Chapter 8E: Exotic Species in the Everglades Protection Area

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INTRODUCTION

Invasive exotic species of animals and plants have become a serious global environmental problem (IUCN, 1999). A recent Cornell University study found that invasive species of plants, mammals, birds, amphibians, reptiles, fish, arthropods and mollusks cost the United States more than $100 billion annually (Pimentel, 2000). Such costs will inevitably continue to increase, especially if efforts to control these invasions are not coordinated. Planning, resources and action must be effectively integrated to reverse the overwhelming spread of numerous invasive species.

Florida is listed along with Hawaii, California, and now Louisiana as one of the states with the highest number of non-indigenous species. South Florida is home to more introduced (exotic) animals than any other region of the United States. With an estimated 26 percent of all resident mammals, birds, reptiles, amphibians and fish not native to the region, South Florida has one of the largest non-indigenous faunal communities in the world (Gore, 1976; Ewel, 1986; OTA, 1993; McCann et al., 1996; Shafland, 1996a; Simberloff, 1996; Corn et al., 1999). Thirty years ago, a Smithsonian publication described tropical Florida as a "biological cesspool of introduced life" (Lachner et al., 1970).

INVASIVE SPECIES AND EVERGLADES RESTORATION

Control of exotic invasive species is a far-reaching issue. The importance of this issue in the Everglades Protection Area (EPA) is demonstrated by the large number of plans, reports, statements and papers written on the topic of non-native species by numerous committees, state and federal agencies, public and private universities, state and federal task forces and other organizations. Most of the plans, reports, statements and papers support an "all-taxa" approach, with the general consensus of these parties being that control and management of non-indigenous species are critical components of ecosystem restoration in South Florida.

The topic of invasive species has been identified as an issue since the beginning of the Everglades restoration initiative. Numerous organized efforts and mandates have highlighted the problems associated with exotic species in the Everglades region. Control and management of invasive exotics are priorities established by the South Florida Ecosystem Restoration Task Force (SFERTF) in 1993. One of the tasks identified in the 1993 charter for the former management subgroup (December 16, 1993) was to develop a restoration strategy that addressed the spread of invasive exotic plants and animals. The U.S. Fish and Wildlife Service (USFWS), designated as the lead agency for this strategy, submitted a brief report (Carroll, 1994) that highlighted some of the following issues:

1. A limited number of species are designated as "nuisance" species and can be prohibited by law.
2. Current screening processes for invasive species are deficient.
3. Agency responsibilities remain vague.
4. There is a general lack of knowledge and awareness of the harmful impacts of invasive species.
5. There is an urgent need for statewide coordination and cooperation to eliminate exotics.

The USFWS report also determined that the greatest obstacles to combating non-indigenous species were a lack of sufficient funding and personnel to ward off potential problems caused by invasive exotic species.

The first annual report of the South Florida Ecosystem Restoration Working Group (SFERWG) in 1994 addressed all non-indigenous plant and animal species in the region. The report's overall objectives were as follows: (1) halt or reverse the spread of invasive species already widespread in the environment; (2) eradicate invasive species that are still locally contained; and (3) prevent the introduction of new invasive species to the South Florida environment. The Everglades Forever Act (EFA) of 1994 requires the South Florida Water Management District (SFWMD or District) to establish a program to monitor invasive species' populations and coordinate with other federal, state and local governmental agencies to manage exotic pest plants, with an emphasis on the Everglades Protection Area (EPA).

The Scientific Information Needs Report (SSG, 1996) of the SFERTF contains a chapter on the South Florida region's harmful, non-indigenous species. One of the overall regional science objectives for restoration is to develop control methods on exotic invasives at entry, distribution and landscape levels. Two specific objectives for stopping the spread of non-indigenous species are to halt and reverse the spread of invasive naturalized exotics and to prevent invasions by new exotic species. Major issues that could impede achieving these objectives include inadequate funding for scientific investigations to develop effective controls, lack of funding to apply control methods to problem species, delays and a lack of consistency in the response to new problems associated with exotics. Most resources for non-indigenous animals have focused on agricultural pests, with little investigation of species that threaten natural areas. Particular needs include the implementation of studies to develop control technology; basic biological and ecological studies to improve understanding of invasive exotic species (e.g., how will water management alterations affect non-indigenous plants and animals; identification of the principal controls on expansion of a species; the impacts of invasive species on native species and ecosystems; identification of what makes a natural area susceptible to invasion; and necessary screening and risk assessment technology that would help identify and focus attention on the greatest potential problems. There is an overall lack of meaningful information concerning the effects of non-indigenous species on South Florida.

The Comprehensive Review Study Final Feasibility Report and Programmatic Environmental Impact Study (USACE and SFWMD, 1999) addresses the presence of exotic animals as one of several factors that precludes any serious consideration of achieving true restoration of the natural system, that is, one in which exotic species are not present. The report discusses how removal of canals and levees, which act as deepwater refugia for exotic fish and conduits into interior marshes for other species, is expected to help control exotic species by slowing their continued movement into relatively pristine areas. On the other hand, restoration of lower salinity levels in Florida Bay might result in increases of reproductively viable populations of exotic fishes, such as the Mayan cichlid, in the freshwater transition zone. This potential problem must be addressed during detailed design.

The U.S. Department of the Interior's (DOI's) Fish and Wildlife Coordination Act Report (FGFWFC, 1999) for the Comprehensive Everglades Restoration Plan (CERP) also considers control and management of non-indigenous species to be a critical aspect of ecosystem restoration in South Florida. This report discusses the effects of the present canal and levee system, as well as that of the preferred alternative to this system, on the distribution of non-indigenous animals. Some components of the CERP involve construction of canals and reservoirs, which could provide additional conduits from points of introduction into the Everglades for species such as fish, amphibians, and snails. Other components involve removal or partial removal of canals, which should reduce the spread of exotic fishes. Removal of levees, which act as artificial terrestrial corridors into the wetland landscape, should reduce the spread of certain species, such as the fire ant. The DOI recommended establishment of an exotic animal task team to work on the issue during detailed planning for removal of existing structures or construction of new facilities as part of the CERP. In relation to planned Water Preserve Areas and flow-ways, DOI recommended that an aggressive plan be developed for the perpetual removal of invasive exotic plants and animals. DOI also recommended accelerating existing control measures, developing more effective techniques, and revising and enforcing existing regulations to prevent further introductions of exotic species (FGFWFC, 1999). The U.S. Army Corps of Engineers (USACE) and the District (SFWMD, 1999) responded in the CERP that the exotic animal task team should be presented to the South Florida Ecosystem Restoration Task Force.

Several other plans and reports also discuss exotic invasive species. The Coordination Act Reports (FGFWFC, 1999) from the Florida Game and Fresh Water Fish Commission (now the Florida Fish and Wildlife Conservation Commission, or FWC) emphasize that the extent of the canal system's role in the spread of exotic fishes into natural marshes, as opposed to the fish remaining primarily in the disturbed areas, is debatable. The draft report, A New Look at Agriculture in Florida (Evans, 1999), discusses the introduction of exotic pests and diseases as a serious obstacle to sustainable agriculture and the importance of exclusion and control strategies. The South Florida Multi-Species Recovery Plan (USFWS, 1999a) identifies exotic animal control as a restoration need for two-thirds of the ecological communities and the individual species covered in the plan. In addition, the South Florida Regional Planning Council's 1991 and 1995 regional plans for South Florida list the removal of exotic plants and animals and the discouragement of introductions of new exotics as regional policies (SFRPC 1991, 1995).

The Florida Department of Environmental Protection (FDEP) formed an Invasive Species Working Group (ISWG) in July 2001. Representatives from 13 state agencies and/or divisions and one state university comprise the ISWG. Florida Gov. Jeb Bush charged this group with developing a comprehensive invasive species plan for state agencies. The plan is in the final phases of development and the group will begin implementation once the governor approves it.

In 2002 the USACE authorized a conceptual plan for a four-part, multimillion dollar Invasive Species Management and Control project to be implemented as part of CERP. The four components of this project include the following: (1) a cost share project with the University of Florida to construct an Invasive Species Quarantine and Research facility in Ft. Pierce; (2) a cost share project with the Florida Department of Agriculture and Consumer Services to renovate the biocontrol facility in Gainesville; (3) a cost share project with multiple partners for the release of biocontrol agents; and (4) preparation of a report to detail federal interest and potential federal involvement in invasive species projects within South Florida.

On a national level, the President's Executive Order on Invasive Species (Executive Order 13112) recognized the threats posed by invasive species and authorized a national invasive species council. Among its other duties, the council prepared a national management plan for invasive species that was finalized and released on January 18, 2001. Implementation of the plan is ongoing through the National Invasive Species Council, chaired by the secretaries of Agriculture, Commerce and the Interior.

NON-INDIGENOUS PLANT SPECIES

The South Florida Ecosystem Restoration Task Force and Working Group has identified non-indigenous plants as a priority. As a result, the Noxious Exotic Weed Task Team (NEWTT) was established in 1997. NEWTT, a direct working team of the South Florida Ecosystem Restoration Task Force and Working Group, has two main directives. First is the development of an assessment to characterize the current problems with invasive exotic plants in southern Florida and identify the highest priority invasive species for control. The second directive calls for the development of a comprehensive interagency strategy for elimination or control of the highest-priority species and management to control and minimize the spread of other pest plant species.

The task team is comprised of federal, state and local government agencies. To comply with the Federal Advisory Committee Act (FACA) and with Florida's "sunshine laws," all NEWTT meetings are open to the public. While non-governmental organizations (NGOs) are not an official part of NEWTT, the Florida Exotic Pest Plant Council (FLEPPC) provides advice and peer review to the task team.

NEWTT has been charged with developing a plan to address the issues and problems of exotic pest plants in Florida, with the Everglades as its primary focus. However, NEWTT has adopted a statewide perspective regarding the issue of exotic pests in the belief that any plan that addresses the issue cannot do so in a fragmented geographic or political framework. Rather, to effectively combat the problems associated with exotic plants and animals a combination of federal, state and local governmental policies must be brought into accordance. In addition, regional issues and experience (e.g., control method development, research results, public education, technology transfer, policy, regulation, and funding) affect all agencies and programs statewide. In turn, national issues related to exotic pest plants affect state and local implementation.

NON-INDIGENOUS ANIMAL SPECIES

The effort to address the issue of exotic animals in the Everglades has lagged behind that of invasive plants. While it is relatively easy to determine the extent to which non-indigenous plants are invading natural areas, the impact of non-indigenous animals on native communities and on those species with which they directly compete is often much less obvious (Schmitz and Brown, 1994). Several reports have highlighted this difficulty:

- The Multispecies Recovery Plan (USFWS, 1999), which states:

> "It is probably safe to say that the most severe exotic species threats to the South Florida Ecosystem come from plants, rather than animals. Therefore, the emphasis on exotics in Florida has been on flora, rather than fauna."

- The Scientific Information Needs report (SSG, 1996) stated the problem this way:

> "The role of nonindigenous animals in South Florida natural areas is so poorly documented that it is difficult to design and mount an effective effort to control those that are harmful to native plant and animal communities."

- In the book, *Everglades: the Ecosystem and its Restoration*, Robertson and Frederick (1994) bluntly state:

> "Although biologists were quick to anticipate the developing problem, their concerns and pleas for regulation have been thoroughly overrun by events…Any present attempt to assess the overall threat posed by nonnative animals to the integrity of the Everglades ecosystem seems futile…In addition, thought may tend to become paralyzed by the obvious, perhaps insurmountable difficulty of effective countermeasures."

In spite of the above daunting conclusions, the SFERTF working group has been gathering available information as a basis for assessing the problem. In February 1998 the working group established an *ad hoc* interagency team to focus on South Florida and evaluate the status of non-indigenous animals in all habitats (freshwater, marine and terrestrial), describe efforts underway to assess their impact, and identify agency needs and problems (Goodyear, 2000).

Non-native animal species of concern include insects, marine and freshwater fish and invertebrates, reptiles and amphibians, mammals and birds. Species currently thought to be of greatest concern include the feral pig (*Sus scrofa*); Norway and black rats (*Rattus norvegicus* and *R. rattus*); nine-banded armadillo (*Dasypus novemcinctus*); European starling (*Sturnus vulgaris*); brown caiman (*Caiman crocodilus*); Tokay gecko (*Gecko gecko*); spinytail iguana (*Ctenosaura pectinata*, *C. similis*); Cuban knight anole (*Anolis equestis*); brown anole (*Anolis sagrei*); boa constrictor (*Boa constrictor*); Burmese python (*Python molurus*); Cuban treefrog (*Osteopilus septentrionalis*); Asian swamp eel (*Monopterus albus*); bromeliad weevil (*Metamasius callizona*); Diaprepes weevil (*Diaprepes abbreviatus*); brown citrus aphid (*Toxopotera citricida*); red fire ant (*Solenopsis invicta*); Pacific whiteleg shrimp (*Liptopinaeus vannamei*); zebra mussel (*Dresseina polymorpha*); red-rimmed melania aquatic snail (*Melanoides tuberculata*); and banded tree snail (*Orthalicus floridensis*).

The SFERTF is establishing a Noxious Exotic Animal Task Team (NEATT). This group will convene and develop a non-native animal report to provide a broad picture of the status of non-indigenous animal species in South Florida. The report will focus on the agencies and their respective departments that are represented in the working group. This report is to be used as a basis for the working group to evaluate members' priorities relative to non-indigenous animals and determine if and how the group might assist the work of individual agencies, enhance interagency collaboration and integrate South Florida efforts into state, regional or national programs.

MANAGEMENT EFFORTS

The District has been closely coordinating all vegetation management efforts with other agencies within the Everglades Protection Area (EPA) since 1990. This close coordination has resulted in detailed, species-based management plans (the Melaleuca Management Plan, the Brazilian Pepper Management Plan, the Lygodium Management Plan) and a maximization of all available management resources. In addition, the District has been required to obtain FDEP permits for all vegetation management activities in public waters since 1979. The permit process has helped to bring peer review and consistency to management approaches statewide. Within the EPA, floating aquatic plant control in canals has been coordinated with the USFWS and Everglades National Park (ENP or Park) since the early 1970s, specifically as it relates to water hyacinth and water lettuce spraying and/or harvesting in and around the S-10 and S-12 structures and within the L-7, L-39, L-40 and the L-29 canals. Currently the District does not have dedicated staff or funding to coordinate efforts for the control of non-indigenous animals within the EPA.

INVASIVE PLANT MANAGEMENT TOOLS

A variety of techniques are used to control exotic invasive plants within the EPA. Biological controls, herbicides, manual and mechanical controls, and cultural practices, such as prescribed burning and water level manipulation, are used separately or in conjunction to slow the spread of exotics. The following section highlights each of these methods. The "Priority Species" section discusses specific species-level controls.

Biological Control

Plants are often prevented from becoming weeds in their native range by a complex assortment of insects and other herbivorous organisms. Whenever a plant enters or is brought into the United States, the associated pests are thoroughly screened by government regulations on plant pest importation. Favorable growing conditions and the absence of these associated pest species have allowed some plants to become weeds outside their native range.

"Classical" biological control seeks to locate such insects and import host-specific species to attack and control the plant in regions where it has become a weed. The "classical" approach has a proven safety record (none of the approximately 300 insect species imported specifically for this purpose have ever become pests themselves) and has been effective in controlling almost 50 species of weeds.

The following performance steps are those of a classical biological control investigation:

1. Identify the target pest and prepare a report outlining problems, conflicts, the potential for a successful program, etc.
2. Survey and identify the pest's native range for a list of herbivores that attack the pest plant.
3. Identify the best potential biocontrol agents based on field observations, preliminary lab tests, and information from local scientists familiar with the plant's native environment.
4. Conduct preliminary host-range tests on the most promising candidate in the pest's native country to obtain permission to import the candidate to U.S. quarantine.

5. Complete host-range tests in U.S. quarantine to ensure the safety of the organism relative to local native plants, agricultural crops and ornamentals.
6. Petition the United States Department of Agriculture (USDA) Technical Advisory Group for permission to release the organism into the United States. Also, obtain permission from necessary state agencies.
7. Culture approved agents to acquire sufficient numbers for release at field sites; test release strategies to determine the best method of releasing the organism into the new environment.
8. Monitor field populations of pest plants to determine if the biocontrol agent establishes self-perpetuating field populations and also to understand plant population dynamics to establish a baseline to measure bioagent effects, especially if they are sub-lethal and subtle, and to determine what portions of life history to observe.
9. Study the agents' level of effectiveness for controlling the target plant. Monitor plant populations with and without the agent to determine impacts.
10. Study the means of integrating biocontrol into overall management plans for the target plant.

In Florida, classical biological control of invasive, non-native plants in non-agricultural areas has focused on aquatic weeds. The first such biocontrol agent introduced in the state was the alligatorweed flea beetle (*Agasicles hygrophila*) in 1964 for control of alligatorweed (*Alternanthera philoxeroides*). Subsequently, alligatorweed thrips (*Aminothrips andersoni*) were released in 1967; the alligatorweed stem borer (*Vogtia malloi*) was released in 1971. The flea beetle and stem borer proved to be fairly effective for suppressing growth of alligatorweed, though harsh winters can reduce their populations. Less effective have been introductions of the water hyacinth weevils (*Neochotina eichhorniae* and *N. bruchi*), released in 1972 and 1974, and the water hyacinth borer, released in 1977 (*Sameodes albigutalis*) for water hyacinth control. Likewise, the effectiveness of a weevil (*Neohydronomous affinis*) and a moth (*Namangama pectinicornis*) released to attempt to control water lettuce has been unpredictable. Water hyacinth and water lettuce continue to be problem plants that require management by other methods, including herbicides and mechanical harvest. Current biological control research is focused on hydrilla, water hyacinth, melaleuca, Brazilian pepper and Old World climbing fern.

Melaleuca snout beetles are damaging melaleuca stands and are also showing signs of range expansion after initial releases in 1997. The second melaleuca agent (a psyllid) was released in April 2002. The first Brazilian pepper insects and additional melaleuca-damaging insects may be approved for release in Florida within a few years. Overseas surveys and host specificity screening are ongoing for insects found feeding on Old World climbing fern in its native range.

Introduction of animals, such as cattle, sheep, goats or weed-eating fish, may also be used to control certain invasive plants. However, the environmental impacts of using such non-selective herbivores in natural areas should be carefully considered before implementation.

Herbicides

Herbicides are pesticides designed to control plants and are a vital component of most control programs. Herbicides are used extensively for managing exotic plant species in South Florida.

Herbicide Application Methods

Foliar application. A herbicide is diluted in water and applied with aerial or ground-based equipment to leaves. Foliar applications can either be directed to minimize damage to non-target vegetation or can be broadcast over a wide area. Broadcast applications are used where damage to non-target vegetation is not a concern or where a selective herbicide is used.

Basal bark application. A herbicide is applied, commonly with a backpack sprayer, directly to the bark around the circumference of each stem/tree at a height of up to 15 inches above the ground.

Frill or girdle (sometimes called "hack-and-squirt") application. Cuts into the cambium (the layer just beneath a tree's bark) are made around the entire circumference of the tree, with no more than three-inch intervals between cut edges. Continuous cuts (girdle) are sometimes used for difficult to control species and for larger trees. Herbicide (concentrated or diluted) is applied to each cut until the exposed area is thoroughly soaked. Frill or girdle treatments are slow and labor intensive, but are necessary in mixed communities to kill target vegetation and minimize impacts to desirable vegetation.

Stump treatment. After cutting and removing large trees or brush, herbicide (concentrated or diluted) is sprayed or painted onto the cut surface. The herbicide is usually concentrated on the cambium layer on large stumps, especially when using concentrated solutions. When using dilute solutions, the entire stump is sometimes flooded (depending on label instructions) with herbicide solution.

Soil application. Granular herbicide formulations are applied by hand-held spreaders, by specially designed blowers or aerially.

Where Herbicides Can Be Used

A pesticide or some of its uses is classified as "restricted" if it could potentially harm humans or the environment if it is not applied by certified applicators who have the appropriate knowledge for using these pesticides safely. Though none of the herbicides commonly used for invasive plant control in the Everglades is classified as "restricted," basic knowledge of herbicide technology and techniques needed for proper application can be obtained by taking restricted-use pesticide certification training. All District herbicide applicators and contractor supervisors are required to obtain and maintain this certification before they can apply herbicides in the Everglades Protection Area.

No pesticide can be sold in the United States until the U.S. Environmental Protection Agency (USEPA) has reviewed the manufacturer's application for registration and has determined that the product's use will not present unreasonable risks to humans or the environment.

The USEPA approves the use of pesticides on specific sites, i.e., for use on individual crops, terrestrial non-crop areas or aquatic settings. Only those herbicides registered by the USEPA specifically for use in aquatic sites can be applied to plants growing in lakes, rivers, canals, etc. For terrestrial uses the USEPA requires herbicide labels to contain the following statement: "Do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high-water mark." The herbicide Rodeo® is registered for aquatic use and can be applied directly to water. Some, though not all, herbicide products that contain 2,4-D can also be applied directly to water. The state supplemental special local need label for the imazapyr-containing product Arsenal® (EPA SLN NO. FL-940004) allows government agencies and their contractors to use it to control melaleuca and Brazilian pepper growing in water.

Herbicide Toxicity to Wildlife

Invasive plant management is often conducted in natural areas for the purpose of maintaining or restoring wildlife habitat. As such, it is essential that these herbicides are not toxic to wildlife. Herbicides used for invasive plant control in the Everglades have shown a very low toxicity to the wildlife on which they have been tested, with the exception of the relatively low LC_{50} (0.87 ppm) of triclopyr ester and fluazifop (0.57 ppm) for fish, neither of which can be applied directly to water. Ester formulations are toxic to fish because it irritates gill surfaces. However, because triclopyr ester and fluazifop are not applied directly to water, are adsorbed by soil particles and have low persistence, exposure to them is low. Consequently, if the product is used properly, there is little risk to fish.

Manual and Mechanical Removal

Manual removal of exotics is extremely time consuming but is often a major component of effective control of invasive plants. Seedlings and small saplings can sometimes be pulled from the ground, but even small seedlings of some plants have tenacious roots that will prevent extraction or cause them to break at the root collar. Plants that break off at the ground often resprout; even small root fragments left in the ground can sprout. Repeated hand pulling or follow-up with herbicide application is often necessary. Removal of uprooted plant material is also important. Stems and branches of certain species (i.e., melaleuca), if laid on the ground, can generate roots, and attached seeds can germinate. If exotic plant material cannot be destroyed by specific methods, such as burning, it is advisable to pile it in a secure, monitored area and destroy any new plants that appear.

Mechanical removal involves the use of bulldozers or specialized logging equipment to remove woody plants. Intense follow-up with other control methods is essential after using heavy equipment because soil disturbance creates favorable conditions for regrowth from seeds and root fragments, as well as recolonization by invasive, non-native plants. Mechanical removal using heavy equipment may not be appropriate in natural areas because of the risk of soil disturbance to non-target vegetation.

In aquatic environments, mechanical controls include self-propelled harvesting machines, draglines, cutting boats and other machines, most of which remove vegetation from the waterbody. These systems generally are used for clearing boat trails, high-use areas or locations where immediate control is required, such as flood control canals and around water control structures.

Cultural Practices

Prescribed burning and water-level manipulation are cultural practices used in the management of pastures, rangelands and commercial forests and in some situations may be appropriate for vegetation management in natural areas. Knowledge of land-use history is critical to understanding the effects of fire and flooding on the resulting plant species composition. Past land-use practices can affect soil structure, organic content, seed bank (both native and invasive exotic species), and species composition. While there is evidence that past farming and timber management practices will greatly influence the outcome of cultural management, very little is known about the effects of specific historical practices. Similar management practices conducted in areas with dissimilar histories can achieve very different results. Even less is known about the effects of invasive plants entering these communities and the subsequent management effects of fire on altered communities.

Understanding the reproductive biology of the target and non-target plant species is critical to the effective use of any control methods, though particularly with methods, such as fire management, that can require significant preparation time. Important opportunities exist when management tools can be applied to habitats where non-native invasive species flower or set seed at different times than native species.

Prescribed Burning

Fire is characteristic of most Florida ecosystems. Consequently, native species have evolved with varying degrees of fire tolerance. Throughout much of the Everglades, suppression of fire has altered historical plant communities. Within these communities, the fire-tolerant woody species have lingered in smaller numbers, and less fire-tolerant species have replaced ephemeral herbs. Little is known about the amount, frequency, timing and intensity of fire that would best enhance the historically fire-tolerant plant species; even less is known about how such a fire management regime could best be used to suppress invasive species. Single fires in areas with a history of many years of fire suppression are unlikely to restore historical species composition. Periodic fires in frequently burned areas do little to alter native species' composition.

Invasion of tree stands by exotic vines and other climbing plants, such as Old World climbing fern, on Everglades tree islands has greatly increased the danger of canopy (crown) fires and the resulting death to mature trees. The added biomass by invasive plants can result in hotter fires and can greatly increase the risk that fire will spread to inhabited areas. In such situations, use of fire to reduce the standing biomass of invasive species may better protect remaining plant populations than if no action were taken, even though non-target native species would be impacted.

Water Level Manipulation

Some success has been achieved by regulating water levels to reduce invasive plant species in aquatic and wetland habitats. De-watering aquatic sites reduces standing biomass, but little else is achieved unless the site is rendered less susceptible to repeated invasion when re-watered. Planting native species may reduce the susceptibility of aquatic and wetland sites.

In most situations, water level manipulation in reservoirs has not provided the degree of invasive plant control that was once thought achievable. Ponds and reservoirs can be constructed with steep sides to attempt to reduce invadable habitat, and levels can be avoided that promote invasive species. However, these management options are rarely adaptable to natural areas.

Carefully timed water level increases following herbicide treatments, mechanical removal or fire management of invasive species can sometimes control both subsequent germination and, in the case of some exotic species, resprouting.

Priority Species

As required by the Everglades Forever Act (EFA), the District assembled a meeting in 1996 with representatives from the Florida Department of Environmental Protection (FDEP or Department), the U.S. Army Corps of Engineers (USACE), the U.S. Fish and Wildlife Service (USFWS), and the National Park Service (Everglades National Park and the Big Cypress National Preserve). The purpose of this meeting was to compile a list of invasive exotic species that were considered the greatest threats to the Everglades. This list was not derived from the Florida Exotic Pest Plant Council (EPPC) Category I invasive plant list; rather, it was a collaborative effort to list "priority species" for the Everglades Protection Area (EPA). The following questions were considered in evaluating these plant species:

- Does the species reproduce rapidly?
- Does the species shift native plant community composition by displacing and/or shading out native plant species and/or altering fire ecology?
- Is the species well adapted to the conditions (i.e., hydroperiod, fire regime) of the EPA?
- Is the species widespread in the EPA? If not, does the species have the potential to rapidly expand?
- Does the species have the potential to spread into remote areas of the EPA?

PRIMARY EXOTIC SPECIES OF CONCERN IN THE EVERGLADES PROTECTION AREA

Melaleuca quinquenervia

Common Names: Melaleuca, paper-bark tree, cajeput, punk tree, white bottlebrush tree

Synonymy: *Melaleuca leucadendron* (L.) L. misapplied

Origins: Australia, New Guinea and the Solomon Islands

Family: Myrtaceae, myrtle family

Botanical description: Evergreen tree to 33 m tall. Slender crown and a soft, whitish, many-layered, peeling bark. Leaves alternate, simple, grayish-green, narrowly lance-shaped to 10 cm long and 2 cm wide, with a smell of camphor when crushed. Flowers in creamy white, "bottle brush" spikes to 16 cm long. Fruit a round, woody capsule about 3 mm wide, in clusters surrounding young stems, each capsule holding 200 to 300 tiny seeds.

Ecological significance: In its native range, melaleuca grows in low-lying flooded areas and is especially well adapted to ecosystems that are periodically swept by fire. These are common conditions in South Florida, making the region an ideal habitat for melaleuca colonization.

Melaleuca was introduced to Florida in 1906 (Fairchild, 1947) and was scattered aerially over the Everglades in the 1930s in an attempt to dry up "useless swampland" (Austin, 1978). The species is hardy and fast growing. These characteristics spurred its use as an ornamental landscape tree, as agricultural windrows and protective, living "guard rails," and as soil stabilizers along canals. As late as 1970, landscapers touted melaleuca as "one of Florida's best landscape trees" (Watkins, 1970).

Melaleuca readily invades canal banks, pine flatwoods, cypress swamps and uninterrupted sawgrass prairies of South Florida (Myers, 1975; Austin, 1978; Woodall, 1981b, 1982; Duever et al., 1986; Nelson, 1994). It grows extremely fast, producing dense stands that displace native plants, diminish animal habitat and provide little food for wildlife (Laroche and Ferriter, 1992).

Life History: Melaleuca prefers seasonally wet sites but also flourishes in standing water and well-drained uplands (Laroche, 1994b). Saplings are often killed by fire, but mature trees can survive fire and severe frost damage (Woodall, 1981). Melaleuca grows at a rate of one to two m per year, easily resprouts from stumps and roots, and is capable of flowering within two years from seed (Laroche, 1994b). Melaleuca flowers and fruits all year, producing up to 20 million windborne seeds per year per tree. The plant is able to hold viable seed for a massive, all-at-once release when stressed (Woodall, 1983). Melaleuca releases volatile oils into the air, especially when blooming. The volatile oils can cause respiratory irritation, asthma attacks, headaches and/or rashes (Morton, 1971b).

Distribution: Melaleuca has been found naturalized in Florida as far north as Hernando, Lake and Brevard counties (Mason, 1997; Wunderlin et al., 2000). It is reported in natural areas in 16 Central and South Florida counties (EPPC, 1996). Melaleuca grows equally well in the deep peat soil of Water Conversation Area 1 (WCA-1) and in the inorganic, calcareous soil of Everglades National Park. In general, wetland areas, such as sawgrass prairie, are more susceptible than drier, upland areas.

Before state and federal control operations were initiated in 1990, melaleuca was distributed throughout South Florida. Pioneering or "outlier" melaleuca had invaded the Holey Land tract, the interior of Everglades National Park, and WCA-2A. Light to moderate infestations occurred in WCA-3 and at the western edge of the east Everglades acquisition area. Moderate-to-heavy infestations occurred in the Loxahatchee National Wildlife Refuge, Big Cypress National Preserve, WCA-2B, Lake Okeechobee, and in the wetlands of Miami-Dade, Broward, Lee, and Collier counties. Baseline surveys in the early 1990s showed that melaleuca had invaded approximately 197,640 hectares in South Florida (Ferriter, 1999b).

Control: There are differing perspectives on the role of melaleuca in South Florida. Some experts believe melaleuca has unlimited potential to spread and could ultimately encroach on all open land (Hofstetter, 1991a). Other experts believe melaleuca could be limited to unused niches in the relatively young Florida landscape (Myers, 1975). Acknowledgement of such alternative views embraces the common thread that melaleuca must be controlled.

Effective melaleuca management requires a combination of control techniques that include herbicidal, mechanical, physical and biological controls. Comprehensive descriptions for each of these management techniques can be found in the "Invasive Plant Management Tools" section of this chapter.

The melaleuca management program is based on the quarantine strategy as described by Woodall in 1981. The least-infested areas (outliers) are addressed first to stop the progression of the existing population. The first phase of control targets all existing trees and seedlings in a given area. Using navigational equipment, work crews return to the same site in succeeding years to remove resulting seedlings from the previous year's control activities. A successful control operation consists of three phases:

- Phase I: Focus on the elimination of all mature trees and seedlings in an area.
- Phase II: Revisit previously treated sites for follow-up treatment to control trees that were missed and remove seedlings that have sprouted as a result of the preceding year's control activities.
- Phase III: Use long-term surveillance and inspect previously treated sites to monitor the effectiveness of the control program and minimize re-infestation.

Single-tree herbicide applications are most commonly delivered as a frill-girdle or cut-stump treatment. The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) and Everglades National Park (ENP or Park) programs favor the cut-stump technique because trees are felled, which limits subsequent seed dissemination. The District uses a combination of two separate ground treatment techniques, often leaving a ring of trees standing at each work location and felling the remaining trees. Standing trees alert the recreating public to hidden stumps, which mitigates navigation hazards. However, a disadvantage is that seedpods dry, and wind can blow seeds several hundred feet from the treatment site.

District and ENP staff also use aerial herbicide applications to control large monocultures of melaleuca. This provides cost-effective control in areas where non-target damage is minimized. Control of outlier trees is coordinated with aerial treatment; ground crews typically treat the trees by employing the previously described methods and techniques.

Where tree densities are high, direct herbicide application can still result in non-target effects. In some cases, aerial application of herbicides may cause less non-target damage to native and herbaceous groundcover. Using aerial application techniques could also result in the use of less herbicide at a given site, and in some situations might lower the cost of initial treatment. Manual removal of seedlings might not be advisable in all situations, depending on the percentage of roots that could potentially be broken below the ground surface. In addition, the resulting soil disturbance may stimulate the germination of more seeds. Mechanical removal using heavy equipment is best suited for rights-of-way and other areas where routine maintenance follows and site disturbance is not a concern.

A key component of an effective, long-lasting melaleuca management program is the introduction of biological control agents. Without biological control, melaleuca elimination would be much more expensive and could not be truly integrated. The current investigation into biological organisms will most likely result in the introduction of seed and sapling feeders. The first introductions of a melaleuca snout beetle *(Oxyops vitiosa*) began in April 1997. As of July 2001 more than 17,000 larvae and 192,000 adults have been released at 140 locations in nine counties. Preliminary results indicate the insect is causing damage to new growth on melaleuca at several release sites. The melaleuca snout beetle is the first of a suite of insects being studied for release.

A new biocontrol for melaleuca was released from quarantine in February 2002. Approximately 150,000 psyllid (*Boreioglycaspis melaleucae*) have now been released, and the agent has established itself at eight South Florida sites. Populations are building quickly and have spread as far as 267 meters from release points. Nymphs suck the plant juices and inject a phytotoxic saliva that kills the tissue surrounding the feeding site. Small potted plants die within two months of a severe infestation. A significant impact is expected at field sites next winter, when the plants produce a flush of new foliage. Entomologists analyzing the problem estimate that at least five insect species will be required to effectively suppress the melaleuca's reproductive capacity.

It generally takes several years for introduced insect populations to build to levels that are effective for control. In the interim and throughout the biocontrol introduction phase, herbicidal and mechanical controls will be required to reduce current infestations and prevent their spread into uninfested areas.

Regional control efforts have resulted in steady progress. Large, untreated monocultures of melaleuca are presently limited to WCA-2B, the Arthur R. Marshall Loxahatchee National Wildlife Refuge, the east Everglades acquisition area, the Everglades buffer strip, and wetlands in

Miami-Dade, Broward and Lee counties. Control efforts by local, state and federal land management agencies have resulted in a decrease in melaleuca acres.

New initiatives: The Areawide Management Evaluation of Melaleuca (TAME Melaleuca) Program was recently established under the USDA Agricultural Research Service's (ARS's) Areawide Pest Management initiative. The goal of this five-year grant is to demonstrate the effectiveness of an integrated approach that can be applied to invaded areas for control of melaleuca. As described above, current control efforts focus on an individual tactic, with little integration of alternative approaches. This new initiative represents a regional demonstration of multiple control tactics and their combined effectiveness. Land managers will have an opportunity to see different strategies in real-life settings and to adapt techniques that will address site-specific melaleuca problems. Funding associated with this grant program will allow the initiation of work on private lands, defraying the cost of melaleuca control for private landowners.

The USDA ARS plans to distribute limited funds to selected locations to develop TAME Melaleuca demonstration sites. Project leaders will work with land managers from each demonstration site to develop site-specific integrated melaleuca management plans. An annual budget of $35,000 per site for five years is available to defray management cost increases that could arise due to participation in TAME Melaleuca. This is a unique opportunity for interested land managers – both public and private – to receive financial and technical support for using integrated melaleuca management tactics that would otherwise be considered too complicated, costly or risky.

Lygodium microphyllum

Common Name: Old World climbing fern

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

Origins: Tropical Asia, Africa and Australia

Family: Lygodiaceae, climbing fern family

Botanical description: Fern with dark brown, wiry rhizomes and climbing, twining fronds of indeterminate growth to 30 m long; main rachis (leaf stalk above petiole) wiry, stem-like. Leafy branches off main rachis (constituting the pinnae) once compound, oblongish in overall outline, 5 to 12 cm long. Leaflets (pinnules) usually un-lobed, stalked, articulate (leaving wiry stalks when detached). Leafblade tissue usually glabrous below. Fertile leaflets of similar size, fringed with tiny lobes of enrolled leaf tissue covering the sporangia along the leaf margin.

Ecological significance: There are two species of exotic climbing fern naturalized in Florida. Old World climbing fern is native to wet tropical and subtropical regions of Asia, Africa, and Australia. It has become a serious threat to South Florida natural areas, especially the Everglades, where it is increasing in density and range. Japanese climbing fern (*Lygodium japonicum*) is native to temperate and tropical Asia. In the United States it occurs from eastern Texas throughout the southern states to North Carolina and North Florida. Japanese climbing fern has not yet been found within the EPA. Old World climbing fern has reached critical mass in South Florida to the extent that new populations, presumably from wind-borne spores, are constantly being reported by natural resource managers and private landowners throughout the southern peninsula.

Old World climbing fern invades many freshwater and moist habitats in Florida. It is common in cypress swamps, pine flatwoods, wet prairies, sawgrass marshes, mangrove communities and Everglades tree islands (Jewell, 1996; Pemberton and Ferriter, 1998). This plant unequivocally alters fire ecology that is important to maintaining Florida native habitats. Prescribed burns and wildfires that normally stop at the margins of flooded cypress sloughs will burn through areas infested with Old World climbing fern. Burning mats of the lightweight fern break free during fires and are kited away by heat plumes, a process that leads to distant fire spotting. Additionally, the plant acts as a "flame ladder," carrying fire high into native tree canopies. Under natural conditions, fire rarely enters the tree canopy. Canopy fires are deadly to native cypress forests and pine flatwoods and have resulted in the loss of some canopy trees and native epiphytes and bromeliads residing on tree trunks (Roberts, 1996).

Old World climbing fern forms dense mats of rachis plant material. These thick, spongy mats are slow to decompose, exclude native understory plants, and can serve as a site for additional fern colonization. It is difficult for other plant species to grow through the dense mat made by this fern, reducing plant diversity. Large expanses of fern material also may alter drainage and water movement.

Life history: Wiry Old World climbing fern rhizomes are able to accumulate into dense mats one meter or more thick above native soil. Vegetative growth and production of fertile pinnules continue throughout the year. Spores can germinate in six to seven days; five-month-old spores retain an 80 percent germination rate (Brown, 1984). Fertile pinnules are usually produced where plants receive sunlight. Such exposed locations also aid wind-borne dispersal of the spores. Old World climbing fern often first establishes itself at pineland/wetland ecotones. It is usually killed back by fire, but not eliminated. Re-growth is common (Maithani et al., 1986).

Distribution: Beckner (1968) and Nauman and Austin (1978) reported that the center of dispersal for Old World climbing fern in Florida is the Loxahatchee River Basin in southern Martin and northern Palm Beach counties. By 1993 the fern had expanded into western Martin County and central Palm Beach County. The fern is now spreading rapidly throughout southern Florida. Results from the District's 1993 regional survey indicated that Old World climbing fern occupied an estimated 10,935 hectares in South Florida. By 1997, this number had climbed to 15,800 hectares (Pemberton and Ferriter, 1998), and by 1999 the species was present in more than 43,000 hectares.

The tree islands of the northern Everglades (WCA-1) are significantly impacted by Old World climbing fern. Large tree islands are completely blanketed by the plant. Recent reports indicate that the fern is spreading south through WCA-2 and WCA-3, the Big Cypress National Preserve, and Lee, Collier, and Miami-Dade counties. A large infestation totaling approximately 1,000 acres was discovered in the Ten Thousand Islands area of Everglades National Park (ENP) in 2000 (Tony Pernas, personal communication).

Increased hydroperiod does not seem to have an effect on this species. It has expanded significantly in areas that have experienced several years of higher-than-normal water levels. This species is also not restricted to elevated Everglades tree islands, as it has been noted growing in open, flooded sawgrass marshes in the Refuge (Jewell, 1996). Old World climbing fern threatens to dominate many native plant communities in South and Central Florida within the next decade (Ferriter, 1999a).

Control: Control options for Old World climbing fern have only recently begun to be explored. The District has funded and implemented a biological control program, but it could be years before any control agents are introduced (Pemberton, 1998). Based on preliminary studies, fire and flooding do not appear to be stand-alone options. While fire kills most aboveground portions of this vine, it does not kill the entire plant. It also appears that flooding does not kill the plant, though flooded soils may limit its establishment.

Herbicides and herbicide application techniques are currently being evaluated and refined (Stocker et al., 1997). The District has initiated several studies to monitor the impacts of aerial herbicide treatments to non-target native plant communities. Preliminary results from winter treatments of Old World climbing fern in deciduous plant communities (i.e., *Taxodium*) show promise. In 2000, the Park and the District conducted a large-scale aerial treatment of Old World climbing fern in the remote western Everglades. The District conducted experimental applications of herbicides on evergreen Everglades' tree islands in the Refuge in 2001. Results of these treatments will be monitored to assess treatment efficacy and non-target damage. Staff from the District, the Park, and the Refuge are closely coordinating monitoring and control efforts and hope to develop an integrated strategy to contain and control this species in the EPA.

Schinus terebinthifolius

Common Names: Brazilian pepper, Florida holly, Christmas berry, pepper tree

Synonymy: None

Origins: Brazil, Argentina and Paraguay

Family: Anacardiaceae, cashew family

Botanical Description: Evergreen shrub or tree to 13 m tall, often with multi-stemmed trunks and branches arching and crossing, forming tangled masses. Leaves alternate, odd-pinnately compound, with three to 11 (usually seven to nine) elliptic, oblong leaflets 2.5 to 5 cm long, with upper surfaces dark green (lateral veins obvious, lighter in color), lower surfaces paler, and leaflet margins often somewhat toothed. Leaves aromatic when crushed, smelling peppery or like turpentine. Flowers unisexual (dioecious), small, in short-branched clusters at leaf axils of current-season stems. Five petals, white, to 2 mm long. Fruit a small, bright red, spherical drupe.

Ecological Significance: Brazilian pepper was imported as an ornamental in the 1840s (Barkley, 1944). Its bright red fruit and shiny, green leaves increased its popularity as a substitute for holly in Florida and quickly earned it the misnomer of "Florida holly" (Morton, 1971a). Its fruit is commonly consumed by frugivorous birds. Seed dispersal by these birds, namely mockingbirds, cedar waxwings, and especially migrating robins, has been responsible for the spread of Brazilian pepper into outlying, non-Brazilian pepper-dominated ecosystems, especially those that offer places to perch, such as trees and utility lines (Ewel et al., 1982). Raccoons and opossums are known to ingest the fruit, and the animals' stools provide additional nutrients for seed germination and seedling growth. Brazilian pepper has invaded a variety of areas, including, but not limited to, fallow farmland, pinelands, hardwood hammocks, roadsides and mangrove forests in areas with a high degree of disturbance and in natural areas with little disturbance (Woodall, 1982; Ferriter, 1997). Brazilian pepper forms dense thickets of tangled, woody stems that completely shade out and displace native vegetation. It has displaced some populations of rare, listed species, such as the beach Jacquemontia (*Jacquemontia reclinata*; House, U.S. and Florida endangered species list), and beach star (*Remirea maritima*; Aubl., Florida endangered species list).

Life history: Brazilian pepper sprouts easily from the trunk and roots, even if the plant is damaged. It flowers every month of the year in Florida; the most intense period of flowering is fall. Brazilian pepper fruits profusely in southern and Central Florida, with wildlife consumption of fruits contributing to the spread of seeds (Ewel et al., 1982). It produces chemicals in its leaves, flowers and fruits that irritate human skin and respiratory passages (Morton, 1978; Ewel et al., 1982).

Distribution: Brazilian pepper is naturalized in most tropical and subtropical regions, including other South American countries, parts of Central America, Bermuda, the Bahama Islands, the West Indies, Guam, Mediterranean Europe, North Africa, southern Asia and South Africa. In the United States, it occurs in Hawaii, California, southern Arizona, and Florida (as far north as Levy and St. Johns counties, and as far west as Santa Rosa County) (EPPC, 1996).

Brazilian pepper does not become established in deeper wetland communities and rarely grows on sites inundated longer than three to six months. In the ENP, for example, it is absent from marshes and prairies with hydroperiods exceeding six months, as well as from tree islands with closed canopies (LaRosa et al., 1992). Once established, however, Brazilian pepper can tolerate extended periods of shallow-water inundation. The effects of deep-water flooding on established Brazilian pepper populations are as yet unclear.

Concern over the occurrence of Brazilian pepper in salt-tolerant plant communities, e.g., mangrove forests in southern Florida, especially in the ENP, led Mytinger and Williamson (1987) to investigate Brazilian pepper's tolerance to saline conditions. Seed germination and transplanted seedlings did not succeed at salinities of 5 parts per trillion (ppt) or greater, which would largely exclude it from becoming established in mangrove forests. However, invasion of saline communities can occur if salinity declines due to changes in drainage patterns resulting from natural phenomena or human activities.

Within the EPA, Brazilian pepper has invaded most of the canal levees and much of the powerline rights-of-way. Some of the WCA-1 tree islands have been colonized to varying degrees by this species. By far the greatest areal coverage of Brazilian pepper within the EPA is an area called the Hole-in-the-Doughnut (HID). Situated within the boundaries of Everglades National Park, the HID comprises approximately 4,000 hectares of previously farmed lands (farming ceased there in 1975). More than 40 percent (1,600-plus hectares) of this area has been invaded by a dense forest of Brazilian pepper. The species has also infested more than 40,000 hectares in the isolated Ten Thousand Islands, and it is widely scattered throughout the ENP, occurring in all habitats, but particularly in disturbed areas. Brazilian pepper is now estimated to occupy more than 400,000 ha in Central and South Florida (Ferriter, 1997; Wunderlin et al., 2000).

Control: Over the years, ENP scientists have researched a number of restoration techniques for areas infested by Brazilian pepper. Only the complete removal of the disturbed substrate has resulted in recolonization by native vegetation to the exclusion of Brazilian pepper. In 1996 the ENP initiated a full-scale substrate removal project for the entire HID. To date, eight percent of what was once Brazilian pepper forest has been restored to native vegetation. The project is funded through the year 2016.

Along canal levees, highways and powerline rights-of-way, most Brazilian pepper control work involves the selected use of herbicides or the use of heavy equipment to physically remove the plant, followed by a herbicide application. Large, single trees are usually treated with a basal-bark herbicide application. This treatment provides for the greatest selectivity, with no non-target effects. In dense stands, foliar herbicides can be used and are most effective when applied aerially.

Biological controls have not yet been approved for general release against Brazilian pepper, though District-sponsored research is ongoing. The University of Florida Department of Entomology and Nematology has been investigating insect vectors of Brazilian pepper since 1994. Exploratory surveys conducted in Brazil have identified several insects as potential biological control agents. Three insect species – a thrip (*Pseudophilothrips ichini*), a sawfly (*Heteroperreyia hubrichi*) and a leaf roller (*Episimus utilis*) – have been selected for further study (Cuda et al., 1999). Host-specificity testing for the sawfly has been completed, and a petition to release this species has been submitted.

Casuarina equisetifolia, Casuarina glauca

Common Names: Australian pine, beefwood, ironwood, she-oak, horsetail tree

Synonymy: *Casuarina littorea* L. ex Fosberg and Sachet, *C. litorea* Rumpheus ex Stickman

Origins: Australia, South Pacific Islands and Southeast Asia

Family: Casuarinaceae, beefwood family

Botanical description: Evergreen tree to 46 m tall, usually with single trunk and open, irregular crown. Bark reddish-brown to gray, rough, brittle, peeling. Branchlets pine needle-like, grayish-green, jointed, thin (< 1mm wide), 10 to 20 cm long, minutely ridged, hairy in furrows. Leaves reduced to tiny scales, six to eight in whorls encircling joints of branchlets. Flowers unisexual (monoecious), inconspicuous, female in small axillary clusters, male in small terminal spikes. Its fruit is a tiny, one-seeded, winged nutlet (samara) formed in brown, woody, cone-like clusters (fruiting heads), measuring up to 2 cm long and 1.3 cm wide.

Ecological significance: Australian pine was introduced into Florida in the late 1800s (Morton, 1980). It has naturalized since the early 1900s along coastal dunes (Small, 1927). Australian pine was planted extensively in the southern half of the state to act as windbreaks and shade trees (Morton, 1980). It is salt-tolerant and seeds freely throughout an area, growing even in front-line dunes (Watkins, 1970; Long and Lakela, 1971). Its rapid growth, dense shade, dense litter accumulation and other competitive advantages are extremely destructive to native vegetation (Nelson, 1994). Australian pine can encourage beach erosion by displacing deep-rooted native vegetation. It can also interfere with the nesting efforts of endangered sea turtles and the American crocodile (Klukas, 1969).

Three species of Australian pine trees have invaded Florida's wild lands. Since their introduction in the late 1800s, they have been widely planted throughout the southern peninsula. It was not until 1992 that the State of Florida banned the further propagation and sale of these trees as ornamentals. Australian pine grows very fast (1 to 3 meters per year), is salt-tolerant, and readily colonizes rocky coasts, dunes, sandbars and islands and invades far-inland, moist habitats, such as the east Everglades area of Everglades National Park (Morton, 1980). Australian pine forms dense forests, crowding out all other plant species. It has crowded out vast areas of natural vegetation along Florida's coastline, where the public vehemently opposes any removal efforts.

Life history: Australian pine is not freeze-tolerant and is sensitive to fire (Morton, 1980). It loses branches easily and can topple in strong winds (Morton, 1980). Australian pine produces allelopathic compounds that inhibit growth of other vegetation (Morton, 1980); it can easily colonize nutrient-poor soils by nitrogen-fixing microbial associations (Wilson, 1997). It reproduces prolifically by seed (as many as 600,000 to the kilogram), with seeds dispersed by birds (especially exotic parrots and parakeets), water, and wind (Morton, 1980). The fruiting heads of this species float (Maxwell 1984).

Distribution: Australian pine occurs throughout South Florida from Orlando south on sandy shores and in pinelands. It occurs as far north as Dixie County on the West Coast and Volusia County on the East Coast (Wunderlin et al., 1995). Australian pine frequently colonizes disturbed sites, such as filled wetlands, road shoulders, cleared land and undeveloped lots (Maxwell, 1984).

Australian pine is primarily a problem along levee berms in the water conservation areas (WCAs). A large portion of the east Everglades and the southern saline Everglades (C-111 basin), as well as coastal areas of the Park, are heavily impacted. The seeds can be wind-blown or carried by birds, and probably also moved throughout the EPA via water flowing in canals. Australian pine has a microbial association with nitrogen-fixing organisms that allows it to colonize and grow prolifically in nutrient-impoverished soils. This nitrogen-fixing capacity, combined with a lack of natural enemies, gives Australian pine a tremendous competitive edge over natural vegetation. Until recently, Australian pine was the dominant tree species growing along the EPA's canal levees. The largest remaining populations of Australian pine in the EPA are original plantings growing along State Road 27 in Broward County and wild populations growing in the east Everglades area.

Control: Fire is sometimes effective for controlling dense stands of Australian pine that have dropped sufficient layers of fuel on the ground. Larger trees usually re-sprout from the base and require follow-up herbicide treatment. There is no biological control research being conducted on Australian pine at this time, though the species is a good candidate for this particular control method. However, it is unlikely that biological control will be an option in the near future due to the tree's popularity in urban landscapes and coastal communities.

The primary method of control is selective use of herbicides. Although several soil-active herbicides are effective, the most common control techniques involve basal-bark and cut-stump herbicide applications. The District has nearly completed its control of mature Australian pine trees growing along canal levees of the EPA and in District-managed lands in the southern Everglades. Periodic follow-up is required to treat seedlings that arise from the residual seedbank. Re-treatment to deplete the existing seed bank is conducted prior to saplings' maturing and flowering.

Colubrina asiatica

Common Names: Latherleaf, Asiatic or common colubrina, hoop withe, Asian snakeroot

Synonymy: None

Origin: Old World

Family: Rhamnaceae, buckthorn family

Botanical description: Glabrous, evergreen, scrambling shrub with diffuse, slender branches to 5 m long; in older plants, stems to 15 m long. Leaves alternate, with slender petioles to 2 cm long; blades oval, shiny, dark green above, 4 to 9 cm long and 2.5 to 5 cm wide, with toothed margins and producing a thin lather when crushed and rubbed in water. Flowers are small, greenish-white, in short-branched, few-flowered clusters at leaf axils; each with a nectar disc, five sepals, five hooded petals, and five stamens. Fruit a globose capsule, green and fleshy at first and turning brown upon drying, about 8 mm wide, with three grayish seeds.

Ecological Significance: Latherleaf is thought to have been brought to Jamaica in the 1850s by east Asian immigrants for traditional use as medicine, food, fish poison and soap substitute (Burkill, 1935; Perry, 1980). It is noted as naturalized in the Keys and Everglades by Small (1933), and as aggressively spreading along these coasts (Morton, 1976; Austin, 1978). Latherleaf invades marly coastal ridges just above the mean high-tide line (Russell et al., 1982) tropical hammocks, buttonwood and mangrove forests, and tidal marshes (Schultz, 1992). It also forms thickets on disturbed, coastal roadsides. Latherleaf can invade disturbed and undisturbed forest sites (Olmsted et al., 1981; Jones, 1996), forming thick mats of entangled stems up to several feet deep and growing over and shading out native vegetation, including trees (Langeland, 1990; Jones, 1996). This species is of particular concern in Florida's coastal hammocks, where it threatens a number of rare, listed native plant species, including mahogany, thatch palm, wild cinnamon, manchineel, cacti, bromeliads and orchids (Jones, 1996). It currently exists in every park in the Florida Keys, where it threatens rare natives, such as bay cedar and beach star.

Life History: Latherleaf requires considerable light, with seedling growth rate increasing where shade is removed; stems may grow 10 m in a single year (Schultz 1992). Latherleaf forms adventitious roots where its branches touch the ground, and it vigorously re-sprouts from cut or injured stems. This species may reach seed-producing maturity within a year (Russell et al., 1982; Schultz, 1992). In Florida, it most often flowers in July, with fruits maturing in September (Jones, 1996), but it is reported as flowering year-round (Long and Lakela, 1971; Wunderlin, 1982). Loose soil is usually required for germination, with seeds able to retain viability in soil for several years (Russell et al., 1982). Long-distance dispersal is aided primarily by storms and extreme tides, which allow ocean currents to carry away the buoyant, salt-tolerant fruits and seeds (Carlquist, 1966).

Distribution: Latherleaf is found naturally from eastern Africa to India, Southeast Asia, tropical Australia, and the Pacific Islands, including Hawaii, where it typically occurs as scattered plants on sandy and rocky seashores (Brizicky, 1964; Johnston, 1971; Tomlinson, 1980). From Jamaica it has spread in the New World to other Caribbean islands, Mexico, and to Florida with the aid of ocean currents and storm tides (Russell et al., 1982). It is now naturalized in Florida in coastal areas from Key West north to Hutchinson Island in St. Lucie County (Schultz, 1992).

Nowhere in Florida are the ecological effects of latherleaf more noticeable than in Everglades National Park (Jones, 1997). Latherleaf is well distributed throughout the Park's coastal areas. It occurs from the Ten Thousand Islands south to Cape Sable along the Gulf Coast, and east along the northern fringe of Florida Bay to the Florida Keys. Latherleaf occupies approximately 500 hectares of the most remote areas of the Park. Coastal hardwood forests are among the most threatened plant communities in southern Florida. The aggressive colonization nature of latherleaf and its continued expansion into these areas is especially disconcerting.

Fortunately, there is no evidence of long-distance dispersal mechanisms on land that could further facilitate its spread inland. Storms and extreme tides appear to be the only dispersal agents.

Latherleaf was casually noted as existing in the Park until the 1970s, when large monotypic stands up to one hectare (ha) in area were observed along the coast of Florida Bay (Russell et al., 1982). In 1974, Park staff reported 130 ha of latherleaf growing at sites along the coast from Christian Point to Santini Bight, including some of the offshore keys. In 1980, a detailed vegetation and mapping study of the coast between Flamingo Bay and Joe Bay revealed 50 ha of high-density stands (Olmsted et al., 1981). Interpretation by Rose and Doren, 1988, of color, infrared, aerial photographs (1:10,000 scale) taken of the Park in 1987 showed that the areal extent of medium- to high-density latherleaf along the same stretch of coastline (Snake Bight to Joe Bay) was 230 ha. Photo interpretation of 1994 to 1995 USGS NAPP color infrared photographs (1:40,000 scale) by the University of Georgia's Center for Remote Sensing and Mapping Science has provided the latest information on the distribution of latherleaf in the Park. Low- to high-density infestations of latherleaf covered nearly 420 ha for the same area. An 84 percent increase in latherleaf's extent over the seven-year period was also reported. From this mapping data, it can be estimated that the areal extent of latherleaf could double every 10 years, spreading at a rate of approximately 25 ha per year.

Control: Latherleaf has been successfully managed in Biscayne National Park, as well as on other public lands. Uprooting the young, shallow-rooted plants, cutting scandent stems, and applying herbicides, either cut-stump or basal-bark, have proven effective (Langeland, 1990). Biological control is currently unavailable and will probably remain so for some time. To date, management efforts within the Park have been restricted because of funding limitations.

Eichhornia crassipes

Common names: Water hyacinth, water orchid

Synonymy: *Piaropus crassipes* (Mart.) Britt.

Origin: Amazon basin

Family: Pontederiaceae, pickerelweed family

Botanical description: Floating aquatic herb, rooting in mud if stranded, usually in dense mats with new plantlets attached on floating green stolons. Submersed roots blue-black to dark purple, feathery, dense near root crown, tips with long dark root caps. Leaves formed in rosettes; petioles to 30 cm or more, spongy, usually inflated or bulbous, especially near base; leaf blades roundish or broadly elliptic, glossy green, to 15 cm wide. Inflorescence a showy spike above rosette, to 30 cm long. Flowers lavender-blue with a yellow blotch, to 5 cm wide, somewhat two-lipped; 6 petals, 6 stamens. Fruit a three-celled capsule with many seeds.

Ecological Significance: Water hyacinth is listed as a weed in 56 countries (Holm et al., 1979). It was introduced into the United States in 1884 at an exposition in New Orleans, reaching Florida in 1890 (Gopal and Sharma, 1981). By the late 1950s, water hyacinth had occupied about 51,000 ha of Florida's waterways (Schmitz et al., 1993). It grows at explosive rates, exceeding any other tested vascular plant (Wolverton and McDonald, 1979) and doubling its populations in as little as six to 18 days (Mitchell, 1976). In large mats it degrades water quality and dramatically alters native plant and animal communities (Gowanloch, 1944; Penfound and Earle, 1948). Large mats of water hyacinth can collect around water control structures and impede flow.

Life history: Water hyacinth reproduces both vegetatively and sexually (Penfound and Earle, 1948; Gopal and Sharma, 1981). It quickly forms new rosettes on floating stolons; the stolons are easily broken and the plants and mats can then be transported by wind and water. Leaves are killed by moderate freezes but they quickly re-grow from the stem tip that lies protected beneath the water's surface. Water hyacinth typically flowers year-round in mild climates, producing abundant seeds in developed mats (Penfound and Earle, 1948). Numerous seedlings are seen in conjunction with lake drawdowns.

Distribution: Water hyacinth now occurs globally in the tropics and subtropics and further north and south, where it can escape severe cold (Holm et al., 1977). It is found in 16 states in the United States, including throughout Florida, north to Virginia (and New York) and west to California and Hawaii (USDA, 1997).

Under ideal growing conditions, these plants can increase their surface coverage by 25 percent each month when not managed (Langeland, 1988). The thick, floating mats of vegetation block boating access within the EPA, clog water control structures, negatively impact water quality, and reduce native plant species. These plants are almost exclusively located in artificial environments. They are common in all canals and around most water control structures. In addition, they can often be found growing at the mouth of airboat trails that transect the canals. However, they do not appear to compete with native vegetation in the EPA away from these disturbed environments.

Control: Water hyacinth and water lettuce are both free-floating, aquatic plants. They create similar problems and are similarly managed. Control methods for both species are discussed below.

The District conducts water hyacinth and water lettuce control operations under a permit from the FDEP and performs all work in accordance with federal and state regulations. The District's primary goal is implementation of a "maintenance control program." Florida Statute Chapter 372.925 defines maintenance control as "a method of managing exotic aquatic plants in which control techniques are utilized in a coordinated manner on a continuous basis to maintain a plant population at the lowest feasible level." Maintenance control results in less use of herbicides, the deposition of less organic matter (from dead leaves and plants), less overall environmental impact by weeds, and reduced management costs.

Herbicides have been the primary method of controlling floating, exotic, aquatic weeds in the EPA. Herbicides used for management of these plants are diquat and 2,4-D. Both are fully approved by the USEPA for application to aquatic sites. Mechanical control has generally been limited to areas in and around structures where plants have impeded water discharge capabilities and must be physically removed. The process of mechanically harvesting water hyacinth and water lettuce is slow and expensive (10 to 15 times greater than with herbicides). Harvested plant biomass must be removed from the water to be effective, and near-shore disposal options are often limited, adding considerable cost to mechanical removal.

Mechanical harvesting cannot be considered a stand-alone option for floating weed management in EPA canals. While insects have been introduced as biological controls for both species, a complement of insect vectors adequate to "control" plant growth has not yet been introduced. USDA-ARS biocontrol researchers have recently completed field assessments in Peru that involved locating and identifying candidate insects for study in U.S. quarantine. Herbicide applications remain the primary control method and are dispersed either by boat or by helicopter.

Pistia stratiotes

Common name: Water lettuce

Synonymy: None

Origin: Africa or South America

Family: Araceae, arum family

Botanical description: Floating herb in rosettes of gray-green leaves, rosettes occurring singly or connected to others by short stolons. Roots numerous, feathery. Leaves often spongy near base, densely soft in pubescence with obvious parallel veins, slightly broader than long, widest at apex, to 15 cm long. Flowers inconspicuous, clustered on small, fleshy stalk nearly hidden in leaf axils, with single female flower below, and whorl of male flowers above. Fruit arising from female flower as a many-seeded, green berry.

Ecological significance: Water lettuce may have been introduced to North America either naturally or by humans (Stoddard, 1989). The plant was seen as early as 1774 by William Bartram in "vast quantities" several miles in length and, in some places, a quarter of a mile in breadth in the St. Johns River (Van Doren, 1928). It has been suggested that trade via St. Augustine, founded in 1565, may have provided an early avenue for introduction into the St. Johns watershed (Stuckey and Les, 1984). Water lettuce is capable of forming vast mats that disrupt submersed plant and animal communities. These mats can collect around water control structures and can interfere with water movement and navigation (Attionu, 1976; Holm et al., 1977; Bruner, 1982; Sharma, 1984). It is considered a serious weed in Ceylon, Ghana, Indonesia, and Thailand and is at least present as a weed in 40 other countries (Holm et al., 1979).

Life history: Water lettuce reproduces rapidly by vegetative offshoots formed on short, brittle stolons. Rosette density varies seasonally, from fewer than 100 to more than 1,000 per square meter in South Florida (Dewald and Lounibos, 1990). Seed production, once thought not to occur in North America, is now considered important to reproduction and dispersal (Dray and Center, 1989). Water lettuce is not cold-tolerant (Holm et al., 1977). It can survive for extended periods of time on moist muck, sandbars and banks (Holm et al., 1977).

Distribution: Water lettuce is now one of the most widely distributed hydrophytes in the tropics (Holm et al., 1977). In North America it occurs in peninsular Florida and locally westward to Texas (Godfrey and Wooten, 1979). It is also found persisting in coastal South Carolina (Nelson, 1993). Water lettuce occurred in 68 public water bodies in Florida by 1982 and in 128 waterbodies by 1989 (Schardt and Schmitz, 1990). In the Everglades region, water lettuce is primarily restricted to canals and around water control structures. It also occurs in the artificial waterbodies of the Park.

Control: See water hyacinth "Control" section.

SECONDARY SPECIES OF CONCERN IN THE EVERGLADES PROTECTION AREA

Other exotic species of concern in the Everglades are primarily restricted to levee berms. These plants include Java plum (*Syzygium cumini*), earleaf acacia, (*Acacia auriculforms*), ficus (*Ficus microcarpa*), bishopwood (*Bischofia javanica*), guava (*Psidium guajava*), Surinam cherry (*Eugenia uniflora*), lead tree (*Leucaena leucocephala*), climbing cassia (*Senna pendula*), wild taro (*Colocasia esculenta*), lantana (*Lantana camara*), Burma reed (*Neyraudia reynaudiana*), napiergrass (*Pennisetum purpureum*), kudzu (*Pueraria montana*), schefflera (*Schefflera actinophylla*) and torpedograss (*Panicum repens*). Hydrilla (*Hydrilla verticillata*) and hygrophila (*Hygrophila polysperma*) are submersed, aquatic plants found primarily in canals and around water control structures.

Shoebutton ardisia (*Ardisia elliptica*) is a shade-loving shrub originally reported from the Hole-in-the-Doughnut (HID). It has spread into adjacent tropical hardwood hammocks in the Long Pine Key area of the Park (Seavey and Seavey, 1994) and was observed to have spread to the Flamingo Bay area in 1995 (Doren and Jones, 1997). Other species of concern in the Park are less widespread and are extremely variable in their distribution, the habitats they invade, and the size of their infestations. Several of these species have persisted from cultivation and have shown the ability to spread from their points of introduction. These species include sisal hemp (*Agave sisalana*), woman's tongue (*Albizia lebbeck*), orchid tree (*Bauhinia variegata*), mast wood (*Calophyllum antillanum*), Surinam cherry, lantana, lead tree, tuberous sword fern (*Nephrolepis cordifolia*), half flower (*Scaevola taccada*), ground orchid (*Oeceoclades maculata*), guava, oyster plant (*Rhoeo spathacea*), bowstring hemp (*Sansevieria hyacinthoides*), schefflera, arrowhead vine (*Syngonium podophyllum*), and tropical almond (*Terminalia catappa*). Infestations consist of scattered individuals, except in the case of sisal hemp, tuberous sword fern, ground orchid, oyster plant, bowstring hemp and arrowhead vine, all of which are species that spread vegetatively and produce locally dense populations. The coastal species mahoe (*Hibiscus tiliaceus*) and seaside mahoe (*Thespesia populnea*), as well as the grasses, cogongrass (*Imperata cylindrica*), Burma reed and napiergrass, have reached the Park by natural expansion from outside sources and are represented by single plants and dense colonies.

INFORMATION GAPS AND FUTURE NEEDS

Rudimentary elements of a good invasive exotic plant management strategy, including legislation, coordination, planning, research, education, training, and resource input, have been in place in Florida for many years. The plants identified above as being primary exotic invasive species in the Everglades region are being controlled to some extent by state or federal agencies. Unfortunately, there are dozens of other exotic species in the Everglades that have unknown distributions and invasive potentials.

Several agencies have also recognized the threat posed to South Florida by exotic invasive animals. Funding and multi-agency coordination for comparable nonindigenous animal management programs are greatly needed. Little can be accomplished without a committed effort to develop ecological understanding of the behaviors, spread, and effects of exotic animals in the Everglades.

Regardless of taxa, species' invasiveness is often somewhat slow to develop. Species that appear benign for many years, or even decades, can spread suddenly and rapidly following events, such as flood, fire, drought, long-term commercial availability, or other factors that can trigger invasiveness. To maximize management resources, these species must be recognized during their incipient phase or, ideally, prior to their introduction.

RESEARCH NEEDS

It is tempting to assume that once restoration is achieved, results will include a reduced need to control exotic species in the Everglades. However, while it is true that the spread of some exotic species can be reduced by increasing hydroperiods (e.g., Brazilian pepper), there has been little or no research to determine the effects that long-range hydrologic changes or nutrient reductions will have on most of the other exotic species throughout the Everglades system. Ongoing tree island research, for example, has focused on the effects of high water on but has completely ignored the effects of exotic plants, such as Old World climbing fern. Nutrient-enrichment studies have looked at changes to native flora but have excluded the study of exotics. Old World climbing fern, melaleuca and Brazilian pepper have successfully invaded areas with the least-apparent human alterations, including the mangrove zones of Southwest Florida and the Big Cypress National Preserve. Exotic plant communities in the Everglades Stormwater Treatment Areas (STAs) will need to be monitored and measured as changes are made to the system's hydrology. A more comprehensive approach is necessary when looking at the long-term restoration process regarding the exotic plant species composition response. It is also necessary to educate the public and policymakers about the fact that invasive exotic species will always require at least a minimum level of maintenance, and that new introductions of exotics must cease if the region is to avoid additional eradication costs.

Also, as previously mentioned, management of invasive animals remains a nascent field of study in the region, with little or no published material available to guide planners and resource managers.

MANAGEMENT EFFORTS

Economic impacts of invasive species in the Everglades Protection Area cannot be directly drawn from the literature. Studies documenting the expansion of some species imply that control would be less costly when populations are small (Laroche and Ferriter, 1992), but no direct analyses of the environmental and cultural costs and benefits of invasive plant control in the Everglades are available in the published literature. The lack of background information limits the strength of arguments supporting control of these pest species. Further, it might be argued that there is no need to study such obvious catastrophes, yet basic foundational research is often needed to construct convincing arguments. A few citations quantify the costs, impacts and benefits resulting from control of aquatic weeds in a few Florida waterbodies (Milon, et al., 1986; Colle et al., 1987), but none exist for wetlands, such as the Everglades Protection Area.

For many of the upland exotic plants, research has not focused on the most effective and current control methods. Specific controls for melaleuca, Brazilian pepper, and a few other species have been the subject of both formal and informal research. For the majority of other species, only general guidelines of herbicide use or mechanical controls apply. A wide range of unknowns remains for each species. Additional research might show, for example, how best to control each plant in various settings, how to minimize non-target damage, or whether treatments during different seasons or different stages of growth of each plant will affect results.

Ecological Impacts of Invasive Species

Relatively little work has been done to investigate the ecological impacts of invasive species in the Everglades Protection Area. While it is easy to visually observe the density of an invasive exotic plant in a natural area, the question of the effect of that density on wildlife has not been extensively studied. Without specific, published proof, resource managers can be somewhat "out on a limb" when arguing for support to manage invasive plants in the context of protecting the ecological integrity of natural areas. Little research has been done to look at the effect of invasive exotic plants on nesting, denning, roosting, feeding, and foraging by Florida's indigenous wildlife.

Melaleuca (Ostrenko and Mazzotti, 1981; Sowder and Woodall, 1985; O'Hare et al., 1997) and Brazilian pepper (Gogue, 1974; Curnutt, 1989) have been found to decrease wildlife species' diversity; however, such studies are rare in the published literature. More publications have come from management, monitoring, or botanical investigations (Ferriter, 1997; Laroche, 1999). For most of the other invasive plants found in the Everglades Protection Area, very few publications of even a general nature are available, and of these virtually none formally assess the ecological impacts of each species.

COORDINATION EFFORTS

Clearly, a need exists for a comprehensive plan that incorporates broad and consistent strategies, reduces agency inconsistencies, and takes into account differing agency mandates to achieve the goal of controlling invasive species. This would result in a strategy that is appropriate for, applicable to and coordinated with state and federal efforts to manage invasive species of plants and animals and which supports each agency in carrying out its role in the broader program of invasive species' control. It is hoped that, when complete, the NEWTT assessment and strategy will fill this need in the area of invasive plants. A similar effort is needed for non-indigenous animals in the EPA.

MANAGEMENT AUTHORITIES AND REGULATIONS

Although U.S. regulations on the import of exotic species in general are extensive, there is virtually no regulation against bringing many exotic plant species into the United States. Barring the primarily agricultural weeds on the Federal Noxious Weed list, importation laws focus on "plant pests" rather than on "pest plants." Insects and pathogens are extensively screened at U.S. ports of entry, but plants are allowed to enter the country virtually unimpeded. Up-front screening methods must be developed to control importation of exotic plant species. Australia and New Zealand have strict regulations regarding exotic plant importation. These countries have developed comprehensive "white lists" of plants that are permitted for import. Any plant that is not on the white list cannot enter either country without first undergoing a risk assessment. At a minimum, state and federal agencies importing plants for food, fiber or forage evaluation should have a protocol that screens plants for invasiveness prior to recommending new plant species for cultivation.

On the federal level, the Federal Department of Agriculture and Consumer Services (FDACS) Division of Plant Industry does much to assist in the control of invasive exotic plants in natural areas. However, in a regulatory context, plants on the FDACS noxious weed list are primarily listed because of their threat to agriculture, rather than any threat to native ecosystems. While the FDACS Division of Forestry combats a whole host of invasive exotic plants in its state forests, most of the flora it controls do not appear on the FDACS list.

In 1999, the FDACS amended its list to include eleven new species that are a threat to natural areas: carrotwood (*Cupaniopsis anacardioides*); dioscorea (*Dioscorea alata* and *Dioscorea bulbifera*); Japanese climbing fern; Old World climbing fern; Burma reed; sewer vine (*Paederia cruddasiana*); skunkvine (*Paederia foetida*); kudzu; downy myrtle (*Rhodomyrtus tomentosa*); and wetland nightshade (*Solanum tampicense)*. The addition of these 11 plants is an indication of a growing trend that the regulatory focus of agricultural rules and regulations is shifting to incorporate the protection of natural areas.

BETTER SUPPORT FOR BIOLOGICAL CONTROL

The process of isolating, testing and releasing a host-specific insect to control an invasive exotic plant in the United States can take more than a decade, as in the case of the melaleuca snout beetle. Once an insect has been properly selected and screened, it must be approved by a federal technical advisory group (TAG) and, in Florida, a state arthropod committee. Although such a process is clearly necessary, it can be extremely lengthy. The committee(s) typically set no deadlines for review, and the review process for each release request might not be a priority for staff at participating agencies, especially in the case of agents that target natural area weeds. The process must be streamlined and formalized. The final federal authorization for biological release comes from the USDA Animal and Plant Health Inspection Service. That approval process is often lengthy, as well.

Compounding the problem in Florida is a lack of specific biological control quarantine facility space for environmental weeds. The only quarantine facility currently available in Florida for this type of work is a small, outdated lab in Gainesville. Available space is shared with researchers screening biological controls for agricultural pests. This space limitation has restricted the number of biological agents researchers can study, creating an extensive backlog. After years of struggle, construction of a new quarantine facility is underway at a USDA site in Davie, Florida. This is a positive step forward in light of the overwhelming need for additional biological control research.

PUBLIC/PRIVATE PARTNERSHIPS

Invasive exotic species recognize no political boundaries. Natural resource managers increasingly recognize that the application of parochial management approaches to these problems are ineffective. Without a regional approach, effective containment of a pest plant is impossible. A regional approach has proven successful with the management of melaleuca on public lands. However, adjacent privately held lands continue to harbor melaleuca. Without incentives for private landowners to remove melaleuca, these contaminated lands will be a seed source for neighboring public lands for years to come. It is hoped that the newly funded, region-wide TAME Melaleuca project will serve as a model for other species-based control programs. Policymakers are beginning to acknowledge that comprehensive invasive species' management will require either the expenditure of public monies on private lands, or property tax breaks that provide a financial incentive for control.

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