Lygodium Management Plan for Florida

FLORIDA EXOTIC PEST PLANT COUNCIL
LYGODIUM TASK FORCE
2001

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Edited by Amy Ferriter

A Report from the Florida Exotic Pest Plant Council's Lygodium Task Force

2001
First Edition

The Lygodium Management Plan was developed to provide information and make recommendations for the integrated management of Lygodium in Florida. This is the first edition of the Lygodium Management Plan for Florida. It will be updated periodically to reflect changes in management philosophies and operational advancements.

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"Nature made a fern for pure leaves."
- Thoreau

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Lygodium Management Plan for Florida

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I. Introduction

In 1984, concerned resource managers organized the Florida Exotic Pest Plant Council (FLEPPC) to unify and exchange information between land management agencies, research scientists, private industry, and other interested groups concerned with the impacts of exotic plants in the State's natural areas. The initial focus of FLEPPC was the uncontrolled expansion of melaleuca *(Melaleuca quinquenervia)* in the Everglades. Much of the progress made in controlling this species in South Florida stems from coordination provided by the Council. A successful effort led by FLEPPC resulted in the listing of melaleuca as a Federal Noxious Weed by the USDA; FLEPPC petitioned the USDA to begin research on the use of biological control agents to control melaleuca; and perhaps most importantly, FLEPPC led the charge in developing a Statewide management plan for melaleuca.

In 1990, the FLEPPC and the South Florida Water Management District convened a task force of Federal, State, and local land managers and scientists. The goal of this "Melaleuca Task Force" was to develop a comprehensive plan for managing melaleuca. The Melaleuca Management Plan for Florida (1990) was a first in the field of exotic plant management in the State. It serves as a framework for facilitating interagency cooperation and coordination of control efforts, improving resource sharing, enhancing public awareness, and has inspired legislative support.

By bringing agencies and organizations together, FLEPPC provided an unparalleled forum for the development of this species-based management plan. Based on the success achieved through the Melaleuca Management Plan, FLEPPC formed a Lygodium Task Force (LTF) in 1999 and charged it to draft a Lygodium Management Plan for Florida.

The Lygodium Management Plan compiles known information and provides recommendations for the integrated control of Lygodium in Florida. The LTF is an interagency group of professionals who have direct experience in managing Lygodium or have the technical knowledge required to develop an integrated management approach. It is the consensus opinion of the LTF that the uncontrolled expansion of Lygodium constitutes one of the most serious ecological threats to the biological integrity of Florida's natural systems.

II. Problem Statement

There are two species of exotic *Lygodium* naturalized in Florida. Old World climbing fern *(L. microphyllum)* is native to wet tropical and subtropical regions of Asia, Africa, Australia and the Pacific. It has become a serious weed in south Florida, where it is increasing in density and range. Japanese climbing fern (*L. japonicum*) is native to temperate and tropical Asia. It occurs from eastern Texas through the southern states to North Carolina and Florida. Previous experience with other invasive exotic plants such as melaleuca has shown that after an "establishment phase," expansion is often exponential. *Lygodium* has successfully established in Florida and resource managers and private landowners statewide are reporting these plants on private and public lands in increasing frequency and magnitude.

Lygodium invades many habitats in Florida, growing over trees and shrubs, smothering whole plant communities. It is difficult for other plants to grow though the thick fern mats. *L. microphyllum* is common in cypress stands, but also infests pine flatwoods, wet prairies, sawgrass marshes, mangrove communities and Everglades tree islands. *L. japonicum* grows in floodplains, marshes, secondary woods and pinelands. There is evidence that these plants also threaten the citrus and timber industries.

Infestations of *Lygodium* alter fire behavior, which is a naturally occurring element and management tool in many of Florida's plant communities. Thick "skirts" of old fronds enclose trees and serve as ladders to carry fire into tree canopies. Trees that can normally survive ground fires are killed when flames are brought into the canopy. Fires that would normally terminate at the margins of cypress sloughs now burn into and through areas infested with *Lygodium*. Portions of the burning fern can also break free and kite the fire to new areas.

In response to the threat that *Lygodium* poses to Florida's wildlands and the agricultural industry, FLEPPC and the South Florida Water Management District sponsored a public workshop to heighten awareness of this problem, share information, and develop an Action Plan to address the climbing fern threat. More than 200 weed scientists, botanists, land managers, and concerned citizens gathered in West Palm Beach on February 22 and 23, 1999 to exchange information regarding what is known about *Lygodium* and its management. The keynote speaker, Congressman E. Clay Shaw (R - Ft. Lauderdale), discussed the urgent need to control invasive exotic plants like melaleuca and *Lygodium* in Florida. He stressed the need for effective biocontrol programs, and pledged his support for the construction of a biocontrol quarantine facility in South Florida. Dr. Dan Austin (Director of Environmental Sciences at Florida Atlantic University) provided background information and an overview of *Lygodium* distribution in Florida. Scientists and land managers from across the state participated in panel discussions about various aspects of *Lygodium* spread and control.

III. Goal

The goal of the Lygodium Task Force is to protect the integrity of Florida's natural ecosystems from the biological degradation caused by *Lygodium microphyllum* and *L. japonicum*.

IV. Objectives

The goal of the Lygodium Task Force can be achieved through the following objectives:

- Eliminate *Lygodium* from Florida's natural ecosystems.
- Achieve an overall reduction of *Lygodium* throughout Florida (including public and private lands), such that maintaining Florida's natural areas Lygodium-free is economically feasible.
- Implement an effective public information awareness and participation program that will encourage support for *Lygodium* management issues.

LTF Recommendations

The Lygodium Task Force offers the following as priority recommendations for launching a successful *Lygodium* management strategy for Florida:

- Initiate an early detection program to identify and respond to new *Lygodium* infestations.
- Develop a Memorandum of Agreement/Understanding (MOA/MOU) among Local, State and Federal agencies to facilitate sharing of resources such as research, personnel, and equipment among signatories.
- Expand research concerning sound management options for *Lygodium*.
- Accelerate existing programs to evaluate and release Lygodium biological control agents in Florida and seek support for the staffing and operation of a biocontrol facility that will focus on environmental weeds, specifically *Lygodium* in Florida.
- Educate the Florida Legislature and the U.S. Congress about the problems associated with *Lygodium* in Florida and the Southeast, and ask for support in managing *Lygodium*.
- Petition and support the addition of *L. microphyllum* and *L. japonicum* to the Federal Noxious Weed List.
- Enhance existing control programs through coordinated efforts to seek additional funding sources.
- Encourage *Lygodium* control programs for Florida's public and private lands by seeking partnerships with concerned citizen groups and non-governmental organizations.
- Cooperate with agencies and organizations such as Florida's five water management districts, the University of Florida's Cooperative Extension Service, the Florida Department of Environmental Protection, and the Florida Department of Agriculture and Consumer Services in the production and dissemination of information intended to educate private property owners, land managers, and the general public about the problems associated with Lygodium.

V. Technical Background

A. Biology of Lygodium

1. Taxonomy

Lygodium microphyllum and *L. japonicum* are hardy, fast-growing ferns imported to North America from their native ranges. *L. microphyllum* originates from Africa, southern Asia, Australia and the Pacific, while *L. japonicum* comes from eastern Asia, Australia and the East Indies. Like other members of the genus, both species twine or climb upon physical support including trees, shrubs or structures via fronds with very flexible and fibrous stipes which extend to 30 m in length.

The genus *Lygodium* may contain as many as 40 (Alston and Holltum 1959) or, due to current revision, as few as 26 species (Garrison 1999). All but a few occur in warm temperate to tropical areas (Mabberley 1997).

There is one species of *Lygodium* that is native to North America. *L. palmatum* is a temperate species recorded from Mississippi, Alabama, and Georgia northeast through New England (Nauman 1993).

The genus *Lygodium* is usually placed in the Schizaeaceae, a small primitive family that also includes *Actinostachys, Schizaea, Anemia*, and *Mohria* (Prantl 1881, Holttum 1973). However, since the *Lygodium* species share unique twining morphology, some references (Flora of North America) place *Lygodium* in its own family, the Lygodiaceae.

Recent molecular (rbcL) research on the phylogeny of ferns found *Lygodium, Actinostachys,* and *Anemia* to have more intergeneric distance than occurs within most fern families (Hasebe et al. 1995). These genera were nevertheless called sister genera and left in the Schizaeaceae. The molecular data and the antiquity of the Schizaeaceae suggest that the group diverged at an earlier time than other groups of ferns (Smith 1995).

2. Botanical descriptions

a. Scientific name: *Lygodium microphyllum*

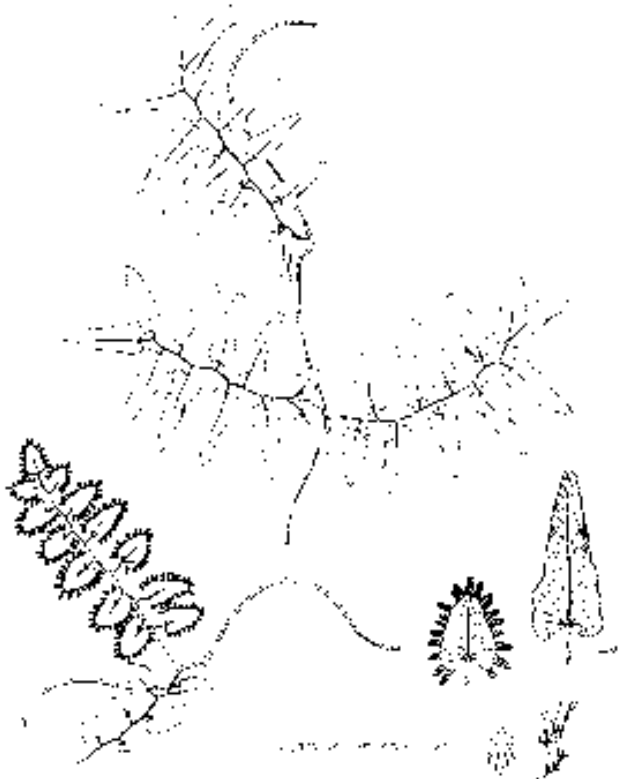
Common name: Old World climbing fern

Synonymy: *Lygodium scandens (L.) Sw., Ugena microphylla Cav.*

Origin: Tropical Asia, Africa, Australia and the Pacific

Family: Schizaeaceae

Botanical Description: Fern with dark brown slender rhizomes and climbing, twining fronds of indeterminate growth, to 30 m long; main rachis wiry, stemlike. Pinnae fertile or sterile with leafy branches off main rachis once compound, oblongish in overall outline. Pinnules usually unlobed, stalked, articulate. Leaf-blade tissue usually smooth below. Fertile leaflets of similar size, fringed with tiny lobes of enrolled leaf tissue (false indusia) covering the sporangia along the leaf margin.



1997 University of Florida, Center for Aquatic Plants

b. Scientific name: ***Lygodium japonicum***

Common name: Japanese climbing fern

Origin: Temperate eastern Asia, East Indies and Australia

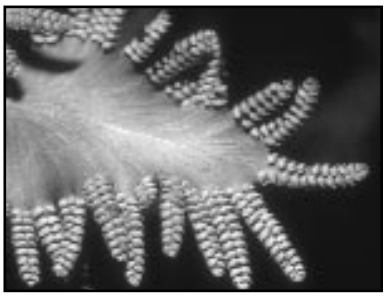
Family: Schizaeaceae

Botanical Description: Fern with slender, dark brown rhizomes and fronds to 30 m long, main rachis wiry and adapted for twining with indeterminate growth. Pinnae fertile or sterile, compound, stalked, spreading from the main rachis; pinnae to 3 dm wide, triangular in overall shape. Pinnules dissected, variously incised or lobed. Fertile pinnules contracted in shape, with two rows of sporangia along the leaf margin, which is enrolled (forming false indusia) to partially cover the sporangia.

1990 University of Florida, Center for Aquatic Plants

3. Reproductive biology, phenology and growth

L. microphyllum and *L. japonicum* reproduce sexually during the sporophyte and gametophyte stages. Fertile pinnae of the sporophytes produce spores within sporangia. When released from the sporangia, the spores will, given needed moist environmental conditions, germinate into tiny, thin-tissued plants called prothallia, the gametophyte generation (where eggs and sperm are formed). The gametophytes have both male and female organs producing sperm and ovules. Fertilization gives rise to the familiar plants (the sporophytes). Spores of the *Lygodium* genus have very thick walls, giving these propagules long environmental viability (Tryon pers. comm. 1999). Culture of the North American member of the genus, *L. palmatum*, is reportedly very simple, as spores collected from fertile fronds readily sprout into prothallia, and, ultimately, new sporophyte plants in three months (Brumback 1985). Similar success has been attained for *L. microphyllum* spores cultured in agar growth media (Lott et al. unpublished data).



Fertile leaflet of L. microphyllum

In sub-tropical climates, both *L. microphyllum* and *L. japonicum* are evergreen and may actively grow throughout the year as both sporophytes and gametophytes. *L. japonicum* in sub-temperate climates, such as northern Florida, is damaged by hard freezes with many or most leaflets turning brown. The browned wiry fronds usually remain aloft in shrubs and trees, providing an easy-to-climb "ladder" for new growth when temperatures rise again. In shady, moist habitats

Lygodium's distinctive growth form has enabled it to be easily recognized in the fossil record, with records extending back through the early Tertiary and into the Upper Cretaceous (Brown 1943). The most widely reported *Lygodium* species fossil in the Northern Hemisphere is *L. kaulfussi*. This extinct species closely resembles the extant North American species, *L. palmatum*. *L. kaulfussi* was a wide-ranging species in the Eocene - fertile foliage has been found in localities throughout Europe and North America, and sterile specimens have been collected in China. (Manchester 1987, Manchester and Zavada 1987).

L. microphyllum prothallus

A L. microphyllum sends out its first fiddlehead-shaped fronds.

of north Florida, many fronds remain green through the winter. The extent to which winter frosts retard sporulation and gametophyte growth is not known, but lab research is in progress at Florida Atlantic University. Rhizomes of *L. japonicum* are certainly hardy much farther north in the United States. The Southwestern (U.S.) Fern Society, still apparently recommending this invasive as an ornamental, does suggest that gardeners in Wichita, Kansas mulch the plant after the first frost (Southwestern Fern Society web site 1998).

L. microphyllum

Both *L. microphyllum* and *L. japonicum* are homosporous ferns which may engage in three types of sexual reproduction: 1) intragametophytic selfing, involving the union of egg and sperm from the same gametophyte; 2) intergametophytic selfing, the cross-fertilization of gametophytes produced by spores from the same sporophytes; and 3) intergametophytic crossing, the cross fertilization of gametophytes arising from different sporophytes (Soltis 1992). Since homosporous ferns have bisexual gametophytes, it has long been held that intragametophytic selfing is an important mode of reproduction in populations of homosporous ferns (Soltis et al. 1988). However, recent studies have found few highly inbred species of ferns (Soltis 1992, Hooper 1997), suggesting that ferns have evolved mechanisms, perhaps antheridiogen activity, to promote outcrossing.

B. Distribution, Ecology and Economic Impacts

1. Native Range

a. Native Range Distribution

L. microphyllum has a very large native range, extending through much of the Old World tropics, spanning almost half of the world's circumference from 18˚E in Senegal to 150˚W in Tahiti between the latitudes of 29˚S in Australia and 27˚N in northeastern India (Alston 1959, Copeland 1994a, So 1994b, Holttum 1968). L. japonicum has a smaller longitudinal native range, but reaches into northern temperate latitudes. It occurs in India and eastward through Southeast Asia and China to Japan and Korea, and southward to Queensland, Australia (Singh and Panigrahi 1984).

The genus *Lygodium* occurs naturally in the tropics nearly worldwide, and in temperate regions of North America, Asia, southern Africa, and New Zealand (Nauman 1993). One species, *L. palmatum*, is native to the eastern United States. *L. microphyllum* has been introduced to Jamaica, Guyana, and southern and central Florida (Pemberton and Ferriter

Native distribution of L. microphyllum. Bob Pemberton, USDA

1998). *L. japonicum* has been introduced to Puerto Rico, and the southeastern United States from Texas to North Carolina and Arkansas (Proctor 1989, Nauman 1993).

b. Native Range Ecology

In its natural range, *L. microphyllum* is found in a variety of habitats including mesic forests, rain forest, and open swampy areas, at altitudes from 0 to more than 1000 m (Serizawa 1975, Edie 1978, Singh and Panigrahi 1984). *L. japonicum* is native to the edges of forests, open forests, and secondary forests from low elevations to "higher elevation" areas including the Himalayas (Serizawa 1975, Edie 1978, Singh and Panigrahi 1984).

Relatively little general information is available regarding faunal uses of ferns in their native ranges. Literature citations reveal 420 insects associated with ferns (Balik et al. 1978, Gerson 1979). New information has resulted from initial forays to evaluate potential biological control of *L. microphyllum*. For instance, several insect feeders including pyralid moths in Hong Kong (Pemberton, pers. comm. 1999), *Cataclysta* species in Australia (T. Wright, pers. comm. 1999), and larval sawfly feeding in Vietnam (M. Purcell, pers. comm. 1999) and Thailand (T. Wright, pers. comm. 1999) have been found. In addition, fungi have been collected from *L. japonicum* in Florida (Alfieri et al. 1994), and a rust fungus has been found to affect several *Lygodium* species in greenhouses (Jones 1987). While both *L. microphyllum* and *L. japonicum* colonies can establish relatively large mats or vine canopies in their native ranges (Pemberton, pers. comm. 1999), these are much smaller than those found commonly in Florida. These species have had small economic value in their native lands, resulting in little effort expended on their study. Because so little is known about them and they are so invasive outside their native range, much more ecological work is needed.

L. microphyllum in its native habitat (billabongs), Litchfield National Park, Northern Territory, Australia. Photo courtesy John Goolsby, USDA.

c. Economic Uses in Native Range

Economic uses of *Lygodium* species are varied in the world's pharmacoepia, but the product often sold is the raw spores. Numerous Internet listings for this form of *L. japonicum* are termed Lygodii spora or the Chinese term, hai jin sha. Other *L. japonicum* herbal products are given the more general term jin sha teng. *L. japonicum* treatments are said to help kidney and urinary functions; reduce swelling, colds, and fever; ease cough and congestion; and work as an anti-gonorrheal agent or as a general "blood tonic." The spores themselves, or tinctures of the spores of *L. japonicum*, are readily available online (e.g., Kamwo Herbs & Tea Company website 1999; Herbs USA website 1999).

The long, fibrous, twine-like rachis of *Lygodium* fronds has found obvious applications in basketry and weavings, particularly in Southeast Asia (People and Plants Online 1999). Fewer uses are recorded for *L. microphyllum* but also include uses as fiber for the weaving of handicrafts (Thaweesakdi Boonkerd, pers. comm. 1999) and herbal therapeutic applications as an anti-diarreheal and swelling reduction agent and as a general skin amendment (EthnobotDB website 1999).

2. Florida

a. Florida Distribution

L. microphyllum was first collected as a naturalized plant in Florida at two Martin County locations in 1965 and 1966 (Beckner 1968). In 1973, it was collected in Highlands County (Alverez sn, bin Avery 1427, FLAS). Lakela and Long (1977) stated that the plant was rare and that a sporulating specimen had been recorded from Martin County. In 1978, *L. microphyllum* was known from 16 localities in Martin County and 23 in Palm Beach County (Nauman and Austin 1978).

At the time, this species occurred in great abundance for several miles along the Florida Turnpike in Martin and Palm Beach Counties (Godfrey 76935, FLAS, specimen notes). In 1973 the plant was collected in Highlands County (Alvarez P7718, FLAS) and in Polk County (Willson 353, FLAS) in 1979. In 1981, it was described as naturalized in Collier County on the Gulf of Mexico coast in southwestern Florida (Robinson, Wunderlin, Hansen and Tloenke 207, USF)

In 1993, the South Florida Water Management District initiated biennial aerial surveys to determine the distribution, density, and spread of four invasive weeds: *Melaleuca quinquenervia, Schinus terebinthifolius, Casuarina* spp., and *L. microphyllum* (Ferriter 1999). Fifty east-west flight lines were established for the entire area south of the north rim of Lake Okeechobee. The lines were spaced at 2.5 mile intervals. The beginning and end point of each line is a precise point of latitude and longitude to permit repeat surveys.

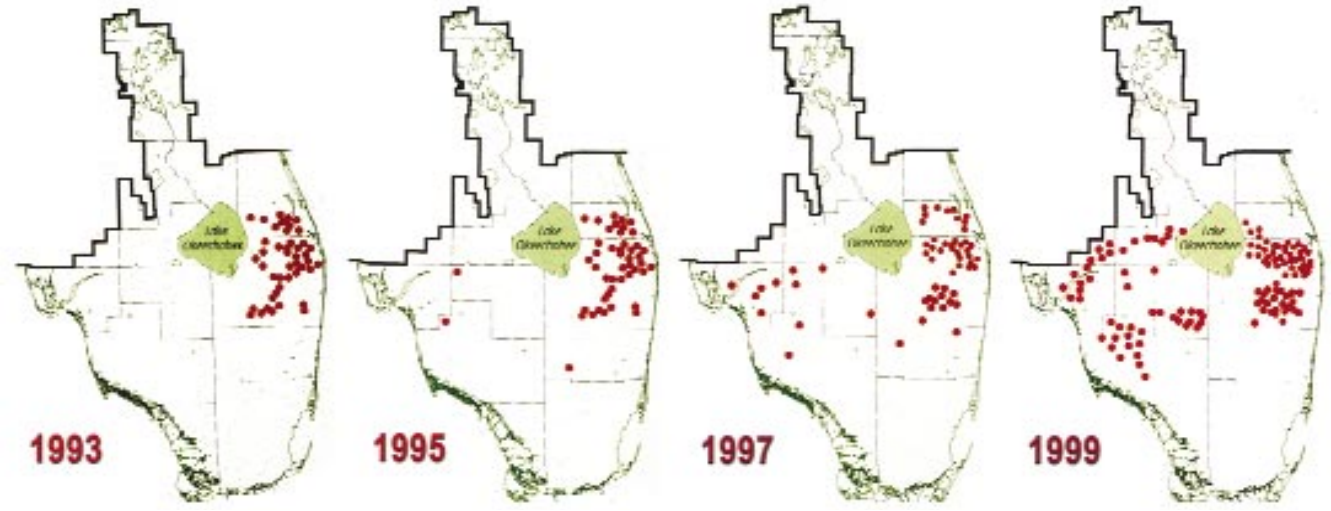
Surveys were conducted in 1993, 1995, 1997 and 1999. In 1978, *L. microphyllum* was limited to the eastern third of Martin and Palm Beach Counties (Austin and Nauman 1978). By 1993, the fern had expanded in western Martin County, central Palm Beach County and was detected in Glades County northwest of Lake Okeechobee. The total area estimated as infested in 1993 was 11,213 hectares (27,686 acres). In 1995, *L. microphyllum* was first detected in Broward County, in Hendry County, and in Sarasota and Collier Counties on the west coast. The infested area was estimated to be 11,831 hectares (29,212 acres) in 1995. In 1997, the fern was detected in Lee and Charlotte Counties, and had covered an estimated 15,892 hectares (39,240 acres). Populations detected at four well-separated sites in Charlotte County - where none were detected in 1995 - were particularly striking. By 1999, the species had expanded into many locations in Lee and Collier Counties. In addition to new sightings, the fern's coverage had increased greatly, covering approximately 44,130 hectares (109,000 acres)

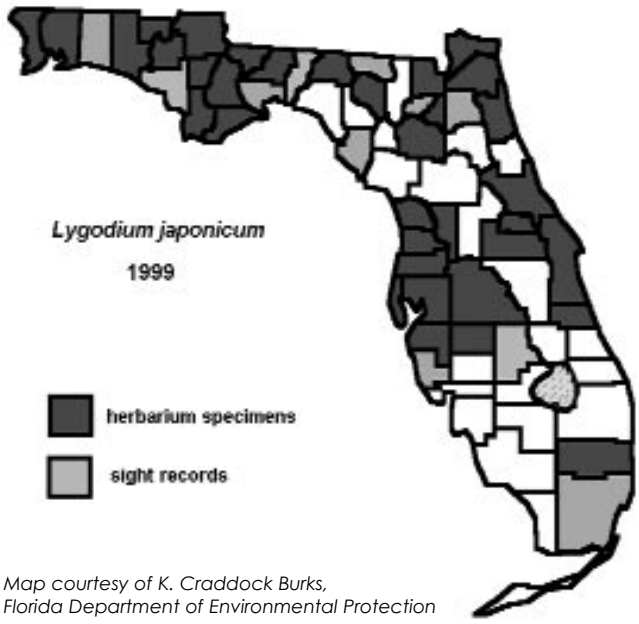
In 2000, Everglades National Park staff (Tony Pernas, pers. comm. 2000) discovered new, but widespread populations of *L. microphyllum* in the western coast of the Park. These populations had not been detected in 1999, and are particularly alarming because of their remote location and seemingly rapid establishment and spread.

L. microphyllum is also expanding its range northward, becoming increasingly common in the Kissimmee River Valley (Highlands, Okeechobee, and Polk Counties) and the bay swamps of the Lake Placid area. The species has recently been noted along the Peace River (Brian Nelson, pers. comm. 2000) and together with *L. japonicum* along Hillsborough County's Little Manatee River (Debbie Butts, pers. comm. 1999).

L. japonicum was introduced to the United States for ornament around 1900, with the first naturalized population noted in 1903 in Georgia (Pemberton and Ferriter 1998). By 1964 (Radford et al.), it was considered "a rare escape from cultivation" in Georgia, Florida, and Alabama. A few

SFWMD Old World Climbing Fern Surveys





Map courtesy of K. Craddock Burks, Florida Department of Environmental Protection

years later, Beckner (1968), focusing on climbing ferns, described *L. japonicum* as having "spread aggressively into moist woods and fields in most parts of Florida and adjacent states." Naturalized populations of *L. japonicum* now occur in the United States from North Carolina through South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana, to east Arkansas and Texas. In Florida, it is frequent across northern counties in wet ditches, swamps, floodplains, marshes, lakes, creeks, hammocks, and pinelands; it also occurs in similar habitats southward into central Florida.

Shown above is *L. japonicum*'s current range in Florida as supported by herbarium specimens (darkly shaded counties) or documented sightings (lightly shaded counties). The number of counties recorded for this species has grown from 29 in 1995 (Wunderlin et al.) to 33 in 1996, to 45 in 1999. These increases are probably due in part to better reporting methods but may also reflect increased spore movement. Occurrences recently noted for Broward and Dade Counties are in disturbed areas near urban centers. The species is known from nearly 20 parks, preserves, and other conservation lands in north and central Florida.

As Nauman and Austin (1978) predicted, the ranges of *L. japonicum* and *L. microphyllum* have met, as *L. japonicum* has moved slowly southward in the state, and the more recently introduced *L. microphyllum* has moved rapidly west and north. Their distributions now overlap in Brevard, Hardee, Highland, Manatee, Polk, and Sarasota Counties. Both species occur at the same site along the Little Manatee River in Hillsborough County.

b. Florida Ecology

L. microphyllum is now well established in central and southern peninsular Florida, where it grows in a number of wetland and mesic habitats including hammocks, cypress swamps, flatwoods, bayheads, and disturbed sites (Nauman 1993, Wunderlin 1998, Pemberton and Ferriter 1998, Gann et al. 1999). In the southeastern United States, *L. japonicum* grows in floodplains, swamps, marshes, secondary woods, pinelands, and disturbed sites (Clewell 1982, Nauman 1993, Wunderlin 1998).

Little is known about the exact ecological requirements of either species in Florida. The broad natural distribution of both species suggests that they can tolerate a wide range of ecological conditions. Although primarily found in wetlands, *L. microphyllum* does show some ability to invade mesic soils. It has been

L. microphyllum invading pine flatwoods.

observed in scrub sites in Martin County (Roberts and Cox 2000, Thayer and Ferriter, pers. observations) *L. japonicum* is not considered a wetland species, but it is invading both wetland and mesic systems in Florida. Neither species, however, appears to become well-established in extremely dry habitats, or in soils with exceptionally long hydroperiods. While *L. microphyllum* is growing in open sawgrass

marshes in the Loxahatchee National Wildlife Refuge (Palm Beach County), it has been suggested that these plants may have become established on slightly elevated areas of organic material. The plants appear to be able to continue to grow irrespective of fluctuating water levels. Similarly, *Lygodium* will become established on tree trunks and rotting logs in wet areas such as cypress domes. Degree of salt tolerance is uncertain, and is in need of investigation for both species.

L. microphyllum covering tree island in the Northern Everglades.

Unlike some invasive exotic plant species, neither species of Lygodium appear to require human disturbance in order to spread and become established. *L. microphyllum* has been found in very isolated areas including remote locations in Everglades National Park and the Fakahatchee Strand State Preserve. *L. japonicum* has also been found in remote conservation areas in the Panhandle. Water and wind of storm events may help disperse millions of tiny spores over long distances, although little is known about *Lygodium* dispersal mechanisms.

Once established, *Lygodium* climbs and blankets other vegetation, ultimately causing mortality to mature canopy and subcanopy trees in the case of *L. microphyllum* (Roberts 1996, 1997). Sometimes, *Lygodium* covers other vegetation so completely, it is not possible to see other plants beneath it (Pemberton and Ferriter 1998). Near the ground surface, a thick mat of old and new fronds also forms, ultimately smothering and stifling native plants including herbs and tree seedlings that would ordinarily maintain the forest canopy if allowed to mature.

Rare plant species such as the tropical curlygrass fern (*Actinostachys pennula*) are severely imperiled by the spread of *L. microphyllum* into their last remaining habitats, such as the northern Everglades tree islands. *L. japonicum* threatens the habitat of at least three Florida endangered species, *Sideroxylon thornei* and *Aristolochia tomentosa* in the Apalachicola River basin and *Polygonum meisnerianum* in the upper St. Marks River watershed. Effects of *Lygodium* on native wildlife appear to be significant, but are in need of investigation.

L. microphyllum is tolerant of fire, and causes natural or prescribed fire to spread into the canopy of cypress and pine-dominated ecosystems (Marthani et al., 1986; Roberts 1996, 1997). These *Lygodium*-induced canopy fires also kill canopy and subcanopy trees. Lygodium may also facilitate the spread of spot fires (Roberts 1996). The effects of fire in *L. japonicum*-infested areas have not been well documented.

Fire in Lygodium-infested pine flatwood.

3. Economic Uses and Impacts in North America

Both species of *Lygodium* have historically been cultivated in Florida, although neither species is currently in horticultural production in the State (Plantfinder, 1999). *Lygodium* appeared in the Royal Palm Nurseries (Manatee County, FL) 1888-89 catalogue, and was sold by this nursery for 30 years during 1888-1930 (Reasoner Brothers 1887-1930). Royal Palm Nurseries, which operated from 1881 until the 1930s, was one of the most important importers and distributors of subtropical and tropical ornamental plants in Florida and the United States (Pinardi 1980). It is possible that the plant they sold was *L. japonicum* (and not *L. microphyllum*) since the two were often confused in early horticultural literature. A photograph of *L. microphyllum* in the 1905 catalogue appears to be *L. japonicum*. Statements in these early catalogues indicate that the fern they sold is more hardy than other ferns (which "should be kept from hard frost"), which also suggests that the fern sold was *L. japonicum* rather than *L. microphyllum*.

> "The Japanese climbing fern makes an excellent house plant….Under favorable growing conditions its leaves continue to grow until stopped by a ceiling or other barrier. Provide it with a lattice or cord trellis lest it appropriate a nearby curtain."
>
> ***- Horticulture Magazine, July 1971***

Sale of live plants continues in North America as evidenced by an online notice for *L. japonicum* from Bushman Plant Farm, Cleveland, TX. The Southwestern Fern Society promotes *L. japonicum* as a "beautiful and tough fern," that "sadly…is not commonly grown by commercial greenhouses," and gives explicit recommendations for its growth and care. The author describes *L. japonicum* as, "incredibly adaptable…(and) can be grown in almost any light." (Southwestern Fern Society website 1998).

Many species of *Lygodium* have economic uses such as handicraft manufacture in their natural ranges, but these uses are not known in Florida.

L. japonicum poses a serious economic risk to pine plantations through its spread and intensification of fire (K. Langeland, pers. comm. 1998). *L. japonicum* has also been identified as a contaminant in pine straw bales (G. Jubinsky, pers. comm. 1999). (See warning below.) Transport of *Lygodium*-infested pine straw could accelerate the spread of this plant within and outside of the State of Florida, and its use in landscapes could lead to increased maintenance costs because the plant can rapidly overtake desirable vegetation.

Lygodium poses an unknown economic threat to the tourism industry through its degradation of natural resources in Florida's parks and recreation areas. Economic impact studies have not been conducted for either species.

WARNING!

Buyers and users of pine straw mulch materials should be aware of a potential hazard associated with a Noxious Weed recently prohibited by the Florida Department of Agriculture and Consumer Services (FDACS).

Lygodium japonicum, commonly known as Japanese climbing fern, has colonized substantial acreages of pine plantations over the last several years, and has now been identified as a contaminant in pine straw bales. As this species was listed as a State Noxious Weed in July 1999, it is now unlawful to introduce, possess, transport, or release any living stage of Lygodium without a permit from FDACS.

In recent visual surveys in north Florida, this weed was found in approximately 25% of pine straw bales at several retail nurseries. Viable spores of this fern can be found on both living and dead fronds collected with pine straw. Climbing fern will readily become an expensive weed problem in landscapes, as it can rapidly overtop more desirable vegetation. FDACS intends to proceed by educating pine straw balers about this problem and is aware that retailers and wholesalers may be carrying contaminated bales. Please be alert when buying pine straw; refrain from buying from contaminated shipments.

C. Proposed and Enacted Laws

1. Federal

Neither *L. microphyllum* nor *L. japonicum* is currently listed by the Federal government as a noxious weed per Part 360- Noxious Weed regulations: 7 U.S.C. 2803 and 2809; 7 CFR 2.17, 2.51, and 371.2(c).

The Florida Exotic Pest Plant Council submitted a request and petition dated August 5, 1999 to the U.S. Department of Agriculture, Animal and Plant Health Inspection Services office (APHIS), requesting that both species be listed as federal noxious weeds pursuant to Section 3(c) of the Federal Noxious Weed Act of 1974 (7 U.S.C. 2809), and requested that APHIS reply regarding their needs for additional information in order to accomplish listing. FLEPPC received a response from APHIS dated October 21, 1999, stating that APHIS is also concerned about ecological and economic impacts associated with both species and is requesting that a Risk Assessment be prepared to provide information in support of listing.

As of February 2000, FLEPPC is in the process of preparing a Risk Assessment for *L. microphyllum* for submittal to APHIS. A Risk Assessment for *L. japonicum* will then be prepared and submitted to APHIS. Should APHIS decide, after review of the Risk Assessments, that listing is appropriate, the regulatory process of listing would take about one year.

2. State

Both *L. microphyllum* and *L. japonicum* were listed by State of Florida Department of Agriculture and Consumer Services (FDACS) per FDACS Rule 5B.-57.007 as Noxious Weeds in July 1999. It is unlawful to introduce, possess, move, or release any living stage of these species except under permit issued by FDACS. No permit shall be issued unless FDACS determines that procedures exist to adequately contain the noxious weed, or that they will not pose a threat to the agricultural industry or the environment. Rule 5B-57.006 also states that FDACS shall cooperate with other appropriate parties to eradicate or control noxious weeds, with strategies to be determined through risk assessment.

3. Local Governments

FLEPPC conducted a survey of Florida counties to determine the current status of county, and/or other municipal ordinances or other regulations related to *L. microphyllum* or *L. japonicum*. The following counties within the South Florida and the Southwest Florida Water Management District (SFWMD and SWFWMD) currently list *L. microphyllum* and *L. japonicum* as "prohibited" and/or require their removal at time of land development: Collier, Martin, Miami-Dade, Palm Beach, and Seminole. None of the counties within the Suwanee River Water Management District (SRWMD), the Northwest Florida Water Management District (NWFWMD), or the St. John's River Water Management District (SJRWMD) currently list these species in any way.

4. FLEPPC

The Florida Exotic Pest Plant Council (FLEPPC) currently lists both *L. microphyllum* and *L. japonicum* as "Category I" invasive species, defined by FLEPPC as "Species that are invading and disrupting native plant communities in Florida. This definition does not rely on the economic severity or geographic range of the problem, but on the documented ecological damage caused."

D. Management Techniques

Modern pest control applies the principles of Integrated Pest Management (IPM), the coordinated use of pest and environmental information with available pest control methods to prevent unacceptable levels of pest damage by most the economical means and with the least possible hazard to people, property, and the environment. The threat from *Lygodium* has only recently been recognized and we are in the early stages of collecting information which can be integrated into an effective management system. Decision making criteria, which will be discussed in the "Resource Management Approach" section, will use information such as the habitat where a target population is growing, size of the population, non-target vegetation, life cycle of the climbing ferns and the associated non-target vegetation, and available resources. Methods may include practices such as early detection, fire, flooding, physical removal by hand or machinery, biological controls, and herbicides. This section presents current information on control methods and provides control recommendations.

Tortricid moth collected in Thailand on L. microphyllum

1. Biological Control
The biological control approach

Biological control of weeds seeks insects and/or diseases of the plant in its native range and after considerable host specificity research, introduces them against the plant in the area where it has become a problem. The plant's co-evolved natural enemies are usually absent where the plant has been introduced and become a problem. The re-association of these enemies with the problem plant can result in a reduction and regulation of the plant (Huffaker 1964, Julien 1992, Pemberton and Turner 1980). Natural enemies of allied species (different *Lygodium* species) may also be employed to reduce the plant. The safety of biological control relates primarily to the selection of target pests that are introduced (non-native) and the use of biological control agents with very narrow host ranges (Pemberton 1985a, 1985b). If insects with host ranges that include non-target species or taxa are utilized, then effects on these non-target species may occur. A project on exotic thistles carried out during the 1960s and 1970s resulted in control of the target thistles but also damage to non-target native thistles (Louda et al. 1997). These negative effects were predictable and could have been avoided through either the use of agents with very narrow host ranges or through the selection of a pest target with fewer native relatives.

Most plants have very specialized insects (Strong et al. 1984) and to a lesser degree diseases that can be employed. Specialist insects typically have host ranges that are limited to plants in a genus, subgenus, section, or even single species. Specialist diseases can have similar host ranges but some can be limited to subspecific taxa. Targeted weeds that are more distantly related to native plants or other valued plants can be expected to have both more natural enemies that can be used against it and fewer potential conflicts with valued plants. Biological control is a very suitable approach for *L. microphyllum*, because it is an introduced species that is taxonomically isolated from all but one U.S. native plant and a few Latin American species. Biological control is an appropriate tool for the control of *L. microphyllum* because it grows among other plants in complex natural vegetation that would be damaged by most control methods. Biological control has solved or lessened the severity of many exotic plants affecting natural areas (Dennill and Donnelly 1991, Pemberton and

Many biological agents such as this sawfly (left) and these moths have been identified to date.

Turner 1990, Room et al. 1981). One of the most successful projects was against the floating aquatic fern *Salvinia molesta* D. Mitch. in Australia (Room et al. 1981).

a. Probability of Finding Natural Enemies

It was assumed that ferns were not generally eaten by insects (Soo Hoo and Fraenkel 1964, Eastop 1973, Southwood 1973), but this was shown to be false (Balik et al. 1978, Gerson 1979). Ferns in studied communities in Mexico experienced as much damage from insects as did angiosperms (Balik et al.1978). These authors also searched the literature and found 420 named insect species associated with ferns. When the insect faunas of specific ferns have been studied, many specialist feeders of these ferns have been found. For instance, bracken fern (*Pteridium aquilinum* (L.) Kuhn s.l.) in Europe has 33 insect species with narrow host plant ranges (Simmonds 1967, Wieczorek 1973, Lawton 1976). Kirk (1977) discovered 24 insect species feeding on bracken in Papua New Guinea; most of them appeared to be specialists. Even the small, architecturally simple ferns in the genera *Salvinia* and *Azolla* have their own insects (Sands 1983, Buckingham and Buckingham 1981).

English-language literature searches have revealed almost no known insect feeders of *Lygodium* ferns. This is typical for tropical plants with little economic importance in their native regions. Most of the species associated with bracken in New Guinea were previously unknown (Kirk 1977).

A similar lack of literature exists with plant pathogens of *Lygodium*. Some fungi have been collected from *L. japonicum* in Florida (Alfieri et al. 1994) and although little is known of these, they probably are not limiting the pest *Lygodium* ferns. Of somewhat more interest is a rust fungus *Puccinia lygodii* (Hariot) Arth. This rust is a pest of *Lygodium* spp. in greenhouses (Jones 1987). Puccinia lygodii is native to tropical South America (Sydow 1925) and has been collected from *L. japonicum* in Louisiana (McCain et al. 1990). It is of interest because rusts often have very narrow host ranges and can be damaging to their host(s). Although biological control usually uses natural enemies from the pest's native range, novel insects and diseases from closely related plants can be effectively employed as well (Julien 1992).

These factors suggest that *L. microphyllum* should have a rich natural enemy assemblage in its native range. It will be important to find enemies that will not accept our native American *L. palmatum* as a host. Because *L. microphyllum* and *L. palmatum* are in different subgenera and live in different climatic zones, this should not be difficult. It will also be important to examine the potential use by prospective biological control agents of *Lygodium* species in the West Indies and Mexico. Representative ferns of many other taxa will also be included in host specificity testing.

b. Biological control program and summary of findings to date

Preliminary examinations of *L. microphyllum* at sites in its native range indicated the presence of insect feeders. Pyralid moth larvae were found in Hong Kong in 1997; sawfly larvae (prob. Hymenoptera, Tenthridinidae) were seen in Vietnam in 1996 (M. Purcell, pers. comm.); and several moth larvae (Lepidoptera) were observed in Australia in 1996 (C. Turner and K. Galway, pers. comm.).

This evidence of *Lygodium* feeding insects in the native region helped launch the biological control program against the weed. The South Florida Water Management District and the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) began cooperative co-funded biological control research on L. microphyllum in 1998. The USDA-ARS Aquatic Plant Control Laboratory, Ft. Lauderdale, Florida and the USDA-ARS Australian Biological Control Laboratory, Brisbane, Australia, are exploring for natural enemies of Lygodium species with the goal of locating potential biological control agents of the plant.

TABLE 1.

Herbivores collected on Lygodium species in Australia and SE Asia.

Name	Collection Locations	Host Plant
Cataclysta camptozonale Lepidoptera: Pyralidae	Australia (Queensland)	*L. microphyllum* *L. reticulatum*
Mustominae sp. Lepidoptera: Pyralidae	Australia (Queensland & Northern Territory), Indonesia, Malaysia, Singapore, Thailand	*L. microphyllum*
Nymphulinae sp. Lepidoptera: Pyralidae	Malaysia, Singapore, Thailand	*L. microphyllum*
Callopistria sp. Lepidoptera: Noctuidae	Australia (Northern Territory), Indonesia, Thailand	*L. microphyllum*
Lepidoptera: Limacodidae	Thailand	*L. microphyllum*
Lepidoptera: Tortricidae	Thailand	*L. microphyllum*
Tube-dweller Lepidoptera	Malaysia	*L. microphyllum*
Stem-borer Lepidoptera: Pyralidae	Malaysia	*L. microphyllum*
Neostrombocerus albicomus Hymenoptera: Tenthridinidae	Malaysia, Singapore, Thailand, Vietnam	*L. flexuosum*
Tortoise beetle Coleoptera: Chrysomelidae	Australia (Northern Territory)	*L. microphyllum*
Flea beetle Coleoptera: Chrysomelidae	Thailand	*L. japonicum*
Leaf-miner Diptera: Agromyzidae	Malaysia	*L. microphyllum*
Hemiptera: Miridae	Australia (Northern Territory)	*L. microphyllum*
Homoptera: Flatidae	Australia (Northern Territory)	*L. microphyllum*
Thrips Thysanoptera	Malaysia, Thailand	*L. microphyllum*
Mite, Acarina: Eriophyidae	Australia, Indonesia, Malaysia, Singapore, Thailand	*L. microphyllum*

c. Exploration in Australia

Exploration for natural enemies of *L. microphyllum* has been conducted in Queensland (7 trips), New South Wales (2 trips), and the Northern Territory (2 trips). Two *Lepidoptera* species in the family Pyralidae are established in culture in Australia. *Cataclysta camptozonale* occurs from Cairns in the tropical north of Queensland to Brisbane in the subtropics. A second pyralid species has been collected from north Queensland across to Darwin in the Northern Territory. Molecular sequencing of the mitochondrial D2 gene shows an exact match with populations collected in Southeast Asia. These data indicate the populations are likely to be the same species. Specimens of all the Pyralidae have been forwarded to the ARS-Systematic Entomology Laboratory for determination and description of new species. Host range testing of the two pyralid species on *L. microphyllum* and related fern species has commenced. Test plant species not available in Australia are now permitted for importation by the authorities.

d. Exploration in Southeast Asia

Exploration has included expeditions to Thailand (3 trips), Malaysia (3 trips), Indonesia (1 trip) and Singapore (2 trips). Plant samples for DNA analysis were taken of *L. microphyllum* and other *Lygodium* species in all four countries and forwarded to ARS-Fort Lauderdale for characterization and comparison to Florida plant stocks. The most common insect on *L. microphyllum* and *L. flexuosum* is an undetermined pyralid moth in the subfamily Musotominae. Three colonies were imported to

quarantine in Brisbane, but later terminated after DNA sequence comparisons proved it to be identical to Australian collections. A third pyralid species, collected from *L. microphyllum* in Malaysia, Singapore, and Thailand, is in quarantine culture in Brisbane, Australia. A large noctuid moth, *Callopistria* sp. has been observed to be very damaging to *L. microphyllum* in the field but few specimens have been obtained so far. Field host range studies of the sawfly indicates *Neostrombocerus albicomus*, is a specialist on the allied fern species, *L. flexuosum*. Acquisition of permits to import Southeast Asian insects has allowed ABCL researchers to import potential agents from this region and conduct host range testing in Australia.

Exploration in Africa

A five-week survey for natural enemies of *Lygodium microphyllum* in west Africa (Benin, Ghana and Cameroon) occurred during May and June, 1999. About 25 populations of these *Lygodium* were examined. Few natural enemies were encountered. The most damaging was a Tenuapalpis mite which caused brown channel-like streaks to the leaves of the plants. This mite was also observed to feed and breed on *Nephrolepis* (Boston type) ferns. *Lygodium* ferns are primitive whereas *Nephroplepis* ferns are modern, indicating that the mite has a broad host range. A host range of this breadth would prevent its use as a biological control agent. A few individual moth larvae were found feeding on the individual leaves of *L. microphyllum* but they were not reared. A limited amount of surveying was done in one of the populations of *L. microphyllum* along the coast of Natal province (ca. 30 degrees south) in South Africa. Plants were examined on two occasions by a South African cooperator Martin Hill and by Ted Center of our Ft. Lauderdale Laboratory. No natural enemies were encountered either time.

The paucity of natural enemies in Africa raised the question about Africa being truly part of the plant's native range. The characteristic spores of *L. microphyllum* occur in million year old Niger River sediments in Nigeria, indicating that the plant has been on the continent for a long time. It appears that few natural enemies have evolved with *Lygodium* ferns in Africa compared to the many found by our project in Southeast Asia and Australia. The difference may relate to the richness of fern species in the genus *Lygodium* in the two regions. Africa has only a few species while Southeast Asia and Australia have about a dozen species. Many of these Lygodium species occur in complexes in the same areas and even in the same habitats.

Host Specificity Testing. This research will be conducted in the USDA-ARS Brisbane Australian Laboratory, the USDA-ARS-Florida Division of Plant Industry Quarantine in Gainesville, and the USDA-ARS Ft. Lauderdale Quarantine, which is scheduled to be constructed during 2000-2001. A major task before and during host specificity testing is the collection and cultivation of plants needed for this research. Most of these plants are ferns. The State of Florida considers more than 40 species to be rare and gives these species legal protection. Most of these ferns are not globally rare but are Caribbean or Latin American species at the northern limits of their ranges. A selection of the rare fern species and other native and commercial ferns need to be used in the host specificity to define the host ranges of candidate insects and to provide evidence that the rare and other valued species will not be injured or used by the insects. The protection given these rare ferns and most of their habitats means that collection permits from various levels of government are required to obtain the plants for testing. Australia requires import permits and quarantine periods before Florida ferns can be used as test plants in Australia.

After quarantine testing demonstrates the safety of a potential biological control agent, it is petitioned for release. The petition process and subsequent Environmental Assessment currently takes from one to two years before a release permit is issued.

e. Future Biocontrol Research

Australia and Southeast Asia explorations will include visits to previously unexplored areas of Micronesia, Southeast Asia, and Australia. Seasonal variation of insect occurrences is considered important, so populations will be examined during different times of year. Min Rayachhetry, of the Ft. Lauderdale laboratory, will survey for pathogens of *Lygodium* species in Australia.

American explorations will be made to search

for natural enemies of tropical American species of *Lygodium*. Some of these insects could be of promise in controlling *L. microphyllum* as new biological associations. *L. microphyllum* may have less resistance to herbivores and diseases associated with *Lygodium* species in tropical America than to those in its native range.

f. Japanese climbing fern *(L. japonicum)*

Currently the biological control effort is limited to *L. microphyllum*. Tropical and subtropical natural enemies are being sought because these will probably be best adapted to south Florida, where *L. microphyllum* lives. Employing tropical and subtropical biological control agents will also avoid the use and possible damage to the rare native North American Climbing Fern *(L. palmatum)*, a temperate climate species living from Tennessee north to New England. Because *L. japonicum* lives in the warm temperate Southeastern U.S., biological control agents that are adapted to cooler climates would be needed for it. Because temperate climate agents could harm *L. palmatum*, they would need to have exceptionally narrow host ranges.

g. Biocontrol Outlook

Many natural enemies of *Lygodium* species have been located during the short duration of the project. Among these are insects that appear to be damaging to the plants. Some of these appear to have narrow host ranges which will likely make them safe to employ. Biological control is a valuable tool for the management of introduced pest species, but it does not always work. Sometimes a desirable agent will not establish or develop high enough populations when introduced. Biological control research is very good at predicting the potential host range (and therefore the safety of candidate agents) but it is difficult, if not impossible, to predict the population levels that an agent will have in the area that it is used. Populations of wild organisms are notoriously difficult to predict, primarily because we can not predict weather, and therefore weather's important direct and indirect influences on population change. Because almost half of the attempted biological control of weeds projects have resulted in population reduction of the target pest (Office of Technology Assessment, 1995), it is worthwhile to attempt this type of control, especially against such an invasive plant as *L. microphyllum*.

2. Herbicidal Control Technology Research

a. Lygodium microphyllum

Initial research efforts to control *L. microphyllum* were conducted by Richard Roberts at Jonathan Dickinson State Park (Martin and Palm Beach Counties) beginning in 1991 (Roberts and Richardson 1994). Burning vines to the soil, burning vines to the rachis mat, spraying with Rodeo herbicide without burning, and burning followed by spraying with Rodeo were evaluated in 5 x 5 meter plots, compared to untreated plots. Rodeo was used because *L. microphyllum* occurs commonly in the park's wetland communities where the herbicide is sometimes applied directly to water. Based on evaluations (between 1991 and 1993) of percent cover and height and number of stems, it was concluded that fire alone cannot be used to manage the plant but short term control may be achieved with herbicide applications. Two five-year studies are being conducted to evaluate Rodeo rates ranging from 1.5% to 3.0% (sprayed to wet), the effects of hand removal vs. leaving the dead biomass on native plants, and specialized spray equipment for applying herbicide to vines growing high in trees (Roberts 1997). *L. microphyllum* coverage has been reduced from 57% to 1% on the 2.5-acre herbicide and hand removal research site and maintained at that level. At a second 125-acre site where the *L. microphyllum* was herbicided and the dead biomass not removed re-establishment of native vegetation has been slower where dead biomass was not removed. These studies are concluding in the summer of 2000.

Stocker et al. (1997) evaluated efficacy and translocation of several herbicides and herbicide combinations against L. microphyllum, as well as mechanical trimming, fire, and flooding. Rodeo, Garlon 3A, Rodeo plus Garlon 3A, Weedar 64, and

Weedar 64 plus Rodeo all resulted in 100% necrosis of plant tissue in the treated area of plots up to one month following application in tests conducted at Barley Barber Swamp (Martin County) (Table 1). In this study, plots treated with Rodeo showed evidence of slight translocation after one month. Dense *L. microphyllum* at the bases of fern-trellised trees in DuPuis Reserve (Palm Beach County) were treated with the same herbicides used in Barley Barber Swamp and with Pathfinder II. All herbicides completely defoliated contacted vines but only the Pathfinder II killed plants above the treated portion (Table 2). The effects on roots and rhizomes was not determined. At Reese Groves (Palm Beach County), Pathfinder II was applied in bands of 1, 2, 4, and 6 foot widths and other herbicides in bands of 4-foot width starting at ground level to vines that had grown to the top of native trees. Evidence for some translocation of herbicide was observed for Rodeo and Garlon 3A but only Pathfinder II resulted in extensive death of tissue away from the treated band (Table 3). Stocker *et al*. (1997) also studied the effect of flooding on regrowth of *L. microphyllum* following mechanical removal, burning, or contact herbicide (Scythe) application at Barley Barber Swamp. It was concluded that flooding has no chance of producing practical management results.

In a two-year study, Stocker (in review, a) conducted further herbicide and application technique evaluations. When herbicides were applied in November 1999, foliar applications of Rodeo or Pathfinder II resulted in complete control and Weedar 64 resulted in excellent control (Table 4). When the same herbicides were applied in May 1998, only Pathfinder II resulted in complete control. An explanation offered for the differences in results between the two years was that plants may have been under water stress because of a very wet winter of 1997/1998 and an extremely dry spring of 1997.

Stocker (in review, a) applied Rodeo at 1.4, 2.8, and 4.2 kg/ha (1.25, 2.8, and 3.7 lb/acre) in proprietary adjuvant (Monsanto MON 59120), Weedone at 1.4, 2.8, and 4.3 kg/ha 1.25, 2.5, and 3.8 lb/acre) in vegetable oil plus limonene penetrants (JLB Oil Plus), and Garlon 4 at 3.0, 6.0, and 9.0 kg/ha (2.7, 5.3, and 8 lb/acre) in JLB Oil Plus to vines in 15 cm (5.4 in) bands beginning 1.5 m (59 in) from the ground in a spray volume of 187 l/ha (20 gal/acre). Herbicide rate did not affect results, therefore data were pooled within herbicide treatments (Table 5). All herbicides resulted in some tissue death in, above and below the treated band. None of the herbicides resulted in as much control away from the treated band as was observed in the previously described experiment (Table 2). This was thought to be a result of weather conditions described in the previous paragraph. To determine if there was a minimum band width necessary to achieve control, Stocker applied Pathfinder II to vines in band widths of 0.1, 0.4, 0.7, and 1.0 m that started 1.4 m above the ground and progressed down the trellis. All band widths resulted in complete control above, below, and in the treated band.

Stocker (in review, b) conducted studies to compare the effectiveness of using fire to reduce biomass before herbicide treatment in plots where regrowth of plants occurred, to herbicide applications only at either 2- or 6-month inspection and re-treatment intervals. It was concluded that fire can be used to reduce the amount of herbicide required to control *L. microphyllum*, in this study by one half, compared to herbicide only treatments. Also, it was concluded that a six-month inspection/ treatment schedule is more efficient than shorter intervals.

Timmer and Vandiver (unpublished) evaluated a large number of herbicides and herbicide combinations at three sites in southern Florida over an 8-month period (Table 6). While excellent control was observed for most of the herbicide/herbicide combinations (Table 6) for four months, complete control was not observed for any of the herbicides tested for the entire eight months and regrowth was observed for all treatments.

The South Florida Water Management District has conducted aerial applications of Rodeo and Weedar 64 to large infestations of *L. microphyllum* in the DuPuis Reserve (Palm Beach County) and Corkscrew Regional Ecosystem Watershed (Lee County, see case study). These applications were made in the winter when non-target deciduous vegetation such as Taxodium distichum was dormant. Excellent control of *L. microphyllum* has been observed where Rodeo was applied at a rate of 8.8 l/ha (7.5 pt/acre). The Weedar 64 treatment (1 gal/acre) was less effective. Non-target effects of these applications are being evaluated.

b. Lygodium japonicum

Less testing of herbicides has been conducted to date on *L. japonicum*. Foresters in north central Florida report that neither prescribed burns nor application of herbicide containing the active ingredient 2,4-D, or combinations, were effective for controlling it in pine plantations (Jaque Bremmen, pers. comm. 1998). In the same area, it was reported that the plant was not as serious a problem in 1999, with a dry spring, as in previous years with wetter springs.

To test the assumption that herbicide efficacy of *L. microphyllum* is similar to *L. japonicum*, several test plots were established at Florida River Island (Liberty County) on August 26, 1998 (Zeller, Valenta and Leslie unpublished data). Foliar treatment of Garlon 4 at 3%, Pathfinder II at 100%, Garlon 3A at 3%, and Rodeo at 1.5% were applied to plots of L. japonicum. In addition to horizontal plots, vertical "trellis" plots were established by treating columns of the fern that extended 15 to 20 feet into the canopy. Treatment of these trellis plots was limited to a two-foot band from 5 to 7 feet from the ground. This was done to evaluate translocation of the herbicide in both an upward and downward direction.

Evaluations of treatments were conducted at 21 DAT (days after treatment) and at 86 DAT. Results of the 86 DAT evaluation are summarized in Table 7. Statistical inference has not been incorporated into these preliminary trials. At 86 DAT, Garlon 4 and Pathfinder II treated plants appeared controlled well. Non-target damage to herbaceous and woody species was severe where Pathfinder II had been applied.

Continued monitoring of the preliminary plots 86 DAT showed the Rodeo plot to have the best long-term control. All Garlon 3A, Garlon 4, and Pathfinder II plots had almost 100% regrowth within 8 months. The Rodeo plot had approximately 5% regrowth of *L. japonicum* and growth of native species.

A new experimental design was derived from the results of these preliminary trials that included replication and multiple herbicide rates. New treatment included Rodeo at 0.75%, 1.5%, and 3.0%; Garlon 3A at 1.0%, 3.0%, and 5.0%; and Garlon 4 at 1.0%, 3.0%, and 5.0%. Long term monitoring and retreatments have been incorporated into this study. Results of current evaluations are summarized in Table 8. As observed in the preliminary trials, Garlon 3A and Garlon 4 had better initial control, but Rodeo again showed better long-term control at 315 DAT. The long-term control observed in the Rodeo plots allows for a more selective spot treatment of *L. japonicum* during retreatments. Regrowth in the Garlon 3A and Garlon 4 plots was much more uniform throughout each plot, making selective re-treatment difficult.

TABLE 1.

Products, rates and responses for L. microphyllum herbicide trial at Barley Barber Swamp

Plots (three for each treatment) were identified and treated on 6 February, and rated on 14 March 1997. Applications were approximately 100 gallons/acre. From Stocker et al. 1997.

Trade Name	Active Ingredient	Rate	Translocation response	Kill response in plot
Rodeo	glyphosate	7.5 pints/acre	2	100% Dead
Garlon 3A	triclopyr amine	3 gal/acre	1	100% Dead
Garlon 3A Rodeo	triclopyr amine glyphosate	3gal/acre 7.5 pints/acre	1	100% Dead
Weedar 64	2, 4-D	1 gal/acre	1	100% Dead
Weedar 64 Rodeo	2, 4-D glyphosate	1 gal/acre 7.5 pints/acre	1	100% Dead

1. No apparent translocation. 2. Slight translocation. 3. Extensive translocation.

TABLE 2.

Products, rates and responses for L. microphyllum herbicide trial at Dupuis Reserve

Plots (three for each treatment) were identified on 5 February, treated on 7 February, and rated on 15 April 1997. Applications were approximately 100 gallons/acre. From Stocker et al. 1997.

Trade Name	Active Ingredient	Rate	Translocation response	Kill response in plot
Rodeo	glyphosate	7.5 pints/acre	2	100% dead
Garlon 3A	triclopyr amine	3 gal/acre	1	100% dead
Rodeo Garlon 3A	glyphosate triclopyr amine	7.5 pints/acre 3 gal/acre	1	100% dead
Weedar 64	2,4-D	1 gal/acre	1	100% dead
Weedar 64 Rodeo	2,4-D glyphosate	1 gal/acre 7.5 pints/acre	1	100% dead
Pathfinder	triclopyr ester	(.75 lbs./gal)	3	100% dead

1. *No apparent translocation.*
2. *Slight translocation.*
3. *Extensive translocation.*

TABLE 3.

Herbicides, rates, translocation and kill responses in "trellised" L. microphyllum plots at Reese Groves

Applications made 26 June 1997, and assessed 9 September 1997. Applications were approximately 100 gallons/acre. From Stocker et al. 1997.

Trade Name	Active Ingredient	Rate	Translocation response	Kill response in plot
Rodeo MON 59120	glyphosate	2% 1%	2	100% Dead
Rodeo MON 59120	glyphosate	2% 2%	2	100% Dead
Garlon 3A Optima	triclopyr amine	1.5% 0.13%	1	100% Dead
Garlon 3A Optima	triclopyr amine	1.5% 0.26%	2	100% Dead
Finale Optima	glufosinate	3% 0.5%	1	100% Dead
Pathfinder	triclopyr ester	Ready to Use	3	100% Dead

1. *No apparent translocation.*
2. *Slight translocation.*
3. *Extensive translocation.*

TABLE 4.

Percent of L. microphyllum killed by herbicides 106 (1997 trial) and 112 (1998 trial) days after treatment

N=6 for all treatments, except N=30 for control, and N=5 for 2.2 kg ha-1 triclopyr ester. From Stocker, submitted for publication.

Herbicide	Rate	Dates applied 4-5 November 1997	6 May 1998
	kg ha-1		
		Mean Percent Control	Mean Percent Control
Control (water)	--	1 ef[1]	5 ef
2,4-D amine	4.3	99 ab	11 def
	2.1	87 c	16 def
	1.1	33 d	3 ef
	0.5	6 e	0 f
	0.3	0 f	1 f
Glyphosate	44.8	100 a	67 bc
	22.4	100 a	40 cd
	11.2	100 a	29 de
	5.6	99 ab	27 de
	2.8	98 abc	29 de
Triclopyr ester	9.0	100 a	100 a
	4.5	100 a	100 a
	2.2	100 a	84 b
	1.1	91 bc	79 b
	0.6	98 abc	12 def

[1] *Means within a column followed by the same letter(s) are not significantly different (P<0.05) using Duncan's Multiple Range Test.*

TABLE 5.

Percent of fern tissue killed in treated band, and above and below treated band, for L. microphyllum in southeastern Florida, 111 days after treatment

N=15 for all treatments. From Stocker, submitted for publication.

	Control	2,4-D ester	Glyphosate	Triclopyr ester
Above	14 c[1]	26 c	82 a	61 b
Band	13 b	81 a	90 a	72 a
Below	13 c	66 b	90 a	59 b

[1] *Means within a row followed by the same letter are not significantly different (P<0.05) using Duncan's Multiple Range Test.*

TABLE 6.

Control of L. microphyllum with herbicides at three locations in southern Florida

All vines were treated on the fence plots. Vines at Commerce Center and Cypress were treated from the ground up four to six ft. Unpublished data, Elroy Timmer and Vernon Vandiver.

Herbicide	Rate per acre	% Control after 4 and 8 months					
		Commerce Center		Fence		Cypress	
		4	8	4	8	4	8
Arsenal	16 oz	95	55	95	60	10	50
Arsenal + Plateau	8 + 8 oz	99	97	92	40	10	45
Escort	1 oz	100	97	95	65	25	80
Escort	2 0z	99	93	96	80	15	60
Escort + Plateau	1.5 + 6 oz	99	96	85	65	45	50
Garlon 4	2 qt	99	20	97	30	98	60
Garlon 4 + Escort	2 qt + 1 oz	100	40	99	70	90	60
Krenite + Arsenal + Escort	1 gal + 8 oz + 1 oz	95	90	95	55	80	70
Krenite	2 gal	80	30	35	25	60	40
Oust	1.5 oz	85	20	20	20	5	0
Plateau	16 oz	95	97	50	30	40	30
Rodeo + Mon 59120	7.5 pt + 2.5%	95	50	92	75	95	92
Rodeo + Mon 59120 + Escort	6 pt + 2.5% +1.5 oz	95	90	99	98	95	80
Rodeo + Arsenal	5 pt + 12 oz	100	97	93	75	95	90
2,4-D	2 qt	90	10	70	10	80	30
2,4-D +Arsenal + Escort	1 pt + 6 oz + 1.5 oz	100	90	95	55	80	65
Vanquish + 2,4-D	1 qt + 1.5 qt	99	40	95	25	80	60
Velpar ULW	2 lb	40	50	75	65	70	50

TABLE 8.

Current results of percent control evaluations of ongoing L. japonicum trials at Florida River Island

These results are based on the average of three replicates; no further statistical analysis has been conducted at this time. Reported herbicide rates are the best of three rates evaluated for each product. All treatments had Kinetic at 0.05% as a surfactant.

L. JAPONICUM HERBICIDE EFFICACY PLOT EVALUATION PERCENT CONTROL					
	DAT				
Herbicide and Rate	21	42	84	180	315
Rodeo @ 1.5%	75%	87%	87%	71%	79%
Garlon 3A @ 5%	87%	100%	83%	0%	0%
Garlon 4 @ 5%	54%	96%	46%	0%	17%

DAT = Days After Treatment

TABLE 7.

Application rates and evaluation results for preliminary herbicide trials on L. japonicum at Florida River Island

PLOT EVALUATION DAT 86 APPLICATION DATE: 8-26-98

TREATMENT RATES				PERCENT DAMAGE	
HERBICIDE	RATE	ADJUVANT	RATE	HORIZONTAL	TRELLIS UP / DOWN
RODEO	1.50%	KINETIC	0.75%	75%	75% / 95%
GARLON 3A	3%	KINETIC	0.75%	95%	100% / 100%
GARLON 4	3%	KINETIC	0.75%	100%	75% / 100%
PATHFINDER II	100%	NA	NA	100%	100% / 100%

3. Monitoring

An IPM program typically incorporates a monitoring program to determine when a pest reaches a predetermined threshold level which would trigger management implementation. In the case of aggressive invasive species such as *L. microphyllum* and *L. japonicum*, the threshold level is essentially zero, because any new occurrence has the potential to rapidly expand and in turn produce spores for further colonization.

Natural area managers and others should be on constant surveillance and steps should be taken to eliminate any new *Lygodium* population that is detected. After a management plan has been implemented, scheduled inspection /re-treatment should be carried out to manage regrowth and detect new infestations. Current information suggests a six-month inspection interval is sufficient (Stocker in review b).

4. Physical removal

Cutting will result in death of fronds above the cut location, but fronds will re-grow from material below the cut and after hand pulling. Cut fronds may harbor viable spores easily dispersed by disturbance. Care should be taken in removing dead fronds to reduce fire fuel or enhance recovery of native ground cover.

In some situations, heavy equipment can be used to successfully remove thick rachis mats that have formed (Street, pers. comm. 1999). This practice should only be used in appropriate areas where soil compaction and non-target damage are not a concern. Disturbance caused by equipment can also facilitate re-establishment of *Lygodium* or other exotic species and scheduled inspections of areas receiving mechanical control should be implemented. When removal of dead fern material is necessary, the use on-site disposal methods (such as burning) is preferred to minimize spore dispersal into *Lygodium*-free areas.

5. Fire

Naturally occurring fires, especially wet season lightening ignited fires, were a dominant historical influence on certain Florida habitats, such as flatwoods, dry prairies, and sawgrass marshes. Anthropogenic exclusion of fire has now altered successional patterns and prescribed burning is an important habitat management tool used by land managers. Prescribed burning may be useful for the management of invasive vegetation. For example, fire has been shown useful for discouraging the growth of skunkvine (*Paederia foetida*) in sandhill habitats (Gann and Gordon 1997). Research is lacking for most species.

As previously discussed, the potential role of fire for managing *L. microphyllum* has been studied by Roberts (unpublished data) and Stocker (in review b). Based on the observations of Roberts, fire alone, without herbicide application, does not control *L. microphyllum*. While reduction of biomass with fire reduced the amount of herbicide needed to control *L. microphyllum* in plot studies conducted by Stocker, practical application has not been demonstrated. Affects of prescribed burning on *L. japonicum* have not been studied.

Habitats, such as cypress swamps and strands (*Taxodium* spp.) should not be burned in the presence of *L. microphyllum*, because trees can be killed or damaged by the burning fern. Also, the role of fire in causing the spread of *L. microphyllum* spores has not been studied and convection currents caused by fire may result in increased dispersal.

Mature trees are frequently killed when Lygodium-infested areas are burned.

6. Flooding

Flooding has not been shown to control Lygodium. Additional studies should be conducted to determine the role of hydrology on germination and survival of spores, gametophytes, and young re-establishing plants. At this time however, flooding is not recommended as a viable management tool.

VI. Resource Management Approach

Management of *Lygodium* will require a number of control techniques to be effective. Elements of effective management for these species include: early detection, biological, herbicidal, mechanical and physical controls (including prescribed burning to reduce plant biomass). A field reporting form is provided for the land manager to document on-site conditions and treatment methodologies, and to schedule maintenance events.

Prior to implementing a site-specific climbing fern management program, the following factors must be considered:

1). **Occurrence** - degree of infestation, density and/or spatial distribution and growth habit (e.g., is the fern trellising into non-target trees and shrubs, primarily acting as a groundcover, or both).

2). **Topography and soils** - How does the fern's occurrence relate to elevation and soils? Are the ferns colonizing on the ground, above the ground on other plants, or in ecotonal areas between wet/dry habitats, etc.? What types of soils are present - organic, mineral, or muck?

3). **Soils and Hydroperiod** - Is the soil type and hydroperiod conducive to the use of heavy equipment for biomass removal? Would soil compaction present a problem? Would cleaning the equipment to prevent spore dispersal to other sites be difficult? Is burning the site for fern biomass reduction an option? Is the coverage of fern extensive enough to warrant aerial treatment with minimal non-target plant damage?

4). **Hydrology** - What is the hydrology of the site? Is the site permanently flooded or does it dry out periodically? Is the fern biomass acting as an impediment to surface water flow? Can the site be drained or flooded for management or treatment? Where within the hydrological gradient does the plant appear to colonize?

5). **Available management techniques** - Which method of treatment or combination of treatments is most effective and suitable for the site? How will access to the site affect treatment options? Will follow-up treatments be possible, and could the treatment method exacerbate the spread of the fern?

6). **Economic factors** - What will be the costs associated with the initial treatment, and long term follow-up control? Is there a source of funding (i.e., grants, mitigation, etc.)? Will the maintenance be conducted by agency staff or by a contractor?

7). **Public perception** - Could there be negative public reaction to treatments? What type of public education will be necessary to avoid a negative reaction? How will the fact that the fern is "photogenic" affect public perception?

8). **Adjacent properties** – Are there adjacent properties that are infested with exotic climbing ferns? Can neighbors be encouraged to coordinate control efforts?

9). **Work schedule** - Determine a reasonable time schedule as a goal for initial treatment and outline a plan for routine maintenance control.

10.) **Treatments** – How to choose one

Lygodium control options include preventative, herbicidal, biological, mechanical and physical methods. Biological control holds the key to effective long-term regional management of the exotic climbing ferns. Without a successful biological control program, climbing fern eradication will be extremely expensive. Overseas searches have been initiated for biocontrol agents in the ferns' native ranges, but the work has just begun. Even after potential biocontrol agents have been isolated, screened and released, a process which may take several years, it may be several more years before the agents build up effective populations in Florida.

In the interim, and during the biological control development and introduction phase, a combination of preventative, herbicidal, mechanical, and physical control measures will be required to reduce current infestations and prevent colonization of un-infested areas. It is extremely important that land managers identify and treat small populations of exotic climbing fern before they become substantial infestations. This element cannot be stressed enough. Early detection and treatment is key to successful and

economical management of this plant.

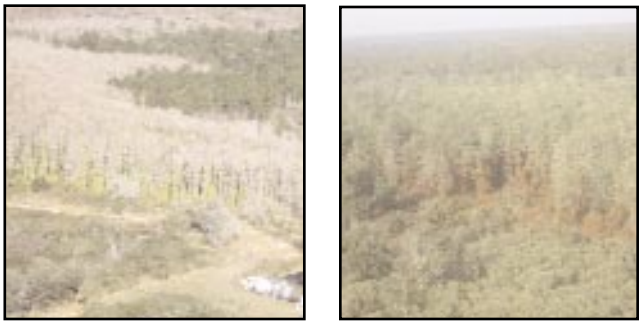
Moving equipment from lygodium-infested areas to (and through) un-infested areas may lead to new infestations of the plant. Tiny spores can be easily moved on vehicles, spray equipment and clothing. Care should be taken to minimize this threat, although equipment sterilization methods and procedures have not been developed to date.

Treatment of individual plants is the most conservative and effective approach in natural areas. However, locating, accessing and treating individual plants can be extremely time-consuming and expensive. Thus, less time consuming and costly methods of herbicide application are constantly being investigated.

Herbicides

Many herbicides have activity against *Lygodium*, however results have been inconsistent. Herbicide performance can be affected by variables such as weather conditions, site conditions, application technique, etc. In the case of a vine such as *Lygodium*, which climbs high into trees, it is important that the herbicide used can translocate and kill the entire plant - not only the parts that can be reached with the herbicide spray. In choosing a herbicide it is also necessary to consider sensitivity of non-target vegetation and whether the herbicide will be applied to water during the application. Only herbicides that are labeled for aquatic use can be applied directly to or over water. Most others can be applied to areas that are occasionally flooded as long as they do not contain water at the time of application. The following recommendations take these considerations into account and suggest herbicides that have been most consistently effective in field trials. Further research should lead to additional recommendations.

Aquatic sites: Apply Rodeo herbicide in a 1.0 to 2.0% aqueous solution to wet foliage or 7.5 pt/acre broadcast application. Include a nonionic surfactant according to instructions on the label. Rodeo is a broad spectrum herbicide. Avoid drift and contact to non-target vegetation with hand held equipment. Make boom applications only when the infestation is too large to treat with handheld equipment. Nontarget damage to species such as *Taxodium* spp. and *Acer* spp. can be minimized if application is made when these species are dormant. Grass species, such as *Aristida* spp. in wet prairies, will be damaged by Rodeo. Do not make broadcast applications of Rodeo where rare native plants will be affected.



Herbicide use at Dupuis: Before (left) and after (right) aerial treatment.

Non aquatic sites: Apply 1.25% Garlon 4 or 0.6 to 1.5% (results have been inconsistent among researchers) Roundup Pro in aqueous solution to wet foliage of small populations, where complete coverage is possible. Avoid contact of either herbicide with non-target vegetation including tree trunks when using Garlon 4.

For boom applications apply Garlon 4 at 2 qt per acre or Roundup Pro at 2.5 qt per acre. Damage to non-target vegetation will occur if Garlon 4 is broadcast over vegetation. Damage to non-target vegetation will occur if Roundup Pro is broadcast over the top of actively growing vegetation.

Where vines climb too high into trees to cover all foliage with the herbicide spray, apply Pathfinder II in a 12 inch (as a basal bark application) band four to five feet above the

ground or cut vines and treat lower portions with 1.25% Garlon 4 or 0.6% Roundup Pro. ***Note that Pathfinder II is not currently labeled for foliar applications. Use of this herbicide on Lygodium is open for interpretation and should be considered on a case-by-case basis.*** A 20% solution of Garlon 4 is approximately the concentration of active ingredient in Pathfinder II. While it has not been tested, application of 20% Garlon 4 diluted in a commercial vegetable oil should also be effective when applied as a band application.

Aerial applications of herbicides at certain times of the year may, in some cases, reduce non-target damage. Wintertime aerial applications in deciduous cypress forests have been preliminarily successful in controlling the fern with partial damage to native species. Bromeliads and native ferns have been most susceptible.

Removal of matted dead fern rachis material may be desirable, particularly if the mat is unusually thick and prohibits the re-colonization of native plants. Also, removing the mat may help with the restoration of historical hydrologic sheetflow in wetland areas. Removal of trellised fern biomass reduces ladder fuels (ladder fuels spread fire from the understory up into the canopies of the trees) and thereby decreases the chance of fire damaging or killing individual trees. Careful consideration of site-specific conditions will determine when and if biomass removal is an option.

Burning is a potential biomass reduction technique. However, it is extremely important to understand the natural burn intervals for the non-target plant community type under consideration. Community types such as pine flatwood, dry and wet prairie, and freshwater marsh typically remain stable with 2-7 year burning intervals. However, other community types such as tropical and coastal hammock, temperate forests, swamps, scrub, and tree islands typically burn less often (i.e., 10-100+ years) and could be adversely affected by more frequent fires. Organic (muck) soils further complicate the possible use of fire as dangers associated with muck fires must be considered.

The use of heavy equipment for biomass removal should be limited to situations where the substrate can support the equipment and soil compaction and ancillary damage can be held to a minimum. Manual removal of fern biomass is very time consuming and expensive. Individual site conditions and objectives should dictate the method of removal.

Lygodium can spread quickly to adjacent properties and may require cooperative efforts among public and private land managers to maximize control efforts. Cooperative efforts such as Memoranda of Understandings (MOUs) between agencies and among public and private landowners can facilitate such relationships. A sample MOU between the South Florida Water Management District and the Fish and Wildlife Conservation Commission is included as an Appendix. It provides for treatments across property boundaries and ensures a coordinated control plan for adjacent lygodium-infested conservation lands.

Removal of matted dead fern rachis material may be desirable, particularly if the mat is unusually thick and prohibits the re-colonization of native plants.

LYGODIUM CONTROL FIELD REPORTING FORM

LOCATION

County _____ Section_____ Township _____ Range _____

Address _____

Landowner _____

Contact person _____ Telephone number _____

SIZE OF PROBLEM

Acres on ground _____ Percent of area covered _____ Number of trees or shrubs affected ____

Is the vine growing up the trees: ☐ Yes ☐ No, If so how high?: _____ ft

Is access to the site a problem? ☐ Yes ☐ No

Problem area located in

☐ Swamp (cypress, maple, bay, holly, willows)
☐ Pine flatwoods (slash pine, palmetto, galberry,)
☐ Scrub (sand pine, palmetto, scrub oaks)
☐ Marsh (sawgrass,rushes,shrubs)
☐ Agricultural area (grove, orchard, row crops, pasture)
☐ Disturbed area (old field, spoil, road side, ditch bank)
☐ Yard
☐ Other, describe: _____

Desirable trees, shrubs or grass in the area? If so, what? _____

_____

Soil type: ☐ sand ☐ muck ☐ marl ☐ other

Hydrology: ___standing water ___wet/muddy ___dry

Type of control:

☐ Mechanical ☐ remove by hand ☐ remove with equipment ☐ Chemical

☐ If ground is wet, use Rodeo* ☐ If ground is dry, use Round Up*or Garlon 4*

FOLLOW-UP SCHEDULE

Initial completion date _____

Date of 1st follow-up inspection_____, % kill____, non target damage acceptable ☐ Yes ☐ No

Regrowth of target ? ☐ Yes ☐ No

New spore germination present ? ☐ Yes ☐ No

Date of 2nd follow-up inspection_____, % kill____, non target damage acceptable ☐ Yes ☐ No

Regrowth of target ? ☐ Yes ☐ No

New spore germination present ? ☐ Yes ☐ No

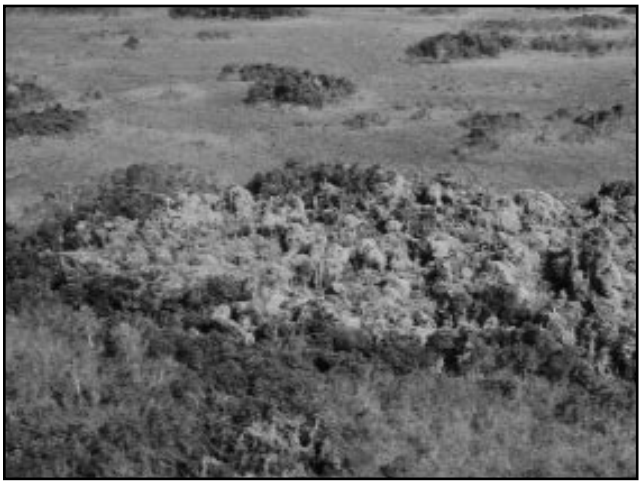
Date of 3rd follow-up inspection_____, % kill___, Non target damage acceptable ___Y ____N

Regrowth of target ? ☐ Yes ☐ No

New spore germination present ? ☐ Yes ☐ No

Final inspection date_____ More control work needed ? ☐ Yes ☐ No

VII. Case Studies



A. Lygodium microphyllum at A.R.M. Loxahatchee NWR

1. Introduction

A.R.M. Loxahatchee NWR (WCA 1), located in western Palm Beach County is approximately 145,000 acres of deep peat wetland with organic soils of up to 8 meters deep. It is the most northern portion remaining of the original Everglades, and is unique with large areas of open sloughs and wet prairies dotted with thousands of small tree islands. Native tree islands range from 0.5 to 300 acres in size and exotic melaleuca heads can be up to 2 miles in length. Wide expanses of sawgrass and wet prairies are interspersed within the refuge interior. The refuge also has a 400 acre cypress swamp, 2030 acres of impoundments and manages Strazzulla Marsh. Over 64 rare species listed by federal, state or international authorities have been document in or near the refuge. Many of the listed species are plants. Of particular concern is the spike-ray fern *(Actinostachys pennula)* also known as tropical curly-grass fern *(Schizaea germanii)*, which is distantly related to *L. microphyllum*. It has been found growing on tree islands now invaded by *L. microphyllum*.

Lygodium control is critical because threatened, endangered, and critically imperiled animal species need native plants and natural plant communities for food, cover, nesting, and for stopover sites during migration.

2. Background

L. microphyllum was first noticed on isolated tree islands in the north, north-central portions of the refuge interior by SFWMD helicopter pilots in 1989-90. The fern also was noted in Strazzulla Marsh around 1992 by SFWMD staff, and in the interior by refuge biologists in 1992. However, the establishment of the fern must have been years earlier, because it needed to grow large enough to be easily seen from the air.

A 1993 aerial survey showed the fern was on a few localized tree islands in the central to north-central portion of the refuge. By 1995 aerial surveys revealed that 12%, or 17,500 acres of the Refuge were infested by Lygodium. As of 1997 aerial surveys by SFWMD indicate that the climbing fern has infested an additional 4,500 acres, totaling an estimated 22,000 acres of the refuge. 1999 aerial surveys showed that the abundance of the fern of the on the refuge continues to increase. The aerial estimate is considered extremely conservative because the fern is probably not detected in areas with sparse infestations or in the understory of forested habitats.

The base of tree islands are muck soils which can range from fairly dry to moist or to completely inundated depending on the water levels. The fern has been observed growing both along the edges and deep in the interior of tree islands, and in areas of open sawgrass. The spores appear to be germinating on native fern tussocks which are usually above the water level.

Although the information is anecdotal, the fern seems to grow particularly well in areas where native tree island vegetation was damaged, or killed by a fire during the drought of 1989-90. Refuge water levels fluctuate through the year with water levels rising July through November and as the rains end, the refuge begins to dry out December through May. In some years the water levels can be low enough to expose large expanses of peat to fern spores, and this may have happened during 1989-90 - the years during which the fern may have begun to expand on the refuge. Evidently, extended hydroperiods do not have a negative impact on fern growth.

In some areas of the refuge interior, the fern has completely covered tree islands, smothering native vegetation. Well established "fern ladders" can be seen ascending to the top of the trees on hundreds of tree islands, in many areas of the cypress swamp and along levees (75 miles) in the refuge. The fern is probably present and at various stages of development on 85% of the tree islands on the refuge. In all probability, all of the refuge's tree islands and the entire cypress swamp are at risk. We are unable to estimate how much sawgrass marsh would be at risk at this time.

L. microphyllum can readily be observed growing in areas adjacent to the refuge including remnant cypress domes in nearby agricultural fields, in housing developments, along road sides, along canal edges, and in old unused agricultural fields. The infestation varies from slight to dense fern ladders. The lands are mostly private, except road right-of-ways.

3. Management efforts

In 1998, Institute for Regional Conservation biologists under contract with the South Florida Water Management District set up test plots in the refuge interior and in the cypress swamp to obtain baseline data on the spread of the fern. Refuge staff have been hand pulling small clumps of climbing fern from the edge of the Cypress Swamp and along the Marsh Trail for years. Although the staff knew of the ferns existence and its growth potential, no funds were allocated in the budget for fern control, nor was a large scale attempt to control the fern been implemented. In the spring of 1999 funds were allocated from the Florida Department of Environmental Protection to treat *L. microphyllum*. In August 1999, contractors started treating infested tree islands in the refuge interior. The fern ladders were cut with machetes and left to die. The fern below the cut was foliar sprayed with 5% Rodeo. By December 8, 1999, approximately $154,800 had been spent to kill the climbing fern on 320 acres of refuge marsh. Within the 320 acres, approximately 80-90 native tree islands of varying size have been treated.

The initial control treatment appears to have worked well in this isolated area. Treated areas will be monitored and retreated on a routine basis to prevent re-infestation. Monitoring efforts will include comparative photographs and a vegetation survey to determine regeneration of native plants in the treatment area. Time will tell if the dead biomass will prevent the recovery of surviving native plants or the germination of native plants. No restoration is planned for the treated areas as refuge staff feel passive spread of native plant seeds will naturally occur through wildlife movement.

No management for *L. microphyllum* is occurring on nearby lands to our knowledge. However, Palm Beach County and the SFWMD are adjacent owners and may have future plans to treat this species on their lands.

Refuge staff is working to secure funding from many sources for the control of *Lygodium* for this effort and will continue to make additional funding a high priority.

B. Lygodium microphyllum at Corkscrew Regional Ecosystem Watershed (CREW)

1. Introduction

The Corkscrew Regional Ecosystem Watershed (CREW) project encompasses approximately 60,000 acres in Lee and Collier Counties. Major components of the watershed include Bird Rookery Swamp, Corkscrew Marsh, Flint Pen Strand, Camp Keais, Strand and the National Audubon Society's Corkscrew Swamp Sanctuary. Water flowing from the eastern portion of CREW is part of the larger Big Cypress watershed and delivers water to Florida Panther National Wildlife Refuge, Fakahatchee Strand State Preserve, Picayune Strand State Forest, Big Cypress National Preserve and Everglades National Park. Water flowing from the western portion of CREW enters the Imperial River and flows into Estero Bay and the Gulf of Mexico.

Bird Rookery Swamp is located mostly west and south of the Corkscrew Swamp Sanctuary in western Collier County. Cypress and maple dominate the strand swamp, a major flow way of the CREW system. There is a mix of wet

flatwoods and cypress dome swamps along the western portion of the property. An area of open marsh, dominated by sawgrass and willow is found in the center of the swamp. A system of logging tram roads, constructed to harvest cypress trees, along with their adjacent borrow ditches remain on the property.

Bird Rookery Swamp supports many listed plant and animal species including the Florida Panther, Wood Stork, and the Florida Black Bear.

2. Background

Lygodium was first located along the logging tram roads within Bird Rookery Swamp in 1994. Bird Rookery Swamp is a relatively undisturbed swamp at its core and maintains a "healthy" hydroperiod, being wet most or all of the year. Since that time numerous, isolated populations of the fern have been found and treated throughout all units of CREW. The majority of the fern locations have been in cypress areas and wet flatwoods. In most cases the fern is found on a single tree with no other occurrence of the plant in the general vicinity. This is probably due to reproduction by aerial borne spores.

Two major concentrations of *Lygodium* have been located in Bird Rookery Swamp. One is on the eastern boundary of the unit and is shared with private property to the east. This area where *Lygodium* is concentrated is in excess of 100 acres in size. At the center of the infestation the fern climbs 40 to 50 ft. into the canopy of the cypress and maple. The other area of *Lygodium* concentration is located in the north central portion of the unit and is shared with the Audubon Corkscrew Sanctuary. In this vicinity the fern is found in dozens of isolated patches less than 1 acre in size.

The core of these infestations is in cypress/ maple swamp areas accessible only by foot travel. *Lygodium* apparently spreads out from these central locations with outlying plants found in trees within a radius covering several hundred acres. Where *Lygodium* is found as individual patches or individual plants, it can be assumed that left untreated it would soon cover the swamp vegetation like it has in other areas.

3. Management efforts

Numerous, isolated patches of *Lygodium* have been treated successfully throughout CREW since 1994. Treatments were made using low-volume broadcast equipment spraying a 3% to 5% solution of Rodeo and surfactant. On sites where the *Lygodium* had climbed up trees and was out of range of the sprayers, the vine was pulled down, bunched up and sprayed in place. After a few years of observation this small-scale treatment process appears to be successful.

On January 7,1999 the first large-scale aerial application treatment using a helicopter was done in Bird Rookery Swamp. Prior to this treatment , fixed radius visual observation plots were established to evaluate herbicide effectiveness and non-target damage from the spraying operation. The helicopter application was made using an aerial tank mix of 7.5 pints of Rodeo with surfactant in 20 gallons of water per acre. Approximately 100 acres of the swamp were treated. All of the cypress and maple trees were dormant or entering dormancy with few leaves present.

The first evaluation was made April 19, 1999. The target *Lygodium* was browned close to 100%. The cypress and maple canopy trees showed slight damage from the herbicide. Midstory plants and understory plants exhibited significant damage.

The July evaluation revealed similar results with the target *Lygodium* apparently dead.

What was to be the final evaluation was made on November 18, 1999. The target *Lygodium* was dead; the cypress and maple trees were showing some damage from the aerial application but would recover. Midstory plants and the understory plants were exhibiting moderate to severe damage. What was considered successful control of the *Lygodium* and acceptable non-target damage, under the circumstances, were overshadowed by the presence of thousands of new *Lygodium* plants germinating in the moist moss collar zone of the swamp trees and cypress knees. Even floating logs were covered with new *Lygodium* plants. There had been an apparent massive spore release and germination.

Quarterly evaluations will be continued to monitor the growth of the new Lygodium. Mop-up operations using ground crews will begin in the winter and drier conditions starting in the year 2000.

C. Lygodium microphyllum at Jonathan Dickinson State Park

1. Introduction

Jonathan Dickinson State Park is located in Martin and Palm Beach Counties, with its entrance 12 miles south of Stuart on U.S. Highway 1. The park consists of 11,470.94 acres and is named after Jonathan Dickinson, a shipwrecked Quaker who wrote of his travels along the east coast of Florida during the late 17th century.

The park supports many unique natural features and significant cultural resources. It contains one of the last remaining coastal sand pine scrub plant communities along the southeast coast, a 2,600-acre wilderness preserve and most of the Loxahatchee National Wild and Scenic River. It also has a long cultural history of human use, with prehistoric Indian camps, a portion of the major battle site of the Second Seminole War, the Trapper Nelson homesite and U.S. Army base. Most of the property was initially obtained by the State of Florida from the U.S. Government and was opened as a state park in 1950.

As defined by the Florida Natural Areas Inventory (FNAI), there are 13 distinct, natural, biological communities in addition to ruderal and developed areas within this site. Plus, there are over 79 designated species listed by federal/state governments and FNAI that have been documented. Of these, 41 are plants and 38 are animal species.

2. Background

Of the 159 non-native plants found at Jonathan Dickinson State Park, *L. microphyllum* has become a primary concern for the continued management of several existing biological communities and many designated species.This has led to some of the earliest efforts to research and develop methods of *Lygodium* control.

When first observed in the early 1970s, its initial establishment was within the ecotone between the pinewoods and wetlands within the park's lower Kitching Creek basin. At the time of the park's 1993 exotic pest plant survey, there were 1,233 acres that showed the presence of this exotic species. More recently, it has been found in floodplains and strand swamps, cypress domes, wet prairies, wet flatwoods, hydric hammocks, depression marshes, ditches and even scrub.

The fern's aggressive behavior has allowed Lygodium to especially spread and cover acres of floodplains and strand swamps, plus cypress domes, posing a long-term threat to these biological communities. Forming a thick mat over vegetation, its dense cover can eliminate understory plants.

The rapid growth and climbing habit of this fern has also caused problems for both wildfires and prescribed burns. Except during times of long-term drought, the waters of these communities have usually provided a natural barrier to fire with little permanent damage (1971). However, in May 1986, this fern's growth caused fires to exceed containment areas and produced tree mortality. It has also caused a prescribed burn to escape the park boundary in March 1991.

The growth of this species into the tree canopy provides an unnatural avenue for fire to spread into the tops of vegetation, especially cypress trees. It can then produce firebrands that have ignited spot fires outside the perimeter of a prescribed burn. Also, trees have been killed by the heat generated by the burning fern. Even with higher humidity and dew points of night burning, there has been cypress tree mortality (June 1989). Because of observed changes in fire control effects caused by this species, the park's fire management plan had to be revised in the late 1980s as we no longer could utilize wetlands to stop or control the spread of wildfires or prescribed burns.

In summary, when first observed nearly 30 years ago, *Lygodium* was just a localized infestation. Today, it has spread to almost all of the park's biological communities.

3. Management Efforts

Before a management control program was implemented, three research/mitigation projects were undertaken in an effort to determine best management practices for the control and elimination of *L. microphyllum*.

Project 1

To control the spread of this exotic pest plant within Jonathan Dickinson State Park, a research program to identify possible management practices was conducted using a variety of herbicide and burn treatments. Since this species is usually restricted to wetland communities, Rodeo (glyphosate) was utilized as the herbicide of choice. Five treatments, i.e., 1) control, untreated and unburned; 2) burned to soil; 3) burned to rachis mat; 4) sprayed with Rodeo herbicide without burning; and 5) sprayed with Rodeo with burning, were applied to a series of ten, 5 x 5 meter study plots within the park. Percent cover and height were recorded for the climbing fern as well as percent cover for other vegetation after each treatment from March 1991 to March 1995. The results indicated there is little reason to support that fire by itself can control the spread of this pest plant. However, short-term control may be attained by herbicide applications.

Further studies and mitigation projects were then implemented to study the future, long-term role for herbicide combinations and techniques in control of this plant.

Project 2

In keeping with this goal, a second research project was started in 1993 with mitigation funding from the Florida Department of Transportation (District IV office, Fort Lauderdale) to focus more on herbicide concentrations and manual removal of *Lygodium*. The project consisted of the control of nuisance cattails (*Typha* spp.) and exotic plant species including Brazilian pepper (*Schinus terebinthifolius*) and *Lygodium* on 13 acres infested with this material.

At each of the four nuisance/exotic plant control sites, transects and 5 x 5 meter (25m2) vegetation plots were permanently established. Within each of these sampling plots, three randomly selected 1 meter square (1m2) were measured for relative percent cover of the plants that were herbicided, as well as other vegetation. Also, plant species not present within the sampling areas, but found within the 25m2 area were recorded after initial measurements.

The mitigation plan called for herbicide application and physical removal of the dead biomass by Aquatic Plant Management, with monitoring being conducted by Peninsula Design & Engineering, with assistance from park biologists and volunteers. More specifically, on the *Lygodium* site (one of four areas), a 2-1/2 acre plot was divided into four separate treatment quadrants, then applying different percentages of Rodeo (consisting of 1.5%, 2.0%, 2.5%, and 3.0% concentrations).

After the herbicide treatment using the above noted specified rates, the Lygodium was left until it showed sign of browning and defoliating, then all the dead biomass was removed from on the ground and approximately 6 feet high on the trees. All the dead material was then hauled off-site to be prescribe burned.

The herbicide treatment began in April 1995 with the first monitoring conducted in December 1996. At the start of the project, it should be noted that the *Lygodium* coverage was 56.9% total. After the herbicide treatment and biomass removal of the dead fern, the sites to date have maintained at less than 1% coverage of *Lygodium*, with native vegetation beginning to recover and flourish. In anticipation of a less expensive alternative, a "herbicide application and leave the biomass study" was also initiated by the park biologist and volunteers at the same time as the above study. This has been helpful in judging the rate of native plant regrowth (which has been much slower than the biomass removal site) and establishing some of the much more intensive future control efforts on *Lygodium*.

Project 3

As a regional mitigation site for the Florida Gas Transmission Company's pipeline project, Jonathan Dickinson State Park also is the site for a third study on *L. microphyllum*. This effort involves the control of three targeted exotic pest plants, specifically *Epipremnum aureus* (Pothos), *Syngonium podophyllum* (Nephthytes) and *Lygodium*. This is located on 125 infested acres along the Loxahatchee National Wild and Scenic River within the park.

The contractor (Aquatic Vegetation Control) is utilizing Rodeo in both back-pack mounted spray equipment for low growing vegetation and an all-terrain vehicle (Argo) with a high-pressure sprayer and extension wand to spray the portions of plants higher in the trees. Eradication efforts were started in March 1996. The most recent observation has indicated good control on the Lygodium on the ground and in the trees, with regrowth and spore germination being monitored by McGlynn Consulting and park staff.

D. Lygodium microphyllum in the DuPuis Wildlife and Environmental Area

1. Introduction

The DuPuis Wildlife and Environmental Area, formerly known as the White Belt Ranch, was purchased in 1986 under the State of Florida's Save Our Rivers program. The 22,000-acre parcel, located in Martin and Palm Beach Counties was purchased to protect and enhance water related resources of the region. DuPuis is adjacent to the 58,000 acre J. W. Corbett Wildlife Management Area. From DuPuis, east through the Corbett WMA, West Jupiter Wetlands and Jonathan Dickinson State Park is a mostly unbroken wildlife corridor, a distance of over 25 miles. DuPuis is a mix of mesic and wet flatwoods, wet prairie, cypress dome swamps, strand swamps and fresh water swale. The property was drained starting in the 1950s and converted into ranch land. Wetland restoration on the property began in the early 1990s. The western portion of the parcel is known as the L-8 Marsh and named after the L-8 canal that separates DuPuis from agricultural fields adjacent to Lake Okeechobee. This marsh is a remnant of the original northeast portion of the Everglades.

The DuPuis Wildlife and Environmental Area supports many listed plant and animal species. The Florida Panther has been documented using DuPuis and there are several active Bald Eagle nests on the property. Rare plants on the property include:

2. Background

L. microphyllum was first noted in 1987, shortly after acquisition. The fern was first seen as a small patch in the southern end of a cypress strand in the property's southeastern corner, immediately west of the J.W. Corbett WMA and just north of the L-8 Marsh. This portion of cypress was kept wet most of the year by the previous landowner via a road that served as a dike and water control structure. The fern initially spread into the surrounding cypress becoming locally dense, and gradually spread north within the strand. It also spread west along a shallow borrow ditch of the road immediately adjacent to the cypress strand. It was later noticed in 1995 spreading 3 miles north along a drainage ditch. In May 1996, the plant was found growing in cabbage palms and saw palmetto an additional mile and a half to the northwest near permanent research plots. *Lygodium* was not observed during data collection in the L-8 marsh between 1992-1994. Much of the marsh was chopped and burned in April 1999. However, the fern is currently prevalent there. In 1997, it was noticed in both cypress and flatwoods (palmettos) in an area about a mile west of the origin. Currently, Lygodium is established in patches throughout the 22,000-acre parcel in cypress, marsh and flatwoods.

There is a large infestation of *Lygodium* on the adjacent J.W. Corbett property located adjacent to the origin of the DuPuis Lygodium. It is not known which area was affected first, but Corbett is historically much wetter than Dupuis, and was only recently that a more natural hydroperiod was restored at Dupius.

The former cattle manager for White Belt Ranch recalls *Lygodium* being limited to a small area of the wettest cypress when the ranch was extensively drained and cattle grazed throughout. Plugging interior drainage ditches may have contributed to the spread of the fern in the early 1990s. It was noticed several miles away and in other cypress stands after ditch plugging, and appeared to spread along disturbed areas, particularly ditches. The fern noticeably spread after a hot prescribed burn in 1994 in the area of origin. The fern spread considerably in the L-8 Marsh after increasing the marsh hydroperiod. In the last two years, the fern has been noticed more in flatwood areas and recently was discovered to have expanded in a roller-chopped area.

In a 1998 aerial inspection of the southeastern problem area, it was estimated that about 600 acres of cypress strand and marsh were severely affected. Lygodium is now found in patches over the entire property (approx. 20,000 acres).

3. Management efforts

Exotic plant control contractors have systematically canvassed the DuPuis property for the last 2 years in search of small concentrations of Lygodium. Low volume spray equipment is used to apply a diluted solution of Pathfinder, a ready mix of Garlon 4 and oil. Where the fern is found in mats, it is pulled away from desirable vegetation and sprayed. The fern has been found in almost all of the natural communities, including the drier flatwoods.

Aerial application was made by helicopter on approximately 300 acres of *Lygodium* infestation January 8, 1999. The areas of treatment included portions of a strand swamp and the relatively open L-8 Marsh. The swamp was dominated by an overstory of cypress and maple. The L-8 Marsh, previously farmed, is an area of sparse sawgrass, cattails, rushes and other aquatic plants such as pickerelweed and smartweed mixed with wax myrtles and willow. Two different aquatic herbicides were used, Rodeo and 2,4-D. Prior to treatment, fixed radius visual observation plots were established in the cypress strand and plots were set up in the marsh. The plots were used to evaluate herbicide effectiveness and assess non-target damage from the aerial application.

The First follow-up evaluations were made April 20,1999. The target *Lygodium* treated with Rodeo was almost completely browned. The *Lygodium* treated with 2,4-D was also browned but not quite to the extent as that treated with Rodeo. The cypress/maple canopy trees showed little ill effects from the aerial application. Mid story trees/shrubs such as red bay and wax myrtle displayed obvious damage.

The next evaluation in July showed about the same scenario but it was becoming apparent that the 2,4-D treatments were not as effective as those done with Rodeo. The 2,4-D did not translocate within the *Lygodium* as well as the Rodeo had translocated.

The last evaluation was completed in November 1999. There was a 95%+ kill rate on *Lygodium* plots treated with Rodeo. *Lygodium* plots treated with 2,4-D exhibited a smaller kill percentage and some of the fern appeared to be growing back. Minimal damage was done to canopy trees but significant non-target damage to smaller trees and shrubs was apparent. There was some germination of new *Lygodium*, apparently from spore release, but at a level that could be handled with ground spot applications.

Further evaluations will monitor the effectiveness of mop-up operations begun in winter 2000. This work is expected to be complete in May 2000.

E. Lygodium microphyllum in Florida Power and Light's Barley Barber Swamp

1. Introduction

Florida Power and Light's Barley Barber Swamp is a 450-acre mature cypress slough that is open to the public during the fall and winter months of the year. Approximately 5000 visitors experience the swamp by guided tours on an elevated boardwalk. The Martin Power Plant cooling pond surrounds the swamp on three sides. The slough drains to the west through culverts to L-65. Hydrology of the swamp is regulated by timed pumping of cooling pond seepage water and weir elevation adjustments at the outfall to L-65.

The Barley Barber swamp provides habitat to turkey, deer, four species of owl, indigo snake, alligator, and two active bald eagle nests.

2. Background

A very small population of *L. microphyllum* was first noticed during a routine vegetative survey in 1985. The fern appeared to increase significantly in 1992, spreading from the upland margin into the swamp. Based on aerial surveys, it is estimated that approximately 45 acres (10% of the swamp) appear infested by *Lygodium*. Scrub habitat appears the most affected by Lygodium growth patterns. An area of monoculture climbing fern was removed and treated with herbicides. What was once a habitat containing leather fern, wax myrtle, Florida holly, and small cypress is now bare substrate, with regeneration of shrub and herbaceous wetland species from seed and rootstock. If extensive exotic management were not conducted by Florida Power & Light, the entire 450 acres would be at risk of becoming a monoculture of *Lygodium*. Adjacent properties owned by private individuals, a railroad, and State of Florida are also infested with climbing fern.

3. Management efforts

An initial management effort was conducted in 1997 at a cost of $24,000 consisting of physical removal of all *Lygodium* above 4 feet in height and herbicide treatment of less than 4 feet in height with Rodeo and Kinetic. Subsequent annual management efforts consist of herbicide treatment with Garlon 4 and Kinetic in the dry areas and Rodeo and Kinetic in the wet areas with an annual budget of approximately $7000. The annual exotic control program keeps the Lygodium problem at a manageable level. It is clear that climbing fern will never be completely eradicated from the property and that if a natural community of native wetland plants is to be maintained at the Barley Barber swamp, climbing fern management will have to be conducted in perpetuity. This is especially true due to the lack of *Lygodium* control by adjacent property owners.

F. Lygodium japonicum on Suwannee River Water Management District Lands

1. Introduction

The Suwannee River Water Management District owns and manages roughly 102,000 fee-simple acres of public lands spread over more than 100 disjunct tracts in north central Florida (roughly from the Georgia border south to Levy County, east to Bradford County, and west to Jefferson County). Habitat on District lands ranges from xeric upland sandhills to low-lying hydric floodplain swamps. Although most of the land is within the 100-year floodplain of the major rivers of the District, it is predominately uplands due to the high, deeply incised riverbanks.

L. japonicum is currently the invasive exotic species that covers the greatest acreage and poses the greatest threat to natural systems on District lands. At this time however, none of the endangered plants and animals on District lands are directly threatened by the presence or spread of *L. japonicum*. Control efforts for this plant were begun in 1999.

2. Background

To date *L. japonicum* has been found on 14 tracts, with 36 sites, and spread over at least 52 acres. A site may contain one plant, a few plants, or several thousand. The vertical distribution ranges from plants a few feet tall to those that are over topping the subcanopy and canopy (at 40-50 ft.).

This species was observed as early as 1984 on four tracts of land that were later acquired by the District (Lynch 1984). However, the contractor did not provide specific locations or acreages, and thus these populations have not been relocated.

In 1996 SRWMD began identifying invasive exotic plant problems on District-owned lands. No systematic surveys have been done; instead, opportunistic sightings by staff or contractors are reported, logged, and scheduled for treatment. Prior to 1999 we knew of less than 5 acres of *L. japonicum*.

Between April and September 1999 an additional 47 acres were observed (8 tracts, 19 populations). This sharp increase is a consequence of an increased search effort and not necessarily an increase in the spread of the species.

If these 47 acres remain untreated, and the plant remains contained within the confines of these communities but continues to spread throughout the contiguous remainder, then 4,538 acres would be at risk for infestation. (196 a bottomland hardwood, 1,276 ac.upland hardwood hammock, 2,952 ac. mixed hardwood and pine, 114 ac. swamp hardwood).

Patterns of establishment and spread are unknown, because we have not been tracking the plant long enough. However, if we are in the early stages of establishment in this region, then our information would indicate that it has a preference for bottomland hardwood communities and ultisols soil type.

Of 20 studied populations: there are nine occurrences on mixed hardwood and pine (NRCS Ecological Type 5); seven on bottomland hardwood (NRCS 20); five on longleaf pine-turkey oak hills (NRCS 4); two on upland hardwood hammock (NRCS 11); and one each on wet hardwood hammock (NRCS 12), swamp hardwoods (NRCS 21), and North Florida flatwoods (NRCS 7). Some populations cross onto more than one ecological group.

Using a Chi-squared goodness of fit test for all seven NRCS soils ecological groups the presence of L. japonicum is significantly different than availability at the $p<0.001$ level ($X2NC = 18634$, $X2\ 0.001 = 22.46$ with $df=6$). Bottomland hardwood (NRCS 20) is preferred and mixed hardwood and pine (NRCS 5) is avoided. The remaining ecological types were not tested individually due to the small sample size for the observed frequency.

Additionally, 16 of these 20 populations are between 50-60 feet elevation (range 40-100 feet). This may be a true preference for moderate elevations or an artifact of our ownership pattern since our property is not randomly distributed across all possible elevations.

Eighteen of these 20 populations are associated with disturbance events: 14 are along a dirt roadway, two are along river banks that are affected by heavy foot traffic and water scour, two are in pine plantations or adjacent to a recently logged area. The remaining two have no evidence of disturbance. However, it is unclear if there is truly a preference for disturbed areas or if this higher rate is a consequence of a higher staff visitation rate in these more intensively used and managed areas.

3. Management efforts

The current problem is relatively small but is expected to worsen for two reasons. First, as this plant continues its establishment in the area there will be more source material available to further hasten its spread. Second, there are undoubtedly additional well-established populations that are as yet undiscovered and thus are spreading unchecked.

For known populations, the District's management approach is dependent on the population size. Large populations are treated through the Department of Environmental Protection (DEP) Upland Invasive Exotic Plant Management Program. The smaller populations

are treated with herbicides by District staff as in-house projects. In house, either Garlon4 at 30% with 70% oil or Roundup Pro at 10% concentration is applied to the foliage during the growing season (March to November). For sites with just a few plants, individual plants are pulled up by the rhizome, bagged, and disposed of. Currently we spend about $10,000 per year on in-house treatments. This includes 20-30 days of personnel time, chemicals, and equipment.

We began treatment in 1999, so we do not have any measures of effectiveness yet. We expect that all sites will require at least two treatments.

However, in at least three instances, treating the problem on our property is not going to be an effective solution, because the parent population is on adjacent non-District land. In such cases, we work with the adjacent public, private, or corporate land owners to coordinate treatment across property lines. In the case of the private landowners, with their permission, we may treat their land using our personnel, equipment, and materials. It is more cost effective to spend the extra resources up front and eradicate the entire local population than to focus solely on our lands and reassess and retreat every year in perpetuity.

In the future the District will continue to utilize available DEP Program monies for large populations and handle the small populations in house. However, a more flexible program that encouraged and accommodated the treatment of private lands that are reservoirs for this species and are immediately adjacent to public lands would increase our effectiveness in controlling this species in north central Florida.

G. Lygodium japonicum on Northwest Florida Water Management District lands

1. Introduction

The Apalachicola River watershed drains 21,794 square miles and includes both the Flint and Chattahoochee Rivers (Northwest Florida Water Management District 1997). Surface area for this watershed extends into Florida, Georgia, and Alabama. At the confluence of both the Flint and Chattahoochee Rivers is the Jim Woodruff Dam, this impounded water forms Lake Seminole. Below the dam is the headwaters of the Apalachicola River, artificially modified before reaching Florida. Several other elements can be identified making water management ever more difficult. These include toxins entering the system, especially from the Atlanta metropolitan area; decreased water volume resulting from urban use; and damming which prevents the natural flow of water. The largest tributary is the Chipola River, which drains approximately 50 percent of the land area that makes up the Apalachicola River basin in Florida (Light et al. 1998). This river system supports the productive Apalachicola Bay that provides 90 percent of Florida's oyster production and one-third of its shrimp production. Continuation of this productivity is dependant on the annual floods that inundate the floodplain forest flushing organic matter into the river, the estuary and then the bay, providing nutrients that drive the food chain (Fernald and Purdum 1998). The upper Apalachicola basin is a unique system that contains both bluff and slope forest communities. This area has more endangered plant species than any other area in Florida, plus the highest species diversity of amphibians and reptiles on the continent north of Mexico (Fernald and Purdum 1998).

Although the Northwest Florida Water Management District (NWFWMD) only manages 35,487 acres of the middle Apalachicola River, protection of this floodplain forest is critical to the production of the bay. Because of the concern for this area and areas with similar value, the Florida Legislature has authorized the NWFWMD to acquire land necessary for water management, water supply, and the conservation and protection of water resources. The Legislature has also prioritized land use as the following: conserve and protect water resources; protect and restore ecosystems; and provide for public recreation where it is compatible (Northwest Florida Water Management District 1997).

Extensive logging has occurred in several sections of the Apalachicola River Water Management Area, especially around Florida River Island, and Pig and Coon Island. Currently, both of these islands are recovering from harvesting activities, and a pioneer floodplain forest consisting of Betula nigra, Liquidambar styraciflua,

Carpinus caroliniana and Platanus occidentalis exists with remnants of later successional species (e.g., *Quercus michauxii, Q. lyrata* and *Taxodium distichum*) scattered throughout. Five natural communities have been identified within this Water Management Area that are based on the Florida Natural Areas Inventory (1990). These include bottomland forest, floodplain forest, floodplain swamp, slough, and mesic flatwoods. All of these communities except the floodplain swamp contain *L. japonicum* at epidemic proportions. Floodplain swamps are the lowest-elevation systems that exist in this Water Management Area, holding water most of the year and not making it particularly conducive for *L. japonicum* growth. In areas where *L. japonicum* growth is extensive, a "*Lygodium* line" can be seen, where growth stops; this "line" of total soil saturation, and/or lengthy hydroperiod.

Although none of the natural communities are classified as being very vulnerable to extinction, floodplain forest are considered rare or uncommon in the state with an S3 ranking, in the Florida Natural Areas Inventory (1990). The remaining four natural communities have an S4 ranking or are apparently secure in the state.

L. japonicum

2. Background

Surveys done on the lower Apalachicola River indicate that 13 different exotic aquatic plant species have been documented. This figure fluctuates from year to year because of the heavy storm and flooding activity that can wash the exotics into Apalachicola Bay where they cannot survive the saline water (Bergquist et al. 1995). *L. japonicum* is listed as one the top contributors to the degradation of this river system (Bergquist et al. 1995). Because this species reproduces quickly and has the potential to climb up into the forest canopy, it could restrict the ability of trees to acquire sufficient sunlight for photosynthesis.

Blanketing growth of *L. japonicum* can be so intense that it blocks out the sun in some of the floodplain tributaries of the Apalachicola River (Langeland and Burks 1998). NWFWMD personnel have reported the presence of *L. japonicum* since the acquisition the Apalachicola River Water Management Area in December 1985, and years before this purchase, there were verified reports of its presence at Florida River Island (Northwest Florida Water Management District 1997). At the present time, *L. japonicum* forms thick ground mats 1.5 to 2 feet (0.5 to 0.6 m) deep, smothering native ground vegetation including seedlings and saplings of overstory tree species. Trellises from this fern are climbing up into the lower canopy of the floodplain forest. If they persist, this species could reach up into the upper canopy, affecting the trees that form the dominant structure of this forest. Since 1996, a noticeable increase in the amount of *L. japonicum* at Florida River Island has been observed.

The most common flood periods on the Apalachicola River occur in January, February, March, or April, and rainfall within Georgia has the greatest influence on the flow of the river. Only 11 percent of the Apalachicola, Chattahoochee and Flint River drainage basin is located in Florida (Leitman et al. 1984). During flood periods this river overflows its banks and inundates a tidal and nontidal floodplain that covers approximately 112 acres (Light et al. 1998). These annual floods are very important for flushing the highly productive floodplain forest and releasing nutrients and detritus into the Apalachicola Bay. Along with the flushing of organic matter, it is quite likely that *L. japonicum* fronds and spores are flushed in the process.

The *L. japonicum* on the Apalachicola River Water Management Area land, especially on Florida River Island is expansive. If left unchecked, future health of the floodplain forest is at stake, thus affecting the health of the lower Apalachicola River and bay system by reducing the amount of natural nutrients and detritus that are flushed from this location. Furthermore, if treatment is not undertaken on Florida River Island, even though surrounded by water and somewhat isolated, the *L. japonicum* will continue to be a source for the spread of exotic plant material.

Two other factors most be taken into account when discussing the Apalachicola River flood cycle:

1. Floods have a tendency to wash L. japonicum plant material down stream having the potential to infest new locations. This flooding does not affect the rhizominous root systems that produce numerous new twining fronds that appear in the spring.

2. Because of the washing of plant material, which also occurs upstream from the island, it is nearly impossible to identify the original source of the L. japonicum on Florida River Island. But, it can be assumed that the original spores and/or fronds came from upstream, making control measures extremely difficult, and emphasizing the need to manage this species throughout the entire Apalachicola River basin.

In winter, most fronds of *L. japonicum* turn brown, but protected sections of the plant can remain green, as observed at Florida River Island. Winter dieback of trellises that have formed up into the lower canopy provide ladders for the next growing season's fronds.

Directly east of Apalachicola River Water Management Area is Apalachicola National Forest, a vast area consisting of managed pine flatwoods. Concentrations of *L. japonicum* have been located inside many of the pine plantations, in stands close to and away from the river. Major transfer of *L. japonicum* material does not appear to take place between the two conservation lands, although the range of spore dispersal is not known, for instance, on fur of passing animals.

To the south and the west of the Water Management Area is Apalachicola River Wildlife and Environmental Area and Apalachicola National Estuarine Research Reserve, although managers (also, personal observations) indicate that *L. japonicum* is not a problem at the present time, the potential for invasion is tremendous. This assumption is reinforced by the annual floods that occur at Florida River Island and the recognition of surrounding area that contains a large population of *L. japonicum*, plus having a great amount of vegetative material washing down stream through the system.

Adjacent land to the north and northwest is privately owned and the degree of infestation on these lands is not known, but brief surveys of this land indicate that high concentrations of *L. japonicum* do occur and could be as severe as Florida River Island.

Despite the serve infestations that have been observed throughout the Apalachicola River, no other *L. japonicum* control work is known to have existed in this region except at state parks.

3. Management efforts

The density of *L. japonicum* at Florida River Island varies with location, with some sites having 100% coverage, totally displacing all the ground cover vegetation. In other locations, generally the lowest lying areas, individuals do not occur, this is just below the "*Lygodium* line." Below this line, the absence of *L. japonicum* is believed to be due to constant soil saturation or prolonged inundation. If left untreated, this fern has the potential to displace many ground cover species. Shrubs and forest tree canopy seedlings and saplings will also decline, thus affecting the stability of this ecosystem.

Before any type of managed control program can be implemented for *L. japonicum* on Apalachicola River Water Management Area, the most efficacious herbicide treatment must be developed. This treatment would take into consideration the type of herbicide, the rate at which it should be applied and the season of application, and any other cultural activity that is necessary to enhance control. Several management directives have developed from the initiation of the herbicide efficacy trials and the heightened awareness of this species:

1. Before any large-scale project can be developed and implemented, a well-tested treatment, in conditions similar to Florida River Island, must be developed.

2. Continue herbicide efficacy trials, focusing on Rodeo applied at different rates and at different seasons. Also, continue reviewing literature for information on the control of this species.

3. A total survey of the Apalachicola River Water Management Area should be conducted, to

determine if other sections of this area are as severely infested as Florida River Island.

4. With the development of an effective treatment, the District will be encouraged to treat other locations on their lands. Particularly the Choctawhatchee River Water Management Area, where L. japonicum is starting to reach levels of seriously displacing vegetation.

It is doubtful that complete eradication of *L. japonicum* can be achieved, but efforts to minimize this species' effect on the floodplains of the Basin is of the utmost importance. The control of invasive exotic plants is starting to become an important component for maintaining the natural communities on Northwest Florida Water Management District lands.

H. Lygodium japonicum at Florida Caverns State Park

1. Introduction

Florida Caverns State Park is a 1300-acre preserve located in Jackson County in the central Panhandle region. The principal attraction of the park is a series of dry limestone caves, one of which has been developed as a public tour cave. Natural communities include floodplain swamp and forest, upland hardwood and upland mixed forest, and a distinctive hardwood-dominated bluff community. Several rare Appalachian relict plant species occur, such as false-rue anemonae (*Isopyrum bitematum),* May apple (*Podophyllum peltatum*), bear's foot *(Polymnia laevigata),* Allegheny spurge (*Pachysandra procumbens*), Wakerobin *(Trillium maculatum),* and Bloodroot (*Sanguinaria canadensis*). Florida Caverns has been a part of the state park system since 1941.

2. Background

The best account of the flora of Florida Caverns is: Phytogeography and Floristic Survey of a Relic Area in the Marianna Lowlands, Florida by Mitchell (1963). *L. japonicum* appears on the list of species he noted for the park. No mention was made of its distribution or abundance. A 1990 park management plan discusses hand-removal of various exotics, but does not single out Lygodium as a particularly pernicious exotic plant.

Prior to 1993, exotic plant removal was limited primarily to spraying chinaberry (*Melia azedarach*) , mimosa (*Albizia julibrissin*) and silverthorn (*Eleagnus pungens*) found in public use areas. In that year, a Biological Scientist position was assigned specifically to Florida Caverns State Park. Lygodium then occurred in about 10 locations along the park drive and in an equal number of locations along powerline rights-of-way. Typically, the plant may cover an area of up to 4,000 square feet and sometimes ascends adjacent trees for 8-12 feet.

3. Management efforts

Spot treatment with 1-2 percent glyphosate herbicide and a backpack sprayer has been used to successfully treat infested areas. In the period 1994 through 1999, 624 stems of *Lygodium* were sprayed. Re-treatment in previously infested areas is often necessary. Much-reduced areas of infestation continue to occur along the park drive and in the Chipola River floodplain. Expenses for herbicide and staff time are covered by the park's annual expense budget. Contract removal has not been necessary.

At this point, a level of maintenance control has been achieved for *L. japonicum* at Florida Caverns. It now occupies a total area of less than one acre in the park, and is not considered as problematical as two privets (*Ligustrum sinense* and *L. lucidum*) and nandina (*Nandina domestica*). The park's intact forest canopy may tend to discourage large areas of infestation by climbing fern (see Langeland and Burks 1998). Undoubtedly, re-infestation from adjacent lands will continue via flooding and perhaps wind dispersal. The land to the southeast was last logged in 1993, and *Lygodium* is present there. Land northwest of the park is owned by the North West Florida Water Management District. It is also floodplain forest and floodplain swamp. *L. japonicum* occurs sporadically there, but there appears to be no large areas of infestation. At present, it is not being treated on any of the lands adjacent to the park.

Summary

Melaleuca was introduced into Florida around 1885. Unbridled by natural controls, and occasionally aided by man, the tree soon began to spread through the "useless swampland" of South Florida, replacing Everglades tree islands, marshes and prairies. By the late 1980s, melaleuca - deemed the "Tree from Hell" - had reached crisis levels throughout the region. Biologists were predicting ecological collapse in the Everglades. Indeed, melaleuca dominated almost a half million acres in South Florida, and showed no signs of stopping.

Early in 1990 the Florida Exotic Pest Plant Council and the South Florida Water Management District jointly convened a task force of federal, state and local land managers, scientists and others. Their charge was to develop a comprehensive, interagency plan for managing this notorious Everglades invader. The result was the first edition of the Melaleuca Management Plan for Florida.

In the ten years since its original publication, this Plan has served as a framework for agencies managing or seeking to protect natural areas infested by melaleuca. It has facilitated interagency cooperation and coordination of control efforts, improved resource utilization efficiency, enhanced public awareness of the problem and inspired legislative support.

The strategy outlined in the Plan is based on finding and controlling outliers (isolated, mature seed-bearing trees) to halt the advance of existing melaleuca populations, and then progressively eliminating trees toward the infestation source. This "quarantine strategy" has been highly successful, with melaleuca acreage declining by nearly a third in the past decade.

The melaleuca management program in Florida is an example of a successful work in progress. Resource managers faced seemingly insurmountable obstacles when the fight began, but interagency cooperation has successfully turned the tide. Achieving this level of success has not been inexpensive. The melaleuca project (including biological, mechanical, chemical and physical control efforts) has cost about $25 million thus far. To place this in perspective however, it was estimated that failing to act against melaleuca would have eventually cost the region $169 million annually in lost revenues. Ecological losses would have been immeasurable.

Will Florida ever face another threat like melaleuca? Unfortunately, the answer is yes. Melaleuca acres are decreasing throughout the region, but *Lygodium* is now overtaking vast areas of unspoiled wilderness. The melaleuca program proves that an invasive species can be effectively contained and controlled if agencies work together to focus attention on developing essential resources such as funding, integrated control strategies, increased public awareness and legislative initiatives.

It is time for the State of Florida to initiate a unified *Lygodium* management program. The Lygodium Task Force hopes that this document will mirror the Melaleuca Management Plan and serve as a resource for scientists, land managers, policy makers and the public.

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Appendix

MEMORANDUM OF UNDERSTANDING

This Memorandum of Understanding (MOU) is entered into this 1st day of December, 1999 by and between the FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION and the SOUTH FLORIDA WATER MANAGEMENT DISTRICT.

I. WITNESSETH

WHEREAS, the South Florida Water Management District (District) is a public corporation of the State of Florida existing by virtue of Chapter 49-25270, Laws of Florida, and operating pursuant to Chapter 373, Fla. Stat. (F.S.) as a multipurpose water management district with its principal office in West Palm Beach, Florida; and,

WHEREAS, the Florida Fish and Wildlife Conservation Commission owns and manages J.W. Corbett Wildlife Management Area (Corbett), a natural area of approximately 60,224 acres located in northern Palm Beach County; and;

WHEREAS, the District owns and manages Dupuis Reserve, a natural area adjacent to Corbett; and

WHEREAS, both Corbett and Dupuis have been invaded by non-native species of plants and animals, including Lygodium microphyllum (climbing fern), a highly invasive non-native plant species that inhibits growth of native plant species and increases risk of destructive wildfires;

WHEREAS, non- native species such as climbing fern adversely effect ecosystem processes, degrade natural biodiversity and negatively impact water resources; and;

WHEREAS, the District has extensive knowledge and expertise in the treatment of climbing fern on public lands; and

WHEREAS, climbing fern spreads quickly to adjacent properties, necessitating cooperative efforts among managers of adjacent properties in order to maximize the efficiency of plant control expenditures; and

WHEREAS, the FWC and the District desire to work in a cooperative effort to control climbing fern on Corbett and Dupuis; and

WHEREAS, the Department of Environmental Protection (DEP), Division of State Lands (DSL), Bureau of Invasive Plants (BIP) has funds available to control nonnative upland plants, $91,000 of which was approved for treating climbing fern in Corbett and Dupuis in FY 1999-2000.

NOW THEREFORE, in consideration of mutual covenants contained herein, the District and FWC agree as follows:

A. SCOPE AND RESPONSIBILITIES

The responsibilities of the FWC are as follows:

1. The FWC shall identify lands that it manages within Corbett which need climbing fern control.
2. The FWC shall designate a site manager for each site identified.
3. The FWC shall perform a final inspection after the completion of each project to determine the success

rate of the control measures.

The responsibilities of the District are as follows:

1. The District shall retain a contractor to perform control and removal climbing fern in compliance with all applicable laws and regulations.

2. The District shall provide all labor, equipment, and supplies, and shall perform all operations for the control of climbing fern on the identified lands and ensure compliance with the conditions set forth in this MOU by all contractors retained by the District pursuant to this MOU.

3. The District shall notify the site manager prior to beginning work on a site.

4. The District shall provide for a contracted supervisor to be present with the ground crew while plant control activities are being conducted. This supervisor shall be a pesticide applicator certified by the Florida Department of Agriculture and Consumer Services. A copy of the supervisor's certification shall be provided to the FWC site manager prior to the initiation of plant control activities. The supervisor shall be responsible for collection, recordation and timely submission of all data and reports including, but not limited to, monthly reports and reports at the completion of initial treatment. These reports will contain number, location and size of plants treated, and type of treatment used. The supervisor will maintain a "Daily Report Form" containing treatment date, treatment location, number of plants treated, type of herbicide used and volume of herbicide used.

5. The District shall ensure that contractors retained pursuant to this MOU make every reasonable effort to avoid damage to all native vegetation and limit treatment to the removal of all exotic species, as specified by the FWC site manager.

B. EFFECTIVE DATE

This agreement shall become effective upon execution by the Executive Director of the District and Director of the FWC Division of Wildlife, or their designees.

C. DURATION

This agreement shall be effective Fiscal Year 1999-2000. This agreement may be extended upon the same terms and conditions by mutual written agreement of all parties.

D. MODIFICATION OF AGREEMENT

This Agreement, may be modified in writing at any time as necessary by mutual consent of the parties. Modifications may be made in whole, by part, or by section, and upon approval shall supercede previous versions of this Agreement. Any proposed changes shall be identified and delineated in writing by the party proposing the change. Approvals of modifications to the text of this Agreement shall be signed by the Executive Director of the DISTRICT, and the Director of the FWC Division of Wildlife, or their designees.

E. NOTICES

All notices and reports required or permitted to be given under the terms and provisions of this Agreement by a party to the other party shall be in writing and shall be sent to the parties as follows:

South Florida Water Management District
Amy Ferriter
3301 Gun Club Road
West Palm Beach, FL 33406

Florida Fish and Wildlife Conservation Commission
James Schuette
8535 Northlake Blvd.
West Palm Beach, FL 33412

F. TERMINATION

This agreement shall terminate automatically unless the same is extended pursuant to Article C by mutual written agreement prior to the expiration date of this Agreement. Either of the parties may terminate their participation in this Agreement at any time, without cause, by providing sixty (60) days prior written notice to the other party.

IN WITNESS WHEREOF, the parties have caused this MOU to be executed the day and year first written above.

FLORIDA GAME AND FRESH WATER FISH COMMISSION

BY: _____

Frank Montalbano III, Director
Division of Wildlife

Legal Form Approved

_____

FWC Attorney

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

BY: _____

Frank R. Finch, P.E.,
Executive Director

Legal Form Approved

_____

SFWMD Attorney

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