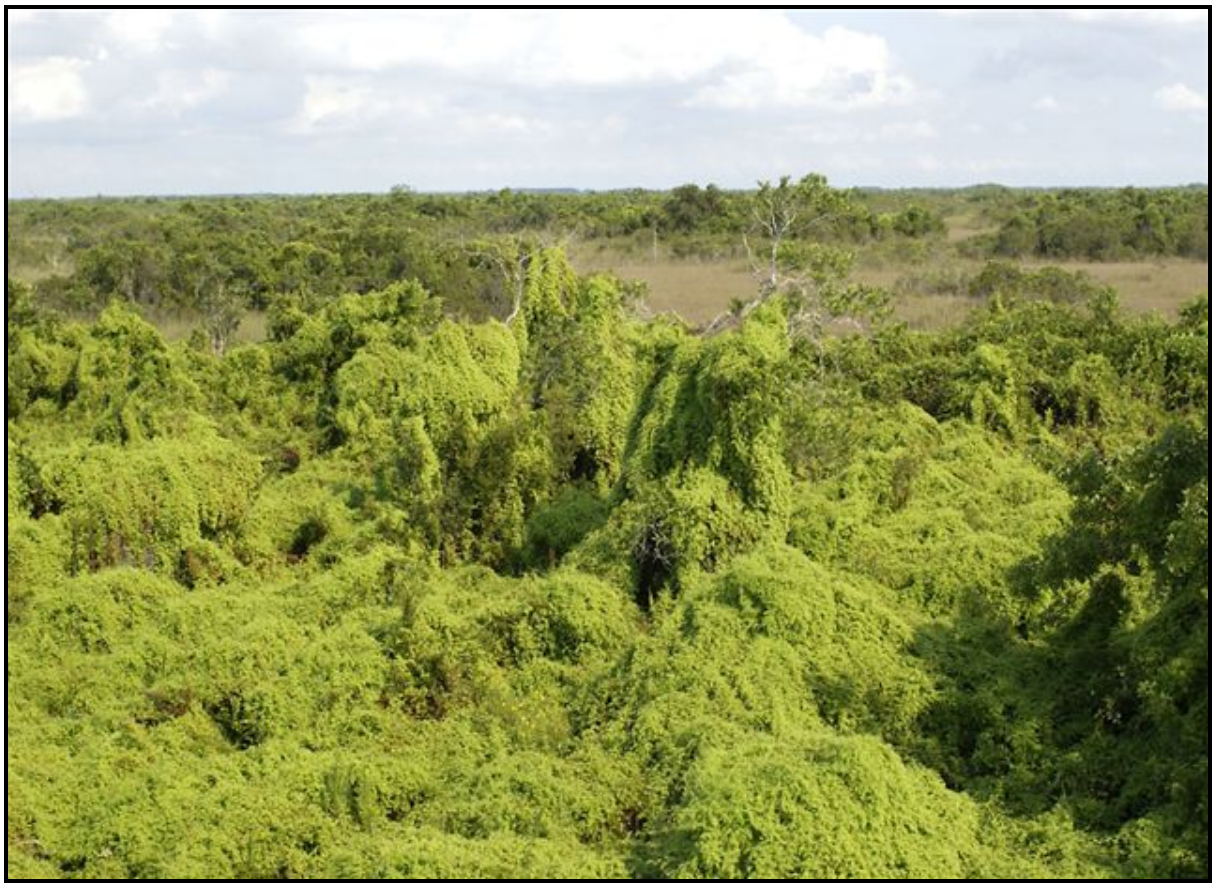
OLD WORLD CLIMBING FERN (*Lygodium microphyllum*) MANAGEMENT PLAN FOR FLORIDA

Florida Exotic Pest Plant Council
Lygodium Task Force

2006
Second Edition



OLD WORLD CLIMBING FERN (*Lygodium microphyllum*) MANAGEMENT PLAN FOR FLORIDA

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

2006
Second Edition

The Second Edition of the Lygodium Management Plan for Florida has been revised to focus primarily on Old World climbing fern (*Lygodium microphyllum*), recognizing the need for a separate management plan for Japanese climbing fern, which is currently more problematic in northern and central Florida. Thus, this revised plan is designed to provide the most up-to-date information for integrated management of the highly invasive Old World climbing fern infesting natural areas in southern and central Florida. Management of this fern in Florida is still in the early to mid-stages of development of a landscape approach to control the fern, both on public conservation and private lands. The plan will be updated every five years to reflect changes in management philosophies.

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I. Introduction

Invasive exotic pest plants are a threat to Florida's natural areas (Simberloff et al. 1997, Gordon 1998, Langeland and Burks 1998). The problems associated with exotic aquatic plants are widely recognized, and their impacts to navigation and flood control have long been the primary concern for Federal and State-sponsored plant control efforts. Unfortunately, many upland and wetland exotic plant management issues were overlooked in the past even though roughly 30% of the total number of plants growing outside of cultivation in Florida are non-native (Wunderlin 1998). Fortunately, this has changed over the past decade and greater funding is now allocated to upland and wetland exotic plant issues. From 1997-2005, the Florida Department of Environmental Protection (FDEP) spent >$31 million to treat 278,000 acres of public conservation lands infested with exotic plants. Of the $31 million, approximately 65% or $20 million was allocated to public conservation lands in south Florida, an area with a high number of introduced, invasive plants (FDEP, Bureau of Invasive Plant Management).

Without an organized forum to address invasive exotic plants in Florida's natural areas, early control efforts were not systematic and were generally ineffective. In 1984, concerned resource managers in Florida organized the Florida Exotic Pest Plant Council (FLEPPC). The FLEPPC was established to exchange information between land management agencies, research scientists, private industry and other interested groups concerned with the impacts of exotic plants in natural areas, and to serve as an advisory body to other groups or agencies.

From the beginning, the number one challenge for the FLEPPC was controlling melaleuca (*Melaleuca quinquenervia*) in the Everglades. Much of the initial progress made in controlling melaleuca in south Florida stemmed from the coordination provided by the FLEPPC. A successful effort led by the FLEPPC resulted in the listing of melaleuca as a Federal Noxious Weed by the USDA. The FLEPPC petitioned the USDA to begin research on the use of biological control agents to control melaleuca. Perhaps most importantly, the FLEPPC led the charge in developing a statewide management plan for melaleuca.

In early 1990, the FLEPPC and the South Florida Water Management District (SFWMD) 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 of its kind in the field of exotic plant management in Florida. It serves as a framework for facilitating interagency cooperation and coordination of control efforts, improving resource sharing, enhancing public awareness, and inspiring legislative support.

By bringing agencies and organizations together, the FLEPPC provided a unique forum for the development of this species-based management plan. Based on the success achieved through the Melaleuca Management Plan, the FLEPPC formed a Lygodium Task Force in 1999 to write a Lygodium Management Plan for both species of *Lygodium*—Old World climbing fern and Japanese climbing fern.

The first edition of the Lygodium Management Plan provided recommendations from the Lygodium Task Force (LTF), a working committee of the FLEPPC, for the integrated control of *Lygodium* in Florida (Ferriter, 2001). The LTF is an interagency group of professionals who either have direct experience in managing *Lygodium* or have the technical knowledge required to develop an integrated management approach. In 1999, it was the consensus of the LTF that the uncontrolled expansion of Old World climbing fern constituted one of the most serious ecological threats to the biological integrity of Florida’s natural systems. In 2004, the LTF met in West Palm Beach to review management and research issues regarding Old World climbing fern. The second edition of the plan evolved from the results and discussion of that meeting. The current plan, however, only addresses the management of Old World climbing fern due to its rapid spread in south and central Florida. An updated management plan for Japanese climbing fern, which is more problematic in north and central Florida, will be completed separately in the future. Managers should be aware that Japanese climbing fern is capable of surviving in sub-tropical climates and is spreading into south Florida. A brief summary of a few key points and excerpts from the first Edition of the Lygodium Management Plan on Japanese climbing fern can be found in Appendix 4.

II. Problem Statement

There are two exotic species of *Lygodium* naturalized in Florida. Old World climbing fern (*L. microphyllum*) is native to wet tropical and subtropical regions of Asia, Africa and Australia. It has become a serious weed in south and central 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 into north and central Florida. Previous experience with other invasive exotic plants has shown that plant populations tend to have a lag phase followed by an exponential rate of expansion. In south Florida, Old World climbing fern populations have reached exponential growth rates (Volin et al. 2004). Resource managers and private landowners are reporting this fern on private and public lands in increasing frequency and magnitude.

Old World climbing fern invades many freshwater and moist habitats in Florida, growing over trees and shrubs, and smothering whole plant communities (Figure 1). It is difficult for other plants to grow through the thick rachis mats produced by the fern. Old World climbing fern is common in cypress stands and bayhead swamps, but also infests maple swamps, pine flatwoods, wet prairies, sawgrass marshes, mangrove communities, Everglades tree islands, and disturbed wet areas. Some Everglades tree islands are so completely blanketed by the fern that it is not possible to see the trees and other vegetation beneath it (Figure 2).

***Figure 1**. Old World climbing fern invading a bayhead swamp in Martin County, exhibiting indeterminate growth, sprawling horizontally and vertically.*

Infestations of climbing fern alter fire behavior, which is a naturally-occurring element and management tool in many of Florida's plant communities. Rachis mats (old plant material) greater than 1 meter thick cover the ground and climb up trees serving as ladders to carry fire into tree canopies. Trees that can normally survive ground fires reaching heights between 6-12 ft. are killed when fire is carried into the canopy >60 ft., scorching leaves and cambium tissue. Fires that would normally terminate at the margins of cypress sloughs now burn into and through areas infested with Old World climbing fern. Large portions of the

burning rachis mat are often caught in the updraft of fires and blown to other areas, starting spot fires that often spread into uncontrollable wildfires (Roberts 1996).

In response to the threat that Old World climbing fern poses to Florida's natural areas, The FLEPPC and the SFWMD sponsored the Second Lygodium Research Review Meeting in June 2004 to review current research and management issues, share information, and update the 2001 Lygodium Management Plan to address the threat posed by Old World climbing fern.

A group of 64 weed scientists, botanists, land managers, and administrators gathered in West Palm Beach, FL in June 2004 to exchange information on Old World climbing fern and its control (Hutchinson et al. 2004). The keynote speaker, Dr. Patrick Gleason, a former SFWMD Governing Board Member, opened the meeting by comparing the fern to a "plague of biblical proportions" that is threatening the Everglades ecosystem. Dr. Gleason stressed the need for immediate action and the release of biological control agents (biocontrol). He questioned if progress was being made to control this highly invasive fern and predicted it would kill all the native vegetation on tree islands in the Loxahatchee National Wildlife Refuge before a control was found. The construction of a biocontrol quarantine facility in south Florida, as addressed in the 1999 plan, has accelerated this process and one biocontrol agent was released in 2005. Amy Ferriter, committee chair for the FLEPPC Lygodium Task Force, provided handouts on what was known and what was not known about *Lygodium* in 1999. Scientists and land managers from across the state gave presentations on their research and management measures to control Old World climbing fern. In addition, land managers, researchers, and program directors held breakout sessions to prioritize

***Figure 2**. Old World climbing fern covering a tree island in the Loxahatchee National Wildlife Refuge in Palm Beach County.*

research and management needs based on current knowledge and critical information gaps. The FLEPPC website has the summarized notes from the meeting.

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 the invasion of Old World climbing fern (*Lygodium microphyllum*) and Japanese climbing fern (*L. japonicum*).

IV. Objectives

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

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

V. Lygodium Task Force Recommendations

An integrated approach using both biocontrols and herbicides is currently considered the best management approach. The consensus of the 2004 Lygodium Task Force meeting was that biocontrols and the development of more effective herbicide treatments are needed to halt the spread of Old World climbing fern in Florida.

- **Increase biocontrol releases:** Additional biocontrol releases are needed to stop the fern's spread. Additional searches need to be conducted for below-ground biocontrol such as insects, fungi, and microbes as potential control agents.
- **Continue herbicide evaluations:** Quantitative studies are needed to determine the efficacy of single herbicide and mixed herbicide applications for both single and multiple treatments. Herbicide efficacy studies are needed to evaluate the percentage active ingredient(s), translocation success, optimal season of treatment, length of control, effects on non-target vegetation, habitat type, initial versus follow-up treatment, and post-treatment monitoring requirements.
- **Obtain safe herbicides for aquatic uses:** Conduct studies to review other herbicides currently registered in Florida and elsewhere for aquatic use to control Old World climbing fern and obtain special local need registration for other herbicides not

yet approved for aquatic use. This is especially important if the fern develops resistance to one or more herbicides, which is common in agriculture systems when a population of weeds is treated multiple times with the same herbicide.

- **Use a regional approach:** Development of a regional approach to control both species of *Lygodium* by creating "*Lygodium*-free" areas in central Florida where Old World climbing fern is spreading north and Japanese climbing fern is spreading south, in extreme south Florida where small populations of both ferns occur, and in the Florida Keys where neither species is documented.
- **Mobilize rapid response efforts:** The development of an early detection system for small infestations is needed so that land managers can treat small, isolated populations before the population becomes unmanageable. Early detection methods will save money both in terms of treatment costs and staff time. Currently, limited staff and the isolated nature of Old World climbing fern populations in most natural areas make complete ground surveys impossible.
- **Learn more about the role of fire:** Conduct more research on Old World climbing fern and fire in south and central Florida. Land managers in south Florida are especially concerned about the effects of fire in infested sites. Questions that need to be answered include:
    - Can fire be an effective management tool?
    - Does fire destroy or spread spores?
    - Does the fern rapidly invade recently burned habitat?
    - What is best time to treat re-growth of the fern after a fire?
    - What are the effects of the pyrogenic nature of the fern on native plants?
    - Does fire in infested areas change the structure and composition of native plant communities?
- **Develop fire BMP's:** Fire, either prescribed or lightning-ignited, is an integral part of the south Florida landscape and land management activities. Thus, development of best management practices for controlling Old World climbing fern in frequently burned areas is recommended.
- **Increase control efforts on private lands:** Develop strategies to control the fern on private lands. Currently, the development of city and county ordinances appears to the best way, but this may impact private property rights. Education and incentives to private landowners may ultimately be best way to deal with infestations on private

lands. Innovative ideas are needed to develop ways and means to reach the private landowners.

- **Increase awareness among land managers:** Finally, all natural area managers need to be keenly aware of Old World climbing fern infestations on the property they manage. Anyone who works in the field of natural resource management needs to be able to identify and treat the fern. New infestations should be treated immediately, with monitoring and re-treatments made a priority.

VI. Technical Background

Biology of Old World Climbing Fern

Taxonomy

Old World climbing fern (*Lygodium microphyllum*) is a hardy, fast-growing evergreen fern imported to North America from its native ranges: Africa, Southeast Asia and Australia. Like others in its genus, Old World climbing fern twines or climbs upon physical support including trees, shrubs or structures via pinnae with very flexible and fibrous stipes which extend to 30m in length. *Lygodium* species grow rapidly and have bright green foliage, which may have contributed to their importation as a groundcover (Nauman and Austin, 1978).

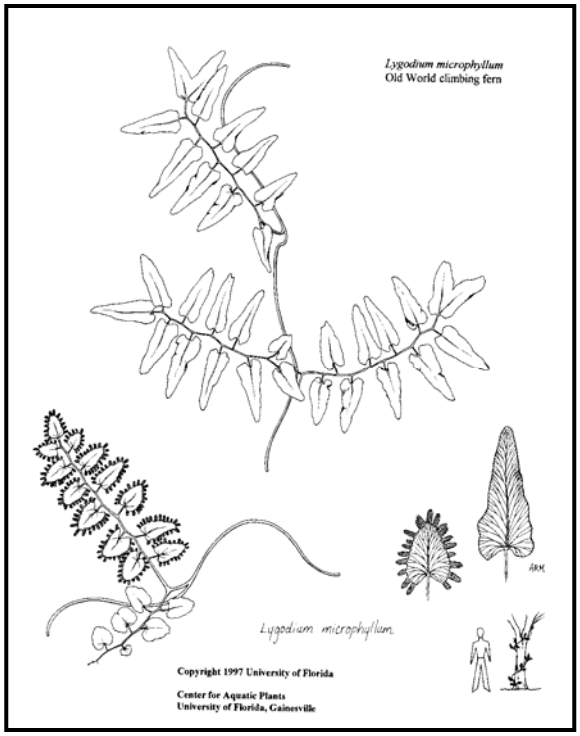

Figure 3. *Infertile (top) and fertile (lower left) leaflets of Old World climbing fern.*

The genus *Lygodium* is currently known to contain as many as 40 species (Alston and Holltum, 1959) or, due to current revision, as few as 26 species (J. Garrison, New York Botanical Garden, *unpublished data*). All occur in the warm temperate to tropical areas of the world (Mabberley, 1997). The genus *Lygodium* is sometimes placed in the Schizaeaceae, a small primitive family that also includes *Actinostachys*, *Schizaea*, *Anemia*, and *Mohria* (Prantl, 1881; Holttum, 1973). Since the *Lygodium* species share unique twining morphology, they are often placed within their own family, the Lygodiaceae (Bierhorst, 1971; Wagner and Smith, 1993).

Recent molecular (*rbc*L) research on the phylogeny of ferns found *Lygodium*, *Acitnostachys*, and *Anemia* to have more intrageneric distance than occurs between most fern families (Hasebe et al., 1995). These genera were nevertheless called sister genera and left in the Schizaeaceae. The molecular analysis showed the family to be very isolated and to have more distance between the genera in the family than occurs in other fern families. The molecular data and the antiquity of the Schizaeaceae (*Anemia* spores are known from the Cretaceous, Smith, 1995) suggest that the group diverged at an earlier time than other groups of ferns. Thus, Lygodiaceae is now the accepted family for the genus *Lygodium*.

Scientific name: *Lygodium microphyllum* (Cav.) R. Br.
Common name: Old World climbing fern
Synonymy: *Lygodium scandens* (L.) Sw., *Ugena microphylla* Cav.
Origin: Southeast Asia, Africa and Australia
Family: Lygodiaceae

Botanical Description

Fern with dark brown, wiry rhizomes and climbing, twining fronds of indeterminate growth, to 30 m (90 ft.) long; main rachis wiry, stem-like. Pinnae (leaflets) fertile or sterile with leafy branches off main rachis once compound, oblongish in overall outline (Figure 3). Pinnules usually unlobed, stalked, articulate. Leaf-blade tissue usually smooth below. Fertile pinnae of similar size (Figure 4), fringed with tiny lobes of enrolled leaf tissue (endusia) covering the sporangia along the leaf margin.

Figure 4. *Fertile leaflet (left) and infertile leaflet (right) of Old World climbing fern.*

Related Species

<u>*Lygodium palmatum*</u> (American climbing fern) – This fern is the only native member of the genus *Lygodium* in the United States. It is restricted to the eastern United States, occurring from Maine to Georgia, but extant populations are known from northern Florida (Nelson, 2000; Wunderlin and Hansen, 2000). It is common nowhere within its range (Nelson, 2000), and occurs in hammocks, the edges of bogs, preferring slightly acidic soils (Wunderlin and

Hansen, 2000). As reflected in its species name, this fern has palmate (hand- or palm-like) pinnae. All pinnules are palmately lobed and fertile lobes mostly lack sterile tissue (Nelson, 2000).

Lygodium japonicum (Japanese climbing fern) – This fern is native to temperate and tropical parts of eastern Asia (Langeland and Burks, 1998). It has been introduced into many areas of southeastern United States, and is common in natural areas in north and central Florida, and may be spreading into south Florida. The FLEPPC also lists this fern as highly invasive. It occurs in damp areas of yards, roadsides, hammocks, creek banks, swamp edges, and upland woodlands (Langeland and Burks, 1998). It differs from Old World climbing fern by having triangular-shaped leaflets and twice compound pinnae (Langeland and Burks, 1998).

Reproductive Biology, Phenology and Growth

Old World climbing fern reproduces during a conspicuous alternation of generations between sporophyte and gametophyte life stages. Spore-forming fertile pinnae (sporophytes) hold spores within sori, which upon release may germinate into prothallia (gametophytes, see Figure 5) given required environmental conditions. Spores of the genus *Lygodium* have very thick walls, lending them long environmental viability (Tryon, *pers. communication* 1999). Spores can remain viable for four years after release from sori (Mike Lott, *pers. communication*), though it is likely they remain viable for longer periods. Culture of the North American member of the genus, American climbing fern (*L. palmatum*), is reportedly very simple, as spores collected from fertile fronds readily sprout into prothallia, and, ultimately, new plants in three months (Brumback, 1985). Similar success has been attained for Old World climbing fern spores cultured in agar growth media (Lott et al., 2003).

In sub-tropical and tropical climates, Old World climbing fern is evergreen, actively growing throughout the year as sporophytes and gametophytes. It is a homosporous fern that is able to reproduce by 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 gametophytes; and 3) intergametophytic crossing, the cross fertilization of gametophytes that result from spores from different sporophytes (Lott et al., 2003).

Because homosporous ferns have bisexual gametophytes, it has long been held that intergametophytic selfing is an important mode of reproduction in populations of homosporous ferns (Soltis et al., 1988). However, studies have found few highly inbred species of ferns (Soltis and Soltis, 1992; Hooper and Haufler, 1997; Lott et al., 2003). More recent work with Old World climbing fern by Lott et al. (2003) found that female gametophytes promote outcrossing by producing a hormone that activates neighboring immature gametophytes to become male. This suggests that ferns have evolved mechanisms, perhaps antheridiogen activity, that promotes outcrossing. However, it is hypothesized that Old World climbing fern exhibits intragametophytic selfing for invasions of new habitats (Lott et al., 2003). This would allow long distance dispersal, presumably by wind, of one spore to a distant location to form a new population which, in theory, once established, could be supplemented genetically with other spores blown in at a later time (Lott et al., 2003). There is evidence that the majority of the spores settle over a short distance of 10-100 yards from the parent plant, but spore density is highly variable at 1.25 miles from the parent plant (Erynn Call, *pers. communication*). It is likely that during hurricanes, with winds 75 mph or more, spores are blown miles from the parent plant.

Figure 5*. Gametophytes (dark green) and sporophytes (light green) of Old World climbing fern.*

Propagule pressure has emerged as one of the most important factors in predicting whether or not a non-indigenous species will become established (Kolar & Lodge, 2001). Also, once a non-indigenous species does become established, propagule pressure can be hugely important for determining the importance of various environmental factors in structuring invasion patterns and has the potential to override some barriers to invasion (see Rouget &

Richardson 2003). There is little documentation of the reproductive biology of Old World climbing fern within its native range. In Florida, its reproductive period extends throughout the year, peaking during the wet season (Volin et al. 2004). Although the number of spores varies with environmental conditions, up to 15,000 spores per cm^2 of fertile leaf area are reported, corresponding to as many as 30 billion spores on infested sites at the time measurements were made (Volin et al. 2004).

Studies conducted in Florida during the last six years indicate that Old World climbing fern possesses several life-history characteristics that may enhance its competitive ability, including plastic reproductive strategies, high and continuous spore production, and a high growth rate across light levels (Lott et al. 2003, Volin et al. 2004). For instance, the rate of increase in height of the fern on infested trees varied both among sites and among individual trees, but overall annual height increase averaged (±SE) 1.16 ± 0.02 m across sites (Volin et al. 2004). Furthermore, Old World climbing fern appears to optimise its morphological and physiological characteristics to maximise photosynthetic area and minimize carbon costs (Lott and Volin, in preparation).

Distribution, Ecology and Economic Impacts

Native Range

Native Distribution:

Old World climbing fern has a very large native range, extending through much of the Old World tropics, spanning more than half of the world's circumference from 18^oE in Senegal to 150^oW in Tahiti between the latitudes of 29^oS in Australia and 27^oN in northeastern India (Alston, 1959; Copeland, 1958; So, 1994b; Holttum, 1968). The northern known limits of Old World climbing fern in its native range occur in China at 24° N in which the plant rarely grows >3-4 ft. in height (Goolsby et al., 2003).

The genus *Lygodium* occurs naturally in the tropics and subtropics nearly worldwide, and in temperate regions of North America, Asia, southern Africa and New Zealand (Nauman, 1993). American climbing fern is the only native *Lygodium* in the eastern United States. Introductions of Old World climbing fern are now documented in Jamaica, Guyana, and southern and central Florida (Pemberton and Ferriter, 1998). Japanese climbing fern has been introduced to Puerto Rico, and the southeastern United States from Texas to North Carolina (Proctor 1989, Nauman 1993).

Native Ecology:

In general, relatively little information is available regarding faunal uses of ferns in their native ranges. Literature citations reveal 420 insects associated with ferns in general (Balik et al., 1978; Gerson, 1979). New information has resulted from initial forays to evaluate potential biological control of Old World climbing fern. For instance, several insect feeders including pyralid moths in Hong Kong (see Biological Control section), the Australian moth (Austromusotima comptonozale; formerly Cataclysta camptonozale) in Australia (Wright, *pers. communication* 1999), and larval sawfly in Vietnam (Purcell, *pers. communication* 1999) and Thailand (Wright, *pers. communication* 1999) have been found. In addition, fungi were collected from Japanese climbing fern in Florida (Alfieri et al., 1994) and a rust fungus affects several *Lygodium* species in greenhouses (Rayamajhi et al. 2005). While Old World climbing fern colonies can establish relatively large mats or vine canopies in their native ranges (R. Pemberton, *pers. communication* 1999), these are typically rare. Outside of their native ranges, such as in Florida, their blanketing growth commonly covers many acres. Generally, the fern has little economic value in its native lands, resulting in little effort expended on its study. Due to the limited knowledge of its ecology, and because of its incredible invasiveness outside its natural range, much still needs to be investigated on Old World climbing fern ecology both inside and outside its native ranges.

Within its natural range, Old World climbing fern is found in a variety of habitats including mesic forests, rainforest, and open swampy areas, at altitudes from sea level to more than 3200 ft. (Serizawa 1975, Edie 1978, Singh and Panigrahi 1984). Within its native range in Australia, it is documented growing in a variety of habitats that include freshwater creeks, perennial creeks, coastal depression wetlands, upland rainforests, and sheltered canyons near permanent springs (Goolsby et al., 2003). In Australia, Old World climbing fern resprouts vigorously following wildfires (Goolsby et al., 2003). In Asia, the fern occurs in lowland rainforest in peat soils, coastal wetlands, and in habitat dominated by wet clay soils (Goolsby et al., 2003). Near its northern distribution in China, Old World climbing fern is found growing in drier rocky soils on hillsides where it is less competitive than Japanese climbing fern (Goolsby et al., 2003).

Native Economic Uses:

Economic uses of *Lygodium* species are varied in the world's pharmacoepia, where the product sold is often the raw spores, but few are actually reported for Old World climbing fern. The long, fibrous, twine-like rachis of *Lygodium* species is utilized for basketry and weavings, particularly in Southeast Asia (People and Plants Online, 1999). Other reported uses include fiber for the weaving of handicrafts and herbal therapeutic applications such as an anti-diarrheal and swelling reduction agent and as a general skin amendment (EthnobotDB website, 1999).

Florida

Florida Distribution:

Old World climbing fern was first collected as a naturalized plant in Florida at two Martin County locations in 1965 and 1966 (Beckner, 1968). In 1973, the plant was collected in Highlands (Alvarez P7718, FLAS) and in Polk Counties (Wilson 353, FLAS) in 1979. Lakela and Long (1977) stated that the fern was rare and that a sporulating specimen was recorded for Martin County. In 1978, Old World climbing fern 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 along the Florida Turnpike for several miles in the vicinity of the Martin/Palm Beach County line (Godfrey 76935, FLAS, specimen notes). In 1981, it was documented as naturalized in coastal Collier County in southwestern Florida (Robinson, Wunderlin, Hansen and Tloenke 207, USF)

In 1993, the SFWMD and the National Park Service began using Systematic Reconnaissance Flights (SRF) to monitor invasive plants over large areas of South Florida. Fifty 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 in an east/west orientation across the state. The beginning and end point of each line is a precise point of latitude and longitude to permit repeat surveys.

The SRF surveys are biennial and ongoing, and have been conducted in 1993, 1995, 1997, 1999, 2001, 2003, and 2005. Each trained survey team consists of two observers and a pilot. The fixed-wing aircraft (172 Cessna) is equipped with three Global Positioning System (GPS) units and two data recorders. The pilot uses one GPS unit to navigate along the calculated flight line. The observers, stationed on opposite sides of the plane, record the

occurrence and density of the target species. Due to its characteristic light green color, Old World climbing fern is easily observed from the air.

As mentioned above, Old World climbing fern was limited to the eastern third of Martin and Palm Beach County in 1978 (Nauman and Austin, 1978). By 1993, the fern had expanded in western Martin County and central Palm Beach County, and was detected in Glades County northwest of Lake Okeechobee. The total area infested in 1993 was estimated at 27,686 acres. The first documented populations of the fern in Broward, Hendry, Sarasota and Collier Counties were in 1995, with an estimated infested area of 29,212 acres. A 1997 survey detected the fern in Lee and Charlotte Counties and estimated that the fern covered 39,240 acres.

The 1999 SRF survey revealed that the species had expanded into new locations in Lee and Collier Counties. In addition to new sightings, the fern's density in established areas was greatly increased, covering approximately 109,000 acres. The 1999 estimate was based on aerial surveys south of the north portion of Lake Okeechobee and extrapolations from reported observations for areas north of Lake Okeechobee. In 2005, the SFWMD extended the aerial surveys north to Orlando (Figure 6), which estimated 120,780 acres of Old World climbing fern for the survey area (Ferriter and Pernas, 2006).

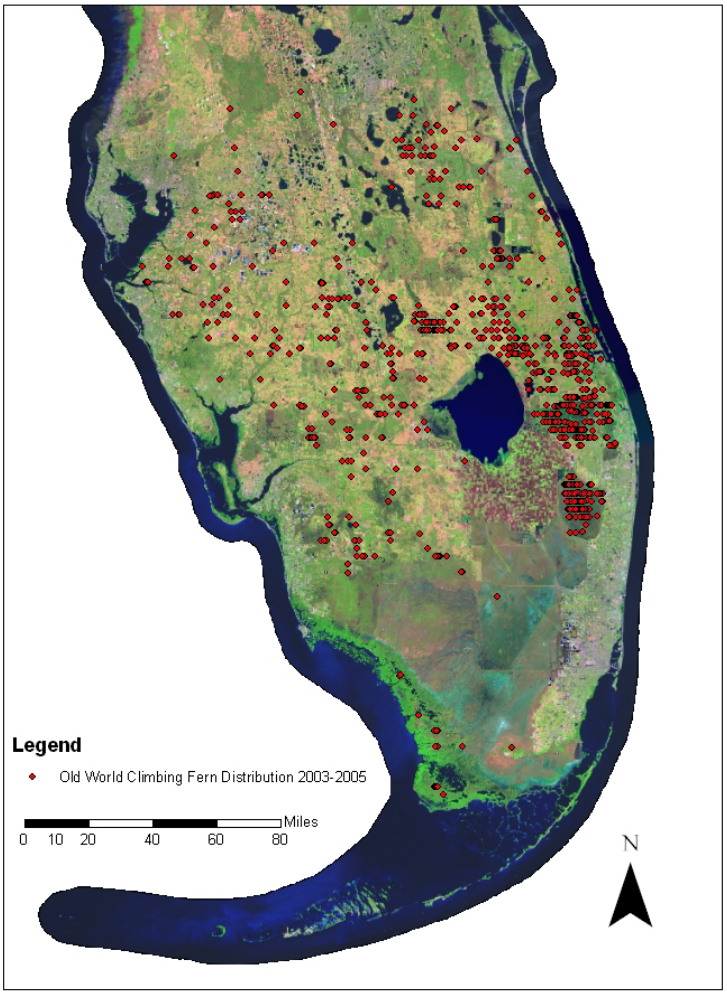

Figure 6. *Distribution of Old World climbing fern in 2005 from the Systematic Reconnaissance Flight aerial survey (Ferriter and Pernas, 2006).*

In 2000, Everglades National Park staff discovered widespread

populations of Old World climbing fern in the western coast of the park, which were not detected in a 1999 survey. These infestations were particularly alarming given their remote location and seemingly rapid establishment. The fern is increasing in distribution to the west and a large infestation (>10,000 acres) was documented in the western section of the Everglades in 2003 (Taylor 2006). These areas can be reached only by helicopter, which can take up to 30 minutes, limiting treatment options to aerial spraying (Figure 7).

The northernmost known distribution of Old World climbing fern in peninsular Florida is approximately five miles east of Orlando (Pemberton, 2003). Though Old World climbing fern is primarily limited in distribution to areas south of Orlando, it can survive temperatures <32° F (Nauman and Austin, 1978; Pemberton, 2003). Spore production and decreased leaf area may occur following episodic freezes (Volin et al., 2004), indicating that Old World climbing fern exhibits dormancy similar to that observed for Japanese climbing fern in north Florida. Large infestations of Old World climbing fern now occur in natural areas near Kissimmee, indicating that it may be spreading northward.

Climate models predict that parts of central Florida, including the Orlando area, are at risk for invasion of Old World climbing fern. Since the fern is partially tolerant of freezing temperatures, it may spread north along the east coast to Jacksonville and west along the Gulf coast to Citrus County where winter temperatures are slightly higher than interior areas of the state (Goolsby, 2004). Based on observations in Orlando where the fern has survived >15 years and withstood several periods when temperatures dropped <32°F (Pemberton, 2003), it is possible that Old World climbing fern will continue to invade wetland habitat further north

Figure 7. *Tony Pernas, National Park Service, inspecting a treated area of Old World climbing fern in the western section of Everglades National Park.*

into peninsular Florida, but it may not exhibit the vigorous, invasive quality it demonstrates in southern Florida, although this warrants further study.

Old World climbing fern 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. Along the Lake Wales Ridge in south-central Florida, *Lygodium* spp. is documented in 213 locations, with at least two infestations of Old World climbing fern in excess of 100 acres (Biehl, 2004). The fern also occurs along the Peace River (Brian Nelson, *pers. communication*) and along Hillsborough County's Little Manatee River (Debbie Butts, *pers. communication*). Near the northern end of its distribution, one of the largest known infestations of approximately 1,800 acres occurs in the St. John's River Water Management District's Blue Cypress Marsh in Indian River County. An additional infestation of 550 acres of Old World climbing fern was recently discovered just south of Blue Cypress Preserve in Ft. Drum Management Area, indicating that it is rapidly colonizing areas north of its historic range. If left unmanaged, population models predict that Old World climbing fern will overtake the five most invasive plants (melaleuca, Brazilian pepper, Australian pine, Hydrilla, and water hyacinth) in combined coverage in south Florida by 2014 (Volin et al., 2004; Figure 8). Theoretically, this would result in several million acres infested with Old World climbing fern if the fern is left untreated.

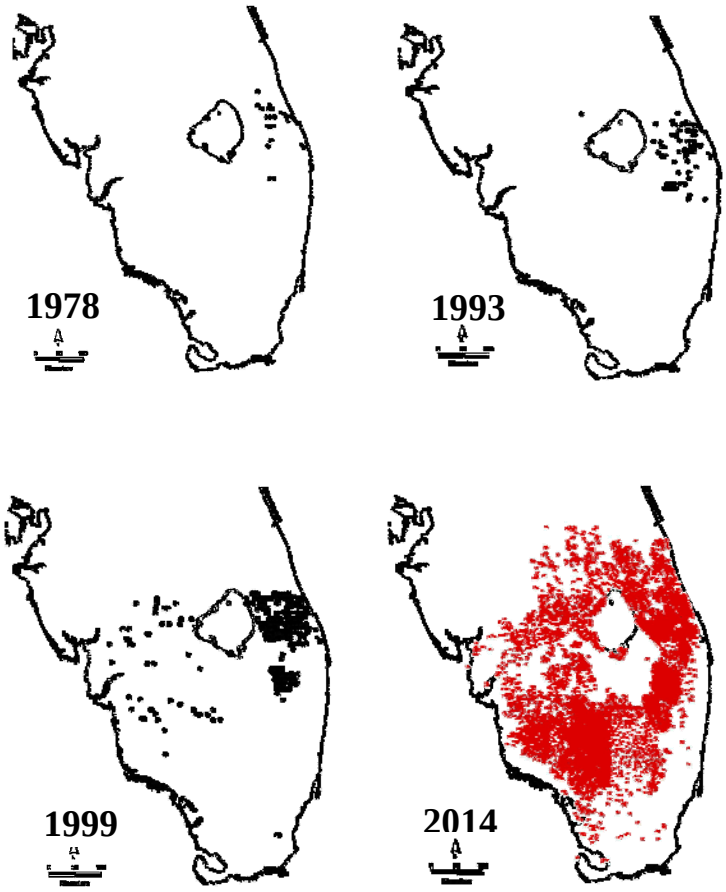

Figure 8. *Predicted spread of Old World climbing fern if left untreated by 2014 based on aerial surveys (1978, 1993, and 1999) by FAU and SFWMD (Volin et al., 2004). Surveys were conducted from the north rim of Lake Okeechobee south.*

As Nauman and Austin (1978) predicted, the ranges of Japanese and Old World climbing fern have met, as Japanese climbing fern has moved slowly southward in the state, and the more recent introduction, Old World climbing fern, has moved rapidly west and north. Their distributions now overlap in Brevard, Desoto, Hardee, Highland, Hillsborough, Indian River, Manatee, Orange, Osceola, Polk, and Sarasota Counties. Both species now occur within multiple natural areas, including Little Manatee River in Hillsborough County, Avon Park Bombing Range in Polk County, and Archbold Biological Station in Highlands County.

Florida Ecology:

Old World climbing fern is now well established in central and southern 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, Gann et al. 1999). It is also commonly found in bayhead and maple swamps, along rivers, coastal prairies, Everglades tree islands, and freshwater marsh. Old World climbing fern populations in Florida differ from populations in native habitats of Australia, Southeast Asia, and Africa by forming dense rachis mats along the ground (often >3-4 ft. thick for established populations; Figure 9) and into the canopy. In south Florida, Old World climbing fern exhibits indeterminate growth up into the canopy, along the ground, and forming dense rachis mats both horizontally and vertically.

Figure 9. *The dense rachis mat of Old World climbing fern can be >3ft. thick and alters fire behavior.*

The rapid spread of Old World climbing fern in Florida can be attributed to wind blown spores that are produced all year, with peaks in the wet season during September and November (Volin et al., 2004). It is estimated that fertile leaflets average 133 sori with an average of 215 spores per sori, with each fertile leaflet producing 28,600 spores, or approximately 38,000 spores per square inch of fertile leaf area (Volin et al., 2004). Thus, it is

easy to envision the invasive potential and rapid spread of this fern. It is unclear if stochastic events, such as major hurricane events, exacerbate spore dispersal.

Little is known about the exact ecological requirements of Old World climbing fern in Florida. The fern occurs primarily in wetlands that are periodically inundated such as bayhead swamps, cypress swamps, coastal prairies, pine flatwoods, mesic hammocks or disturbed sites (ditches, canals, etc.). The fern has also been observed growing in xeric scrub habitat in Martin County (Roberts and Cox, 2000). These observations and the broad natural distribution of this fern suggest that it is tolerant of a wide range of ecological conditions. Environmental variables that were highly correlated with the presence of Old World climbing fern across habitats in the Everglades ecosystem included duration and depth of inundation and soil water content (Volin et al., 2004). Although primarily found in wetlands, Old World climbing fern does show some ability to invade mesic soils, but does not appear to become well-established in extremely dry habitats, or in soils with exceptionally long hydroperiods. While Old World climbing fern has been observed growing in sawgrass marsh in Loxahatchee National Wildlife Refuge (Palm Beach County), it is suggested that plants may become established in slightly elevated areas associated with organic soil accumulation. Similarly, Old World climbing fern will become established on tree trunks and rotting logs in wet areas such as cypress domes. The degree of salt tolerance is uncertain, and is in need of investigation.

Unlike many invasive exotic plant species, Old World climbing fern does not require human disturbance to spread and become established. It is often found in the center of undisturbed natural areas miles from roadways or disturbed sites. The fern is commonly observed in disturbed sites such as ditches and along canal banks, and is common in pastures along ditches, wet areas, and creek banks. It is unclear if cattle graze on climbing fern or if grazing has any effect on the plant.

Once established, Old World climbing fern climbs and then blankets other vegetation, ultimately causing mortality to canopy and subcanopy trees (Roberts 1996, 1997). In some cases, the fern covers other vegetation so completely that it is not possible to see other plants beneath it. Near the ground, a thick mat of stems and roots also forms, ultimately smothering plants in the groundcover layer. Significant impacts to native plant communities are attributed to Old World climbing fern, which alter the ecological processes of the

Everglades by altering habitat structure and composition (Brandt and Black, 2001). In the Loxahatchee National Wildlife Refuge, the percent cover of native vegetation was higher in un-infested plots compared to plots infested with the fern in three different stratums: ground (66% vs. 9%), shrub (33% vs. 4%), and canopy (64% vs. 3%) (Brandt and Black, 2001).

Old World climbing fern is tolerant of fire and causes natural or prescribed fire to spread into the canopy of cypress and pine-dominated ecosystems (Roberts 1996, 1997). These *Lygodium*-induced canopy fires also kill canopy and subcanopy trees (Figure 10), and Old World climbing fern may also facilitate the spread of spot fires (Roberts 1996). In many instances, it has bridged the gap between wetlands and uplands resulting in the spread of fire into wetlands such as cypress strands and bayhead swamps that seldom carry fire from adjacent upland habitats with more frequent fire intervals.

In addition to structural and functional alterations to native ecosystems, Old World climbing fern can significantly reduce species diversity. Rare plant species, such as the tropical curlygrass fern (*Actinostachys pennula*) are severely imperiled by the spread of Old World climbing fern into their last remaining habitats, such as the northern Everglades tree islands. In the bayhead swamps along coastal Martin County, infestations of Old World climbing fern have the potential to severely impact a small isolated population of thinned-leaved vanilla orchid (*Vanilla mexicana*). The rare Okeechobee gourd (*Cucurbita okeechobeensis*) may also be threatened by infestations of Old World climbing fern in pond apple swamps around Lake Okeechobee and elsewhere. The potential for deleterious affects on rare native plants by Old World climbing fern are highest

Figure 10. *Fire creeping into a cypress dome and scorching a bald cypress tree in Jonathan Dickinson State Park during a prescribed burn in 2000.*

in areas like the Fakahatchee Strand State Preserve and areas in the Florida Keys such as Big Pine Key National Wildlife Refuge where multiple species occur. The affects of Old World climbing fern on native wildlife appear to be significant, but is in need of investigation.

Economic Uses and Impacts:

Historically, both invasive species of *Lygodium* were cultivated in Florida, but it is now illegal in Florida to possess either fern. Old World climbing fern was used as an ornamental plant for many years. It first appeared in the Royal Palm Nurseries (Manatee County, FL) catalog in 1888, and was sold by this nursery until 1930. Royal Palm Nurseries 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 Japanese climbing fern and not Old World climbing fern since the two were often confused in early horticultural literature. A photograph identified as Old World climbing fern in the 1905 catalog appears to be Japanese climbing fern. Statements in these early catalogs indicate that the fern they sold was more hardy than other ferns (which "should be kept from hard frost"), also suggesting that the fern sold was Japanese climbing fern.

Unfortunately, the sale of live plants continues in North America as evidenced by an online notice for Japanese climbing fern from Bushman Plant Farm, Cleveland, TX. Also, the Southwestern Fern Society promotes Japanese climbing fern as a “beautiful and tough fern,” that “sadly…is not commonly grown by commercial greenhouses,” while giving explicit recommendations for its growth and care. The author further lauds Japanese climbing fern 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. Old World climbing fern poses an economic threat to the tourism industry through its degradation of natural resources in Florida’s parks and recreation areas. Large “poodle-cut” areas of the fern’s rachis are an eye sore when treatment is near a highly visible area such as a roadway, canoe trail, or campground. Ultimately, the largest economic impact of Old World climbing fern may be the cost to control it in natural areas, agricultural areas such as ranchlands, and hunt leases.

Management and Control Costs

The costs associated with the treatment and control of Old World climbing fern are high, but vary depending on the type of treatment (Table 1). During 2001-2003, the Florida Turnpike Enterprise expended $494,430 to treat the fern along a 100-mile stretch of the Turnpike in southern Florida (*see* Case Study *below*). Between 2002-2004, $446,000 was paid to contractors to treat and monitor Old World climbing fern in Jonathan Dickinson State Park (Philip Myers, *pers. communication*). The Loxahatchee National Wildlife Refuge spent $455,000 for contractors to treat the fern on tree islands in the northern section of the Everglades (Bill Thomas, *pers. communication*). The Upland Invasive Exotic Plant Management Program, located in the FDEP Bureau of Invasive Plant Management, allocated approximately $6.4 million to treat both of the climbing ferns from 1998-2003, which accounted for 24% of the bureau's budget; most of this funding was allocated to Old World climbing fern treatments in south Florida (Drew Leslie, *pers. communication*).

Table 1. Cost per acre of ground and aerial treatments to control Old World climbing fern.

Treatment	Agency (year)	Herbicide	Cost / Acre
Ground	Loxahatchee NWR (1999)[1]	Glyphosate	$300-$1100
	Palm Beach Co. Nat. Res. Dept. (2000-03)[1]	Glyphosate	$500-$700
	Jonathan Dickinson St. Park (2001-2003)[2]	Glyphosate	$637
	Loxahatchee NWR (1999)[3]	Glyphosate	$45-$150
Aerial	Bird Rookery Management Tract – SFWMD (1999)	Glyphosate	$150
	Everglades National Park (1999-2002)	Glyphosate	$111-$125
	Loxahatchee NWR (2002)[4]	Glyphosate	$85
	Loxahatchee NWR (2002)[4]	Escort XP	$40
	Everglades National Park (2003)	Escort XP	$118
	Blue Cypress Mngt. Tract – SJRWMD (2004)	Escort XP	$66
	Everglades National Park (2005)[5]	Escort XP	$147

1 – Cost/acre for cut and spray method varied depending on infestation level.
2 – Average cost for cut and spray method to treat 700 acres during 2001-2003.
3 - Treatment cost for foliar spray method.
4 - Cost of treatment did not vary regardless of level of infestation.
5 – Estimated cost based on re-treatment

Most large-scale treatments of Old World climbing fern on public lands are performed by private contractors. On average, an eight-person crew of herbicide applicators can "poodle-cut" and spray heavily infested areas at a rate of one acre/day at a cost of $1800/day (Figure 11), but costs are highly variable depending on the level of infestation (Jim Burney, *pers. communication*). On average, a two-person crew with a gas powered sprayer can foliar treat an acre of Old World climbing fern at a cost of $400-500 per day. Costs per acre and area covered per day are highly variable based on the level of infestation. Treatment costs per acre are further complicated by events such as hurricanes and extreme wet seasons, which make access and maneuverability even more difficult.

Ground treatments consist of either foliar spraying of small infestations or cutting the rachis at 3-5 ft. above ground level (poodle-cut) and spraying the base of the infestations with 1-3% product glyphosate (4 lbs. a.i./gal.;6.8 kg a.i./liter). Ground treatment is expensive, costing approximately $500-700/acre (Kraig Krum, *pers. communication*). At Jonathan Dickinson State Park in Martin County, the cut and spray method cost $637/acre to treat 700 acres (Philip Myers, *pers. communication*). In the Loxahatchee National Wildlife Refuge, ground treatments (cutting and spraying) with glyphosate ranged from $300–$1100/acre depending on infestation levels, while broadcast foliar spraying from the ground cost $45–150/acre (Bill Thomas, *pers. communication*).

Figure 11. *Ground treatments typically consists of cutting the fern (poodle-cut) at 3-5 ft. above the ground and spraying the uncut portion with herbicide.*

Aerial treatments are considerably less expensive than ground treatments ranging from $40-147/acre, but result in greater non-target damage. Spray rates of glyphosate and metsulfuron methyl are 7.5 pints product/acre and 1-2 oz. a.i./acre, respectively. In 1999, a

cypress strand infested with Old World climbing fern in the Bird Rookery Management Tract in Collier County cost about $150/acre to treat with glyphosate (Jim Goodwin, *pers. communication*). In 2004, aerial application of metsulfuron methyl (2 oz. a.i./acre) for treatment of Old World climbing fern in Blue Cypress Management Area in Indian River County costs $66/acre. At Loxahatchee National Wildlife Refuge, aerial spraying of glyphosate and metsulfuron methyl were $85 and $40 per acre, respectively, regardless of the level of infestation (Bill Thomas, *pers. communication*). Aerial treatments of Old World climbing fern in Everglades National Park cost slightly more than treatments in other areas, due to longer flight times required to reach infested areas in the western Everglades.

Proposed and Enacted Laws

Federal

Neither Old World climbing fern nor Japanese climbing fern 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 (FLEPPC) 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 requesting that APHIS reply regarding their needs for additional information in order to accomplish listing. The FLEPPC received a response from APHIS dated October 21, 1999, stating that APHIS was also concerned regarding the ecological and economic impacts associated with both species, and requesting that a Risk Assessment be prepared to provide information to support listing. However, due to the widespread distribution of *Lygodium* spp., they do not meet the APHIS definition of a “quarantine pest” and approval for inclusion as a noxious weed is unlikely. To restart the petition process, further research may be necessary to more accurately determine the potential North American distribution. This, coupled with support of legislative representatives, may assist with adding both species to the Federal Noxious Weed List. However, there are no plans to restart the petition process at this time.

State

Both Old World climbing fern and Japanese climbing fern were listed as noxious weeds by The State of Florida Department of Agriculture and Consumer Services (FDACS) in 1999 (Florida Statute 5B.-57.007). 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. Florida Statute 5B-57.006 states that FDACS shall cooperate with other appropriate parties to eradicate or control noxious weeds, with strategies to be determined through risk assessment.

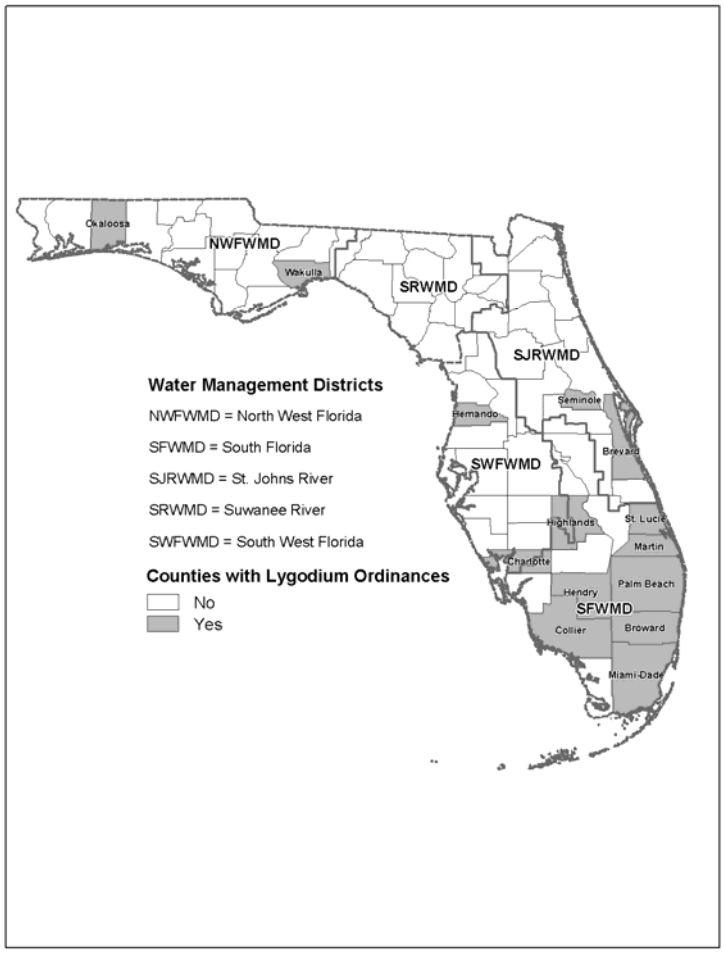

Figure 12. *Florida counties with ordinances prohibiting Lygodium spp.*

Local Governments

The FLEPPC conducted a survey of Florida counties to determine current status of county and/or other municipal level ordinances or other regulations related to both of the invasive climbing ferns (Figure 12). Fourteen counties have created and adopted ordinances that restrict or limit the use of *Lygodium* species. According to the 1999 Lygodium Management Plan, five (5) Florida Counties (Collier, Martin, Miami-Dade, Palm Beach, and Seminole) had ordinances that either prohibited and/or required the removal of Old World climbing fern or Japanese climbing fern at the time of development. For the 2006 update of the management plan, nine additional counties have been added. These counties are: Brevard, Broward, Charlotte, Hendry, Hernando, Highlands, Okaloosa, St. Lucie and Wakulla.

Other

The FLEPPC currently lists both Old World climbing fern and Japanese climbing fern as "Category I" invasive species, defined by the 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."

Management Techniques

The appropriate management approach to controlling Old World climbing fern depends on many factors such as habitat type, size of the population, presence of threatened or endangered species, non-target vegetation, life-cycle of the associated non-target vegetation, access, treatment costs, and available resources. In the past, treatments have used the "poodle cut" method in which the vines are cut 3-4 ft. above the ground and the foliar area of vine below the cut is foliar sprayed with herbicide. A 1-3% solution of glyphosate product was the primary herbicide used in the past. Glyphosate is a non-selective herbicide that causes damage or mortality to many vegetation types. The impact and rapid spread of Old World climbing fern has lead to an increased effort to find, test, and release biocontrol agents. In February 2005, the first biocontrol agent was released in Jonathan Dickinson State Park. More biocontrol agents are expected to be released in the future.

Current Management

Because the threat from Old World climbing fern has only been recognized within the last 20 years, we are in the early to mid-stages of collecting information that 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 as well as the associated non-target vegetation, and available resources. Methods may include cultural practices such as early detection, fire and flooding, physical removal by hand or machinery, biological controls, and herbicides. This section will present the current information on control methods and provide control recommendations based on the available information.

Old World climbing fern control is currently limited to the use of herbicides. Searches in Australia and Southeast Asia have been completed for biocontrol agents in the fern's native ranges. The first biological control agent (*Austromusotima camptonozale*) was released in south Florida in February 2005 with subsequent releases of other species planned over the next 1-4 years. Additional searches for biocontrol agents are planned in other areas of the world. Even after potential agents have been isolated, screened and released—which often takes more than a decade—it may take several more years for the agents to build up effective populations. Thus, the continued use of herbicide will be required for control and management of this invasive fern.

Mechanical removal and prescribed burning will temporarily reduce the biomass of Old World climbing fern, but the plant can return to pre-treatment levels within 12-17 months in most cases (Dick Roberts, *pers. communication*). Integration of biological control into existing control programs 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.

In the interim, herbicidal 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 Old World climbing fern before they become substantial infestations. This element cannot be stressed enough. **Early detection and treatment is the key to successful and economical management of this plant.**

As a supplement to this state-wide plan, all land managers working within the potential range of Old World climbing fern should implement a site specific management plan. Such plans can provide detailed guidance for a particular natural area including: location maps of current infestations, monitoring methods and protocols, treatment options and methods, re-treatment schedules, and, as plans are updated, lessons-learned information based on past experiences.

Biological Control

The consensus among land managers, biologists, and other natural area workers is that biological control combined with herbicide treatments are the best hope for long-term

management and control of Old World climbing fern. 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) also may 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, 2002, Louda et al., 2003). 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 (Pemberton 2002; Strong and Pemberton 2000). Biological control is a very suitable approach for Old World climbing fern 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 also is an appropriate tool because Old World climbing fern grows among complex natural vegetation systems that may be damaged by other control methods.

Evidence of Lygodium feeding insects in the fern's native region helped launch the biological control program against Old World climbing fern (Pemberton et al. 2002; Goolsby et al. 2003). The *SFWMD* and the USDA-Agricultural Research Service (ARS) began cooperative co-funded biological control research on Old World climbing fern in 1998. In 2001, the FDEP began providing funds to assist host specificity testing in both Australia and Florida. The USDA-ARS Aquatic Plant Control Laboratory, Ft. Lauderdale, Florida and the USDA-ARS Australian Biological Control Laboratory, Brisbane, Australia, have been exploring for natural enemies of *Lygodium* with the goal of locating potential biological control agents of the plant. The Australian Biological Control Laboratory is a cooperative lab between the USDA-ARS and the Australian Commonwealth (CSIRO).

Host specificity testing is conducted in the USDA-ARS Australian Biological Control Laboratory in Brisbane, Queensland and the in the Florida Division of Plant Industry (DOACS-DPI) Quarantine Facility in Gainesville, Florida. The State of Florida DPI provides quarantine space at minimum cost to the project to assist USDA-ARS in developing biocontrols of important pests in Florida. Some research in both Gainesville and Ft. Lauderdale is done through cooperative programs with the University of Florida. A major component of the host specificity testing program was and 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. All four Caribbean *Lygodium* species were obtained from the Dominican Republic and Cuba. A selection of the rare fern species and other native and commercial ferns are 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 by the insects.

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 about two years before a release permit is issued.

Summaries of findings to date

Exploratory surveys for biocontrols have focused on Australia and Southeast Asia (1997 – 2005) because the regions have the highest diversity of *Lygodium* species, which correlates with a higher arthropod herbivore richness. Surveys also were conducted in West Africa (Benin, Ghana and Cameroon) in 1999, with additional short visits in South Africa during the late 1990s, and New Zealand in 2003. In addition, insect herbivores and diseases were sought during visits to the Dominican Republic and northern Argentina, areas outside the native range of Old World climbing fern, to collect neotropical *Lygodium* species to use in host specificity testing. Two mite and 20 insect species were discovered feeding on several species of *Lygodium* (Pemberton et al. 2002, Goolsby et al. 2003). Of these 22 species, 6-8 may have potential as biocontrol agents of Old World climbing fern (Table 2). Goolsby et al. (2003) found that the majority of the *Lygodium* herbivores were Lepidoptera (moths), while Coleoptera (beetles) and Hemiptera (Homoptera) are under-represented in surveys.

Relative to the amount of surveying done, the number of insects associated with *Lygodium* species is small. For instance, in 25 populations of *Lygodium* examined in West Africa, only one natural enemy was discovered. This was *Tenuapalpis* mite that is damaging to *Lygodium* but not a specialist. In New Zealand and South Africa no arthropod herbivores were found on the *Lygodium* species surveyed. In the Dominican Republic and Argentina the same *Tenuapalpis* mite was found along with some low density moths in Argentina. The insect herbivores of *Lygodium* species usually occur in low densities, but could occur in higher densities in south Florida where their co-evolved natural enemies are absent (Goolsby et al. 2003). Low densities of fern herbivores in other geographical areas also have been reported for other biocontrol programs (Kirk 1977, Room et al. 1981, and Hill 1998). Ferns were once thought to be almost free of insect herbivores but studies focusing on specific ferns and ferns in general found that arthropod herbivores will forage on ferns (Pemberton and Ferriter 1998).

Table 2. Biocontrol agents for Old World climbing fern management in south Florida (Goolsby et al., 2003).		
Species (Family)	**Native Range**	**Damage**
Floracarus perrepae **(Eriophyidae: mite)**	Australia, China, India, Indonesia, Malaysia, New Caledonia, Singapore, Sir Lanka, and Thailand	Leaf necrosis, Defoliation
Neomusotima conspurcatalis **(Lepidoptera: moth)**	Australia, China, Indonesia, Malaysia, Singapore, and Thailand	Defoliation
****Austromusotima camptozonale*** **(Lepidoptera: moth) Formerly: *Cataclysta***	Australia	Defoliation
Austromusotima sp. **(Lepidoptera: moth) Formerly: *Cataclysta***	Australia	Defoliation
Ambia **sp. (Lepidoptera: moth)**	Singapore and Thailand	Stem necrosis
Callopistria **spp. (Lepidoptera: moth)**	Australia, China, India, and Thailand	Defoliation
Neostromboceros albicomus **(Hymenoptera: wasp)**	Thailand and Vietnam	Defoliation
Endelus bakerianus **(Coleoptera: beetle)**	Singapore and Thailand	Leaf necrosis
Released in Jonathan Dickinson State Park (Martin County) on February 14, 2005. Additional releases are planned for 2005.		

After eight years of surveys, potentially useful insects and a mite have been found. Few diseases have been encountered during the surveys. One yet to be determined disease causing brown areas on the leaves was found in Sri Lanka in 2004. The Lygodium biocontrol project, however, does not have the same range of choices for potential biological control agents as other projects associated with higher, more architecturally complex plants such as melaleuca and Brazilian pepper.

The first insect to be evaluated was the Australian moth (*Austromusotima camptonozale*, formerly *Cataclysta camptonozale*) (Yen et al. 2004), which is one of a complex of pyraloid moths that have evolved with *Lygodium* ferns (Figure 13). The larvae eat the leaves of the plant and at high densities can completely defoliate the fern. The moth can produce a generation every month during the summer and every few months in the winter depending on temperature. After preliminary testing in Australia, the moth underwent full testing in

Gainesville and was found to be a very narrow specialist able to utilize only a few *Lygodium* ferns. It is a tropical insect unable to survive in the temperate part of Eastern North America where the native *Lygodium palmatum* grows. The moth also was unable to utilize any of the four *Lygodium* species native to the Caribbean. Based on these results, a petition was submitted for release of the moth in February 2003 (Buckingham et al. 2003). USDA-APHIS granted a release permit in August 2004 and releases began in February 2005. The FDEP is providing funding for mass rearing and release of the moth.

The second candidate agent to be evaluated is an eriophyid gall mite, *Floracarus perrepare*, native to Australia and tropical Asia. Feeding on new leaves by adult mites causes the leaf margin to roll and thicken forming a leaf roll gall into which eggs are laid and a colony of mites develops. Galls can be physiological sinks which can cause photosynthate to go to the gall instead of new growth. Controlled potted plant studies in Australia showed that the growth of *Lygodium* was reduced when infested with the mite (Goolsby et al. 2004). The biology and host specificity research was done in Australia and the mite was found to be a narrow specialist with a host race limited to two *Lygodium* ferns including Old World climbing fern (Ozaman and Goolsby, 2005, Goolsby et al., *in press*). Based on these findings, a release petition was written and submitted in February 2004 (Goolsby and Pemberton 2004). The federal interagency scientific review body, the Technical Advisory Group for Biological Control of Weeds, recommended that the mite be released in November 2004. At this writing, USDA-APHIS is preparing the Environmental Assessment on the candidate. The mite is expected to be permitted

Figure 13. *The Australian moth, Austromusotima camptonozale (formerly Cataclysta camptonozale) was the first biocontrol agent released in Florida to control Old World climbing fern. Photo: USDA*

for release, perhaps by mid-2006.

The third agent that was evaluated is another pyralid moth, *Neomusotima conspurcatalis*, which is native to tropical Asia east to northern Australia. The damage, biology, and specificity are all similar to *Austromusotima camptonozale* (Solis et al. 2004). The release petition has been written and will be submitted during the spring of 2005 (Pemberton and Goolsby 2005).

An introduced South American rust disease is known to infect Japanese climbing fern in northern and central Florida. The rust was examined to see if Old World climbing fern would be an acceptable host (Rayamjhi et al. *in press*). The rust, which is known only from *Lygodium* species, could be induced to infect Old World climbing fern under controlled conditions but its virulence and damage was less than on Japanese climbing fern. The disease may not have much potential as a control agent of Old World climbing fern, although it can be damaging to Japanese climbing fern in the field.

Future Biocontrol Research

Of considerable interest are perhaps two species of pryalid moths in the genus *Ambia,* which bore into the stems of Old World climbing fern and *L. flexuosum* (Solis et al. unpublished). The stem above the boring larvae is killed because the vascular tissue is cut. Attempts to raise the moth in the Brisbane and Gainesville quarantine labs have not yet been successful. The larval development time takes many months and the larvae seem to require larger stem diameters than can be easily obtained with potted plants. There are also questions about host races and taxonomy. These moths are the highest priority for the overseas research.

A sawfly native to Thailand, *Neostrombocerus albicomus*, is another leaf feeder which has come into the Gainesville quarantine facility. This insect is larger than the moths and can eat a larger amount of leaf tissue during its development. If the sawfly is eventually released in Florida, it may escape attack by parasitoids because there are relatively few sawflies in Florida to generate sawfly parasitoids.

An assortment of other natural enemies has been found including a thrip, *Octothrips lygodii*, which damages the leaves (Goolsby et al. 2003). The thrip is probably a specialist, but

opinions differ regarding the value of thrips as potential biological control agents. The Sri Lankan brown leaf disease should be identified and evaluated. If it belongs to a taxonomic group with specialist diseases, it should also be evaluated as a potential agent. Future surveys will focus on Sumatra in Indonesia and the Malayan Peninsula including Singapore. Additional surveys in India may also have merit (Goolsby et al. 2003).

Biocontrol Outlook

It is expected that *Austromusotima camptonozale* will establish in Florida. How much impact it has on Old World climbing fern depends largely on the mortality that it experiences, particularly from ants and parasitic wasps that may move onto it from related pyralid moths. A complex of agents probably will be needed to subdue *Lygodium*.

As noted, more biocontrol agents are expected to be released. The floracarus mite may be in the field by the end of 2005. The second pyralid moth, *Neomusotima*, may follow in 2006. It is not possible to predict their impact, but the combined feeding effects of these different agents acting in somewhat different ways may help reduce the abundance of *Lygodium*. The stem boring *Ambia* moth(s) may hold the most promise if they can be successfully reared and evaluated. Biological control has proved to be a valuable tool for the management of introduced pest species, but it does not always work against all pests. 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), continued biocontrol research and implementation is worthwhile, especially against such an invasive plant as Old World climbing fern.

Herbicidal Control Technology Research

Limited information is available on the success of herbicides for long-term control of Old World climbing fern. Experienced applicators who routinely treat Old World climbing fern recommend multiple treatments (2-8+) to obtain maintenance control of individual infestations (Jeffrey Hutchinson, *unpublished data*). Most state agencies and private contractors who treat Old World climbing fern use glyphosate at rates of 1-3% product (4lbs. a.e./gal.; 6.8kg a.e./liter) per gallon of water. Glyphosate was also recommended in the 2001 FLEPPC Lygodium Management Plan following preliminary screening trials (Ferriter, 2001). However, glyphosate is a broad spectrum herbicide that also damages non-target native plants that it contacts. Ground treatments with backpack sprayers are more selective because specific areas are treated, limiting herbicide contact with native plants (Figure 14).

Aerial spraying is generally not as selective as ground treatments since the herbicide is broadcast applied over desirable plants as well as the target invasive plants. However, selecting the appropriate seasonal period for aerial spraying, such as the winter months when bald cypress and red maple are dormant, may reduce non-target damage to canopy vegetation.

Figure 14. *Control of Old World climbing fern is currently limited to ground or aerial application of herbicide.*

Several herbicides or herbicide combinations have been evaluated for control of Old World climbing fern (Stocker et al. 1997, Thomas and Brandt 2003). In these cases, ground crews made foliar applications with herbicide or used mechanical methods (hand-held cutters) in combination with herbicides, but control of Old World climbing fern was variable and always unsuccessful without follow-up treatments. Timmer and Vandiver (*unpublished data*) found metsulfuron methyl (Escort XP) exhibited herbicide activity against Old World climbing fern (Table 3). Escort XP is an herbicide used for weed control in pastures, which has minimal effects on grasses (WSSA, 1994). Therefore it has the potential to selectively control Old World climbing fern in grassland-dominated habitats. In 2004, a Special Local Need Permit (FIFRA Section 24c) was approved for government application of Escort XP to control Old World climbing fern in/on freshwater habitat (sloughs, wet prairies, and sawgrass marsh), hydric forests (flatwoods, floodplains, hammocks, and swamps), Everglades tree islands, and Everglades prairie scrub in Florida (EPA SLN No. FL-030010).

Current Herbicide Research

Aerial application of glyphosate and metsulfuron methyl herbicides can provide effective Old World climbing fern control, but results are inconsistent with regard to long-term management or continual follow-up treatments (Brandt 2004). The results of aerial spraying of glyphosate from the Bird Rookery Management Area were initially successful in eliminating Old World climbing fern, but resulted in a high mortality of native bromeliads and required annual follow-up treatments to control re-sprouts (*see* Case Study *below*).

Table 3. Control of Old World climbing fern with herbicides at three locations (Commerce, Fence, and Cypress) in south Florida after four and eight months. All vines were treated on fence posts.

% Control After Four and Eight Months

		Commerce*		Fence		Cypress*	
Herbicide(s)	**Rate/Acre**	**4 m**	**8 m**	**4 m**	**8 m**	**4 m**	**8 m**
Arsenal	16 oz.	95	55	95	60	10	50
Arsenal + Plateau	8 + 8 oz.	99	97	92	40	10	45
Escort XP	1 oz.	100	97	95	65	25	80
Escort XP	2 oz.	99	93	96	80	15	60
Escort XP + Plateau	1.5 + 6 oz.	99	96	85	65	45	50
Garlon 4	2 qt.	99	20	97	30	98	60
Garlon 4 + Escort XP	2 qt. + 1 oz.	100	40	99	70	90	60
Krenite **+ Arsenal + Escort XP**	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 XP	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 XP	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 lbs.	40	50	75	65	70	50

***Vines at the Commerce Center and Cypress sites were treated from the ground up to 4-6 feet. Elroy Timmer and Vernon Vandiver, unpublished data.**

There appear to be tradeoffs between using glyphosate and metsulfuron methyl; Comparisons of treatments using glyphosate (7.5 pints Rodeo/ac) and metsulfuron methyl (1oz Escort XP/ac and 2oz Escort XP/ac) indicate there are advantages to each herbicide (Brandt, 2004). Glyphosate resulted in more non-target damage to native plants but provided better control of Old World climbing fern (Table 3), while metsulfuron methyl resulted in less non-target damage and less control of Old World climbing fern. Regardless of the treatment used, multiple treatments are required to control the re-growth of Old World climbing fern on tree islands.

Table 5. Control (visual ratings of percent necrotic foliage) of Old World climbing fern following one or two applications of Escort XP (metsulfuron methyl) in DuPuis Reserve, Martin County, Florida.			
	Evaluation dates		
Application rates and treatment dates	**May 2003**	**October 2003**	**March 2004**
2 oz./acre (applied Oct. '02)	97%	82%	83%
2 oz./acre (applied Apr. '02 & June '03)	88%	97%	94%
1 oz./acre (applied Apr. '02 & June '03)	50%	82%	67%
Untreated control	0%	0%	0%
Kenneth Langeland and Michael Link, *unpublished data,* 2004.			

Test trials using two applications of 1 oz./acre and 2 oz./acre of metsulfuron methyl (60% a.i.) provided some control nine months after the second application, but neither application rate eradicated Old World climbing fern (Langeland and Link, *in press*) (Table 5). Two treatments using 2 oz./acre of metsulfuron methyl provided significantly better results (94% reduction of *Lygodium*) than applications of 1 oz./acre (67% reduction of *Lygodium*) . Little difference was found between spring and fall applications, indicating that there may be no seasonal effects when using metsulfuron methyl. Treatments using 2 oz./acre followed with a second application one year later at the same rate resulted in no injury to maidencane *(Panicum hemitomon*) and saw-grass (*Cladium jamaicense)*. A significant increase in the dry weight biomass of maidencane indicated that Old World climbing fern may have been suppressing its growth (Table 6). Additionally, metsulfuron methyl has proven to be effective in long-term control of Japanese climbing fern in north Florida. Treatments resulted in less damage to native vegetation than other herbicides but repeat applications were required (Zeller and Leslie, 2004).

Table 6. Dry weight biomass (g/m^2) of living Old World climbing fern and *Panicum hemitomon* following treatment with Escort XP (metsulfuron methyl) in DuPuis Reserve, Martin County, Florida.		
Application rates and treatment dates	***Lygodium microphyllum***	***Panicum hemitomon***
2 oz./acre (applied Oct. '02)	45	135
2 oz./acre (applied Apr. '02 & June '03)	45	408
1 oz./acre (applied Apr. '02 & June '03)	238	87
Untreated control	506	5
Kenneth Langeland and Michael Link, *unpublished data*, 2004.		

Aerial spraying of metsulfuron methyl (2 oz. Escort XP/acre) over freshwater marsh at Blue Cypress Conservation Area in January 2004 resulted in a significant reduction (ca 95%) of Old World climbing fern and minimal non-target damage. However, non-target damage was observed on royal ferns (*Osmunda regalis*) and swamp fern (*Blechnum serrulatum*). An evaluation of the site one year later revealed that Old World climbing fern was re-sprouting in many of the treated sites. However, the majority of Old World climbing fern infestations were small in area (<two square yards) and <2-3 ft. in height. Evaluation of the site will continue indefinitely and a second application of metsulfuron methyl (2 oz. Escort XP/acre) was applied in February 2005.

It is important to examine the use of other herbicides, such as metsulfuron methyl, alone and in combination with other herbicides to control Old World climbing fern. Repeated exposure of plants to herbicides with the same mode of action can result in plant populations that develop a resistance to a specific group of herbicides (Tranel and Wright 2002). Other research questions include:

1) Are the most common herbicides used to treat Old World climbing fern absorbed by this fern and subsequently translocated to the rhizomes?
2) Does Old World climbing fern exhibit the potential to become resistant to herbicides following repeated applications?

Answers to these questions are important for the long-term management of this fern in natural areas of Florida. They need to be addressed as part of an integrated management approach, which includes herbicide applications and rates, biocontrol agents, and land management activities such as prescribed fire.

Past Herbicide Research

Initial research efforts to control Old World climbing fern were conducted by Richard Roberts at Jonathan Dickinson State Park (Palm Beach County) beginning in 1991 (Roberts and Richardson 1994). Burning vines to the soil, burning vines to the rachis mat, spraying with glyphosate herbicide (Rodeo) without burning, and spraying with glyphosate followed by burning were all evaluated as control methods. Based on evaluations of percent cover, plant height and stem densities, between 1991 and 1993, it was concluded that fire alone cannot be used to manage the fern but short term control may be achieved with herbicide

applications. Subsequent studies were conducted to evaluate the effects of glyphosate concentration (ranging from 1.5% to 3.0% product, sprayed to wet), native plant recovery benefits of hand removal of fern biomass, and evaluating specialized spray equipment for reaching vines growing high in trees (Roberts 1997). Although Old World climbing fern coverage was reduced from 57% to 1%, it returned to pre-treatment levels within two years if follow-up treatments were not conducted. In addition, the re-establishment of native vegetation was slow where dead biomass was not removed.

Stocker et al. (1997) evaluated the efficacy and translocation of several herbicides and herbicide combinations against Old World climbing fern, 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 Old World climbing fern plant tissue within one month following application at Barley Barber Swamp (Martin County). In this study, plots treated with Rodeo showed evidence of slight translocation.

At DuPuis Reserve (Palm Beach County), Stocker et al. (1997) used the same herbicides from the Barley Barber Swamp study, plus Pathfinder II, to treat dense climbing Old World climbing fern only at the bases of trees. All herbicides completely defoliated contacted vines, but only Pathfinder II killed plants above the treated portion. The effect on roots and rhizomes was not determined. At Reese Groves (Palm Beach County), Pathfinder II was applied in bands between one and six ft. wide. Other herbicides were sprayed in four ft wide bands starting at ground level and progressing upward to vines that had grown to the top of host trees. Evidence of some herbicide translocation was observed for Rodeo and Garlon 3A but only Pathfinder II resulted in extensive death of tissue away from the treated band. Stocker *et al.* (1997) also studied the effect of flooding on regrowth of Old World climbing fern following mechanical removal, burning, and contact herbicide (Scythe) application at Barley Barber Swamp. It was concluded that flooding did not offer practical management results.

In a 2-year study, Stocker (*unpublished data*) conducted further herbicide and application technique evaluations. Foliar applications of Rodeo or Pathfinder II in November 1999 resulted in complete control while Weedar 64 resulted in excellent control. When the same herbicides were applied in May 1998, only Pathfinder II resulted in complete control. An explanation offered for the differences in results was that plants may have been under water stress because of a very wet winter in 1997/1998 and an extremely dry spring in 1997. Coverage of Old World climbing fern returned to pre-treatment coverage within two years.

Figure 15. *Aerial spraying Old World climbing fern at Blue Cypress Conservation Area in Indian River County.*

Stocker (*unpublished data*) applied Rodeo at 1.4, 2.8, and 4.2 kg/ha in proprietary adjuvant (Monsanto MON 59120), Weedone at 1.4, 2.8, and 4.3 kg/ha in vegetable oil plus limonene penetrants (JLB Oil Plus), and Garlon 4 at 3.0, 6.0, and 9.0 kg/ha in JLB Oil Plus to vines in 15-cm bands beginning 1.5 m from the ground in a spray volume of 187 l/ha. Herbicide rate did not affect results; therefore data were pooled within herbicide treatments. All herbicides resulted in some tissue death in, above and below the treated band. However, none of the herbicides resulted in as much control away from the treated band as was observed in the previously described experiments. 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 conducted additional studies (*unpublished data*) on the effectiveness of using fire to reduce biomass prior to herbicide treatment in plots where re-growth of plants occurred

compared to herbicide applications only at either two or six month inspection and re-treatment intervals. It was concluded that fire can be used to reduce the amount of herbicide required to control Old World climbing fern, in this study by ~50%, compared to herbicide treatments alone. Also, it was concluded that a six-month inspection/treatment schedule is more efficient than shorter intervals.

Timmer and Vandiver (*unpublished data*) evaluated a large number of herbicides and herbicide combinations at three sites in southern Florida over an 8-month period (Table 3). While excellent control was observed for most of the herbicide/herbicide combinations 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 SFWMD has conducted aerial applications of Rodeo and Weedar 64 to large infestations of Old World climbing fern in the DuPuis Reserve (Palm Beach County) and Corkscrew swamp (Lee County) (Figure 15). These applications were made in the winter when non-target deciduous vegetation such as bald cypress (*Taxodium distichum*) is dormant. Excellent control of Old World climbing fern occurred where Rodeo was aerially applied at a rate of 7.5 pt/acre, and little to no damage to most non-target species was observed. The Weedar 64 treatment (1 gal/acre) was less effective and less selective. Adequate control (<5% coverage) is being maintained at the Corkscrew swamp site, but annual retreatments with glyphosate are required (Jim Goodwin, *pers. communication*).

Recommended Herbicides

Many herbicides have activity against Old World climbing fern, however results are 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 Old World climbing fern, which climbs high into trees, it is important that the herbicide used can translocate and kill the entire plant, beyond which is sprayed. In choosing an herbicide, it is also necessary to consider sensitivity of non-target vegetation and whether the herbicide will be applied over water during the application. Only herbicides that are labeled for aquatic use can be applied directly to or over water. Other herbicides 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 identify which herbicides have produced the most consistent results in field trials.

Aquatic sites: Apply glyphosate (1.0–3.0% product/gallon of water) or metsulfuron methyl (0.02–0.04 ounces product/gallon of water) in aqueous solution to wet foliage for ground treatments. **Only herbicides that are labeled for aquatic use can be applied directly to or over water.** When Old World climbing fern has climbed into the canopy, cut the vines 3-4 ft. above the ground ("poodle-cut") and foliar spray all living portions of the fern below the cut. For aerial treatments, apply glyphosate (7.5 pt product/acre) or metsulfuron methyl (0.5 to 2 ounces product/acre) broadcast application. Include a non-ionic surfactant according to instructions on the label. Glyphosate is a broad spectrum herbicide, while metsulfuron methyl is more selective and its effects on grasses are minimal. When spraying with hand held equipment, avoid drift and contact to non-target vegetation. Boom applications can be applied when infestations are too large to treat with handheld equipment and applied when non-target vegetation is dormant.

Non-aquatic sites: Apply glyphosate (1–3% product/gallon of water) or metsulfuron methyl (0.02–0.04 ounces product/gallon of water) in aqueous solution to wet foliage of small populations, where complete coverage is possible. Avoid contact of either herbicide with non-target vegetation. For boom applications apply glyphosate at 2.5 quarts product/acre. Damage to non-target vegetation will occur if either herbicide is broadcast over the top of actively growing vegetation. For ground treatments in which vines climb into the canopy, cut vines 3-4 ft. above ground level ("Poodle cut"), and foliar spray lower portions below the cut area with glyphosate (1-3% product per gallon of water) or metsulfuron methyl (0.02-0.04 ounces/gallon of water).

Aerial applications of herbicides at certain times of the year may, in *some* cases, reduce non-target damage. Aerial application during the winter months is suggested for bald cypress and some variations of maple swamps, in which the dominant trees are deciduous. Under such conditions, successful control of Old World climbing fern without significant damage to dominant native tree species is possible. However, native ferns, bromeliads, and sable palms may suffer significant damage using winter aerial spraying.

Monitoring

Land managers and other field personnel should be on constant surveillance for infestations, and steps should be taken to eliminate newly-detected Old World climbing fern

populations. Two examples of successful monitoring and treatment programs for Old World climbing fern are from Avon Park Air Force Range in Polk County and Bird Rookery Swamp in Lee and Collier Counties. In both cases, intensive monitoring resulted in treatments of all infestations (*see* Case Studies *below*).

All field personnel should be aware of the fern's impact to natural habitats; they should be trained to identify the fern and report locations of new populations to the appropriate personnel. **Newly discovered populations should be quickly treated.** Maintaining treatment records and location maps of Old World climbing fern in natural areas is invaluable in the event there is a turnover in personnel that treat this plant and will allow new personnel to continue treatments and monitoring of all known Old World climbing fern sites (Figure 16).

Current information from south Florida land managers suggests that six months is the minimum period before regrowth can be detected in follow-up monitoring. However, small

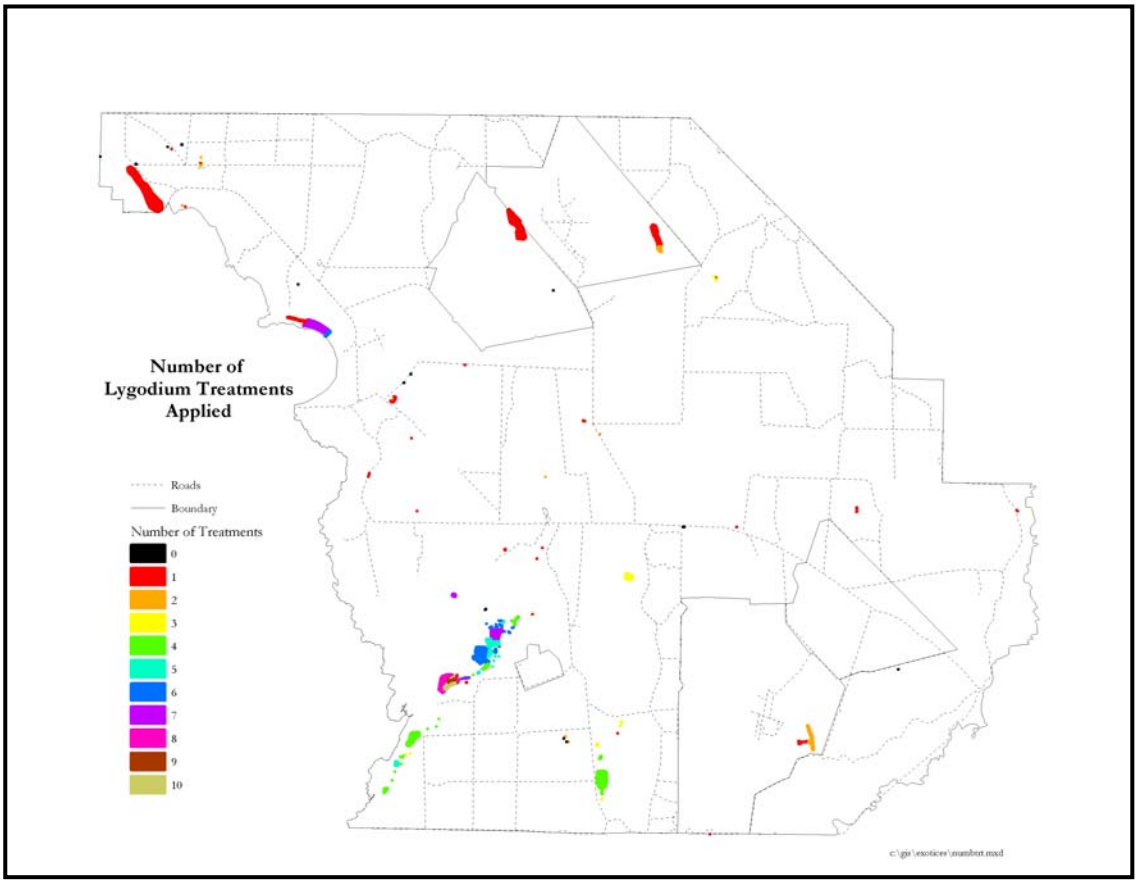

Figure 16. *Locations and number of herbicide treatments for Lygodium at Avon Park Air Force Range in Polk County.*

infestations are difficult to spot even on the ground and may go undetected until Old World climbing fern has grown into the canopy and formed large patches on the ground. One-year monitoring and re-treatment intervals may be more realistic in natural areas where thousands of acres are infested with Old World climbing fern and personnel and funding is limited (Thomas and Brandt, 2003). For large infestations, available funds may be better allocated to re-treatment by aerial application, which can cover large treatment areas more efficiently and cost effectively. Regardless, in the case of aggressive invasive species such as Old World climbing fern, the threshold level is essentially zero, because any new occurrence has the potential to rapidly expand and in turn produce spores for further colonization.

Physical and Mechanical Removal

Physical removal of climbing fern biomass is very time consuming, labor intensive, and expensive. Individual site conditions and objectives should dictate the method of removal. Regardless, it is clear from past mechanical treatment projects that follow-up treatments with herbicide will be necessary. Cutting will kill vines above the cut, but it has no affect on the portion of vines below the area cut. Vines will re-grow from the cut stems as well as roots and rhizomes below the ground after hand pulling. It is impossible to remove the roots and rhizomes by hand pulling, but this method will reduce current growth. Cut vines may be removed prior to spraying the lower portions or dead vines may be removed after spraying for aesthetic reasons, to remove fuel, or, potentially, to enhance re-establishment of native vegetation. Removal of trellised fern biomass reduces ladder fuels (ladder fuels spread fire from the understory up into the canopies of the trees) and decreases the chance of having damaging crown fires, but is extremely labor intensive. Prior to removal of fern trellises, the site should be evaluated and weigh the advantages of their removal to the risk of pulling down rare bromeliads.

In extreme situations, heavy equipment may be used to remove rachis mats that have formed. 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. However, disturbance caused by equipment may allow for re-establishment of Old World climbing fern as well as other invasive plants.

When disposing of removed vines, avoid disposal in un-infested areas, as associated spores may germinate and establish. Physical removal is not recommended except for small isolated populations in which subsequent re-growth can be treated with herbicide or in situations where rare plants are found. All fertile leaflets that are removed need to be securely placed in an air tight plastic bag to prevent their escape. Mechanical treatments (e.g., mowing) are not recommended except in highly disturbed areas where invasive plant coverage is high (>90%). The heavy equipment used for mowing large areas of Old World climbing fern in natural habitat will likely result in the further spread of spores, creation of additional sites suitable for spore germination, and additional impacts to native plants. If heavy equipment is used in an area highly infested with Old World climbing fern, the equipment needs to be sprayed with a high pressure sprayer at the site prior to leaving the site to avoid distributing spores to other areas.

Fire

Prescribed fire can be used to remove thick rachis mats and increase the ease of access of sites heavily infested with Old World climbing fern. However, it is extremely important to understand the natural burn intervals for native plant communities in Florida (see Myers and Ewel 1990). Community types such as pine flatwoods, dry and wet prairies, and freshwater marsh typically remain stable with three- to eight-year burning interval. Other community types such as tropical and coastal hammock, temperate forests, swamps, and Everglades tree islands require longer burn intervals between 15 -100+ years and could be adversely affected by a prescribed burn. Organic (muck) soils further complicate the possible use of fire as dangers associated with muck fires must be considered to eliminate smoke hazards.

Along with invasive plant management, the use of prescribed fire is one of the most commonly used land management techniques in natural areas of south Florida. Annually, thousands of acres of natural areas and pastures are burned in south Florida using prescribed fire. Regardless of the level of Old World climbing fern infestation, fires will occur in natural areas of south Florida through naturally occurring lightning ignited fires, accidental/arson fires, and from planned or escaped prescribed fires.

Past results from prescribed fires indicate that fire alone will not control Old World climbing fern. In its native range in Australia, Old World climbing fern re-sprouts vigorously following fire (Goolsby et al., 2003). In Florida, Old World climbing fern re-sprouts quickly from

rhizomes following fire, often reaching pre-burn infestation levels within two years. Follow-up treatments after prescribed fires will require less herbicide as long as they are completed within two to six months. At a minimum, it is suggested, based on conversations with land managers that follow-up treatments should occur at a minimum of six months following fire. In heavily infested sites at Jonathan Dickinson State Park, Old World climbing fern re-grew to post-fire densities within 17 months following a prescribed burn (*see* Case Study *below*).

Land managers in south Florida generally agree that prescribed fire alone or in most instances is not an acceptable management tool for control of Old World climbing fern. In Fisheating Creek Wildlife Management Area in Glades County, an area of pine flatwoods un-infested with Old World climbing fern prior to a prescribed fire became 50% infested within one-year after being burned (Grant Steelman, pers*. communication*). In Jonathan Dickinson State Park in Martin County, prescribed fires have escaped into cypress strands killing 200 to 300-year-old bald cypress trees, while Old World climbing fern coverage re-established at the site following the fire. The heavy infestations of Old World climbing fern within the state park also resulted in a change to the fire management plan, since wetlands such as cypress strands could no longer be used as fire breaks during prescribed burns (Dick Roberts, *pers. communication*).

In bayhead swamps at Archbold Biological Station in Highland County, isolated spot fires were utilized to burn rachis mats climbing <15 ft. into red bays, bald cypress, and wax myrtle after the surrounding upland area had been burned (Jeffrey Hutchinson, Pers. observation). Re-growth of Old World climbing fern was treated with glyphosate 3-4 months following the burn, and in most cases no re-growth was observed after herbicide application. However, the project was limited to <20 individual sites <5-15 ft^2. This method (spot burning) is not feasible in larger sites infested with Old World climbing fern, but may be suitable to control small, outlier populations.

Regardless, prescribed fire is an important management tool to promote biological diversity in Florida and is used by many land management agencies (e.g., Water Management Districts, FDEP, DOF, FFWCC) in Florida. Many habitats in south Florida such as pine flatwoods, sawgrass marsh, and others require frequent burning to maintain habitat integrity and suitable habitat for listed plants and animals. More research is needed on the long-term relationship between prescribed fire, Old World climbing fern, and herbicide treatment. It is

also important that land managers who participate in prescribed burning report their observations to the FLEPPC on the effects of fire on Old World climbing fern.

Flooding

In one study (Stocker, *unpublished data*), flooding did not control Old World climbing fern re-growth. Lou Toth (*pers. communication*) found that areas of Old World climbing fern sprayed with glyphosate along the Kissimmee River did not re-grow after a portion of river was flooded as part of the Kissimmee River Restoration Project, suggesting that flooding may offer control in some instances. Bill Thomas (*pers. communication*) states that flooding may also inhibit re-growth of Old World climbing fern. The general consensus of field biologists is that Old World climbing fern needs areas void of standing water for germination and early sporophyte development. However, once it has established rhizomes in the soil, it may be able to survive frequent periods of inundation. Additional studies are recommended to determine the role of hydrology on germination and survival of spores, gametophytes, and sporophytes. At this time however, flooding is not recommended as a management tool.

Private Contractor Perspective

Management of Old World climbing fern on public lands will require the use of a qualified herbicide application contractor in most cases of moderate to heavy infestations or light infestations over large areas such as within Everglades National Park. However, any herbicide applications should be integrated into a comprehensive management program involving other land management practices. Preparing a reasonable bid and conducting a successful treatment program for Old World climbing fern following the bid award requires considerable skill, experience, and planning. The following aspects concerning the bidding process and subsequent treatment program are understood and taken into consideration by professional contractors.

Bid Parameters: This is often the most difficult aspect of the whole process for a contractor because the landowner or steward may not fully understand the magnitude of the project in regard to site access, potential non-target damage, herbicide choice limitations, weather constraints, and the cost for physically removing trellising Old World climbing fern from trees. Another primary concern of contractors preparing a bid is how to determine a price per acre unit cost if a defined area is not provided. If a defined area is not provided and an "all encompassing" price per acre is the unit requested, then the contractor must bid on a

worse case scenario because he doesn't know if the landowner will select heavy, medium, or light infestations or how the landowner will calculate billable acreage. Is it acres actually treated or the total acreage of the site to be inspected and treated as necessary? From a reputable contractor's perspective, the most accurate unit for preparing an Old World climbing fern control bid is either a fixed-price per work area or a not-to-exceed time and materials cost. This eliminates any ambiguity on the part of all bidders, resulting in a more consistent range of bids.

One concern among contractors is the low-bid scenario in which cost is the only parameter and the project will be awarded to the lowest responsible bidder. Competition among contractors may result in someone under-bidding a project and then falling short on the Scope of Work. If a contractor fails to complete work, it may be necessary to bring in a second contractor to complete the project successfully. Although this is a rare occurrence, some land owners may wish to consider contracts as Request for Proposals or Qualifications in which cost is only one graded component. State agencies are required by law to use the lowest bidders in most situations; however, state contracts include remedies (including not paying the contractor) for a contractor's failure to perform under contract. In particular, the current contract used by BIPM's Upland Invasive Exotic Plant Management Program includes a "demerit" system that can lead to an irresponsible contractor losing the opportunity to bid on future projects. Several public agencies have "piggybacked" on the Uplands Program contract.

Site Evaluation: During the bidding process the primary due diligence on the part of the contractor is a thorough site inspection and evaluation of current and expected site conditions as it relates to target and non-target plant distribution and age class, site access and onsite transportation, herbicide selection, application methodology selection, crew configuration, and work scheduling through the season(s).

The most beneficial thing that a landowner can do during this process is to provide potential bidders with accurate site maps (preferably in GIS with GPS point locations) depicting the exact work area and to make the site available for adequate inspection by providing site access with properly marked boundaries in the field. Poor maps or insufficiently delineated project boundaries can lead to widely variable bid ranges due to contractors "guessing" the actual work area boundaries.

Pre-Commencement Meeting: Upon contract award, a pre-commencement meeting is imperative in order to determine the expectations of the project for both landowner and contractor. Typical considerations are project management, field personnel, success criteria for mortality, reasonable levels of non-target damage, methods and materials, billing cycles, and work schedule. The importance of this step should not be underestimated. Communication early on in a project will diminish the chance of problems due to differing interpretations or "gray areas" usually present in bid specifications. Logistical concerns such as staging areas, access routes, working hours, location of the closest medical facility, and other site specific items can also be discussed at this time.

One important aspect of developing a successful treatment program for extremely sensitive native vegetation communities that is often overlooked is the contractor's willingness and assertion to develop a "consulting team" comprised of chemical manufacturers' technical representatives, the contractor, pertinent public agency staff, and the landowner. In most cases, this proves crucial in regards to herbicide selection and rates, application techniques, application timing, and realistic non-target expectations. This is especially important given the wide selection of effective herbicide mixtures and application options available today.

With this in mind, the extent of anticipated non-target or collateral damage to native plant species, particularly other ferns and host shrubs, bears a closer examination due to the natural history characteristics of Old World climbing fern. Specifically, there are three points of concern that should be expressed at this time. The first item of concern is the level of non-target damage (mortality of desirable native plants) that is expected during the chemical control operation. This is an unavoidable consequence because the fern is typically overgrowing native vegetation in large mats, intertwined with native species in outlying areas, and/or trellising up mature native trees. However, collateral damage can be moderated by proper herbicide selection based on native species, as well as cutting the fern from "host shrubs" and treating the base to the extent that the budget allows.

Secondly, the need for regular maintenance inspections should not be overlooked due to the potential re-colonization of the site by spores. This is an incredibly resilient species that will take full advantage of open areas left following the initial herbicide treatments and subsequent management practices.

Lastly, if the work site is highly visible within an urban area it should be noted that a significant outcry from residents should be expected once the Old World climbing fern is dead and hanging in the branches of mature trees (>60 ft. in some cases). The resentment of “neighbors” should not be underestimated because the dead material will exist for at least four to five years and may be perceived by some as a fire hazard. However, the reality is that even if the removal of treated material is within the realm of reason using bucket trucks or high lifts, damage to “host trees” during fern removal should be expected and the cost for physical removal will be three to four times the herbicide cost. One possible alternate solution would be a series of closely controlled burns, possibly a few trees at a time over a 6-18 month period.

A determination during this meeting as to the actual Scope of Work, including methods and materials, and scheduling regarding treated material will allow the project to be conducted more smoothly and with the support of any potential complainers. Regular maintenance treatment events can also be scheduled at this time.

Conducting the Project: Once the Scope of Work, methods and materials to be used, and a practical schedule of events have been defined, the next step is conducting the initial control treatment. It should be noted that for >95% Old World climbing fern control, the initial event is actually comprised of one comprehensive treatment of the entire site followed by a single touch-up event conducted approximately three weeks later, once the Old World climbing fern has had a chance to yellow. For the contractor, it is now time to mobilize the appointed Crew Supervisor with the appropriate number of crew members (typically six to ten men), deploy the proper off-road transportation (airboat, swamp buggy, ATV, etc.) (Figure 17), and develop a suitable staging and mixing area with proper spill containment and secure storage.

***Figure 17**. Tracked swamp buggy equipped with a 25 gallon sprayer used by private contractors to reach Old World climbing fern infestations in south Florida.*

Throughout the initial treatment event, a reputable contractor continually monitors crew supervision, crew safety, work quality and progress, and current and expected site conditions. This requires an additional layer of contractor supervision, typically the Project Manager or a Quality Control Officer, and the additional site transportation needed for inspection without detracting from the duties of the crew supervisor and field efficiency. By properly using the Project Manager to regularly inspect work progress and changing site conditions, he can modify methods and materials or work zones to move the project forward in the most efficient manner without distracting the Crew Supervisor from his daily duties of crew management and safety. Unfortunately, this is a very costly layer of project management that is usually overlooked by the landowner's purchasing department when a lowest bid model is used for awarding a contract.

Conducting regular site inspections is also essential to provide an accurate record of project progress. A reputable contractor would prefer that the landowner be present at quarterly completion markers at a minimum. These inspections will allow for modifications as needed to ensure that the expectations of the landowner are being met and to avoid confusion or miscommunications at project completion.

In addition to actual field operations, the contractor is also responsible for the accurate preparation and submission of daily work logs, backup herbicide purchase documentation, and error-free billing. Once again, the reputable contractor has considerable expense in training Crew Supervisors in the proper preparation of daily work logs, thorough review and revisions of the field documents by company administration and project management, and accurate preparation of billing. In all cases, the company's billing department will work closely with the landowner's contract administrator and purchasing department to ensure that all appropriate field data and backup documents are in order.

Maintenance Control: Management of extensive Old World climbing fern should be thought of in terms of maintenance control rather than eradication. Due to the life history characteristics of this species, immediate eradication of established populations from most sites is an unrealistic expectation. Rather the landowner should expect the necessity of funding annual inspection and maintenance events for several years subsequent to conducting the first herbicide applications. Case studies have demonstrated that a vigilant IPM maintenance program is essential in order to avoid pre-initial treatment event infestation levels. This unavoidable truth is based on the incredible regeneration potential of spores present on the site as well as those dispersed from adjacent properties. Bare areas left by herbicide treatment, prescribed fire, and roller chopping seems to exasperate the problem of spore re-generation in the absence of a logical IPM program. Effective biological control agents will be crucial for any long-term, viable IPM program.

Summary: In summary, a reputable herbicide application contractor will: (1) conduct a thorough due diligence prior to submitting a bid or proposal; (2) request and participate in a pre-commencement conference(s) upon being awarded a contract; (3) develop a "consulting team" as needed during the pre-commencement stage; (4) conduct the initial herbicide treatment program while operating as an extension of the landowner's staff; (5) provide proper documentation and accurate billing; and (6) plan and conduct maintenance applications as needed.

Funding

Florida Department of Environmental Protection

The FDEP's Bureau of Invasive Plant Management (BIPM) is the lead agency in Florida responsible for coordinating and funding control of aquatic and upland plants in public waterways and conservation lands. Established in 1997 under Florida Statute 369.252, BIPM is responsible for establishing a coordinated statewide approach to manage invasive plants. The Uplands Program of the Bureau funds invasive plant removal projects throughout the state, but is limited to projects on public conservation lands (local, county, city, state, and federal). Invasive plant projects are evaluated by eleven regional working groups throughout the state and ranked on the severity and impact of the plant to natural

communities. Other factors are also considered in the evaluation of projects that include: matching funds, benefits to listed species, target species invasive potential, continuous site management, and current control technologies. In addition, the Bureau operates an Herbicide Bank that provides herbicides to funded projects for maintenance control. Funding for the programs has increased yearly since inception, but depends on approval by state legislators. In 2003, approximately $6.3 million was spent on 101 projects that resulted in treatment of 34,409 acres. An additional $109,885 was spent providing herbicides to assist land managers in additional control.

All public conservation lands in the State of Florida are eligible for funding from the Bureau. A proposal and maps delineating the project site are required which are submitted to the appropriate regional working group. More information is available on funding on the web at: www.dep.state.fl.us/lands/invaspec/2ndlevpgs/Uplandsplntman.htm

United States Fish and Wildlife Service

Two sources of funding are available for private landowners through the United States Fish and Wildlife Service, both of which can be used to treat Old World climbing fern. The Private Stewardship Grant program provides funding and technical assistance to private landowners to improve habitat for the benefit of listed species. More information available at: http://endangered.fws.gov/grants/private_stewardship.html. The second grant is the Partners for Fish and Wildlife Grant which is designed for private landowners to restore fish and wildlife habitat on their land. More information on the Partners for Fish and Wildlife Grant is available at: http://partners.fws.gov.

United States Department of Agriculture, Natural Resource Conservation Service

The Natural Resource Conservation Service offers three sources of funding for private landowners that can be utilized to treat and control Old World climbing fern. These include:

- Wetlands Reserve Program: provides an opportunity for landowners to receive financial and technical assistance to enhance wetlands in exchange for retiring marginal land from agriculture. USDA pays 75% of the cost to restore a wetland and the landowner pays 25%. More information is available at www.nrcs.usda.gov/programs/farmbill/2002/**.**

- Wildlife Habitat Incentive Program (WHIP): provide financial assistance to landowners to

improve upland and wetland habitat. Priorities are on burning, exotic plants, and brush control. USDA pays 75% of the cost to restore a wetland and the landowner pays 25%. More information is available at: www.fl.nrcs.usda.gov/programs/flwhip.html.

- Environmental Quality Incentive Program (EQIP): EQIP is a competitive program and applicants apply for the installation of Best Management Practices that include pest management (exotic control). The EQIP has a 50/50 cost share between the landowner and NRCS. Information is available at: www.fl.nrcs.usda.gov/programs/eqip/eqip2003.html or www.nrcs.usda.gov/programs/eqip/eqip2003.html

County Sources of Funding

Currently, Palm Beach County has an ordinance that requires all properties within the County to remove two vines, Old World climbing fern and air potato (*Dioscorea bulbifera*). In February 2003, the County created the Invasive Vine Strike Force Program in order to assist property owners with the treatment and removal of these vines. This program provides free treatment of the two vines for properties with infestations of approximately two-acres or less. Higher priority is given to properties that are near a designated conservation area and/or properties where the vines cover native vegetation as opposed to covering other invasive non-native vegetation. Interested property owners submit a registration form to have the property inspected by staff and, if qualified, treated by a County contractor. If necessary, the County will perform one re-treatment within six months of the initial treatment after which the property owner is required by County ordinance to keep their property free and clear of the two vines. To date, over 1,268,000 square ft. of Old World climbing fern (887,000 $ft.^2$) and air potato (381,000 $ft.^2$) have been treated on over 120 properties.

Palm Beach County has several large-scale neighborhoods where the minimum property size is 1.25 acres and a majority of the properties still retain large stands of native vegetation. These “exurban” areas encompass over 44,000 acres, contain approximately 24,000 buildable lots, and contain large populations of numerous invasive plant species. These areas contain the largest concentrations of Old World climbing fern in Palm Beach County and are, therefore, the primary target of the Invasive Vine Strike Force. This exciting program offered by Palm Beach County is an excellent example of the type of local government driven program that fulfills a role in helping to control the spread of Old World climbing fern on private lands.

In addition to private land owner assistance, Palm Beach County funds the Public Lands Grant Program to assist municipalities and other public agencies with the removal of prohibited plant species (air potato, Australian pine, Brazilian pepper, carrotwood, earleaf acacia, kudzu, old-world climbing fern, melaleuca, Queensland umbrella tree). Currently, the county provides a total of $400,000 for a minimum 50/50 matching-grant program, with a $50,000 maximum for each individual project.

Other Sources of Funding

Other sources of funding for treatment and control of Old World climbing fern may be available through local, state, and federal sources. Amounts are variable, cost-sharing may or may not be required, and time limits may apply. The USFWS Partners for Wildlife program coordinator in Naples maintains a list of the most current grants for natural resource managers. Information can be obtained by writing or calling: Partners for Fish Wildlife Program Coordinator, Florida Panther NWR, 3860 Tollgate Blvd., Suite 300, Naples, FL 34114. Phone: 941-353-8442 (x232). Additional discussion on possible funding sources can be found under Financial Support in the following section.

VII. Resource Management Approach

A resource management approach for Old World climbing fern must be implemented at two levels, regionally and site-specific. The management techniques discussed in the previous section applies to Old World climbing fern and should be combined to achieve integrated pest management. Elements of effective management include: monitoring (early detection/rapid response), herbicidal, and biological controls. In some instances mechanical controls and/or physical controls such as fire or flooding may be incorporated. However, mechanical controls are limited due to the sensitive nature of the areas where we are working and, to date, physical controls have not been shown as effective management tools against Old World climbing fern.

One of the most important elements for controlling Old World climbing fern was previously discussed under the header "monitoring." This section covered an early detection and rapid response method. All land managers must identify and treat small populations of Old World climbing fern before they become substantial infestations. <u>This element cannot be stressed enough.</u>

Early detection and rapid response is the key to successful and economical management of Old World climbing fern.

The response to finding an occurrence of Old World climbing fern will depend on the location and the level of infestation. However, a decision on how to control a particular infestation should be reached quickly and treatment should occur rapidly in order to control further spread. Treating Old World climbing fern before it climbs into the tree canopy should reduce the distance of spore spread under normal weather conditions.

<u>Regional Approach</u>

The threat of Old World climbing fern to our natural areas is such that a site by site, uncoordinated approach is not feasible. The intent of the Old World Climbing Fern Management Plan is to bring all land managers together in a comprehensive, coordinated approach to controlling Old World climbing fern. An example of this approach's effectiveness

is demonstrated by the success of the FLEPPC Melaleuca Management Plan, which greatly improved the coordination and implementation of control efforts on public lands.

As of 2005, the overlap of Old World climbing fern and Japanese climbing fern occurred as far north as central Orange County and central Brevard County on the east coast (Figure 18). Reports of Old World climbing fern in the Ocala National Forest were reviewed by FNAI staff and only Japanese climbing fern was documented. Several county parks in Lake County have been surveyed by FNAI staff and as of the Spring 2005, only Japanese climbing fern has been found. While a reduction of both species needs to be a priority for every land manager, one part of a coordinated regional approach must be to rally early detection and rapid control of *Lygodium* by both public and private land managers in central Florida in order to slow or stop the northward spread of Old World climbing fern and the southward spread of Japanese climbing fern. This approach is in line with economic management of these species.

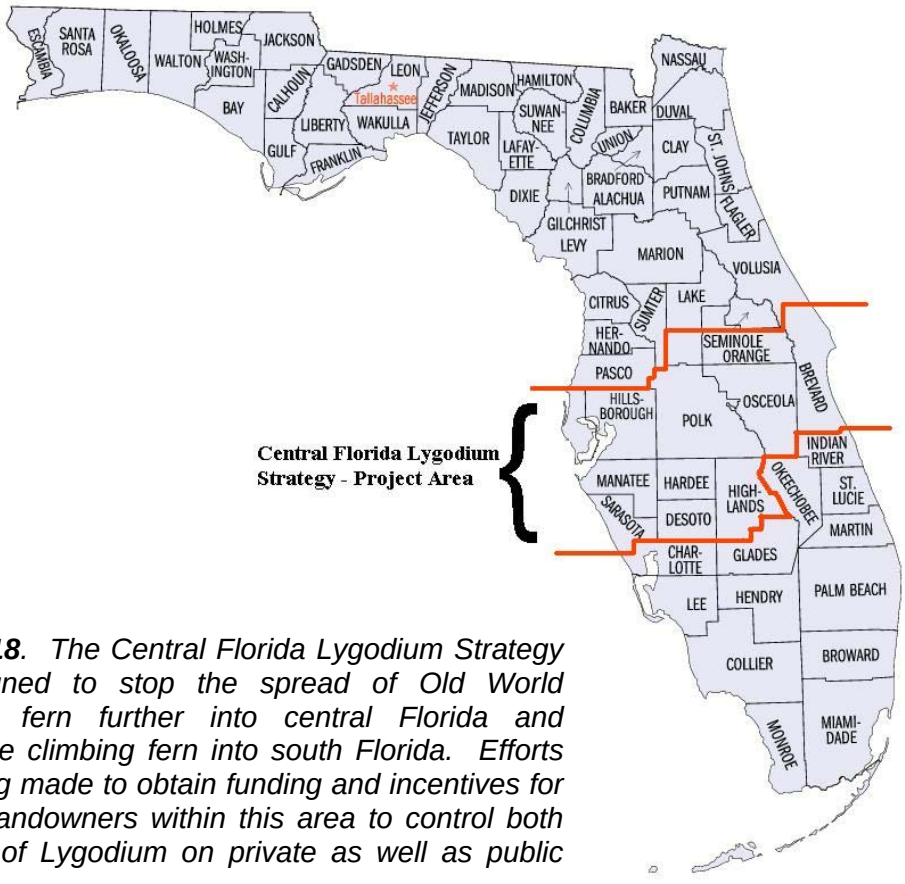

Figure 18. *The Central Florida Lygodium Strategy is designed to stop the spread of Old World climbing fern further into central Florida and Japanese climbing fern into south Florida. Efforts are being made to obtain funding and incentives for private landowners within this area to control both species of Lygodium on private as well as public lands.*

To effectively slow or stop invasion, a comprehensive regional approach is critical. Priorities to this end must be established and funding and resources focused. Contiguous areas of control must be established to facilitate slowing the invasion. The initial objective is to create a contiguous area of control from coast to coast across central Florida and to hold the distribution of the climbing ferns in this area in check, thereby not allowing infestations of the level observed in south Florida. Ensuring that infestations are small enough for ground, rather than aerial herbicide application will both reduce the rate that these species spread and reduce the potential non-target damage from aerial treatments. The ultimate objective will be to secure adequate funding for control of larger infestations to the south and the north on both public and private lands and for additional research and operational releases of biological controls for long-term maintenance.

All public and private land managers across Florida must be involved in this larger regional approach to the following extent:

Monitoring. All public land managers should be participating in the Florida Natural Areas Inventory (FNAI) Florida Invasive Plant Geodatabase project, which is gathering georeferenced data on occurrences of invasive exotic plants on public conservation lands. Detailed guidelines are available, along with developed survey instruments and further background information, by visiting FNAI's public download website, ftp://146.201.56.15 and opening the folder "FLInvasivesGeoDB." Observations of *Lygodium* (as well as other invasive exotic plants) should be reported to Kathy Burks, kburks@fnai.org, for tracking of invasion and control efforts. In addition, Systematic Reconnaissance Flights (SRF) are conducted biannually by the SFWMD. Surveys have been conducted since 1993 for south Florida and, in early 2005, from the north rim of Lake Okeechobee north to Orlando. These surveys are an invaluable resource for general locations of regional infestations of Old World climbing fern (as well as Melaleuca, Australian pine, and Brazilian pepper).

Assessment of level of infestations. Ground control efforts for Old World climbing fern should become the highest priority for land managers in central Florida and any area where only low levels of infestations are found. Central Florida presents a prime opportunity for a high intensity of ground control through coordination of land managers that would save a lot of money and prevent infestations similar to those currently observed in south Florida.

Coordination among adjacent public land managers for control. In all areas of Florida, south to north, coordination across contiguous areas by public land managers should be achieved through better communication, shared resources and involvement in regional working groups. A model for cooperation among land management agencies in Florida is the Lake Wales Ridge Working Group: a group of scientists, land managers, educators, students, interns, and administrators that meet monthly (and more often by email) to discuss conservation and management issues along the Lake Wales Ridge Ecosystem in south-central Florida.

Coordination with adjacent private land managers. It is incumbent for public land managers to achieve better communication with adjacent private land managers. Effective control of Old World climbing fern on public conservation lands cannot be achieved without involving public-private partnerships. Lack of control on adjacent private lands will be a constant spore source and will ultimately create additional costs for control on public conservation lands. Cooperative management of Old World climbing fern between public lands and private landowners must include treatment assistance, funding, and technical support.

Development of focused educational products. Critical partners, from legislators to ranchers, must understand the severity of the threat posed by the Old World climbing fern to Florida's natural resources and economy. Educational products and field events will be necessary to engender support for funding needs and control efforts. Agencies/organizations might collaborate on development of these educational materials.

Support of biological control efforts. Legislative support and funding is always needed for biological control efforts. While not every land manager or agency can provide funding, we can provide a constituency for support of existing and future biological controls through participating as research sites and voicing support when needed.

Coordinated county control approaches. A regional approach is likely to be successful only where counties and state agencies develop consistent and complementary approaches for control on public and private properties. County land managers should vigilantly control the Old World climbing fern on their properties. Additionally, counties should increasingly develop codes that require management of Old World climbing fern on private properties.

These codes may be accompanied by financial incentives or control assistance (ex. Palm Beach County Invasive Vine Strike Force which began in February 2003).

Financial assistance. Old World climbing fern control funding for agricultural land-owners may be available through Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) and other NRCS programs. The Florida Cattleman's Association has requested that NRCS EQIP allocate specific funding for Old World climbing fern control between Highways 50 and 70 in central Florida. Development of other funding sources for monitoring and control efforts on private lands is integral to success of this strategy. Additionally, increased funding from the FDEP Bureau of Invasive Plant Management (BIPM) designated for Old World climbing fern control may also be necessary for success of this regional approach. One source would be designated funding for *Lygodium* control on public conservation lands similar to that currently designated for melaleuca control.

Site Specific Approach

Several factors need to be taken into account when approaching Old World climbing fern management on a property. Consideration of the following factors will allow a site manager to achieve the best level of control.

Monitoring. It is extremely important that a site manager know where infestations of Old World climbing fern exist on the property. This can only be achieved through some level of monitoring. This does not have to be intense systematic surveying, it can also be something as simple as making sure all staff and contractors know how to identify the fern and have them report to the responsible land manager any observed occurrences and whether or not they treated the infestation. The land manager should keep track of all reported occurrences and treatments for planning future treatments. Occurrence points (GPS preferable) will also be valuable since infestations require multiple treatments and should be re-visited for at least seven years following the last observation because of potential for re-colonization from the "spore bank". Red flagging tape on trees adjacent to newly discovered populations can be very useful for finding small, inconspicuous populations.

Level of infestation. How big or small is the infestation? This will determine how you will treat. The Recommended Herbicides section provides specifics on treating different sizes of infestations as well as low-lying ferns versus ferns that are climbing high into trees.

Information is also provided on aerial application of herbicides. Ideally, you should be treating small, outlying infestations as your number one priority as well as other infestations that can be treated by ground control. When an infestation gets so large that it warrants aerial spraying, non-target damage is often hard to avoid.

Location. Is the infestation in or over water? If yes, you need to use a product that is labeled for aquatic use or you need to plan the time of year that you treat so that the area is dry (always read the label). Is it in a remote location where access is limited? You may need access to helicopters, swamp buggies or air boats to transport your crews. Again, you may want to treat during a drier period when access is not so difficult.

Available management techniques. Currently, herbicide application is the only effective tool for treating Old World climbing fern. Biocontrol insects are not yet available for release on all properties, but with the recent release of the Lygodium moth in February 2005, land managers need to stay apprised of the efficacy of this insect and its possible incorporation into an integrated pest management plan on their property once operational releases commence. Burning has not been proven as an effective tool. If you are planning a prescribed burn in an infested area, you must plan to visit the site within a month or two after the burn to “mop-up” re-sprouts of the fern. Physically removing the fern either by hand-pulling or larger mechanical removal also needs to be watched. The simple removal of the biomass will not remove the spores or underground plant material. You must plan on revisiting all areas of treatment. Care is necessary in disposal of removed material to minimize the probability of spore dispersal during movement.

Decontamination of equipment. Inadvertent movement of spores or plant material to and from infested areas by herbicide applicators and their associated equipment 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.

Economic factors. What will be the cost of long-term maintenance of Old World climbing fern? It is important to realize that the initial “treatment” should include the first treatment and (depending on size of infestation) up to seven years of revisiting the site for re-treatments every six months to a year. It is necessary to take this long term approach when

calculating a budget (see Management and Control Costs section for estimate of dollar amounts). For those land managers that only have small infestations, this is the argument for why treatments should occur rapidly, it will cost much less than waiting and treating larger infestations.

Work schedule. A work schedule should be laid out that prompts revisiting a treatment site every six months to one year.

Public perception. If you are treating large infestations in areas with frequent public access, consider starting an education effort. Flyers could be provided as the public enters the site and signs can be erected near treatment sites to educate.

Adjacent properties. Coordination with adjacent land managers will ultimately reduce the cost of treatments on your property by removing adjacent spore sources. If possible, jointly plan treatments of Old World climbing fern with neighboring properties, both public and private.

Know your resources. The FDEP Bureau of Invasive Plant Management (BIPM), through its Upland Plant Management Section funds individual invasive plant removal projects on public conservation lands throughout the state. Projects are considered based on recommendations from eleven Regional Invasive Plant Working Groups. The BIPM has also established service contracts with regional invasive plant control contractors with an established fee schedule to help all Florida governmental entities streamline the hiring of plant removal contractors. As of August 2004, for infestations of either *Lygodium* on public conservation lands that are less than 10 acres in size, the Upland Plant Management Section staff will arrange for a qualified contractor to conduct initial herbicidal control of that plant population. Visit http://www.dep.state.fl.us/lands/invaspec/ for additional information on all of these programs.

VIII. Lygodium on Private Lands

As mentioned previously, another problem facing land managers battling Old World climbing fern is the presence of the fern on adjacent private property. This is especially problematic for land managers that have the fern under control in a natural area, but large populations exist on adjacent private lands. At Bird Rookery Swamp in southwest Florida, excellent control was achieved with an initial aerial application of Rodeo followed by annual re-treatments, but a large population of Old World climbing fern is present just across the boundary that is a constant source of spores (*see* Case Study *below*). A similar situation exists for several areas managed by the Southwest Florida Water Management District where Old World climbing fern infestations are currently small (totaling roughly 200 acres). Maintenance control has been achieved, but large populations still exist next to the natural areas (Brian Nelson, *pers. communication*). Private lands surrounding Jonathan Dickinson State Park are heavily infested with Old World climbing fern. On many public conservation lands, if maintenance-level control could be achieved, long-term mop-up and monitoring would be required due to nearby infestations on private lands. Sometimes, private landowners appear to be wary of local, state, or federal employees and refuse to allow treatment of Old World climbing fern on their land. In other instances, private land owners often are willing to cooperate.

It can be expected that invasions of Old World climbing fern and other invasive plants on private lands will increase as more and more areas of Florida are developed adjacent to natural areas. To minimize rapid infestations from adjacent properties, cooperative efforts among the public land managers and private land owners are needed. Progress is underway by The Nature Conservancy of Florida and the Lake Wales Ecosystem Working Group to develop a model for cooperative management of *Lygodium* between public lands and private landowners that includes treatment assistance, funding, and technical support. Cooperation between state lands managers and private landowners is extremely important in the long term as land managers begin to eliminate Old World climbing fern from natural areas.

A serious threat posed by Old World climbing fern to private landowners, but seldom mentioned, is the pyrogenic nature of the fern which easily ignites and could result in destruction of residential homes. In some areas of south Florida, large populations of the fern are growing within 10-15 yards of residential homes (see the cover of Wildland Weeds

2004, Vol. 7). If any of these infested areas were to ignite, either accidentally or by lightning, it is highly probable that homes would be damaged or destroyed. This threat alone should be sufficient to convince homeowners to control this plant. It may be more difficult to convince landowners of larger undeveloped properties to control the fern. This may be due to apathy, lack of funds, or weariness of government involvement. Regardless, innovative ideas are needed to develop partnerships, provide technical assistance, and potentially funding to private landowners who are willing to control Old World climbing fern on their property.

IX. Spread of Spores by Herbicide Applicators:

Herbicide applicators and their associated equipment moving from 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.

Figure 19. *Equipment can easily spread rachis segments and sporangia of Old World climbing fern that contain countless spores.*

Herbicide applicators appear to be a minor component in the spread of *Lygodium* spores in natural areas (Hutchinson and Langeland 2006). The recent, rapid spread of Old World climbing fern across the landscape of south Florida indicates that other factors such as normal wind patterns from the southeast and stochastic events such as hurricanes are more responsible for its spread across south Florida. References using known Old World climbing fern spores indicated that the spores germinated quickly (12-30 days) in water and were easily observed under a dissecting microscope, while no germination was observed from samples collected from herbicide applicators and placed in growing media.

During the collection of samples taken in June 2004, tracked vehicles driven by herbicide applicators were observed with Old World climbing fern leaflets containing sporangia away from the treatment sites (Figure 19). This could lead to the spread of the fern along routes (i.e., trails, fire lanes, roadways) to and from the treatment sites as the fertile leaves fall off the vehicles or spores are released. All-terrain vehicles used for treatment may be the most likely source of spread of spores away from infested areas since they are driven around and

away from the treatment area, while most workers remain within a specified area. Phil Myers (District Biologist, Florida Park Service, Hobe Sound) believes that his field crew may have spread Old World climbing fern into tropical hardwood hammocks at St. Lucie Inlet State Preserve by using a chainsaw that had been used to cut rachis mats at a distant site. The small infestation was treated and no re-growth or additional plants have been observed at St. Lucie Inlet State Preserve.

Methods to Limit Spore Dispersal

At a minimum, precautionary measures for herbicide applicators to limit the spread of Old World climbing fern spores should include brushing off their clothes, boots, and equipment before leaving a treatment area with a small hand-held broom. All clothing worn during treatment should be washed before it is worn to another treatment site. A reasonable alternative would be to require herbicide applicators treating Old World climbing fern to wear low-cost lightweight, disposable jumpsuits similar to the jumpsuits used by spray painters. These suits could be removed within the treatment site and properly disposed of in plastic bags. The additional cost of jumpsuits could be incorporated into grants for private applicators and would result in minimal costs to state agencies whose personnel treat the fern.

Vehicles (e.g., 4-wheel drive trucks, ATVs) and equipment (e.g., sprayers, chainsaws, machetes) used within a treatment area should be thoroughly cleaned before leaving the treatment area. This includes removing macro-debris (i.e., *Lygodium* strands, parts of leaflets), micro-debris (i.e., sweeping crevices on the frame with a broom), and washing underneath the equipment. Ideally, the use of high pressure air or water within the treatment site could be used to clean equipment. This could be accomplished with the use of a sprayer system and a 100-150 gallon tank utilized by wildland firefighters in Florida that connects to the electrical system of the vehicle. Again, the cost of this type of spray system is between $1000-1400 including all accessories and could be incorporated into initial grants. Public land agencies that conduct prescribed fires have these vehicles available and should consider using them when treating Old World climbing fern.

X. Lygodium Strike Team

In August of 2004, the FDEP Bureau of Invasive Plant Management Uplands Sections (BIPM) implemented a Lygodium Strike Team designed to treat infestations of Lygodium of 10 acres of less in size that occur on public conservation lands (see Wildland Weeds, Fall 2004, Pg. 9). This new initiative is designed to treat populations of Lygodium that are too large for in-house treatment but too small to design a formal project and apply for funding under the BIPM program. To qualify for this new program, land managers of public conservation lands need only to have the area and access points delineated. BIPM staff will arrange for a qualified contractor to conduct the initial treatment of the site which includes all labor, equipment, herbicides, and other costs necessary for treatment. Treatments will be either foliar application or "poodle-cuts." For more information, contact BIPM at 850-245-2822 or visit their website.

This new program implemented by BIPM provides an additional resource that can be used by land managers to treat Lygodium on public lands in Florida. It may be especially valuable to land managers of conservation lands that have few staff and limited infestations of Lygodium, such as areas along the northern and southern limits of the known range of Lygodium.

XI. Case Studies

Management of Old World Climbing Fern in Everglades National Park

Jonathan Taylor

Introduction

Everglades National Park (NP) was designated as a National Park on December 6, 1947 and has since been designated a World Heritage Site, an International Biosphere Reserve, and a Wetland of International Importance. Covering an area greater than 1.5 million acres, Everglades NP is the only subtropical preserve in North America. Located in three counties (Dade, Monroe, and Collier Counties), 86% of Everglades NP is designated wilderness and is the largest designated wilderness area east of the Rocky Mountains. The park contains both temperate and tropical plant communities, including sawgrass prairies, mangrove and cypress swamps, pinelands, and hardwood hammocks, as well as marine and estuarine environments. Elevation in the park ranges from 0 to 8 ft. The park typically experiences a distinct wet (May to September) and dry season (October to April). More than 230,100 acres of mangrove forest exist within the park boundary, making it the largest mangrove ecosystem in the western hemisphere. The park is known for an abundance of bird life and is the most significant breeding grounds for tropical wading birds in North America. In addition, the park is a valuable cultural resource with greater than 2000 years of human occupation. An estimated one million visitors per year visit the park providing economic benefits to the local economy.

Background

Old World climbing fern was first discovered in Everglades NP in 1999. At that time, aerial coverage of the fern was estimated to be 200 acres. Treatment efforts with both prescribed fire and herbicide have suppressed the formation of dense stands and reduced above ground biomass. However, despite treatment efforts, this fern has expanded its range in Everglades NP. In 2005, the total area infested is estimated at 10,000 acres. Everglades NP has been unsuccessful in containing the spread of this invasive weed.

Old World climbing fern is predominantly found in remote western portions of Everglades NP from Cape Sable to Everglades City. The areas affected the most are best described as coastal prairies dominated by graminoids such as sawgrass (*Cladium jamaicencse*), spartina (*Spartina bakeri*) and juncus (*Juncus roemerianus*), with scattered areas of woody

vegetation such as wax myrtle, swamp bay, Dahoon holly, etc. It appears that the infestations do not start in these wooded areas. Old World climbing fern seems to prefer germinating on the tussocks created by graminoids but does grow upon the mangroves and hardwoods that delineate the affected prairies, and very small populations were found in 2003 growing at the base of melaleuca trees (*Melaleuca quinquenervia)* and within two tree islands in the north east portion of Shark River Slough. In 2005, an individual plant was found and treated in Mahagony Hammock.

Systematic reconnaissance flights (SRF) are conducted every two years to track the distribution of Old World climbing fern within park boundaries. Informal reconnaissance surveys are also conducted at various times throughout the year by Everglades NP employees, researchers, volunteers. Reconnaissance based on previous SRF's is conducted prior to treatment efforts in order to prioritize sites; they are also conducted following treatments to determine efficacy.

Management efforts

Aerial application of herbicide is currently the best treatment method at Everglades NP. Infested areas are remote and access is limited to helicopters, although some sites could be accessed by boat. Landing ground crews to treat Old World climbing fern is problematic. Most of the affected areas do not have suitable landing sites for helicopters, and for those affected areas that have relatively close, suitable landing sites, ground crews could only work under the driest of conditions (Figure 20). Even then, it is unclear how long the deep peat soils could reasonably support sustained foot traffic between affected areas and the landing site. The dense vegetation would be an additional hurtle the work crews would have to overcome.

Figure 20. *Aerially sprayed Old World climbing fern in the western section of Everglades National Park.*

From 1999 to 2002, aerial treatments of Old World climbing fern involved the use of Rodeo. While the fern was effectively treated, all native plants were also killed. Afterwards, treated areas were re-colonized almost exclusively by Old World climbing fern. Native plants have not recovered in Rodeo-treated areas. Based on these results, a request was made in 2003 to the FLEPPC to convene a meeting of the Lygodium Task Force to seek advice on more selective treatment alternatives that would minimize non-target damage. The meeting concluded with a recommendation to use the herbicide Escort XP. It was known to be somewhat selective; sparing graminoids and some broadleaf woody species.

Since 2003, Escort XP has been used to treat Old World climbing fern, and it does so effectively with less non-target damage. Graminoid species have not been noticeably affected. Woody species scattered in the prairies or around the fringes of the treatment areas such as bay trees (*Persea* spp), wax myrtle (Myrica cerifera) and buttonwoods (*Conocarpus erectus*) appear unharmed. However, non-target affects were not completely avoided. Both native ferns and cabbage palms (*Sabal palmetto*) were killed by the Escort XP treatments. Regardless, Escort XP has proven better than any other herbicide alternative.

Treatment History

Aerial treatments of known infestations were conducted in 1999, 2000, 2002, 2003 and 2005. As of 2005, approximately 3560 acres have been treated.

Lygodium in the Avon Park Air Force Range

R. Scott Penfield

Introduction

Avon Park Air Force Range (AFR) is 106,000 acres in size and is located approximately 60 miles south of Orlando and about 75 miles from the East and West Coasts. The Air Force uses the property to primarily to practice bombing missions utilizing practice charged type bombs that minimally disturb the ground but are highly pyrogenic, frequently starting fires.

Background

The property is composed of mostly native vegetation, with over half of the acreage classified as very high quality by the Florida Natural Areas Inventory. The installation harbors over 1,000 plant species, with 47% of these plants being indigenous to peninsular Florida. Avon Park AFR is one of the few remaining ecologically-intact natural areas in Florida where one can traverse from a ridge of oak scrub down a seepage slope through dry, prairie flatwoods, oak hammock, and marsh to the edge of either the Kissimmee River to the East or the Arbuckle creek to the west.

Under a Presidential Executive Order, the Air Force is required to control all invasive species that appear on the installation. There is an ongoing program to control invasive species – mostly cogon grass and tropical soda apple. These invasive plants usually infest sites with disturbed soil and do not spread quickly across the landscape.

Botanical surveys conducted on the property in early 1999 revealed three or four small locations with two or three plants each of Old World climbing fern. None of these locations were considered serious in nature. However, in late 1999 we discovered a major infestation of six to ten acres. This infestation caused the Air Force to conduct random ground surveys in a number of the cypress swamps on the property. It was discovered that small infestations, sometimes not more than a single plant, were common throughout the installation.

Management Efforts

Two main steps were taken to control the infestations. The first step was to complete an “on the ground” survey of all possible locations within the installation. A Student Conservation

Association intern was hired in 2000 to walk systematic transects in every cypress strand, cypress head, bay swamp, and other potential habitats where *Lygodium* spp. may likely have established (both invasive species are found on AFR). The on the ground survey combined Global Positioning System (GPS) and Geographic Information System technology to document where the fern was present, where it was not present, and the location of treated areas. This is a 100% walking survey of potential affected communities. All locations of *Lygodium* were directly mapped with GPS or if forest canopy was too dense, locations were selected from aerial imagery. Narratives were written with on the ground directions to get to the infestation. Information was provided on the success/failure of herbicide treatments. This monitoring system will be used for continued monitoring efforts and, as data is gathered, predictions on where and when sites need to be revisited can be refined. The monitoring system also allows small detected invasions to be quickly and effectively treated. The ground survey includes looking for plants plus providing oversight to herbicide contractors. A similar program for Everglades tree islands is being developed by the South Florida Water Management District to reduce response times between locating small populations and deploying herbicide applicators (L. Rodgers, *pers. communication*).

Survey Costs

The survey portion of this project also included re-surveying treated areas and documenting sites where *Lygodium* had been completely killed. From 1999- 2003, a total of 6,689 acres were surveyed at a cost of $4.83/acre. This cost estimate does not include infrastructure costs such as office use, GIS support, equipment, or vehicles. Because of the need to re-survey known locations, our monitoring and survey costs are relatively high.

Control

The Air Force had no resources available to accomplish in-house control of the fern; therefore the Air Force began soliciting funding to treat existing infestations. Because of the rapid expansion this weed, herbicide applications will likely have to be conducted ad infinitum, and native species are likely to be seriously degraded if not totally destroyed during initial treatment efforts.

The first heavily infested location of *Lygodium* at Avon Park AFR was treated in 1999, and was re-treated nine times. We initially emphasized herbicide ground treatments of outlier locations, leaving the large infestations to treat last. As of 2005, all but one known location

has been treated; the untreated population is inaccessible due to military operations, but it was partially treated two years ago and does not currently have a heavy infestation. The site was burned in the winter of 2005 and is scheduled to be treated again.

A total of 556 acres of *Lygodium* (including both Old World climbing fern and Japanese climbing fern) have been found on the installation, all of which are in some stage of control. We have reduced the size of the total infestation down to 499 acres (or roughly a 10% reduction). However, infestations within these areas are significantly reduced in size, both vertically and horizontally, compared to initial discoveries in which the ferns often formed ground and canopy coverage. With few exceptions, most sites are not infested with the fern or have very small populations.

In the Spring of 2005, FNAI's *Lygodium* specialist staff visited the areas treated under BIPM funding program. Field surveys determined that most climbing populations were dead, largely due to "poodle-cut" treatments and rigorous follow-up treatments (Lockhart 2006). Treatment of remaining populations will be limited by access due to military operations and fallen trees from the 2004 hurricanes. Comments were very favorable regarding the effectiveness of our treatment program.

Treatment Costs

Our cost of control on all sites with multiple treatments to date averages $572/acre.

Conclusion

Containment with herbicide and constant monitoring is a realistic approach. However because this species has no boundaries and additional locations appear each year off the installation, control of infestations as they occur is the only measurement of success. This will be a constant maintenance program for many years to come. As a matter of interest this is one of the costliest natural resource management programs being undertaken by the Air Force at Avon Park. Without the State of Florida providing assistance to accomplish control of *Lygodium*, management would be difficult since there are no long-term Federal resources available.

A.R.M. Loxahatchee National Wildlife Refuge

Bill Thomas

Introduction

A.R.M. Loxahatchee National Wildlife Refuge (WCA 1), located in western Palm Beach County is approximately 145,000 acres of deep peat wetland with organic soils >24 ft. deep. It is the northernmost portion the Everglades, with large areas of open sloughs and wet prairies dotted with 1000's of small tree islands. These tree islands range from 0.5 to 300 acres in size; exotic melaleuca heads can be up to two 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 and 2,030 acres of impoundments.

Over 64 listed animal and plant species have been documented in or near the Refuge. Of particular concern is the spike-ray fern *(Actinostachys pennula)* also known as tropical curly-grass fern, which is distantly related to Old World climbing fern. The extreme impact of Old World climbing fern to these native, listed species underscores the importance of controlling this weed in the Refuge.

Background

Old World climbing fern was first noticed on isolated tree islands in the north-central portions of the Refuge interior by SFWMD helicopter pilots in 1989. The fern also was noted in the adjacent Strazzulla Marsh by SFWMD staff in 1992, and in the interior by refuge biologists in 1992. However, the establishment of the fern must have been years earlier, as it is visible from air only after substantial growth. Old World climbing fern 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 undeveloped-non agricultural fields.

A 1993 aerial survey showed the fern was on a few localized tree islands in the north-central portion of the refuge interior. By 1995, aerial surveys revealed that 12%, or 17,500 acres, of the Refuge were infested with Old World climbing fern. In 1997, aerial surveys by the SFWMD indicated that the fern had infested an additional 4,500 acres totaling an estimated 22,000 acres of the Refuge. The 1999 aerial survey by Refuge staff confirmed that the fern was continuing to spread and that infestation levels were increasing, however, no estimated

infestation acreages were adopted. Refuge staff conducted another aerial survey in 2000 and estimated that Old World climbing fern infested roughly 18,000 acres of the Refuge interior at varying degrees from light to heavy, similar to acreages reported in the 1999 SFWMD survey.

The Refuge contracted with an independent company to conduct a Surveillance and Reconnaissance Flight (SRF) exotics survey in March 2002 using aerial survey techniques perfected by the National Park Service and SFWMD. Results from the 2002 SRF survey indicated that Old World climbing fern infested nearly 34% of the Refuge, or 48,000 acres, at varying density levels. In 2003, the SRF survey was conducted as a collaborative effort between the FWS, NPS, and SFWMD. This survey estimated that the fern impacted 34%, or 48,000 acres, of the Refuge, a similar result as the 2002 survey. It was estimated that nearly 42,000 acres were moderately to heavily infested, and that 6,000 acres were lightly infested. SRF results are considered conservative because the fern is probably not detected at smaller or sparser infestation levels from the air, nor in the understory of forested habitats. The overall infestation level would probably be much higher.

Management efforts

For years prior to 1999, refuge staff hand pulled and foliar sprayed small infestations of the fern within or on the edge of the Cypress Swamp and along the Marsh Trail. Although staff knew of the ferns existence and its explosive growth potential and invasiveness, no dedicated funds were allocated in the budget specifically for fern control nor was a large-scale attempt to control the fern implemented. Since 1999, private contractors have been hired to treat Old World climbing fern in delineated treatment areas within the Refuge interior. A force account labor crew, hired in late 2002, continues to canvass the relatively pristine interior central slough, performing exotics treatments including Old World climbing fern. The Refuge's exotics crew continues to target small infestations of the fern and other exotics around the headquarter area, on perimeter and compartment levees, and within the Cypress Swamp.

As of 1999, contractors and Refuge staff had treated nearly 250 acres of pure Old World climbing fern within the Refuge. By 2008, it is expected that Refuge crews and private contractors will have performed initial and follow-up treatments of the fern on some 50,000 acres of the Refuge interior. The Refuge's Integrated Pest Plant Management Plan

(IPPMP), completed in 2001, should provide guidance and strategies for managing invasive exotic plants, including Old World climbing fern. The IPPMP will be updated in FY06 as control methodologies and research results are updated. Although each invasive plant is addressed separately, the overall strategy is to work from south to north—from areas of least infestation to areas heavily infested.

In 1999, funds were allocated from the FDEP to treat Old World climbing fern in the Refuge interior. In August of 1999, FDEP contractors began treating infested tree islands in the north-central interior. The preferred method ('poodle cut') was for the fern ladders to be cut with machetes and left to die, while that portion of the fern that remained rooted below the cut was foliar-sprayed with 5% glyphosate. Smaller infestations were foliar-sprayed with 5% glyphosate without cutting. In all, approximately 140 tree islands of varying size were treated on approximately 309 acres at an initial cost of $155,000 (approx. $500/acre). The FDEP subsequently awarded the Refuge with a re-treatment work order in 2000 totaling $60,000. In addition, the Refuge received over $240,000 from the FDEP in 2000 to treat Old World climbing fern in the Cypress Swamp. Approximately 12 to 15 acres were treated in the Cypress Swamp. Although widespread, the overall percent cover of the fern in all vegetative layers was estimated to be 2.1% (G. Gann, *pers. communication*).

Refuge staff monitored the 1999 treatments to collect information on treatment efficacy within the tree islands (Thomas and Brandt, 2003). After three years post-treatment, the percent cover of native species had increased in all vegetative layers, while the percent cover of Old World climbing fern had decreased substantially. Minimal non-target damage was observed on the tree islands. However, some damage to native ferns and wax myrtle occurred in the interior and exterior of tree islands where foliar applications of glyphosate were performed on Old World climbing fern in lieu of using the 'poodle cut' technique. Dominant canopy species such as red bay and dahoon holly suffered minimal damage. Many of the treated tree islands remain relatively free of Old World climbing fern nearly four years post-treatment, indicating that although ground treatments are extremely costly they can effectively control this species on a small scale over a short-term period. Most of the re-growth on properly treated islands occurs on the island fringes. Horizontal root rhizomes and runners have been found to run into the center of islands (Laura Brandt, *pers. communication*).

Although ground treatments are considered effective at small scales, the extent of Old World climbing fern coverage on the Refuge makes ground treatments economically unfeasible. Ground treatments at the Refuge cost approximately $500/acre and $1100/tree island. The delineated treatment area (309 acres) includes a significant proportion of un-infested wet prairie and saw-grass marsh. Using this conservative estimate it is estimated that it would take nearly $12.5 million and approximately 10 years to perform initial treatments for this invasive fern on the Refuge. For economical reasons alone, aerial application techniques must be researched and perfected as this is the only logistically feasible and cost effective method for controlling this weed on the Refuge.

In 2001, the SFWMD funded a collaborative research study on the effectiveness of aerial spray on heavily infested tree islands in the Refuge interior. Applications of two different concentrations of the herbicides metsulfuron methyl and glyphosate occurred in October of 2001. Two different rates of the herbicide glyphosate (3.75 pints & 7.5 pints/acre) were applied to the west and east side of one island, and two different rates of the herbicide metsulfuron methyl (1 ounce and 2 ounces/ acre) were applied to the west and east side of a second tree island, respectively. Both islands were severely infested with Old World climbing fern.

At one year post-treatment, significant differences in control were observed between the two herbicides (Brandt, 2004). However, increased herbicide concentrations did not significantly increase mortality of target and non-target species. Glyphosate was more effective and resulted in higher Old World climbing fern mortality (~97%), but killed or adversely impacted more native species. Metsulfuron methyl applications caused less damage to native species, but resulted in lower mortality of Old World climbing fern (~66%). The variability in the non-target damage may be due to the density of the fern mats in the island interior which may have shielded native species exposure to herbicides. Non-target species located near the edges of tree islands, such as St. John's wort and buttonbush, suffered the most damage. Both islands contained large amounts of climbing fern re-growth 24 months post-treatment, most of which was observed sprouting from the dead rachis mat. Old World climbing fern control was 57% and 8% on glyphosate and metsulfuron methyl treated islands respectively. Technicians reported that the island treated with metsulfuron methyl was nearly at pre-treatment levels at the 24 month monitoring interval.

Table 4. Percentage of live Old World climbing fern on tree islands in the A.R.M. Loxahatchee National Wildlife Refuge (Palm Beach County) pre-treatment, 12 months post-treatment, and 24 months post-treatment using Rodeo and Escort XP herbicides.			
Herbicide	**Percent Live Old World climbing fern (+S.E.)**		
Rate (# of points)	**Pre-treatment**	**12 months Post-treatment**	**24 months Post-treatment**
Rodeo			
3.7 pints/acre (n=8)	55.9% (10.9)	4.3% (3.9)	23.7% (14.6)
7.5 pints/acre (n=13)	36.1% (7.1)	1.0% (0.7)	20.4% (7.8)
Escort XP			
1 oz./acre (n = 14)	54.9% (9.3)	17.2% (6.6)	32.5% (7.5)
2 oz./acre (n = 17)	41.4% (7.5)	20.8% (7.8)	39.7% (6.7)
Data collected using vertical line intercept points. Laura Brandt, unpublished data, 2004.			

A major concern to all agencies involved is whether Old World climbing fern is building a resistance to metsulfuron methyl. Photo points and data confirm these findings. Based on these results, it is believed that the best plan of attack would be an initial application of glyphosate to kill the dense overstory of the fern followed by a second application of metsulfuron methyl as more native species are exposed. Regardless of which aerial application is adopted, re-treatments will be necessary. Aerial treatment costs range from $40 per acre (metsulfuron methyl) to $85 per acre (glyphosate) including helicopter costs (Amy Ferriter, *pers. communication*), which is significantly less than ground treatments. Studies will continue to determine the most cost-effective and efficient aerial treatment technique to control Old World climbing fern and limit non-target damage.

Refuge staff is working to secure funding from many sources for the control of Old World climbing fern for this monumental effort and will continue to make additional funding a high priority. The Comprehensive Conservation Plan completed in 2000 identifies a funding need totaling one million dollars per year solely for Old World climbing fern management. A funding request for this amount was submitted through the Refuge Operation Needs System seeking dedicated federal funds needed for effective Old World climbing fern management on the Refuge. In FY04, the Refuge received four million dollars for invasive exotic plant control. The majority of the funding, $2.275 million, will be used to clear all exotic plants in the southeastern and central interior including Old World climbing fern as specified in the Integrated Pest Plant Management Plan. A separate Old World climbing fern project totaling

$250,000 will be completed in the north-central interior linking to the 1999 *FDEP* funded *Lygodium* project. A 2,500-acre aerial project was planned for late 2004 using metsulfuron methyl, but the project was delayed due to hurricane defoliation of the fern on the tree islands. Remaining funding will be allocated to fund biocontrol research and releases, and additional research studies such as herbicide trials, spore dispersal, growth models, and rapid detection of the fern through the use of satellite imagery (IKONOS).

Old World climbing fern in the Bird Rookery Swamp of the Corkscrew Regional Ecosystem Watershed (CREW)

Jim Goodwin

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.

Bird Rookery Swamp is located mostly west and south of the Corkscrew Swamp Sanctuary in western Collier County. The interior of the swamp is relatively undisturbed, with a canopy dominated by cypress and red maple. The wetland maintains a long hydroperiod and is inundated for most or all of the year. 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.

Background

Old World climbing fern was first located along the logging tram roads within Bird Rookery Swamp in 1994. Since that time numerous, isolated populations have been found and treated throughout all units of CREW. The majority of the fern infestations are 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 Old World climbing fern have been located in Bird Rookery Swamp. One is on the eastern boundary of the unit, which is shared with private property to the east. This infestation is in excess of 100 acres in size. At the center of the infestation the fern climbs 40-50 ft. into the canopy. The other area of Old World climbing fern concentration is located in the north-central portion of the unit, which is shared with the Audubon Corkscrew Sanctuary. Here, the fern is found in dozens of isolated patches less than one acre in size. The core of these infestations occurs in swamp areas accessible only

by foot travel. Old World climbing fern spreads out from these central locations with outlying plants found in areas covering several hundred acres.

Management Efforts

Since 1994, numerous, isolated patches of Old World climbing fern have been successfully treated throughout CREW. Treatments were made using low-volume broadcast equipment spraying a 3% to 5% solution of glyphosate and surfactant. On sites where the fern had climbed up trees and out of sprayer range, 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 treatment, three fixed-radius 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 glyphosate 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 and had few leaves present.

The first post-treatment evaluation was made in April 1999. The treated fern was nearly all browned. The cypress and maple canopy trees showed slight damage from the herbicide. Midstory plants and understory plants exhibited significant damage. The July 1999 post-treatment evaluation revealed similar results with the target Old World climbing fern apparently dead. The final evaluation was made on November 18, 1999 and the target was dead. The slightly-damaged cypress and maple trees were recovering, while understory plants continued to exhibit moderate to severe damage.

What was considered successful mortality of Old World climbing fern and, under the circumstances, acceptable non-target damage was overshadowed by the presence of thousands of new plants germinating in the moist moss collar zone of the swamp trees and cypress knees. Even floating logs were covered with new Old World climbing fern plants. This regeneration of the fern clearly came from spore germination. After several months of observation it was discovered that very few of the newly germinated plants survived, possibly attributable to drought conditions at the time.

Growth of new infestations is monitored quarterly, and mop-up operations using ground crews are preformed annually in the winter under drier conditions. Annual monitoring and treatments has reduced Old World climbing fern coverage, but the fern has proven difficult to eradicate. Results to date (Jan 2005) indicate that the fern can be contained with constant and expensive follow-up treatments. Unfortunately, a large population of the fern is present on private lands to the east, which will provide a continual source of spores to Bird Rookery Swamp.

Old World climbing fern Management at Jonathon Dickinson State Park

Phil Myers and Dick Roberts

Introduction

Jonathon Dickinson State Park, consisting of 11,470 acres, is located in Martin and Palm Beach Counties. The Park supports many unique natural features and significant cultural resources. There are 13 distinct natural communities, as defined by the Florida Natural Areas Inventory, in addition to ruderal and developed areas within the Park. In addition, there are 79 (41 plant and 38 animal) FNAI, state, federal listed species documented from the Park. The Park also contains one of the last remaining coastal sand pine scrub communities along the southeast coast, a 2,600-acre wilderness preserve and most of the Loxahatchee National Wild and Scenic River. Many of these unique natural features of the Park are currently threatened by Old World climbing fern.

Background

Of the 159 non-native plants found at Jonathon Dickinson State Park, Old World climbing fern is now the primary exotic plant of concern for the continued management of most natural communities and many designated species within the Park. Some of the earliest efforts to research and develop control methods for this invasive fern were carried out within the Park.

When first observed in the early 1970's, Old World climbing fern's initial establishment was within the ecotone between the pine flatwoods and wetlands within the lower Kitching Creek basin. At the time of the Park's 1993 exotic pest plant survey, the fern was present within 1,233 acres of the Park. The fern is now found in floodplains, strand swamps, cypress domes, wet prairies, wet flatwoods, hydric hammocks, depression marshes, ditches and even scrub.

In particular, the fern's aggressive behavior has allowed it to spread and cover acres of floodplains, strand swamps and cypress domes, posing a long-term threat to these natural communities. Forming a thick mat over vegetation, its dense cover can eliminate understory plants.

The rapid growth and climbing habit of Old World climbing fern has also caused problems for both wildfires and prescribed burns. Except during times of long-term drought, these communities have usually provided a natural barrier to fire with little permanent damage. The fern's growth into the tree canopy provides an unnatural avenue for fire to spread into the tops of vegetation, especially cypress trees, which can then produce fire brands 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, especially bald cypress.

For example, this fern's growth habit caused fire to exceed containment areas and produced tree mortality in May 1986. Infestations of this plant also caused a prescribed fire to escape the Park boundary in March 1991. Even with higher humidity and dew points of night burning, cypress tree mortality occurs (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 1980's as we no longer could utilize wetlands to stop or control the spread of wildfires or prescribed burns.

Management Efforts

A. *Past projects*. Past research efforts demonstrated that fire by itself cannot control the spread of Old World climbing fern (citation?). Other work showed that a 3% glyphosate solution was the most effective herbicide mix and that biomass removal was very effective, but cost prohibitive. Further treatments on the Loxahatchee River used high pressure sprayers and extension wands without cutting the vine. This method was effective in initial control but once contractor work was completed, re-treatment became difficult for Park staff lacking the application equipment.

B. *Current methods*. Currently Old World climbing fern is being treated by cutting the vine out of reach by sprayers (using machetes) and treating the remainder with a 3% solution of glyphosate with surfactant. Contractors working the Park have recently added a small amount of metsulfuron methyl to their spray mix (1oz./100 gal.) and reduced the amount of glyphosate to a 2% solution. Spray indicator dye is used to mark sprayed areas. No matter what the treatment, it has proven necessary to re-treat all areas multiple times.

C. *Contractor resources.* The Bureau of Invasive Plant Management awarded several grants for treatment of Old World climbing fern in the Park. Work was conducted in

the past year by Aquatic Vegetation Control (AVC) on approximately 300 acres in the Loxahatchee River and Kitching Creek areas. Excellent control was established with initial treatment. Re-treatment has proven necessary and is planned for 2004-2005. The Bureau of Invasive Plant management grants have proven critical in starting to control Old World climbing fern in the Park

D. Park staff work. Park staff has been treating Old World climbing fern for years but lack sufficient resources to maintain control. Treatment involved cutting and spraying the vine as described above. Park workers have used a small chainsaw to cut thick infestations of the fern.

E. Spraying has also followed prescribed fire with mixed results. Areas of heavy infestation that were burned to the ground have proven difficult to treat. Re-growth of different amounts post-fire were sprayed using standard herbicide mix. Re-growth died but the fern continued to send up new shoots. The small amount of leaf area compared to the large amount of fern rachis in the ground probably didn't allow enough herbicide to get into the plant. Re-growth of Old World climbing fern following fire probably depends on the amount of the original infestation. Past light infestation could be sprayed after 6-12 inches of re-growth. Heavy infestations should be allowed to grow 12 – 36 inches but be sprayed before the fern need cut again. Treatment after fire has proven a good method for treating the fern in saw palmetto clumps, by increasing ease of access.

Old World climbing fern seems to replace itself in about 17 months following fire and the vine starts to climb between three – six months, necessitating cutting the vine.

Spraying following cutting has proven to work best in thickly infested areas (when cutting large amounts of vine off trees) after some new growth is formed (15-45 days depending on season and amount of rain). One precaution though is that vines can start climbing only three – four months after being cut so failure to spray a site after cutting can quickly become wasted effort. Areas where small amounts of cutting were needed can be treated immediately after cutting.

Old World climbing fern in Blue Cypress Conservation Area (St. Johns River Water Management District)

Ken Snyder and Jeff Hutchinson

Introduction

Blue Cypress Conservation Area (BCCA) encompasses 54,458 acres in Indian River County. Along with Fort Drum Marsh Conservation Area (20,862 acres) directly to the south and Three Forks Marsh Conservation Area (52,000 acres) to the north, these conservation lands form the headwaters of the St. Johns River. Primary habitats within BCCA include freshwater lakes, freshwater marsh, cypress strand, and maple swamp. The entire area is important breeding and foraging habitat for the federally endangered snail kite and several other state or federally listed species of birds. Marsh habitat dominates the site and prominent plant species include sawgrass, maidencane, buttonbush, and willow. Cypress strands are scattered throughout the area and are dominated by bald cypress along with other trees such as red maple, red bay, wax myrtle, and sable palm. Maple swamps also occur throughout the area and are dominated by red maple and red bay, with occasional dahoon hollies, wax myrtle, and buttonbush.

Background

Isolated populations of Old World climbing fern were first known from the southern portion of BCCA in cypress and maple swamps in 2001-02, primarily as isolated patches <1-2 acres in size. These sections of BCCA are relatively undisturbed and are representative of the native plant community types found in this area. In 2003, aerial flights revealed that large areas of the southern end of BCCA were infested to some degree, with most infestations occurring in cypress and maple swamps and willow thickets.

The 2003 reconnaissance flights revealed Old World climbing fern occurred over 1,800 acres in BCCA. The rapid invasion appeared to have taken place within 1-3 years, and the fern was found climbing into the cypress and maple canopies to heights >30 ft. Complete ground and canopy coverage was also observed on several maple swamp islands surrounded by marsh habitat. Old World climbing fern was also observed growing in sawgrass, willow, buttonbush habitat, but infestations were not as severe as in cypress and maple swamps, which are slightly higher in elevation.

Infestations of Old World climbing fern at the southern end of BCCA are only accessible by airboat, making monitoring difficult. Water level fluctuations further limit airboat access to the wetter months (August-February). Due to limited access and scale of coverage, ground treatments are too expensive if not impossible. Aerial herbicide application remains the treatment method of choice in this instance.

Management Efforts

Once the large area of Old World climbing fern infestation at BCCA was discovered, appropriate measures were taken to control the fern. Aerial application of Escort XP (2 ounces product/acre) was conducted in January 2004 treating all observable infestations. Cypress and maple trees were dormant with few leaves present during herbicide application.

Site evaluations were made in January and February 2005. The majority (>99%) of Old World climbing fern in the canopy of trees was dead, but re-growth was common throughout the treatment area. Airboats surveys found isolated populations in marsh areas along airboat trails approximately 1-2 miles east of the main infestations. Minimal damage was observed to most non-target vegetation, except native ferns such as royal (*Osmunda regalis*) and swamp fern (*Blechnum serrulatum)*, which suffered high damage. However, most damaged native ferns appeared to be re-sprouting. Though the results of aerial spraying with Escort XP cannot be considered a complete success, minimal non-target damage was observed and significant reductions of Old World climbing fern resulted. Re-growth is occurring and subsequent re-treatments were conducted in January 2005. Evaluations of treated areas in BCCA will continue on six-month intervals. Prior to the January 2005 treatment, an additional infestation of Old World climbing fern was discovered to the south in Fort Drum Marsh Conservation Area. This new infestation underscored the need for additional funding for expanded monitoring and treatments.

A total of 2350 acres were treated in 2005. Initial evaluations indicate that Old World climbing fern cannot be controlled with a single aerial application of Escort XP, but significant reductions in coverage can be achieved. Additional evaluations should reveal if aerial treatments with Escort XP can be an effective treatment for long term control with limited long-term damage to non-target vegetation.

Lygodium spp. Along Florida's Turnpike

Lauren Linares

Introduction

Florida's Turnpike and Homestead Extension are limited-access toll highways that pass through 11 counties, extending from Florida City at the northern tip of the Florida Keys to a junction with Interstate 75 in north-central Florida near Orlando. Along their more than 300-mile combined path, the roadways intersect a number of ecosystems – including imperiled pine rockland and scrub – as well as densely urban, agricultural, and disturbed areas. Federal- and state-listed plant and animal species have been documented on Turnpike rights-of-way, and there have been projects to restore and maintain environmentally sensitive areas. The Florida Turnpike Enterprise's Roadway Maintenance Environmental Program has made the eradication of invasive plant species an important component of the program whenever possible.

Background

In recent years, the Turnpike Enterprise has increasingly recognized the need to remove nuisance plants, especially if they are safety hazards. For example, the threat to transportation posed by Australian pines (*Casuarina* spp.) became clear after Hurricane Andrew. The Turnpike spent $2 million to remove tall trees along the highway and at interchanges in Broward and Palm Beach counties (amid much public protest), and replaced the trees with native landscaping. Turnpike Enterprise staff became aware of potential Old World climbing fern infestations along the roadway in 2001. By summer of that year, efforts were under way to assess the problem and to develop a management plan.

Management Efforts

The Turnpike Enterprise conducted its first Old World climbing fern inventory in Palm Beach, Martin, St. Lucie, and Indian River counties (Mileposts 109 to 156) in 2001. Staff coordinated with the FDEP to use its existing Old World climbing fern contractors and produced a scope of services specifically for Turnpike work; the scope included a stipulation that if a 95 percent kill was not achieved within two months of treatment, an additional Old World climbing fern treatment was required at no additional cost to the Turnpike Enterprise.

The first round of eradication began in early 2002. Working along the roadway presented unique challenges in terms of adhering to proper MOT (maintenance-of-traffic) and safety. Contract work crews often used a small boat to cross wet ditches and access heavily vegetated banks. Cooperation with adjacent landowners was sometimes an operational constraint. One landowner whose property was infested with Old World climbing fern was contacted, but refused to cooperate with the removal effort. By mid 2004, the initial Turnpike project was completed at a cost of $500,000, including treatment of an Old World climbing fern infestation at the Broward/Miami-Dade County line. Roadway Maintenance staff learned why removal of the fern was important, and how to recognize and identify the plant.

Despite best efforts, a second roadway inventory indicated that Old World climbing fern has extended its range. It is now found between Milepost 100 and 200, with sporadic occurrences farther north and south. Both species of *Lygodium* exist in some locations, and the vine is particularly prevalent at bridges passing over streams.

The Turnpike has budgeted $300,000 yearly for the next several years to continue its *Lygodium* management. Its goals are:

- Reduce further spread of the vine
- Incorporate control measures into contract specifications as research results become available
- Obtain cooperation from adjacent property owners, including local, county, and state agencies
- Continue to educate public as well as staff about invasive plants

XII. SUMMARY

Old World climbing fern (*Lygodium microphyllum*) is a recent invader to Florida's natural areas, first being documented in 1958 herbarium records. Two years later it was documented invading natural areas. Thus, in a period of less than 50 years, this fern has invaded an estimated 250,000 acres in Florida, many of these areas being acquired and managed for conservation purposes. The exact time of its introduction is unknown, but it is likely that the fern existed in south Florida prior to 1958. At some point between the late 1980's and 1990's Old World climbing fern began an exponential increase in distribution in Martin and Palm Beach Counties. By 2004, the fern had invaded most counties in south Florida and expanded in central Florida as far north as Orlando.

Due to the increased threat of this invasive fern, the FLEPPC and the *SFWMD* jointly convened a task force in 1999 comprised of local, state, and federal land managers, scientists, and others to develop a control plan. The result was the first edition of Lygodium Management Plan for Florida published in 2001. The plan has served to guide agencies in managing and seeking to protect natural areas from Old World climbing fern. The first edition focused on the both species of *Lygodium* present in Florida, but the second edition focuses on Old World climbing fern due to it severe threat in south and central Florida.

Since the first edition of the plan, several significant events have occurred to halt the invasion of Old World climbing fern in Florida. The first was the construction of Biocontrol Quarantine facility in Ft. Lauderdale to test potential biocontrol agents on Old World climbing fern. In 2005, the first biocontrol agent was released in Florida and several more introductions are planned in the future. Second, funding has increased for management and research. The FDEP Bureau of Upland Plants spent approximately 6.5 million dollars over a five year period from 1998-2003 to treat *Lygodium* on public lands throughout the state. In addition, the bureau recently initiated a Lygodium Quick Strike Program that funds contractors to treat areas on public lands infested with ten acres or less of either species of *Lygodium* and is available immediately for use on any public lands.

An increase in funding in research from various agencies such as the *SFWMD* and FDEP has also lead to an understanding of the reproduction biology and invasive potential of the fern in Florida. In Florida, Old World climbing fern is capable of intragametophytic selfing indicating that one wind-blown spore can form a new population a considerable distance

from the founding population. Research and natural history observations indicate that the fern exhibits different life history patterns (e.g., indeterminant growth, high invasiveness) as well as similarities (e.g., fire adaptive) in Florida compared to it native habitat in southeast Asia, Australia, and Africa.

Third, an additional herbicide, metsulfuron methyl, was approved for treatment of Old World climbing fern over water. Preliminary results using metsulfuron methyl have been promising in that much less damage to non-target damage is observed. If the fern develops resistance to an herbicide, it is important that alternative herbicides are available for treatment. Additional herbicides with aquatic labels are needed in the fight to control Old World climbing fern. Fourth, educational efforts on the invasive potential of the fern have improved to the point that most personnel working in natural areas of Florida know the potential impacts of the fern and aggressively treat the fern. Publications are available from County Extension agents and websites such as FLEPPC's have information available, but more work is needed to inform the private landowner. Finally, the initiative developed by The Nature Conservancy to limit the spread Old World climbing fern north and Japanese climbing fern south, creating partnerships with private landowners, and seeking additional funding for control and technical assistance on private lands is another step in the battle.

Control of another highly invasive plant, melaleuca (*Melaleuca quinquenervia*), was successful on public lands through multiple facets that include herbicide research, introduction of biocontrols, and an education campaign. Now efforts are underway to inform homeowners and manage melaleuca on large areas of private lands (TAME website). Control of Old World climbing fern is still evolving with herbicides that limit damage to non-target plants and the introduction of biocontrols. Eventually, successful management of the fern will be achieved through an integrated resource management approach of biocontrols, herbicide treatments, and education. In the interim, initial steps have been taken at the local level by several counties which have enacted ordinances prohibiting *Lygodium*. In 2005, ten counties in south and central Florida had ordinances prohibiting Old World climbing fern, while four counties to the north had ordinances prohibiting Japanese climbing fern. Regardless, if control is achieved in natural areas and conservation lands, it is equally important to control it on private lands, nearby or distantly located, since the fern exhibits long-range dispersal.

XIII. LITERATURE CITED

Alfieri, S.A. Jr., K.R. Langdon, C. Wehlburg and J.W. Kimbrough, 1994. Index of Plant Diseases in Florida. Florida Dept. of Agric. and Consumer Services, Div. Of Plant Industry Bull. 11.

Alston, A.H. and R.E. Holltum,1959. Notes on taxonomy and nomenclature in the genus *Lygodium* (Schizaeaceae). Reinwardtia 5:11-22.

Alston, A.H., 1959. The ferns and fern allies of west tropical Africa. Crown Agents for Oversea Governments and Administrations, London.

Balik, M.J., D.G. Furth and G. Cooper-Driver. 1978. Biochemical and evolutionary aspects of arthropod predation on ferns. Oecologia 35:55-89.

Beckner, J. 1968. Lygodium microphyllum, another fern escaped in Florida. American Fern Journal 58: 93.

Biehl, T. 2004. Lygodium infestations in the Lake Wales Ridge. Wildland Weeds 7: 4-5.

Bierhorst, D. W. 1971. Morphology of vascular plants. Macmillian Co., N.Y.

Brandt, L. A. 2004. Effectiveness of different aerial spray for control of Lygodium microphyllum on tree islands in the A. R. M. Loxahatchee NWR – 24 month monitoring period. Unpublished report, USFWS, A.R.M. Loxahatchee NWR, Boynton Beach, FL. 23 pp.

Brandt, L. A., and D. W. Black. 2001. Impacts of the introduced fern, Lygodium microphyllum, on the native vegetation of tree islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge. Florida Sci. 64: 191-196.

Brumback, W.E., 1985. Raising the climbing fern from spores. Arnoldia 45:1,27-29.

Buckingham, G.R., J. Goolsby and R.W. Pemberton. 2003. Proposed field release of the Australian "*Cataclysta*" *camptozonale* (Hampson) (Lepidoptera: Crambidae), a defoliator of the Australian Old World climbing fern, *Lygodium microphyllum* (Cav.) R. Br. (Lygodiaceae) in Florida. On file at the U.S. Department of Agriculture, Agricultural Research Service Biological Control Documentation Center, National Agricultural Library, Beltsville, Maryland, USA. (Petition to release a biological control agent).

Call, E. 2004. *Personal communications.* South Florida Water Management District, West Palm Beach, Florida.

Copeland, E.B., 1958. Fern flora of the Philippines, volume 1. Institute of
Science and Technology Bureau of Printing. Manila.

Dennill, G.B. and D.Donnelly. 1991. Biological control of *Acacia longifolia* and related weed species (Fabaceae) in South Africa. Agric. Ecosys. Environ. 37: 115-136.

Edie, H.H. 1978. Ferns of Hong Kong. Hong Kong University Press, Hong Kong.

EthnobotDB website, 1999. http://probe.nal.usda.gov:8300cgi-bin/w…classs=Taxon&object=*Lygodium*.

Ferriter, A. (ed.). 2001. Lygodium Management Plan for Florida (1st Edition). Florida Exotic Pest Plant Council. 50 pp.

Ferriter, A. and T. Pernas. 2006. An Explosion in Slow Motion: Tracking the spread of *Lygodium microphyllum* in Florida. Wildland Weeds. Spring 2006, Vol. 9.

Gann, G.D., K.A. Bradley, and S.W. Woodmansee. 1999. Initial report: long-term monitoring of Old World climbing fern (*Lygodium microphyllum* (Cav.) R. Br.) in southeastern Florida. Unpublished report submitted to the South Florida Water Management District by The Institute for Regional Conservation, Miami, Forida.

Gerson, U. 1979. The association between Pteridophytes and arthropods. Fern Gaz. 12:29-45.

Goolsby, J.A. 2004. Potential Distributionof the Invasive Old World climbing fern, *Lygodium microphyllum* in North and South America. Nat. Areas J.24: 351-353.

Goolsby, J.A. and R.W. Pemberton. 2004. Proposed field release of the Australian *Floracarus perrepae* Knihinicki & Boczek (Acariformes: Eriophyidae), a leaf roll galler of the Old World climbing fern, *Lygodium microphyllum* (Cav.) R. Br. (Pteridophyta: Lygodiaceae) in Florida. On file at the U.S. Department of Agriculture, Agricultural Research Service Biological Control Documentation Center, National Agricultural Library, Beltsville, Maryland, USA. (Petition to release a biological control agent).

Goolsby, J. A., A. D. Wright, and R. W. Pemberton. 2003. Exploratory surveys in Australia and Asia for natural enemies of Old World climbing fern, *Lygodium microphyllum*: Lygodiaceae. Biological Control 28: 33-46.

Goolsby, J. A., R. Zonneveld, and A. Bourne. 2004. Prerelease assessment of impact on biomass production of an invasive weed, *Lygodium micrphyllum* (Lygodiaceae: Pteridophyta), by a potential biological control agent, Floracarus perrepae (Acariformes: Eriophyidae). Environ. Entomol. 33:997-1102.

Goolsby, J.A., R. Zonneveld, J.R. Makinson and R. W. Pemberton. *In press*. Host-range and cold temperature tolerance of *Floracarus perrepae* (Acariformes: Eriophyidae) a potential biological control agent of *Lygodium microphyllum* (Pteridophyta: Lygodiaceae). Australian J. Entomology (Nov. 2004).

Gordon, D. R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: lessons from Florida. Ecological Applications 8: 975-989.

Hasebe, M., P.G. Wolf, K.M. Pryer, K, Ueda, M. Ito, R. Sano, G.J. Gastony, J. Yokoyama, J.R. Manhart, N. Murakami, E.H. Crane, C.H. Huafler, and W.D. Hauk, 1995. Fern phylogeny based on *rbc*L nucleotide sequences. Amer. Fern. J. 85:134-181.

Hill, M. P. 1998. Herbivore insect fauna associated with *Azolla* species (Pteridophyta: Azollaceae) in Southern Africa. Afr. Entomol. 6: 370-372.

Holttum, R.E., 1968. Flora of Malaya, Volume 2 (Ferns of Malaya). Government Printing Office, Singapore.

Holttum, R.E., 1973. Posing the problems. Pp. 1-10 in A.C. Jerney, J.A. Crabbe and Thomas, eds. The phylogeny and classification of the ferns. Bot. J. Linn. Soc. 67 (suppl.1):I-xiv, 1-284.

Hooper, E.A. and A.H. Haufler, 1997. Genetic diversity and breeding system in a group of neotropical epiphytic ferns (Pleopeltis; Polypodiaceae). Amer. J. of Bot, 84(12):1664-1674.

Huffaker, C.B. 1964. Fundamentals of biological control of weeds. Pp. 631-649 *in* P. Debach, ed. Biological control of insect pests and weeds. Chapman and Hall Ltd., London.

Hutchinson, J. and K. Langeland. 2006. Potential Spread of *Lygodium microphyllum* Spores by Herbicide Applicators. Wildland Weeds. Spring 2006, Vol. 9.

Hutchinson, J., K. Langeland, and A. Ferriter. 2004. Notes from the Lygodium Research Review Meeting. Wildland Weeds 7: 6-8.

Jones, D.L., 1987. Encyclopaedia of ferns. Timber Press, Portland, Oregon, USA.

Julien, M.H. 1992. *Biological control of weeds, a world catalogue of agents and their target weeds*. ed. 3. Commonwealth Agricultural Bureau, Wallingford Oxon, UK

Kirk, A.A. 1977**.** The insect fauna of the weed *Pteridium aquilinum* (L.)(Polypodiaceae) in Papua New Guniea: a potential source of biological control agents. J. Aust. Entomol. Soc. 16:403-407.

Kolar, C.S. & Lodge, D.L. 2001. Progress in invasion biology: predicting invaders. Trends in Ecology and Evolution 16: 199–204.

Lakela, O. and R.W. Long, 1977. Ferns of Florida, ed 2. Banyan Books, Miami, FL.

Langeland, K.A. and K.C. Burks 1998. Identification and Biology of Non-Native Plants in Florida's Natural Areas. University of Florida. 164 pp.

Langeland, K. A., and M. Link. *In press*. Evaluation of metsulfuron methyl for selective control of Lygodium microphyllum in association with Panicum hemitomon and Cladium jamaciensis. Florida Scientist.

Lockhart, C. 2006. More on the Double-Trouble Ferns: Status Surveys of Lygodium Treatment Sites. Wildland Weeds Spring 2006, Vol. 9.

Lott, M. S., J. C. Volin, R. W. Pemberton, and D. F. Austin. 2003. The reproductive biology of the invasive ferns *Lygodium microphyllum* and *L. japonicum* (Schizaeaceae): implications for invasive potential. American Journal of Botany 90: 1144-1152.

Louda, S.M., D. Kendall, J. Conner, and D. Simberloff. 1997. Ecological effects of an insect introduced for the biological control of weeds. Science 277:1088-1090.

Louda, S.M., R.W. Pemberton, T. Johnson and P.A. Follet. 2003. Non-target effects- the achilles' heel of biological control? (Retrospective analyses to reduce risk associated with biocontrol introductions) Annual Review of Entomology. 48: 365-395.

Mabberley, 1997. The plant book, ed. 2. Cambridge Univ. Press, Cambridge.

Myers, P. 2004. *Personal communications*. Florida Park Service, District 5 Administration, Hobe Sound, Florida

Myers, R. *L* and J. J. Ewel (eds.). 1990. Ecosystems of Florida. University of Central Florida Press, Orlando. 765 pp.

Nauman, C.E. 1993. *Lygodium* C. Presl. *In*, Flora of North America Editorial Committee, Eds., Flora of North America: Volume 2, Pteridophytes and Gymnosperms. Oxford University Press, New York.

Nauman, C.E. and D.F.Austin, 1978. Spread of the exotic fern *Lygodium microphyllum* in Florida. Amer. Fern J. 68:3, 65-6.

Nelson, G. 2000. The Ferns of Florida. Pineapple Press. Sarasota, FL.

Office of Technology Assessment, Congress of the United States. 1995. *Biologically based technologies for pest control*. OTA-ENV-636, US Government Printing Office, Washington, DC.

Ozaman, S.K. and J.A. Goolsby. 2005. Biology and phenology of the eriophyid mite, *Floracarus perrepae*, on its native host in Australia, Old World climbing fern, *Lygodium microphyllum*. Experimental and Applied Acarology 35: 197–213

Pemberton, R.W. 1985a. Native plant considerations in the biological control of leafy spurge. Pp. 365-390 *in* E.S. Delfosse, ed. Proc. 5th Int. Symp. Biol. Contr. Weeds, Aug. 1984, Vancouver, Canada.

Pemberton, R.W. 1985b. Native weeds as candidates for biological control research. Pp. 869-877 *in* E.S. Delfosse, ed. Proc. 5th Int. Symp. Biol. Contr. Weeds, Aug. 1984, Vancouver, Canada.

Pemberton, R.W. 2002. Future and appropriate targets for biological control of weeds in the eastern United States. pp. 375-386. IN: R. Van Driesche, B. Blossey and M. Hoddle, S. Lyon and R. Reardon (eds.) Biological control of invasive plants in the eastern United States. US Forest Service Forest Health Technology Enterprise Team-2002-04, Morgantown, West Virginia.

Pemberton, R. W. 2003. Northward range extension in Florida of the invasive fern Lygodium microphyllum (Lygodiaceae). Sida 20: 1759-1761.

Pemberton, R.W. and C.E. Turner. 1990. Biological control of Senecio jacobaea in northern California, and enduring success. Entomophaga 35: 71-77.

Pemberton, R.W., and A.P. Ferriter. 1998. Old World climbing fern (*Lygodium microphyllum*), a dangerous invasive weed in Florida. Amer. Fern Journal 88(4): 165-175.

Pemberton, R.W. and J.A. Goolsby. 2005. Proposed field release of *Neomusotima conspurcatalis* (Warren) (Lepidoptera: Crambidae), a defoliator of the Australian Old World climbing fern, *Lygodium microphyllum* (Cav.) R. Br. (Lygodiaceae) in Florida. (Petition to release a biological control agent to be submitted in 2005).

Pemberton, R.W., J. Goolsby, and T. Wright. 2002. Old World climbing fern (*Lygodium microphyllum* (Cav.) R.Br.) pp.139-147. IN: R. Van Driesche, B. Blossey and M. Hoddle, S. Lyon and R. Reardon (eds.) Biological control of invasive plants in the eastern United States. US Forest Service Forest Health Technology Enterprise Team-2002-04, Morgantown, West Virginia.

People and Plants Online. 1999 griffin.rbgkew.org.uk/peopleplants/handbook/ethno.html

Prantl, K., 1881. Die Schizeaaceen, Pp. 7-85, Morphology der gefasskryptogamen volume 2. Verlag Von Wilhelm Engelmann, Leipzig.

Proctor, G.R. 1993. Ferns of Puerto Rico and the Virgin Islands. The New York Botanical Garden. Bronx, New York.

Rayamajhi, M.B., R.W. Pemberton, and T.K. Van. 2005. First report of the pathogenicity of *Puccinia lygodii*, a potential biocontrol agent of *Lygodium microphyllum* in Florida. Plant Disease.

Roberts, D. 1996. Climbing fern wreaks wetland havoc. Fla. Department of Environmental Protection Resource Management Notes 8(1): 13.

Roberts, D. 2004. *Personal communications*. Florida Park Service Jonathan Dickinson State Park, District 5, Hobe Sound, Florida.

Roberts, D. 1997.Old World climbing fern research and mitigation at Jonathan Dickinson State Park. Florida Department of Environmental Protection Resource Management Notes 9(2): 30-32.

Roberts, D. and D. Richardson. 1994. Exotic climbing fern. Resource Management Notes 6(4):16.

Roberts, D. and A. Cox. 2000. Sand pine scrub vegetation response to two burning and two non-burning treatments. Pages 114-124 *in* W. Keith Moser and Cynthia F. Moser (eds.). Fire and Forest Ecology: Innovative Silviculture and Vegetative Management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

Rodgers, L. 2006. *Personal communications*. South Florida Water Management District, West Palm Beach, Florida.

Room P.M., K.L. Harley, I.W. Forno, and D.P. Sands. 1981. Successful control of the floating weed salvinia. Nature 294:78-80.

Rouget, M. & Richardson, D.M. 2003. Inferring process frompattern in alien plant invasions: a semimechanistic model incorporating propagule pressure and environmental factors. American Naturalist 16: 713–724.

Serizawa, Shunsuke. 1975. Pteridophytes of the Ryukyu Islands (1). Science Report of the Takao Museum of Natural History No. 7.

Simberloff, D., D. C. Schmitz, and T. C. Brown (eds.). 1997. Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida. Island Press, Washington, D. C.

Singh, S. and G. Panigrahi. 1984. Systematics of the genus *Lygodium* Sw. (Lygodiaceae) in India. Proc. Indian Acad. Sci. (Plant Sci.) 93(2): 119-133.

Smith, A.R., 1995. Non molecular phylogenetic hypothesis for ferns. Amer. Fern J. 85:104-122.

So, M.L., 1994a. Common ferns of the Philippines. Colleges of Arts and Sciences, Trinity College, Quezon City, Philippines.

So, M.L., 1994b. Hong Kong ferns. Urban Council, Hong Kong.

Solis, M. A., S. H. Yen, and J. A. Goolsby. 2004. Species of *Lygomusotima* new genus and *Neomusotima* Yoshiyasu (Lepidoptera: Crambidae) from Australia and Southeast Asia feeding on *Lygodium microphyllum* (Schizaeaceae). Annals of the Entomological Society of America 97: 64-76.

Solis, M.A., S-H.Yen, J.A. Goolsby, J.A. Goolsby, T. Wright and R.W. Pemberton. A new stem-boring musotimine species (Lepidoptera: Crambidae) from Thailand Feeding on Lygodium microphyllum (Schizaeaceae) (unpublished manuscript).

Soltis, D. and P. Soltis, 1992. The distribution of selfing rates in homosporous ferns. Amer. J. of Bot. 79(1):97-100.

Soltis, P., D. Soltis, and K. Holsinger,1988. Estimates of intragametophytic selfing and interpopulational gene flow in homosporous ferns. Amer. J. of Bot. 79(1):97-100.

Southwestern (U.S.) Fern Society website, 1998. URL: http://www.star-telegram.com/np/swfern/frnlsn01.html

Stocker, R.K., A. Ferriter, D. Thayer, M. Rock and S. Smith. 1997. *L microphyllum* hitting south Florida below the belt. Wildland Weeds. Winter 1997. pp. 6-10.

Strong, D.R and R.W. Pemberton. 2000. Biological control of invading species: risk and reform. Science 288: 1969-1970.

Strong, D.J., J.H. Lawton, and R. Southwood. Insects on plants. Harvard University Press, Cambridge.

Taylor, J. (2006). Dealing with Remote Infestations: A Case Study at Everglades National Park. Wildland Weeds. Spring 2006, Vol. 9.

Thomas, B., Jr., and L. A. Brandt. 2003. Monitoring ground treatments of Old World climbing fern (*Lygodium microphyllum*) on the Arthur R. Marshall Loxahatchee NWR. Wildland Weeds (Summer 2003): 9-11.

Tranel, P. J., and T. R. Wright. 2002. Resistance of weeds to ALS-inhibiting herbicides: what have we learned? Weed Science 50: 700-712.

Tryon, S. 1999. *Personal communications*. University of South Florida, Tampa, Florida.

Volin, J. C., M. S. Lott, J. D. Muss, and D. Owen. 2004. Predicting rapid invasion of the Florida Everglades by Old World climbing fern (*Lygodium microphyllum*). Diversity and Distributions 10: 439-446.

Wagner, W. H., Jr., and A. R. Smith. 1993. Pteridophytes. Pp. 263-264 *in* Flora of North America Editorial Committee, eds. Flora of North America north of Mexico, Vol. 1. Oxford University Press, N. Y.

Wright, T. 1999. *Personal communications*. Commonwealth Scientific and Industrial Research Organization, Australia.

WSSA. 1994. Herbicide Handbook, 8th Ed. Weed Science Society of America, Lawrence, KS. 493 pp.

Wunderlin, R. P. 1998. Guide to the Vascular Plants of Florida. University Press of Florida, Gainesville.

Wunderlin, R. P., and B. F. Hansen. 2000. Flora of Florida Volume I: Pteridophytes and Gymnosperms. University Press of Florida. Gainesville, FL.

Yen, S. H., M. A. Solis, and J. A. Goolsby. 2004. *Austromusotima*, a new Musotimine genus (Lepidoptera: Crambidae) feeding on Old World climbing fern, *Lygodium microphyllum* (Schizaeaceae). Annals of the Entomological Society of America 97: 397-410.

Zeller, M., and D. Leslie. 2004. Japanese climbing fern control trials in planted pine. Wildland Weeds 7: 6-9.

Appendix 1. Prioritized research needs and recommendations from land managers, researchers, and program directors from the 2004 Lygodium Research Review Meeting in West Palm Beach.

Land Managers

1. Determine the optimal timing to chemically treat Old World climbing fern infested areas.
    a) What time of year should chemical treatment occur?
    b) What types of control methods should be employed in both initial treatments and post treatments to effectively control Old World climbing fern? Should chemical treatment be used initially, followed by fire or vice versa?
    c) How often and when should the treated areas be revisited?
    d) What time of year is best suited for the various treatment methods?
2) What are the effects of fire as a method of treatment?
    a) How does fire effect the below ground biomass of Old World climbing fern? Does it quickly re-sprout or does it die off?
    b) How are Old World climbing fern spores affected when fire is used as a treatment method? Does it act as a mechanism to spread the spores further or does it kill the active spores?
    c) Fire is often used as a method to clear out native plant communities of potential fuel sources. How does this management practice influence the spread of Old World climbing fern? Does the opening up of the forest floor make conditions prime for Old World climbing fern to become established?
3) Development of more efficient and less destructive herbicides.
    a) More effective and efficient herbicide mixtures need to be developed.
    b) Will Old World climbing fern develop resistance to herbicides following repeated application?
    c) What are the effects of the various mixtures of herbicides on the native plant communities?
    d) How does the application of herbicides affect the various life cycle stages of Old World climbing fern? Does it kill the spores along with the rest of plant? Does it translocate through the fern and kill the below ground biomass?
4) The detection and subsequent treatment of Old World climbing fern in its early stages is extremely important in obtaining “Maintenance Control”.
    a) What are the best methods for detecting Old World climbing fern in the early stages of infestation?

b) What is the most cost effective and efficient early detection method?

5) Decontamination
   a) What are the best methods to decontaminate field crews and equipment to prevent the further spread of Old World climbing fern to areas not currently infested?
   b) When should decontamination efforts be employed?

Researchers

1) Experiments in limiting factors on Old World climbing fern growth
   a) Microbial communities/soil communities as biocontrols (greenhouse studies outside of the USA first).
   b) Biocontrols (time of release of insects, number of populations required, etc.).
   c) Comparative studies on controlling factors in Old World climbing fern growth (hydrology, nutrients loads {P or N limited}, physiology, etc.).
2) Herbicide efficacy trials
   a) Review other potential herbicides for use in wetlands besides glyphosate and metsulfuron methyl.
   b) Translocation of herbicides. Does it kill the roots/rhizomes? What is the re-growth rate after application?
   c) Timing and season of application (summer vs. winter; wet vs. dry season).
   d) Variation in herbicide mortality on Old World climbing fern and non-target plants by habitat (cypress strands/domes, coastal prairies, bayhead swamps, disturbed sites, etc.).
   e) Combinations of herbicide mixtures for effective treatment.
   f) Herbicide resistance over repeated applications.
3) Synthesis of management projects
   a) Inferences on Old World climbing fern control methods across different habitats and the landscape.
   b) Effects of herbicides on controlling Old World climbing fern and non-target damage.
   c) Development of a uniform monitoring protocol to document success and failures of treatment methods.
   d) Increase the quality of data being produced.
4) Rhizome control agents

a) Are below ground biocontrols important since approximately 50% of the plant consists of roots and rhizomes?
b) Review potential biocontrols (fungal agents, microbes, insects, etc.) that utilize the rhizomes.

5) Development of Early Detection System
   a) Development of detection system to detect small populations since current methods only allow detection of larger populations that form extensive mats or grow into the canopy.
   b) Improvement and refinement of IKONOS to detect small populations.
   c) Standardized field surveys (systematic surveys on foot in high risk habitat).

Program Directors

1) Control Methodologies—effectiveness of control treatment, length of control, best combination of controls, etc.
   a) Chemical
      i) Getting necessary data to support special local needs labeling for certain herbicides – i.e. metsulfuron methyl (obtained a label for aquatic use and found while doing Old World climbing fern treatments, discovered it controlled Brazilian pepper, but metsulfuron methyl is not labeled for Brazilian pepper).
      ii) What is effect of multiple applications? Is there an ideal follow-up schedule that would allow regeneration of natives and still control Old World climbing fern.
      iii) Aerial spot treatment techniques rather than aerial broadcast? What is the cost?
      iv) Quantify treatments rates and herbicide combinations.
      v) What percent glyphosate is most effective? Is it helpful to go over 2%?
      vi) What is the best herbicide to control Old World climbing fern? Is it helpful to combine certain chemicals (glyphosate and metsulfuron methyl) in a tank mix? Would it be better to alternate treatments, i.e. first treatment with glyphosate, second treatment (follow up) with metsulfuron methyl?
      vii) Timing of treatments and re-treatments. Is there a better treatment time to reduce spore production? How much leaf area is needed before re-treatment can be effective?
      viii) Quantify typical duration of control by habitat type and by treatment method (ground versus aerial).
   b) Mechanical/cultural

i) Can the burning of rachis mats be an effective management technique?
ii) What is the best way to dispose of biomass and fertile leaflets?
iii) What are the impacts of burning on Old World climbing fern re-growth and on native plants?
iv) Does dead rachis carry fire into the tree canopy?

c) Integrated Pest Management
i) What combination of biocontrol, chemical, mechanical/cultural is most effective? Is it different by habitat/community type?
ii) Most effective management strategy? Should outliers be treated first or large infestations? Because of the large amount of spores, is it better to reduce the spore load by treating large infestations and then the outliers? This plant is not like melaleuca!
iii) Burning in combination with chemical treatments. Spray – burn – spray combo? Or Burn–spray. Might work in a prairie community of Everglades National Park!
iv) Decontamination techniques for applicators to avoid exacerbating the problem. Is it really a problem? Are the spores already everywhere and the disturbance causes them to grow or are they growing in areas because they were carried there by people on clothes and/or machinery?

d) Biocontrol
i) What is the most efficient way to utilize biological control – develop mass rearing techniques, determine how many insects are needed, how best to attack plant with biocontrols (insects, pathogens)?
ii) What are the effects, if any, of grazing on Old World climbing fern – especially with cattle?

2) Control Methodologies
a) Non-Target: Determine impacts of different control treatments on non-target plants and on different communities (tree islands, cypress, prairie...).
i) What is the non-target damage of metsulfuron methyl? Greenhouse experiments to determine selectivity of metsulfuron methyl. Does it kill off non-targets completely or do they recover quickly enough that it is acceptable?
ii) What are the effects of multiple herbicide applications? Is there an ideal follow-up schedule that would allow regeneration of natives and still manage Old World climbing fern?

3) Socioeconomic

a) What are the impacts to different landowners that will motivate them to control Old World climbing fern? Socioeconomic issues could include effects on property values, ecotourism. What incentives could be provided to private landowners to initiate and maintain control? Include demonstration projects by public agencies to demonstrate control.
b) What are the socioeconomic issues of Old World climbing fern on private land owners? Impact of Old World climbing fern on property values? On ecotourism?
c) Educate public in order to support management efforts – measure public awareness and public involvement.
d) Incentives for landowners – ranchers, single family home-owners. Are ranchers losing money because of loss of hunt leases, reduced cattle grazing, and timber?
e) Survey to determine motivating factors for different landowners to remove Old World climbing fern.
f) Demonstration projects on private properties of Old World climbing fern control (i.e. TAME).

4) Ecology
   a) What are the quantitative data on the ecological impacts of Old World climbing fern – what are its effects on native plant communities; how long are the spores viable; do the spores spread through fire? Also map spread of Old World climbing fern throughout Florida (extend Systematic Reconnaissance Flights).
      i) Extend survey flights to remainder of state.
      ii) What is spore viability over time?
      iii) Are spores spread from prescribed fire?

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Appendix 4. Japanese Climbing Fern (*Lygodium japonicum*)

Prepared by Chris Lockhart, Florida Natural Areas Inventory

This summary includes some general information to assist managers with additional information to distinguish the two species of invasive Lygodium climbing ferns, plus a few excerpts from the first edition of the Lygodium Management Plan (Ferriter 2001).

Lygodium japonicum (Thunb.)Sw., like *L. microphyllum*, is in the family Lygodiaceae, (some authors place this genus in Schizaeaceae). Synonyms include *Ophioglossum japonicum* Thunb. Ex Murray, and *L. dissectum*. Commonly known as Japanese climbing fern, this plant is native to temperate and tropical zones of eastern Asia, East Indies and Australia, where it grows in open forests, forest edges, and secondary forests from low to higher elevation areas (Serizawa 1975, Edie 1978, Singh and Panigrahi 1984).

Botanical Description: Characters similar to *L. microphyllum*: Fern with slender, dark brown rhizomes and fronds to 30 m (90 ft.) long, main rachis wiry and adapted for twining with indeterminate growth. Distinguishing characters: Pinnae fertile or sterile, twice compound, stalked, spreading from the main rachis; pinnae 10 to 20 cm 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. A color photograph and more distinguishing characters can be found in Langeland and Burks (1998).

Reproductive Biology: The reproductive biology is very similar to that of *L. microphyllum*. Both ferns produce hermaphroditic gametophytes which allows for three types of sexual reproduction, including self-fertilization. Florida populations of *L. japonicum* do not appear to utilize the outcrossing strategies observed in *L. microphyllum* (e.g., antheridiogen pheromone, delayed sexual expression of the male gametophyte). As a result, the production of *L. japonicum* sporophytes by means of self-fertilization, the predominant form of its reproduction, tends to occur more rapidly than those of *L. microphyllum*. These reproductive differences diminish by week 16 after germination (Lott 2003).

Founder populations can be very small. Self-fertilization by *Lygodium* species provides for a system of reproduction and establishment of distant populations. Refer to Chapter A.3 for more details on reproductive biology.

Growth and Seasonality: In sub-temperate climates, like northern Florida, *L. japonicum* leaflets turn brown after exposure to hard freezes. Fronds in the understory, particularly those in shady moist habitats, may remain evergreen. Browned wiry fronds or partially browned fronds may persist through the winter months. (Partially browned fronds may also result after herbicide treatments when an incomplete kill is achieved). Where fronds had climbed shrubs or trees, the remaining rachis provides a ladder for new growth when temperatures rise again. In sub-tropical climes, both climbing ferns are evergreen, and may actively grow throughout the year, but faster in warmer months (Ferriter 2001, Lott, personal communication 2005).

A study by Lott and Volin (2001) determined that spore production peaked during the summer and fall seasons at the Hillsborough County and Suwannee River study sites. Fertile leaflets tend to be larger in *L. japonicum* than in *L. microphyllum*. As a result, the number of sori per fertile leaflet and subsequent spore production on them is greater in *L. japonicum*. While leaflet size is attributed to a lower spore count per square centimeter, counts are offset by its larger leaflet size.

Distribution: *Lygodium japonicum* was introduced as an ornamental around 1900. It has been introduced to Puerto Rico, and the southeastern United States, from Texas to North Carolina. The first record of a naturalized population was in Georgia in 1903. Naturalized populations were described as “rare” in 1964 by Radford et al., in Georgia, Florida, and Alabama. Puerto Rico, Hawaii, plus nine southeastern states now have naturalized populations in the United States. (Ferriter 2001, USDA Plants 2005). Once considered a “northern Florida” problem, L. japonicum has joined L. microphyllum in central Florida, and has recently been documented in Palm Beach and Collier counties in southern Florida (FNAI 2005). Currently, occurrences are documented for more than 40 of Florida’s 67 counties (Plantatlas 2005).

In Florida, *L. japonicum* can be found in sunny or shady, usually damp areas along the banks of ditches and other water bodies, on seepage slopes and slopes of phosphate

mines, in mixed upland forests, short hydroperiod wetlands and swamps, pinelands and pine plantations (Langeland and Burks 1998; Lockhart, FNAI, *pers. observations*). Both climbing ferns can occupy the mesic ecotonal areas. *L. microphyllum* tends to be more common in wetter habitats, including cypress swamps. *L. japonicum* appears to do better in mixed forest and pine flatwood communities (Lott, personal communication, 2005). L. japonicum commonly forms patches of dense mats in the understory, and sends a few climbing strands into the canopy. Unlike *L. microphyllum*, it does not seem to form "the dense arboreal blankets in tree canopies seen with Old World climbing fern …, possibly due in-part to freeze damage to populations above the Florida frost line" (Zeller and Leslie 2004).

Economic Impacts: A major concern regarding the impact of *L. japonicum* is its risk to northern slash pine plantations. This fern is now considered a contaminant in pine straw bales, typically collected from these plantations. A system of burning, accumulation, monitoring, and treatment with herbicide is necessary prior to harvesting to prevent this contamination (J. Valenta, *pers. communication* 2005). Contaminated pine straw bales are still sometimes found in retail and commercial outlets. Transport of contaminated pine straw bales can accelerate the spread of this fern to new areas. Their use in landscapes increases maintenance costs because the fern "can rapidly overtake desirable vegetation" (Ferriter 2001).

Treatment: Preliminary treatments by Zeller and Leslie (2004) showed that treatment with glyphosate appears to have a more lasting effect than triclopyr. Experiments with various other chemical combinations are underway, including Escort, Plateau and others. Land managers have observed better results when a surfactant is used, and preliminary information suggests that adding a rainfast may also enhance effectiveness during inclement weather.

Early detection and treatment is essential to inhibit further expansion of both invasive ferns. Information is not yet available regarding the effects of recent hurricanes in 2004 and 2005 on the dispersal of either species of *Lygodium*. A hawk's eye will be needed to root out new populations and stomp out the old.

Note: A separate management plan will develop the information presented here. Input is welcome.

Additional references not already cited in this document:

FNAI. 2005. Invasive Plants Geodatabase. Florida Natural Areas Inventory, Florida State University. http://www.fnai.org/invasiveplants.cfm (access 29 November 2005)

Lott, M. and J. Volin, 2001. Dispersal, reproduction and physiological ecology of two invasive non-indigenous fern species, Lygodium microphyllum and Lygodium japonicum. Final Progress Report to Florida Department of Environmental Protection, Bureau of Invasive Plant Management.

Plantatlas 2005. http://www.plantatlas.usf.edu (access 29 November 2005)

USDA Plants. 2005. Lygodium japonicum. PLANTS database website, Natural Resources Conservation Service, U. S. Department of Agriculture http://plants.usda.gov (access 22 November 2005).