among the populations probably occurs only during the worst mast failures, with a transitory effect on reproduction in the next breeding season.

To sustain the whole complement of species that use hydric hammocks, large, undisturbed tracts need to be preserved as refuges. Many wildlife management techniques consider species on a one-by-one basis, identifying specific needs and prescribing appropriate actions. Management for single species has a place in hydric hammock refuges, and, indeed, refuges may be the only areas where rare and endangered species can be preserved, but primary emphasis should be on maintaining the full spectrum of native species diversity. For this purpose, hydric hammock refuges should be minimally disturbed by logging, clearing, grazing, and other human uses that significantly alter forest structure and function.

Because the number of species present is correlated with habitat area, it is useful to consider the size of hydric hammock necessary to preserve the full array of its plant and animal inhabitants. Habitat fragmentation, for example, by clearcutting or development, results in smaller and more isolated patches, each of which can support only a subset of the original community (Harris 1984). This relationship can be described by a species-area curve, but the nature of the relationship can vary greatly from one area to another; the specific mathematical relationship should be documented for the local biota in the habitat of interest. The only data available for Florida (Harris and Wallace 1984) are on summer-resident birds in mesic hammock (Figure 31). The species-area relationship predicted from territory-size data of mesic-hammock birds (Figure 31a) is remarkably concordant with actual measurements of the species-area curve (Figure 31b); each shows an average maximum avifauna of about 16 species, and each shows an inflexion point at about 8 ha, above which the size of the tract makes little difference in the number of species present. The management lesson is that nearly all the avifauna restricted to mesic hammock habitat can be retained in tracts no smaller than 8 ha.

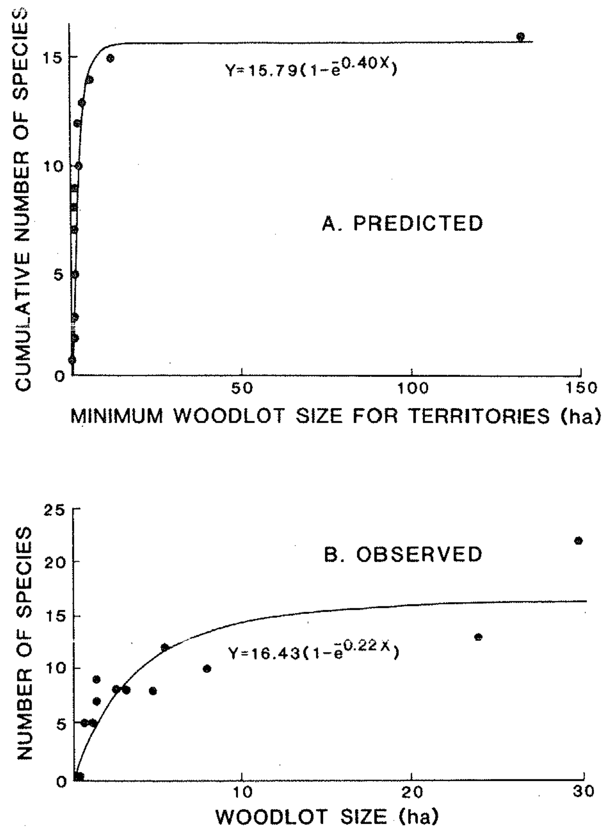



**Figure 31. Species-area curves for summer resident bird species in mesic hammock in northern Florida, in habitat islands of different size, calculated as negative exponential functions with nonlinear regression producing least-squares estimates, from data in Table 2 of Harris and Wallace (1984): (a) relationship predicted from published data on sizes of home ranges in eastern North America for species occurring in mesic hammock; (b) the number of summer-resident bird species observed in fragments of mesic hammock. Species seen at least three times in four visits were defined as residents.**

An important uncertainty must be noted, however, about the utility of the current state of knowledge of the species-area relationship: the available data do not provide insight into the size of tract needed to retain the large or rare species that occur in but are not restricted to hammocks. Considering the sparse data points on the right side of Figure 31, it should be no surprise that it is impossible to predict the area of habitat required to retain wide-ranging species like wild turkeys, swallow-tailed kites, red-tailed hawks, great horned owls, and American crows in the regional avifauna. Presumably tracts much larger than 8 ha are required for this purpose.

Several mechanisms have been shown to be responsible for the relationship between species richness and area.

First, small areas may not meet the home range or territory requirements of particular species, so these species are excluded; large animals and predators are particularly vulnerable because of their requirement for relatively large areas. Figure 31 suggests that this mechanism is directly relevant in Florida forests. Second, fragmentation of forests of the cool-temperate zone by cleared habitats allows brown-headed cowbirds (*Molothrus ater*) to penetrate the remaining woodlots, where their parasitic nesting behavior extirpates certain vulnerable species (Whitcomb et al. 1981; Brittingham and Temple 1983). These species require the deep interior of the forest away from its edges to breed successfully, because they nest on or near the ground or have open-cup nests and hence lack adaptations to prevent cowbird parasitism. Only two species of these forest-interior specialists breed this far south (the Acadian flycatcher and hooded warbler). Cowbirds are uncommon (but increasing) in this region. Third, avifaunas may become impoverished in fragmented forests when predators on ground nests penetrate the remaining woodlots (Wilcove 1985); no data are available on this factor in Florida, but absence of many of the most-vulnerable ground-nesting species within the distribution of hydric hammock suggests that this mechanism has little effect.

The ability of a hydric hammock refuge to sustain high species diversity will depend not only on the size of the tract, but also on its surroundings. A refuge embedded within a large hydric hammock, or within a mosaic of forest types, is more likely to succeed than one located in a sea of disturbance. As the area surrounding a hydric hammock becomes progressively developed, cleared, or otherwise altered, the distinctiveness and isolation of the hammock will increase. Species movements into the hammock may be hindered by the lack of suitable resting spots between the source and the hammock. Hydric hammock species that regularly use resources beyond the bounds of the forest are likely to decline. Steps can be taken to mitigate the adverse effects of small refuge size and human alterations of the landscape. One is to juxtapose hydric hammock refuges and closely related, undisturbed wetlands and upland forest, making use of the intimate ties among these communities via water and animal movements. Another may be to provide natural corridors for wildlife movement between hydric hammock patches (Harris 1984), but the technology to make this suggestion work has not yet been developed (Simberloff and Cox 1987).

## 5.6 MULTIPLE-USE MANAGEMENT

Most hydric hammocks are used for more than one purpose. Timber production, cattle grazing, and hunting are combined, and habitat for many game and non-game wildlife species is maintained, either incidentally or intentionally, on most large ranches and timber company holdings. On some publicly owned hydric hammocks such as those in state parks, high management priority is given to maintaining the full spectrum of wild plant and animal species, providing for nonconsumptive recreation, and protecting the watershed. All the above uses are combined on other public lands, for example on state and national forests. Small private landowners use their hydric hammock lands in a great variety of ways and combinations. Some uses interfere with others, but some can also be beneficial to some other uses. The key to multiple-use management is to maximize the positive interactions and to minimize the negative ones (Table 11).

**Table 11. Matrix of interactions of multiple uses in hydric hammocks based on typical current practices. Negative (detrimental) impacts of current uses on important parameters are indicated by (-) and positive (beneficial) impacts by (+).**

| Uses | Timber production | Grazing | Wildlife | Hunting | Nonconsumptive recreation |
|---|---|---|---|---|---|
| Timber production (small clearcuts) | - soil fertility<br>+ growth<br>+ quality<br>+ profit<br>+ protect | - winter<br>+ summer<br>+ costs<br>+ access<br>+ protect<br>- forage | - mast<br>+ edge<br>+- diversity<br>- cavities<br>+ protect | - squirrel<br>+- deer<br>+- turkey<br>- hog<br>- quality | - aesthetics<br>- visibility<br>- access<br>- quality<br>+ diversity |
| Livestock grazing | - growth<br>- quality<br>- profit<br>+ protect | | - browse<br>- diversity<br>+ protect | - deer<br>+- turkey<br>- hog<br>- quality | + visibility<br>- access<br>- quality |
| Wildlife protection + habitat improvement | - growth<br>- quality<br>- profit<br>+ protect | + forage<br>+ protect | + mast<br>+ browse<br>+ cavities<br>+ cover<br>+ diversity<br>+ protect | + squirrel<br>+ deer<br>+ turkey<br>+ hog<br>+ quality | + aesthetics<br>- visibility<br>- access<br>+ quality<br>+ diversity |
| Hunting | +- protect | - protect | +- protect | - all species<br>- quality | - aesthetics<br>- access<br>- quality |
| Nonconsumptive recreation | - profit<br>- protect | - protect | - protect | - quality | - aesthetics<br>- quality |

Multiple uses are accommodated in two general ways. One is to designate specific areas for each use or set of highly compatible uses. The other is to modify or regulate the uses to be more compatible with each other, without subdividing the area. Some combination of these two approaches usually is practiced.

There are innumerable examples of multiple use management. The setting aside of areas of particular value for special uses has already been discussed in Chapter 5.5. This technique is also applicable for all other uses. For example, a special area may be needed for a cattle pen or feeder, for an area of improved pasture, for a game food-plot, for keeping bee hives, for a tree-seed orchard, for a nature study area, or for a swimming, boat launching, or picnicking area. A setback zone along streams and other aquatic areas often is established in which no logging, site preparation, or perhaps even cattle grazing is allowed in order to protect watershed, wildlife, and recreation values.

Another key to successful multiple-use management is moderation. Many uses can negatively affect each other if overdone (i.e., overgrazing reduces the available forage, excessive recreational use lowers the quality of recreation for everyone, etc.). Therefore, for single-use management, some restraint is advisable. When multiple uses compete, considerable additional moderation is often required of each use in order to accommodate the other uses. Examples of the ways uses can be restrained to benefit other uses are summarized in Table 12. (A more complete discussion is given in the preceding sections of this report.)

**Table 12. Examples of constraints of uses to accomplish multiple-use management of hydric hammocks.**

| Use | Constraint |
|---|---|
| Timber | Reduce total area used for timber production.<br>Grow timber on longer rotations.<br>Use less intensive harvesting or site-preparation methods.<br>Reduce or eliminate logging when the ground is soft or wet.<br>Reduce the size of individual timber harvests.<br>Maximize edge, interspersion, and contrast of timber stands.<br>Retain as many cavity and mast trees and rare species as possible.<br>Create and retain brush piles and windrows.<br>Retain and protect buffer strips along waterways (and elsewhere).<br>Retain pockets of old growth.<br>Protect special sites (Indian mounds, sinkholes, rock outcrops). |
| Grazing | Reduce the total area used.<br>Reduce the density of livestock per unit area.<br>Reduce the duration of use.<br>Rotate use from area to area.<br>Fence and maintain buffers along waterways.<br>Fence and protect patches of old-growth timber, sinkholes, rock outcrops, Indian mounds, and recreational areas.<br>Keep livestock free of parasites and disease.<br>Modify prescribed burning to benefit wildlife.<br>Reduce burning intensity or area to protect timber. |
| Hunting | Reduce area open to hunting.<br>Restrict or eliminate use of dogs.<br>Restrict or eliminate use of off-road vehicles. |

(Continued)

**Table 12. (Concluded).**

| Use | Constraint |
|---|---|
| | Restrict all motorized access.<br>Reduce the number of hunters.<br>Reduce the length of season for some or all species.<br>Eliminate hunting of particular species.<br>Eliminate use of lead shot.<br>Require hunter education course on conservation and safety.<br>Post and enforce special rules. |
| Nonconsumptive recreation | Reduce area of use.<br>Reduce number of users.<br>Prohibit certain uses.<br>Prohibit pets from part or all of area.<br>Restrict motorized access.<br>Eliminate off-road vehicles.<br>Reduce season of use.<br>Require educational class or provide educational materials.<br>Post and enforce specific rules. |
| Wildlife | Reduce size of area designated mainly or exclusively for wildlife.<br>Reduce area maintained in old-growth forest.<br>Reduce population or production targets for some species.<br>Reduce number of cavity and mast trees that need to be left.<br>Reduce size of food plots, buffer strips, or other special areas.<br>Reduce requirements for species monitoring, tree marking, special seasons for recreation, size restrictions of timber harvesting, etc. |
| Water | Restrict rate of withdrawal from surface waters.<br>Restrict rate of withdrawal from aquifer.<br>Restrict volume of water inputs.<br>Regulate timing of water inputs.<br>Regulate quality of water inputs. |

There are many ways that multiple uses can benefit each other. One important way is that each use can contribute to management efforts that benefit all uses. Some examples are protecting against poaching, vandalism, trash dumping, and other forms of illegal trespass. Not only do more uses enable more personnel and money to be used to address these problems, but the increased number of legitimate users themselves help guard against abuses, especially if the users are educated and inspired to help. Other management efforts that can benefit from the combined resources of multiple uses are road and trail construction and maintenance, fire protection, prescribed burning, surveying, fencing, timber-stand improvement, education courses, safety and emergency equipment and training, overhead costs (buildings, vehicles, etc.), and other fixed costs and duties.

The multiple-use management of hydric hammocks is not an exact science. Complete knowledge is not available for any aspect, interactions among the various uses and resources are complex, and situations vary considerably from one site to the next. Goals of management also vary with time and from one landowner to the next. However, management is invariably necessary. With clear objectives in mind and a common-sense approach, management can produce good results.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

This publication explains how the nature and functioning of the hydric-hammock community determines its best management. Numerous activities and their impacts on hydric hammocks are described. Various management strategies are outlined as the basis for rational decisions that will both protect the inherent values of hydric hammock and provide for human use of this community. Some hydric hammocks produce high quality timber, with values reaching as high as $3,700 per acre and annual growth reaching $50 per acre per year. Hydric hammocks play an important role in storage, flow, and discharge of regional water. Coastal hydric hammocks provide some protection from hurricanes by damping the winds and storm tides and holding the soil. Hydric hammock probably occupied about a half million acres of land when Columbus landed in the New World, but clearing for real estate development, pine plantations, and agriculture has decreased the original acreage by about half. Some of these losses are permanent, but areas cleared for pine plantations reseed with hammock trees beneath the pines within 20 years and, with no intervention, eventually revert to hammock. The long-term prospects for hydric hammock are poor because of Florida's rapidly expanding human population and the rise in sea level expected to result from the greenhouse effect.

17. Document Analysis a. Descriptors

| | | |
|---|---|---|
| Florida | ecology | mitigation |
| history | grazing | |
| hunting | planning | |

b. Identifiers/Open-Ended Terms

| | | |
|---|---|---|
| forested wetland | timber management | timber production |
| wastewater | water management | |
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