Chapter 8E: Exotic Species in the Everglades Protection Area

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INTRODUCTION

Invasive exotic species have become one of the most serious global environmental problems today (IUCN, 1999). A recent Cornell University study found that invasive species – plants, mammals, birds, amphibians, reptiles, fish, arthropods, and mollusks – cost the United States alone over $100 billion annually (Pimentel, 2000). Such losses and costs will inevitably continue to increase, especially if efforts to control these invasions are scattered. Planning, resources, and actions must be integrated effectively in order to turn back the overwhelming spread of numerous invasive species.

Florida is listed with Hawaii and California, and now Louisiana, as one of the states with the greatest number of nonindigenous species. South Florida contains more introduced animals than any other region in 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 nonindigenous faunal communities in the world (Gore, 1976; Ewel, 1986; OTA, 1993; McCann, et al., 1996; Shafland, 1996a; Simberloff, 1996; Corn et al., 1999). More than 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 great number of plans, reports, statements, and papers that have been written by numerous committees, state and federal agencies, public and private universities, state and federal task forces, and various other organizations. Most of the plans, reports, statements, and papers support an "all-taxa" approach.

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The general consensus of these parties is that control and management of nonindigenous species is a critical component 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. Several organized efforts and mandates have highlighted the problems associated with exotic species in the Everglades region. Control and management of invasive exotics are the priorities established by the South Florida Ecosystem Restoration Task Force (SFERTF) in 1993. One of the tasks 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) was designated as the lead agency for this strategy and submitted a brief report (Carroll, 1994). This report 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 are deficient, (3) responsibilities remain vague, (4) there is a general lack of awareness and knowledge of the harmful impacts of invasive species, and (5) an urgent need exists for statewide coordination and cooperation to eliminate exotics. The greatest obstacle to combating nonindigenous species, as identified in this report, was the lack of sufficient funding, knowledge, and staffing to stay ahead of problems.

The first Annual Report of the South Florida Ecosystem Restoration Working Group (SFERWG) in 1994 addressed all nonindigenous species, plants, and animals. The overall objectives stated were to (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 of 1994 (EFA) requires the South Florida Water Management District (SFWMD or District) to establish a program to monitor invasive species populations and to coordinate with other federal, state, and local governmental agencies to manage exotic pest plants, with an emphasis in the EPA.

The Scientific Information Needs Report (SSG, 1996) of the SFERTF contains a regionwide chapter on harmful nonindigenous species. One of the overall regional science objectives for the restoration is to develop control methods on exotic invasives at entry, distribution, and landscape levels. The specific objectives for work on nonindigenous species are to (1) halt and reverse the spread of invasive naturalized exotics, and (2) prevent invasions by new exotic species. The major issues in South Florida are inadequate funding for scientific investigations to develop effective controls, lack of funding to apply control methods to problem species, and delays and lack of consistency in responses to new problems. Most resources on nonindigenous animals have been focused on agricultural pests, with little investigation of species that threaten natural areas. Particular information needs are as follows: (1) studies to develop control technology, (2) basic biological and ecological studies to improve understanding of invasive exotic species (e.g., how water management alterations will affect nonindigenous plants and animals), (3) what are the principal controls on expansion of a species, (4) what are the impacts of invasive species on native species and ecosystems, (5) what makes a natural area susceptible to invasion, and (6) screening and risk assessment technology to help focus on the greatest potential problems. Overall, the major issue is the lack of meaningful information concerning the effects of nonindigenous 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 preclude any serious consideration of achieving true restoration of the natural system, one in which exotic species are not present. It discusses how removal of canals and levees, which act as deepwater refugia for exotic fish and as conduits into interior marshes for other species, is expected to help control exotic species by slowing further 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, and this must be addressed during detailed design.

The Fish and Wildlife Coordination Act Report for the Comprehensive Everglades Restoration Plan (CERP) (FGFWFC, 1999) from the Florida Game and Fresh Water Fish Commission (currently known as the Florida Fish and Wildlife Conservation Commission [FWC]) also considers the control and management of nonindigenous species as a critical aspect of ecosystem restoration in South Florida. The report discusses the effects of the present canal and levee system and of the preferred alternative of this system on the distribution of nonindigenous animals. Some CERP components involve the 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, a process 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 species such as the fire ant. The U.S. Department of the Interior (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 CERP. In relation to planned Water Preserve Areas (WPAs) and flow-ways, it was recommended that an aggressive plan be developed for the perpetual removal of invasive exotics, both plants and animals. It was also recommended that existing control measures should be accelerated, more effective techniques should be developed, and regulations should be revised and better enforced to prevent additional introductions of exotic species (FGFWFC, 1999). The U.S. Army Corps of Engineers and the District (USACE and SFWMD, 1999) responded that in CERP this recommendation (for team establishment) should be presented to the SFERTF.

Several other plans and reports also address exotic invasive species. The Coordination Act Reports (FGFWFC, 1999) 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, 1999) 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 their introductions 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. Jeb Bush, governor of the state of Florida, charged this group with developing a comprehensive invasive species plan for state agencies. The plan is complete, and the group will begin implementation after it is accepted by the governor. In a separate but complimentary program, the FDEP also administers funding for invasive plant control efforts in Florida through regional working groups.

In 2002, the USACE authorized a conceptual plan for a multimillion-dollar Invasive Species Management and Control project to be implemented as part of CERP. The main components of this project include cost-share agreements to improve quarantine facilities for biocontrol agents, a cost-share project with the District for the release of biological-control agents, and preparation of a report to detail federal interest and potential federal involvement in invasive species projects within South Florida.

On a national level, the U.S. President's Executive Order on Invasive Species (Executive Order 13112) recognized the threats posed by invasive species and authorized a national invasive species council that would, among other duties, prepare a national management plan for invasive species. This plan was finalized and released in 2001. Implementation of this plan is ongoing through the National Invasive Species Council, which is chaired by the secretaries of agriculture, commerce, and the interior.

NONINDIGENOUS PLANT SPECIES

The South Florida Ecosystem Restoration Task Force and Working Group identified nonindigenous plants as a priority. As a result, the Noxious Exotic Weed Task Team (NEWTT) was established in 1997. NEWTT is a direct working team of the South Florida Ecosystem Restoration Task Force and Working Group. This task team has the following two main directives: (1) the development of an assessment to characterize the current problems with invasive exotic plants in southern Florida and to identify the highest priority invasive species for control, and (2) the development of a comprehensive interagency strategy for elimination or control of the highest priority species and for management to control and minimize the spread of other pest plant species.

The task team is made up only of government agencies – federal, state, and local. To comply with the Federal Advisory Committee Act and Florida's Sunshine Law, all NEWTT meetings are open to the public. While nongovernmental organizations are not an official part of the NEWTT, the Florida Exotic Pest Plant Council (EPPC) provides advice and peer review to the task team.

NEWTT developed a comprehensive strategic plan covering the issues and problems of exotic pest plants in Florida, with programmatic and management focus on the Everglades. However, a statewide perspective was used in developing this strategic plan, because any plan that addresses the issues of exotic pest plants cannot do so in a fragmented geographic or political framework. Federal, state, and local governmental policies affect, interact, and sometimes contradict one another, and therefore must be addressed synthetically. In addition, the issues and experiences learned regionally (regarding control method development, research results, public education, technology transfer, policy, regulation, and funding) affect all agencies and programs throughout the state. Likewise, national-level issues related to exotic pest plants affect state and local policies and programs. The USACE is entering into an agreement with NEWTT to develop a report on federal invasive species interests in Florida.

NONINDIGENOUS 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 nonindigenous plants invade natural areas, the impact of nonindigenous animals on native communities and on those species with which they compete directly is often less obvious (Schmitz and Brown, 1994). Several reports have highlighted this difficulty as follows:

- The Multi-Species Recovery Plan (USFWS, 1999) states the following: "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) states the problem as follows: "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 the following:

> 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 these daunting conclusions, the South Florida Ecosystem Restoration Task Force and Working Group has been gathering information that is available as a basis for an assessment of the problem. In February 1998, the South Florida Ecosystem Restoration Task Force and Working Group established an ad hoc interagency team to focus on South Florida and evaluate the status of nonindigenous animals in all habitats (freshwater, marine, and terrestrial), describe efforts underway to deal with them, and identify agency needs and problems (Goodyear, 2000).

Nonnative animal species of concern include insects, marine and freshwater fish, invertebrates, reptiles, amphibians, mammals, and birds. Species currently identified as the 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 (*A. 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 established a Noxious Exotic Animal Task Team (NEATT) in 2003. This group convened and is developing a nonnative animal report to provide a broad picture of the status of nonindigenous animal species in South Florida. It will focus on the agencies, along with their respective departments, that are represented on the South Florida Ecosystem Restoration Task Force and Working Group. This report is to be used as a basis for the South Florida Ecosystem Restoration Task Force and Working Group to evaluate its members' priorities relative to nonindigenous animals and to determine if and how it 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 EPA since 1990. This close coordination has resulted in detailed, species-based management plans (Melaleuca Management Plan, Brazilian Pepper Management Plan, and Lygodium Management Plan) and a maximization of all available management resources. In addition, the District has been required since 1979 to get permits from the FDEP for all vegetation management activities in public waters. The permit process has helped to bring peer review as well as statewide consistency to management approaches. Within the EPA, floating aquatic plant control in canals has been coordinated with the USFWS and the Everglades National Park (ENP or Park) since the early 1970s. Specifically, this relates to water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia statiotes*) spraying and/or harvesting in and around the S-10 and S-12 structures and within the L-7, L-39, L-40, and L-29 canals. Currently, the District does not have dedicated staff or funding to coordinate efforts and control nonindigenous animals within the EPA.

INVASIVE PLANT MANAGEMENT TOOLS

Many different techniques are used to control exotic invasive plants within the EPA. Biological controls, chemical controls, 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. More detailed descriptions of each of these methods are presented below. Specific species-level controls are discussed in the "Priority Species" section of this chapter.

Biological Control

Plants are often prevented from becoming serious weeds in their native range by a complex assortment of insects and other herbivorous organisms. When a plant 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 serious 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 are the performance steps of a classical biological control investigation:

1. Identify the target pest and prepare a report outlining the problem conflicts, 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
4. Conduct preliminary host-range tests on the most promising candidate in the native country in order to obtain permission to import 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 Technical Advisory Group of the U.S. Department of Agriculture (USDA) for permission to release into the United States, and obtain permission from necessary state agencies
7. Culture agents that are approved to have sufficient numbers to release at field sites, and test release strategies to determine the best method
8. Monitor field populations of pest plants to:

   a) Determine if biocontrol agent establishes self-perpetuating field populations

   b) Understand plant population dynamics to have a baseline to measure bioagent effects, especially if they are sublethal and subtle, and to know what portions of life history to watch
9. Study effectiveness of the agents for controlling the target plant, and monitor plant populations with and without the agent to determine impacts of the agent
10. Study means of integrating biocontrol into overall management plans for the target plant

In Florida, classical biological control of invasive nonnative plants in nonagricultural areas has focused on aquatic weeds. The first biocontrol agent introduced was the alligatorweed flea beetle (*Agasicles hygrophila*) in 1964 for control of alligatorweed (*Alternanthera philoxeroides*). Subsequently, the alligatorweed thrips (*Aminothrips andersoni*) was released in 1967 and the alligatorweed stem borer (*Vogtia malloi*) in 1971. The flea beetle and stem borer proved to be fairly effective for suppressing growth of alligatorweed, although 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, effectiveness of a weevil (*Neohydronomous affinis*) and a moth (*Namangama pectinicornis*) released for control of water lettuce has been unpredictable. Water hyacinth and water lettuce continue to require management by other methods, such as herbicide and mechanical harvesting. Current biological control research is focused on water hyacinth, hydrilla (*Hydrilla verticillata*), melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolious*), and Old World climbing fern (*Lygodium microphyllum*).

Melaleuca snout beetles (*Oxyops vitiosa*) are damaging melaleuca stands and are 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 and *Lygodium* insects and additional melaleuca-damaging insects may be approved for release in Florida within a period of years. Overseas surveys and host-specificity screening for additional agents is ongoing.

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

Herbicides

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

Herbicide Application Methods

Foliar applications. A herbicide is diluted in water and applied to the leaves with aerial or ground equipment. Foliar applications can either be directed, to minimize damage to nontarget vegetation, or broadcast. Broadcast applications are used where damage to nontarget vegetation is not a concern or where a selective herbicide is used.

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

Frill or girdle (sometimes called hack-and-squirt) applications. Cuts into the cambium are made completely around the circumference of the tree, with no more than 3-inch intervals between cut edges. Continuous cuts (girdle) are sometimes used for difficult-to-control species and for large trees. Herbicide (concentrated or diluted) is applied to each cut until the exposed area is thoroughly wet. Frill or girdle treatments are slow and labor intensive, but they are sometimes necessary in mixed communities to kill target vegetation and to minimize impact to desirable vegetation.

Stump treatments. After cutting and removing large trees or brush, an 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 herbicide solutions. The cambium is next to the bark around the entire circumference of the stump. When using dilute solutions, the entire stump is sometimes flooded (depending on label instructions) with herbicide solution.

Soil applications. Granular herbicide formulations are applied by handheld 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 cause harm to humans or to the environment unless it is applied by certified applicators that have the knowledge to use the pesticide safely and effectively. Although none of the herbicides commonly used for invasive plant control in the Everglades are classified as restricted-use, the basic knowledge of herbicide technology and application techniques that are needed for safe handling and effective use of any herbicides can be obtained from restricted-use pesticide certification training. All District applicators and contractor supervisors are required to obtain and maintain this certification before applying herbicides in the EPA.

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 use of the product will not present unreasonable risk to humans or to the environment.

The USEPA approves 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 have 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." Rodeo® is registered for aquatic use and can be applied directly to water. Certain, but not all, products that contain 2,4-dichlorophenoxyacetic acid (2,4-D) can also be applied directly to water. The state supplemental "special local need" (SLN) label for the imazapyr-containing product, Arsenal® (USEPA SLN NO. FL-940004) allows government agencies and their contractors to use it to control melaleuca and Brazilian pepper growing in water. An SLN label was also obtained for Escort® (Metsulfuron methyl) herbicide in 2003. This herbicide will be used by government agencies to treat Old World climbing fern.

Herbicide Toxicity to Wildlife

Invasive plant management is often conducted in natural areas to maintain or restore wildlife habitat. Therefore, it is essential that the herbicides are not toxic to wildlife. Herbicides used for invasive plant control in the Everglades have shown very low toxicity to the wildlife they have been tested on, with the exception of the relatively low LC_{50} of triclopyr ester (0.87 parts per million [ppm]) and fluazifop (0.57 ppm) for fish, neither of which can be applied directly to water. Ester formulations are toxic to fish because of irritation to fishes' gill surfaces. However, because triclopyr ester and fluazifop are not applied directly to water, are adsorbed by soil particles, and have low persistence, exposure is low, which results in low risk when properly used.

Manual and Mechanical Removal

Manual removal is very time consuming, but it is often a major component of effective invasive plant control. 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 will often resprout, and even small root fragments left in the ground may sprout. Repeated hand pulling or follow-up with herbicide applications are often necessary. Removal of uprooted plant material is important. Stems and branches of certain species (e.g., melaleuca) that are left on the ground can sprout roots, and attached seeds can germinate. If material cannot be destroyed by methods such as burning, then it should be piled in a secure area that can be monitored, and new plants should be killed as they appear.

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

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

Cultural Practices

Prescribed burning and water level manipulation are cultural practices that are used in management of pastures, rangeland, and commercial forests. In some situations, they may be appropriate for vegetation management in natural areas. Land use history is critical in understanding the effects of fire and flooding on the resulting plant species composition. Past practices may have affected the 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 may achieve very different results. Even less is known about the effects of invasive species entering these communities or about the subsequent management effects of fire on the altered communities.

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

Prescribed Burning

Fire is a normal part of most of Florida's ecosystems, and as a result native species have evolved 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 be best used to suppress invasive species. Single fires in areas with 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 of fires spreading to inhabited areas. In these situations, the use of fire to reduce standing biomass of invasive species may better protect the remaining plant populations than by doing nothing, even though impacts to nontarget native species will occur.

Water Level Manipulation

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

In most situations, water level manipulation in reservoirs has not provided the level of invasive plant control that was once thought achievable. Ponds and reservoirs can be constructed with steep sides to reduce habitat invasion, 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 subsequent germination, and, with some exotic species, resprouting.

PRIORITY SPECIES

As required by the EFA, the District assembled a meeting in 1996 with representatives from the FDEP, USACE, USFWS, and the National Park Service (NPS – specifically, 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 to be greatest threat to the Everglades. This list was not derived from the Florida EPPC list of Category I invasive plants; rather, it was a collaborative effort to identify "priority species" for the EPA. Several factors were considered in evaluating these plant species as follows:

- 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 (e.g., hydroperiod, fire regime) of the EPA?
- Is the species widespread in the EPA? If not, does the species have the potential to expand rapidly?
- 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, cajeput, punk tree, white bottlebrush tree

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

Origin: Australia, New Guinea, and Solomon Islands

Family: Myrtaceae, Myrtle Family

Botanical Description: Evergreen tree to 33 m tall, with a slender crown and soft, whitish, many-layered, peeling bark. Leaves are alternate, simple, grayish green, narrowly lance shaped, to 10 cm long and 2 cm wide, with a smell of camphor when crushed. Flowers 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 colonization.

Melaleuca was introduced to Florida in 1906 (Fairchild, 1947) and was scattered aerially over the Everglades in the 1930s to dry up "useless swampland" (Austin, 1978). It 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. Melaleuca was recommended as late as 1970 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 it 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 approximately 1 to 2 m per year, resprouts easily 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. It 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, which cause respiratory irritation, asthma attacks, headaches, and/or rashes in some people (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 from natural areas in 16 Central and South Florida counties (EPPC, 1996). Melaleuca grows equally well in the deep peat soil of Water Conservation Area 1 (WCA-1) and in the inorganic, calcareous soil of the 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 interior of the Park and WCA-2A. Light to moderate infestations occurred in WCA-3 and the western edge of the East Everglades Addition (EEA). Moderate to heavy infestations occurred in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Big Cypress National Preserve, WCA-2B, Lake Okeechobee, and wetlands in 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. Melaleuca's potential spread in South Florida is considered by some experts to be unlimited, ultimately encroaching on all open land (Hofstetter, 1991a). Others believe it will be limited to underutilized niches in the relatively young Florida landscape (Myers, 1975). However, both views share a common thread, that is, melaleuca needs to be controlled whether or not it could ultimately cover the peninsula.

To be effective, the integrated management of melaleuca requires a combination of control techniques. Essential elements of effective management include herbicidal, mechanical, physical, and biological control. Comprehensive descriptions for each of these management techniques are located in the "Invasive Plant Management Tools" section of this chapter.

The melaleuca management program is based on the quarantine strategy as described by Woodall (1981). The least infested areas (outliers) are addressed first in order 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 the following years to remove seedlings resulting from control activities of the previous years. A successful control operation consists of three phases as follows:

- **Phase I:** Focus on the elimination of all mature trees and seedlings present in an area

- **Phase II:** Previously treated sites are revisited for follow-up treatment to control trees previously missed and to remove seedlings that may have resulted from control activities of the preceding year
- **Phase III:** Long-term surveillance and inspection of previously treated sites to monitor the effectiveness of the control program and to maintain reinfestation levels as low as possible

Single-tree herbicide applications are most commonly delivered as a frill-girdle or cut-stump treatment. The Refuge and the Park programs favor the cut-stump technique because trees are felled, limiting the subsequent seed dissemination. The District uses a combination of two individual 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, mitigating navigation hazards. The disadvantage is that the seed pods dry, and seeds can be windblown for several hundred feet from the treatment site.

The District and the Park also use aerial applications of herbicides to control large monocultures. This provides cost-effective control in areas where nontarget damage is minimized. Control of outlier trees is coordinated with the aerial treatment and the trees are typically treated by ground crews, as described above.

Direct herbicide application can still result in nontarget effects where tree densities are high. Aerial application of herbicides may, in some cases, cause less nontarget damage to native and herbaceous groundcover. It also may result in less herbicide being used on a site and, in some situations, may lower the cost of initial treatment. Manual removal of seedlings may not be advisable in all situations due to the percentage of roots broken below the ground surface. In addition, the soil disturbance that results may stimulate more seeds to germinate. Mechanical removal using heavy equipment is best suited for rights-of-way and other similar areas where routine maintenance follows and site disturbance is not a concern.

A key component of an effective and long-lasting melaleuca management program is the introduction of biological control agents. Without biological control, melaleuca elimination will be much more expensive and could not be truly integrated. The first releases of a melaleuca snout beetle began in April 1997. As of August 2003, more than 18,000 larvae and 210,000 adults have been released at 150 different locations in twelve counties. Melaleuca snout beetle larvae are flush feeders, consuming the seasonal flush of newly developed, expanding leaves at branch tips. Severe larval feeding results in tip dieback, defoliation, and reduced flowering. In recent studies, for instance, an 80-percent reduction in flowering was observed among damaged melaleuca trees as compared to a similar undamaged group. The melaleuca snout beetle is the first of a suite of insects that is being studied for release.

The second melaleuca biocontrol agent was released from quarantine in February 2002. Approximately 350,000 psyllids (*Boreioglycaspis melaleucae*) have now been released, and the agent has established at 23 sites in South Florida. Populations are building quickly and have spread as much as 20 miles from the release points. Nymphs suck the plant juices and inject a phytotoxic saliva that kills the tissue surrounding the feeding site. Although only a short time has elapsed since the release of the insect, preliminary data have shown that psyllid attack results in a 60-percent mortality rate among seedlings after a single year of introduction. Entomologists analyzing the problem estimate that four to five insect species will be required to effectively suppress melaleuca's invasive capacities.

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

Through regional control efforts, steady progress has been made. Today, large untreated monocultures of melaleuca are limited to WCA-2B, the Refuge, the EEA, 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) was established under the USDA Agricultural Research Service's (ARS) Areawide Pest Management grants initiative. The goal of this five-year interagency project is to demonstrate the effectiveness of an integrated approach for the control of melaleuca that can be applied in the invaded habitats in the United States and beyond. As described above, current control efforts concentrate on an individual tactic, with little integration of alternative approaches. This project represents an areawide demonstration of multiple control tactics and their combined effectiveness. Land managers will have an opportunity to view different strategies in real-life settings and to adapt techniques to address site-specific melaleuca problems. Funding associated with this grant will allow work to be initiated on private lands, defraying the cost of melaleuca control for private landowners.

The TAME Melaleuca team has selected six demonstration sites and will be distributing limited funds to selected locations to develop demonstration sites in 2004. Project leaders are working 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 may 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 they otherwise might consider too complicated, costly, or risky.

Lygodium microphyllum

Common Name: Old World climbing fern

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

Origin: 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, 5-12 cm long. Leaflets (pinnules) usually unlobed, stalked, articulate (leaving wiry stalks when detached). Leaf-blade 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 (*L. japonicum*) is native to temperate and tropical Asia. It occurs from eastern Texas through the southern states to North

Carolina and northern Florida. Japanese climbing fern has not yet been found within the EPA. Old World climbing fern has reached a critical mass in South Florida such 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 seriously alters fire ecology, which is important to maintaining Florida habitats. Prescribed burns and wildfires that normally stop at the margins of flooded cypress sloughs will burn through areas infested with this fern. Burning mats of this lightweight fern break free during fires and are kited away by heat plumes, leading 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. Old World climbing fern has caused the loss of some canopy trees with such crown fires, as well as a loss of 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 act as a site for additional fern colonization. It is difficult for other plant species to grow through the dense mat made by this fern, thereby 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 or more meters thick above native soil. Vegetative growth and production of fertile pinnules continues throughout the year. Spores can germinate in about 6 to 7 days, and 5-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 in the wind-borne dispersal of the spores. Old World climbing fern often establishes first at pineland/wetland ecotones. It is usually killed back by fire but not eliminated, and regrowth is common (Maithani et al., 1986).

Distribution: The center of dispersal in Florida is reported by Beckner (1968) and by Nauman and Austin (1978) as the Loxahatchee River basin in southern Martin and northern Palm Beach counties. By 1993, the fern expanded into western Martin County and central Palm Beach County. It is now spreading rapidly throughout the southern part of the state. Results from the 1993 District regional survey showed 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); 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 with this plant. Recent reports indicate that the fern is spreading south through WCA-2 and WCA-3. A large infestation totaling approximately 1,000 acres was discovered in the western coastal areas of the Park in 2000. By August 2003, this population expanded to cover more 10,000 acres of coastal scrub prairie (Tony Pernas, pers. comm.). Populations were also reported in the Collier-Seminole State Park, the Fakahatchee Strand State Preserve, the Florida Panther National Wildlife Refuge, the Ten Thousand Islands National Wildlife Refuge, and on the boundary of Biscayne National Park. Big Cypress National Preserve populations are expanding in and are now found throughout northern portions of this preserve.

An increased hydroperiod does not seem to have an effect on this species, as it has expanded greatly in areas that have experienced several years of higher-than-normal water levels. This species is not restricted to elevated Everglades tree islands; 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 Florida and Central Florida within the next decade (Ferriter, 1999a).

Control: Control options are only now being explored. A biological control program funded by the District has been implemented, 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. When fire kills most aboveground portions of this vine, it does not kill the plant. It also appears that flooding will not kill this plant, although 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 nontarget native plant communities. Preliminary results from winter treatments of Old World climbing fern in deciduous plant communities (e.g., *Taxodium*) show promise. In 2000, the Park and the District partnered to conduct a large-scale aerial treatment of Old World climbing fern in the remote western Everglades. In 2001, the District conducted experimental applications of herbicides on evergreen Everglades tree islands in the Refuge. Results of these treatments are monitored to assess treatment efficacy and nontarget damage. 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. The USEPA granted Florida governmental agencies a "special local needs" label for Escort® (Metsulfuron methyl) herbicide. It is hoped that this herbicide will provide selective control of Old World climbing fern in native plant communities.

Schinus terebinthifolius

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

Synonymy: None

Origin: Brazil, Argentina, Paraguay

Family: Anacardiaceae, Cashew Family

Botanical Description: Evergreen shrub or tree to 13 m tall, often with multistemmed trunks and branches arching and crossing, forming tangled masses. Leaves alternate, odd-pinnately compound with 3 to 11 (usually 7 to 9) leaflets, these elliptic-oblong, 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; petals five, 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). It has bright red fruits and shiny green leaves that increased its popularity as a substitute for holly in Florida, quickly earning the misnomer Florida holly (Morton, 1971a). Its fruits are commonly consumed by frugivorous birds. The dispersal of seeds by these birds – namely, mockingbirds, cedar waxwings, and especially migrating robins – has been responsible for the spread of this species into outlying, non-Brazilian pepper-dominated ecosystems, especially those that include perches, such as trees and utility lines (Ewel et al., 1982). Raccoons and opossums are known to ingest the fruits, with the animals' stools providing 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. It is found in areas with a high degree of disturbance as well as 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*), a state and federally listed endangered species), and beach star (*Remirea maritima*), a state listed endangered species.

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

Distribution: Brazilian pepper is naturalized in most tropical and subtropical regions, including Brazil and 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 it rarely grows on sites inundated longer than three to six months. For example, it is absent from marshes and prairies with hydroperiods exceeding six months, as well as from tree islands with closed canopies, in the Park (LaRosa et al., 1992). However, Brazilian pepper can tolerate extended periods of shallow-water inundation once it is established. The effects of deepwater flooding on established Brazilian pepper populations are unclear.

Concern over the occurrence of Brazilian pepper in salt-tolerant plant communities (e.g., mangrove forests in southern Florida, especially in the Park) led Mytinger and Williamson (1987) to investigate its tolerance to saline conditions. Seed germination and transplanted seedlings did not succeed at salinities of 5 parts per thousand (ppt) or greater, which would largely exclude it from becoming established in mangrove forests. Invasion of saline communities can occur, however, 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 tree islands of WCA-1 have been colonized to varying degrees by this species. By far the greatest areal coverage of Brazilian pepper within the EPA is an area known as the Hole-in-the-Doughnut (HID). Situated within the boundaries of the Park, the HID comprises approximately 4,000 hectares of previously farmed lands (farming ceased in 1975). More than 40 percent (1,600-plus hectares) of this area has been invaded by a dense forest of Brazilian pepper. This species also has infested more than 40,000 hectares in the isolated Ten Thousand Islands and is widely scattered throughout the Park, occurring in all habitats, particularly disturbed areas. Brazilian pepper is now estimated to occupy more than 400,000 hectares in Central Florida and South Florida (Ferriter, 1997; Wunderlin et al., 2000).

Control: Park scientists have researched a number of restoration techniques over the years. Only the complete removal of the disturbed substrate has resulted in recolonization by native vegetation to the exclusion of Brazilian pepper. The Park initiated a full-scale substrate removal project for the entire HID in 1996. To date, 8 percent of the Brazilian pepper forest has been restored. Currently, the project is funded through 2016.

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

Biological controls have not yet been approved for general release against Brazilian pepper, although District-sponsored research is ongoing. The University of Florida's Department of Entomology and Nematology has been investigating insect vectors of Brazilian pepper since 1994. From exploratory surveys conducted in Brazil, several insects have been identified as potential biological control agents. Three insect species – a thrips (*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 was submitted to the federal Technical Advisory Group in 2003.

Casuarina equisetifolia, Casuarina glauca

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

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

Origin: Australia, South Pacific Islands, 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 (< 1 mm wide), 10 to 20 cm long, minutely ridged, hairy in furrows. Leaves reduced to tiny scales, 6 to 8 in whorls encircling joints of branchlets. Flowers unisexual (monoecious), inconspicuous; female in small axillary clusters, male in small terminal spikes. Fruit a tiny, one-seeded, winged nutlet (samara) formed in woody, cone-like clusters (fruiting heads), brown, to 2 cm long and 1.3 cm wide.

Ecological Significance: Australian pine was introduced to Florida in the late 1800s (Morton, 1980). It naturalized since the early 1900s along coastal dunes (Small, 1927). Australian pine was planted extensively in the southern half of the state as windbreaks and shade trees (Morton, 1980). It is salt tolerant and seeds freely throughout the 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, and it can interfere with the nesting of endangered sea turtles and the American crocodile (Klukas, 1969).

Three species of Australian pine trees invade Florida's wildlands. Since the introduction of the trees in the late 1800s, they have been widely planted throughout the southern peninsula. It was not until 1992 that the state banned the further propagation and sale of these trees as ornamentals. Australian pine grows very fast (approximately 1 to 3 meters per year); is salt tolerant; readily colonizes rocky coasts, dunes, sandbars, and islands; and invades far-inland, moist habitats such as the EAA (Morton, 1980). It 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 topples in high winds (Morton, 1980). Australian pine produces allelopathic compounds that inhibit growth of other vegetation (Morton, 1980), and it can colonize nutrient-poor soils easily by nitrogen-fixing microbial associations (Wilson, 1997). It reproduces prolifically by seed – as many as 600,000 seeds per kilogram – with seeds dispersed by birds (especially exotic parrots and parakeets), water, and wind (Morton, 1980). Also, the fruiting heads of this species are able to float (Maxwell, 1984).

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

Australian pine is mainly a problem along levee berms in the WCAs. A large portion of the east Everglades and the southern saline glades (C-111 basin), as well as coastal areas of the Park, are heavily impacted. The seeds are windblown, carried by birds, and probably moved throughout the EPA via water flow in canals. Australian pine has a microbial association with nitrogen-fixing organisms, and this allows it to colonize and grow prolifically in nutrient-impoverished soils. With this nitrogen-fixing capacity and a lack of natural enemies, Australian pine has a tremendous competitive edge over natural vegetation. Until recently, Australian pine was the dominant tree species growing along the canal levees of the EPA. The largest remaining populations of Australian pine in the EPA are the original plantings growing along State Road 27 (S.R. 27) in Broward County and wild populations growing in the EEA.

Control: Fire is sometimes effective in dense stands with sufficient fuel (tinder) on the ground. Larger trees usually resprout from the bases and require some form of follow-up herbicide treatment. There is no biological control research being conducted at this time, even though Australian pine is a good candidate for this control method. It is not likely 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 seed bank. Retreatment is conducted prior to saplings maturing and flowering in order to deplete the existing seed bank. The District, the NPS, and the FDEP have entered into a Feasibility Study with the USDA to evaluate the potential for developing biological controls for this species in 2004.

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 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 by eastern Asian immigrants in the 1850s 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 by (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 such as mahogany, thatch palm, wild cinnamon, manchineel, cacti, bromeliads, and orchids (Jones, 1996). It is also currently in every park in the Florida Keys, where it threatens rare, native species 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). It forms adventitious roots where branches touch the ground, and it vigorously resprouts from cut or injured stems. This species may reach seed-producing maturity within a year (Russell et al., 1982; Schultz, 1992). It flowers in Florida most often 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 at least 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, southeastern Asia, tropical Australia, and the Pacific Islands, including Hawaii, where it typically occurs as scattered plants on sandy and rock seashores (Brizicky, 1964; Johnston, 1971; Tomlinson, 1980). From Jamaica, it has spread in the New World to other Caribbean islands, Mexico, and Florida with the aid of ocean currents and storm tides (Russell et al., 1982). In Florida, it is now naturalized 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 the 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 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 in area were observed along the coast of Florida Bay (Russell et al., 1982). In 1974, Park staff reported 130 hectares 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 hectares of high-density stands (Olmsted et al., 1981). Interpretation of 1987 color infrared aerial photographs (1:10,000 scale) of the Park by Rose and Doren (1988) showed that the areal extent of medium- to high-density latherleaf along the same stretch of coastline (Snake Bight to Joe Bay) was 230 hectares. Photo interpretation of the 1994/95 U.S. Geological Survey National Aerial Photography Program (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 hectares for the same area. An 84-percent increase in latherleaf extent over the seven-year period was reported. From this mapping data, it can be estimated that the areal extent of latherleaf may double every 10 years, spreading at the rate of approximately 25 hectares 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 not currently available – a situation that is not likely to change anytime soon. To date, management efforts within the Park have been restricted due to 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 is a showy spike above rosette, to 30 cm long. Flowers lavender-blue with a yellow blotch, to 5 cm wide, somewhat two-lipped; petals 6, stamens 6. Fruit a three-celled capsule with many seeds.

Ecological Significance: Water hyacinth is reported as a weed in 56 countries (Holm et al., 1979). It was introduced to 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 occupied about 51,000 hectares of Florida's waterways (Schmitz et al., 1993). It grows at explosive rates, exceeding any other tested vascular plant (Wolverton and McDonald, 1979), doubling its populations in as little as 6 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; with stolons easily broken, the plants and mats are transported by wind and water. Leaves are killed back by moderate freezes, but they quickly regrow from the stem tip protected beneath the water surface. It 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 also further north and south where it can escape severe cold (Holm et al., 1977). It is found throughout Florida, north to Virginia (and New York) and west to California and Hawaii – 16 states in all (USDA, 1997).

Under ideal growing conditions, these plants can increase their surface coverage by 25 percent per 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 of the water control structures. In addition, water hyacinth can often be found growing at the mouth of airboat trails that transect the canals. However, the plants do not appear to compete with native vegetation in the EPA away from these disturbed environments.

Control: Water hyacinth and water lettuce both are free-floating aquatic plants. They cause similar problems and are managed in a like manner. Consequently, control methods for both species are discussed together in this section.

The District conducts operations under permit from the FDEP and performs all work in accordance with both federal and state regulations. The District's primary goal is to implement a "maintenance control program." Chapter 372.925, Florida Statutes (F.S.) 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 the use of fewer herbicides, the deposition of less organic matter (from dead leaves and plants), less overall environmental impact by weeds, and reduced management costs.

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

Mechanical harvesting cannot be considered a stand-alone option for floating weed management in the EPA canals. While insects have been introduced as biological controls for both species, they have not yet introduced the compliment of insect vectors to “control” plant growth. The USDA Agricultural Research Service (ARS) biocontrol researchers have completed field assessments in Peru searching for and identifying candidate insects for study in U.S. quarantine. Herbicides applications remain the primary control method and are applied either by boat or 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 pubescent 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 by natural means or by humans (Stoddard, 1989). It 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 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 less 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 water bodies by 1989 (Schardt and Schmitz, 1991). In the Everglades region, water lettuce is mainly restricted to canals and around water control structures. It also occurs in the artificial water bodies 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 mainly restricted to the 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*).

Shoebutton ardisia (*Ardisia elliptica*) is a shade-loving shrub that was originally reported from the 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 extremely variable in their distributions, the habitats they invade, and the sizes of their infestations. Several of these species have persisted from cultivation and have shown the ability to spread from their points of introduction including the following: 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*), shefflera, 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 species that spread vegetatively and produce locally dense populations. The coastal species, mahoe (*Hibiscus tiliaceus*) and seaside mahoe (*Thespesia populnea*), and 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 clones.

INFORMATION GAPS AND FUTURE NEEDS

The elements of a comprehensive invasive exotic plant management strategy – legislation, coordination, planning, research, education, training, and resource input – have been in place in Florida for many years. The plants identified above as primary exotic invasive species in the Everglades region are all being controlled to some extent by most state or federal agencies. Unfortunately, there are dozens of other exotic species in the Everglades with unknown distributions and invasive potentials. The threat of exotic invasive animals is recognized but is not being addressed by any agency. Funding and coordination for a comparable nonindigenous animal management program are badly needed. Little can be done without a committed effort to develop ecological understanding of the spread, effects, and behaviors of exotic animals in the Everglades.

Regardless of taxa, the invasiveness of a species is often somewhat slow to develop. Species that appear benign for many years or even decades can suddenly spread rapidly following certain events, such as flood, fire, drought, long-term commercial availability, or other factors. There is a need to recognize these species during their incipient phase or prior to introduction to maximize available management resources.

RESEARCH NEEDS

It is tempting to assume that when restoration goals are achieved, results will include a reduced need to control exotic species in the Everglades. Although 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 what effects long-range hydrologic changes or nutrient reductions will have on most of the other exotic species throughout the system. Ongoing tree island research has focused on the effects of high water but has virtually 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 study of exotics. Old World climbing fern, melaleuca, and Brazilian pepper have successfully invaded those areas with the least apparent human alterations, including the mangrove zones of southwest Florida and remote areas of Big Cypress National Preserve. Exotic plant communities in the Everglades Stormwater Treatment Areas (STAs) will need to be monitored and measured as changes to the hydrology are made. A more comprehensive approach needs to be taken when looking at the long-term restoration process with regard to the exotic plant species composition response. It is necessary to educate the public and policy makers that invasive exotic species will always require some level of maintenance and that new introductions will need to be stopped in order to avoid future 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 EPA cannot be directly drawn from the literature. Studies documenting the expansion of some species imply that control would be cheaper when populations are small (Laroche and Ferriter, 1992). However, no direct analyses of the environmental and cultural costs and benefits of invasive plant control in the Everglades are available in the literature. The lack of such background information limits the strength of arguments supporting control of these pest species. Further, it might be argued that there should be no need to study such obvious catastrophes. Yet, basic foundational research is often needed to construct convincing arguments. A few citations do quantify the costs, impacts, and benefits resulting from control of aquatic weeds in a few Florida water bodies (Milon, et al., 1986; Colle et al., 1987), but none exist for wetlands such as the EPA.

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 very few others 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. For example, additional research might show how best to control each plant in different settings, how to minimize nontarget damage, or whether treatments during different seasons or stages of growth of each plant will affect results.

ECOLOGICAL IMPACTS OF INVASIVE SPECIES

Relatively little work has been done investigating the ecological impacts of invasive species in the EPA. 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 ecological integrity of natural areas. Little research has been performed to evaluate the effect of invasive exotic plants on nesting, denning, roosting, feeding, and foraging of 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 been established from management, monitoring, or botanical investigations (Ferriter, 1997; Laroche, 1999). For most of the other invasive plants found in the EPA, very few publications are available of even a general nature, and of these, virtually none formally assess ecological impacts of each species.

COORDINATION EFFORTS

There is a clear need 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 (both plants and animals) and which supports each agency in carrying out its role(s) 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 nonindigenous animals in the EPA.

Management Authorities and Regulations

Although federal regulations on the importation 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*, not *pest plants*. Insects and pathogens are screened extensively at ports of entry, but plants are allowed to enter this country virtually unimpeded. Up-front screening methods need to be developed for new importation of exotic plant species. In Australia and New Zealand, there are strict regulations regarding exotic plant importation. These countries have developed comprehensive "white lists" of plants that are permitted for import. If a plant is not on the white list, it cannot enter the country without performing a risk assessment. At a minimum, state and federal agencies importing plants for food, fiber, or forage evaluation should have a protocol that screens for invasiveness prior to recommending new plant species for cultivation.

On the state level, the Florida Department of Agriculture and Consumer Services (FDACS) Division of Plant Industry's staff 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, not to native ecosystems. While FDACS (Division of Forestry) fights a whole host of invasive exotic plants in its state forests, most of the plants it controls are not even on its own agency's list.

In 1999, the FDACS amended its list to include 11 new species that are threats to natural areas including the following: carrotwood (*Cupaniopsis anacardioides*), dioscorea (*Dioscorea alata* and *D. bulbifera*), Japanese climbing fern, Old World climbing fern, Burma reed, sewer vine (*Paederia cruddasiana*), skunkvine (*P. foetida*), kudzu, downy myrtle (*Rhodomyrtus tomentosa*), and wetland nightshade (*Solanum tampicense)*. The addition of these plants is a good indicator of a growing shift in agricultural rules and regulations to incorporate the protection of natural areas in their regulatory focus.

Better Support for Biological Control

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. After an insect has been properly selected and screened, it must be approved by a federal technical advisory group and, in Florida, a state arthropod committee. Although the process is necessary, it can be extremely slow. There are no deadlines for review set by the committee(s), and the review process for each request for release does not seem to be a priority for staff at participating agencies, especially in the case of agents that target natural-area weeds. The process needs to be streamlined and formalized. The final federal authorization for biological release comes from the USDA's Animal and Plant Health Inspection Service. This approval process is often very slow.

Compounding the problem is a lack of specific biological control quarantine facility space in Florida for environmental weeds. The only quarantine facility currently available in Florida for this 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 agents the researchers can study, creating a serious bottleneck. After years of struggle, construction of two new quarantine facilities is underway at the USDA site in Davie, Florida and the University of Florida site in Ft. Pierce, Florida. This is a positive step forward in light of the overwhelming need for additional biological control research.

Develop Public/Private Partnerships

Invasive exotic species recognize no political boundaries. Natural resource managers increasingly recognize that parochial management approaches to these problems are ineffective. Without a regional approach, effective containment of a pest plant is impossible. This strategy 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 TAME Melaleuca project will serve as a model for other species-based management. Policy makers are beginning to acknowledge that comprehensive invasive species management may require the expenditure of public funds on private lands, or property tax breaks that provide a financial incentive for control.

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