Chapter 9: The Status of Nonindigenous Species in the South Florida Environment

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SUMMARY

Successful restoration of the South Florida ecosystem, which includes the last vestiges of a once vast Everglades hinges on being able to reverse the environmental degradation that has occurred from human activities over the last 100+ years and prevent degradation from future human activities. While it is clear through the efforts of the Comprehensive Everglades Restoration Plan (CERP) and Restoration Coordination and Verification (RECOVER) programs that numerous factors (e.g., water quantity and quality, and abundance of flora and fauna) are a factor in the restoration effort, the potential impact of invasive species has only recently become a high priority for CERP planning.

In support of the collective activities of the many agencies involved in Everglades restoration and CERP, this chapter reviews the broad issues involving nonindigenous species in South Florida and their relationship to restoration, management, planning, organization, and funding. This chapter also provides an overview of nonindigenous species using a comprehensive, all-taxa format for understanding and presenting an inclusive picture of the magnitude of the invasive species threats that exists in South Florida. While detailed information on many of the included nonindigenous species is still unknown, this is the first document to provide a complete listing with species annotations for those species either known, or considered to be, serious threats to Everglades restoration. The species are also presented using the RECOVER and Science Coordination Group (SCG) modules for Everglades restoration regions and the species impacts are also discussed by regions in which such information on the species exists.

In addition to providing a comprehensive look at nonindigenous species across taxa, this document has also taken an important step toward trying to determine what, if any, control or management has been initiated for targeted species. Working with the Science Coordination

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Group and the Noxious Exotic Task Team and the Florida Invasive Animal Task Team of the South Florida Ecosystem Restoration Task Force, this progress assessment technique has been established in coordination with the development of the SCG system-wide ecological indicator for invasive plants. Through continued collaboration, it is hoped that a coherent and integrated method across all agencies is established for evaluating progress on controlling invasive plants. It is anticipated that a parallel system for exotic animals will also be developed within the next 2 to 3 years.

This chapter highlights several key aspects where recent progress has been made, and where future efforts are being further developed or needs are better identified and described. Two notable areas include monitoring (both pre- and post-treatment) and information sharing and tracking. This document also describes the efforts and successes in integrating and coordinating the numerous monitoring programs for invasive exotic plants and the development of a similar system for all taxa. Information sharing and project tracking are being developed under a new web-based system to help agencies implement their many invasive species projects with the ability for improved coordination and integration and for cross-cut budget development.

INTRODUCTION

Biological invasions affect Florida's citizens in many ways. Floridians pay a great price for invasive species—costs measured not just in dollars, but also in unemployment, damaged goods and equipment, environmental degradation, flooding, navigation restrictions, and disease epidemics. Invasive species continue to significantly impact the national economy. Researchers at Cornell University estimate that biological invasions are costing Americans approximately $138 billion every year (Pimentel et al., 2000). These costs are expected to grow with increasing world trade. Recently, Florida's Invasive Species Working Group compiled a list of state expenditures for invasive species prevention, control, and management efforts and determined that more than $100 million was spent by state agencies in Florida in 2003–2004.

Florida is listed with Hawaii, California, and Louisiana as one of the states with the greatest number of invasive 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 non-native faunal communities in the world (Gore, 1976; Ewel, 1986; OTA, 1993; McCann et al., 1996; Shafland, 1996; Simberloff, 1996; Corn et al., 1999). More than 30 years ago, a Smithsonian publication described tropical Florida as a "biological cesspool of introduced life" (Lachner et al., 1970).

Why is Florida being invaded? The state has a neotropical climate and a patchwork of habitats. The southern third of Florida is a peninsula and a habitat island, bounded on three sides by water and the fourth by frost, and is typified, as are oceanic islands, by a naturally impoverished flora and fauna (Simberloff, 1996). Because of these characteristics, Florida is an epicenter for biological invasions dating back to early commerce between the city of St. Augustine and South America (Statewide Invasive Species Management Plan for Florida, 2003). Waves of introductions accelerated during the twentieth century with the rise of the ornamental plant and pet industries and through unintentional contaminants of imported commodities.

Florida is also at high risk for the introduction of new invasive nonindigenous species due to the state's southeastern-most location. Florida is expected to act as one of the nation's sentinels against nonindigenous species. Yet, federal and state systems in place to intercept, eradicate, or contain these species have not kept pace with the influx of these multi-taxa invaders to Florida. The frequency at which nonindigenous organisms entered Florida, via plant and animal material brought in by tourists, smugglers, and as cargo, grew exponentially during the 1990s. The number of tourists entering Florida in the last 10 years grew 20 percent, approaching 50 million people yearly. Perishable cargo nearly tripled to more than 6 million tons. Mail deliveries and smuggling operations also grew exponentially. However, the resources needed to regulate these activities have stayed nearly the same (Florida Pest Exclusion Advisory Committee, 2001).

As a consequence, two Mediterranean fruit fly infestations in Florida cost federal and state taxpayers nearly $50 million to eradicate. An Asiatic citrus canker infection has cost more than $600 million in containment and eradication measures to date. The tick-borne Heartwater disease, an outbreak of which could kill 50–90 percent of Florida's cattle, other ruminant livestock, and the state's native-deer population, is as close as the Caribbean islands or the ill-fated import of just one infected tick. Equine piroplasmosis, a parasitic disease also transmitted by ticks, along with Heartwater disease and other lesser-known animal and plant maladies, have already cost more than $400 million to address.

Many of these introduced nonindigenous species have become highly invasive and disruptive in Florida's public waterways and conservation lands. Florida encompasses approximately 36 million acres with over 10 million acres in public ownership. Nearly half of that area is federal land, with state agencies and five water management districts owning approximately 5.4 million acres. Many of these lands and waterways are impacted by nonindigenous species that diminish and degrade ecosystem functions and disrupt public use. More than $300 million have been spent by state, federal, and local agencies since 1980 to control invasive nonindigenous aquatic, wetland, and upland plants on publicly owned waterways and conservation lands.

At least 15 federal and state agencies have jurisdiction in Florida over the importation and movement of nonindigenous species, introductions of new species, prevention, eradication, and management of non-native species, and biological control research and implementation. Historically, policies held by these agencies often conflicted and there was no clear level of statewide leadership and mechanisms needed for coordination of management activities (Statewide Invasive Species Management Plan for Florida, 2003).

INVASIVE EXOTIC SPECIES IN SOUTH FLORIDA

Control of invasive non-native species is an important issue for the overall ecological health of South Florida's public conservation lands. The importance of this issue in the Everglades Protection Area (EPA) is demonstrated by the great number of plans, reports, statements, and papers 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. The general consensus of these parties is that control and management of invasive 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 nonindigenous species are in 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. In 1998, the SFERTF established the Noxious Exotic Weed Task Team (NEWTT) that produced two major products. The first report, Weeds Won't Wait (Doren and Ferriter, 2001), included a comprehensive assessment of the problem of invasive plants in Florida, particularly those affecting Florida, and a strategy for dealing with invasive plants. As a follow-up to that report, the NEWTT developed a web-based information sharing and project tracking database for all invasive species projects associated with Everglades restoration (www.ecostems.org).

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) a general lack of awareness and knowledge of the harmful impacts of invasive species is generally lacking; and (5) an urgent need exists for statewide coordination and cooperation to eliminate exotics. The greatest obstacle to combating invasive non-native species, as identified in this document, is the lack of sufficient funding and manpower to stay ahead of problems.

The South Florida Ecosystem Restoration Working Group's (SFERWG) first Annual Report in 1994 addressed all invasive nonindigenous plant and animal species. 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 1994 Everglades Forever Act (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. This work is ongoing through various interagency working groups.

Reinforcing the abovementioned efforts, the Scientific Information Needs Report (SSG, 1996) of the SFERTF contains a region-wide chapter on harmful invasive non-native species. An overall regional objective for restoration is to develop control methods for nonindigenous species at entry, distribution, and landscape levels. The specific objectives are to halt and reverse the spread of established invasive nonindigenous species and to prevent invasions by new nonindigenous 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 these new problems. Most resources for nonindigenous animals have focused on agricultural pests, with little investigation of species that threaten natural areas. Accelerated study of control technologies and the basic biology and ecology of invasive nonindigenous species are needed to answer priority questions: how will water management alterations affect introduced plants and animals, what are the principal controls on expansion of a species, what are the impacts of invasive nonindigenous species on native species and ecosystems, what makes a natural area susceptible to invasion, and what are the most effective screening and risk assessment technologies to help focus on the greatest potential problems? Overall, the major issue is the lack of meaningful information concerning the effects of invasive nonindigenous species in South Florida.

The Comprehensive Review Study Final Feasibility Report and Programmatic Environmental Impact Study (USACE and SFWMD, 1999) addresses the presence of non-native animals as one of several factors that preclude any serious consideration of achieving true restoration of the natural system, one in which nonindigenous species are not present. It discusses how removal of canals and levees, which act as deepwater refuges for non-native fish and as conduits into interior marshes for other species, is expected to help control invasive 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 nonindigenous fishes, such as the Mayan cichlid in the freshwater transition zone. These unintended negative consequences of the restoration effort must be addressed during the detailed design.

The USFWS Fish and Wildlife Coordination Act Report for the Comprehensive Everglades Restoration Plan (CERP) also considers control and management of non-native 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 components of the Comprehensive Plan involve construction of canals and reservoirs, which could provide additional conduits from points of introduction into the Everglades for species such as fish, amphibians, and snail species. Other components involve removal or partial removal of canals, a process that should reduce the spread of non-native 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 and Burmese python. The USDOI also recommended establishment of the Florida Invasive Animal Task Team (FIATT) to work on the issue as part of CERP.

In relation to the planned Water Preserve Areas (WPAs) and flow-ways, it was recommended that an aggressive plan be developed for the perpetual removal of invasive nonindigenous 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 [team] should be presented to the South Florida Ecosystem Restoration Task Force.

Several other plans and reports also include invasive nonindigenous species. The Coordination Act Reports (FGFWFC, 1999) from the Florida Game and Fresh Water Fish Commission (currently known as the Florida Fish and Wildlife Conservation Commission, or FWC) emphasize that the extent of the canal system's role in the spread of non-native 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 non-native 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 non-native 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 nonindigenous plants and animals and discouragement of 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 nine state agencies and one state university comprise the ISWG. Jeb Bush, Governor of the State of Florida, charged this group with developing a comprehensive invasive species strategic plan for all state agencies. The plan is complete and has been accepted by the governor. The ISWG is in the process of implementing 22 action items to foster better communication between state agencies, track agency expenditures, increase public awareness and rapidly assess new potential threats to Florida's agricultural and environmental communities.

In a separate but complimentary program, the FDEP also administers funding for invasive upland plant control efforts in Florida through regional working groups. The Upland Invasive Plant Management Program was established within the FDEP in 1997. To implement a statewide program, the FDEP formed Regional Invasive Plant Working Groups (working groups) comprised of federal, state and local government agencies, non-governmental organizations, and other interested stakeholders, in 11 areas of the state and encompassing all of Florida's 67 counties. This program funds individual non-native plant control projects on public conservation lands throughout the state based upon the recommendations from the working groups. The FDEP melds these regional priorities into an integrated process that provides the needed support infrastructure (e.g., control method development, research results, public education, technology transfer, policy, oversight, and funding) to conduct an efficient and cost-effective statewide control program. Program funding is provided through the Invasive Plant Management Trust Fund, as set forth in Section 369.252(4), Florida Statutes (F.S.). This trust fund provided nearly $7 million to fund upland plant control projects for Fiscal Year 2004 (FY2004) (October 1, 2003 through September 30, 3004).

In 2002, the USACE authorized the Melaleuca Eradication and Other Exotic Plants project. This project was listed in the Restudy as an "other project element," but funding was not initially authorized for it under CERP in the 1999 Water Resources Development Act (WRDA). The 2002 authorization assigned the project's four major components at an estimated cost of $5.5 million for the USACE. These components include the following:

1. A cost-share agreement with the University of Florida for the design and construction of a new facility for biocontrol in Ft. Pierce, FL.
2. A cost-share agreement with the Florida Department of Agriculture and Consumer Service (FDACS) for the design and construction of the upgrade and renovations for the existing biocontrol facility in Gainesville, FL. (Note that the sponsors did not pursue these first two components due to funding and timing constraints.)
3. A cost-share agreement with the SFWMD for the "controlled release" of biological agents. In July 2004, a design agreement was signed by the SFWMD and the USACE to proceed with development of this cost-share project. A final draft of the Project Management Plan (PMP) for this project is completed. Once signed, work will begin on the Project Implementation Report (PIR). The PIR will seek to determine the best method to fund the rearing, release, and monitoring of approved biocontrol agents. It is anticipated that the project will initially benefit melaleuca and lygodium biocontrol projects at the time of PIR completion. The PIR is scheduled for completion in 2007, and presidential and congressional approval should occur in 2008 with the first appropriation expected in FY2009. The project is anticipated to be implemented for 15 years with a federal cost of about $4 million.
4. Concurrently with the development of the PIR is the preparation of a special report on invasive species to determine federal interest and future federal involvement in invasive species projects in South Florida. This report examines the potential for entering into cost-share programs with local sponsors, determines what the federal role should be as developed in the Weeds Won't Wait strategy, and makes recommendations to the USACE and U.S. Congress for further action.

As part of this effort, the USACE commissioned a report entitled "Filling the Gaps: Ten Strategies to Strengthen Invasive Species Management in Florida." This report, released by the Environmental Law Institute in August 2004, provides a comprehensive overview of the federal framework affecting invasive species management in Florida, focusing on the Everglades. Although the recommendations are largely directed at federal agencies, steps that can be taken at all levels of government are included.

The Aquatic Nuisance Species Task Force (ANSTF) was established in 1991 to provide a forum for governmental and non-governmental agencies to share information related to aquatic nonindigenous species and to implement the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. This Task Force is co-chaired by the USFWS and NOAA. Through the use of regional panels, the ANSTF strives to facilitate and coordinate aquatic invasive species issues across jurisdictional boundaries. Control and management plans are complete for five aquatic species in the United States, and a plan is under development for the Asian swamp eel (*Monopterus albus*), a species of interest to the Greater Everglades.

The U.S. President's Executive Order on Invasive Species (Executive Order No. 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.

INVASIVE PLANT SPECIES IN SOUTH FLORIDA

The South Florida Ecosystem Restoration Task Force and Working Group identified invasive non-native plants as a priority. As a result, the Noxious Exotic Weed Task Team (NEWTT) was established in 1998. The NEWTT is a direct working team of the South Florida Ecosystem Restoration Task Force and Working Group. As previously discussed, the NEWTT has produced Weeds Won't Wait nd a web-based information sharing and project tracking system, as part of the overall effort in managing invasive species in the Everglades. Weeds Won't Wait provides a comprehensive assessment to characterize the current problems with invasive exotic plants in Florida with an emphasis on Everglades restoration issues, and to identify the highest priority invasive species for control. This report also documents a comprehensive interagency strategy for elimination or control of the highest priority species and for management, control, and containment of other pest plant species.

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

The NEWTT developed an assessment and a strategic plan (see Doren and Ferriter, 2001) covering the issues and problems of exotic pest plants in Florida, with a 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 they 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 nonindigenous pest plants affect state and local policies and programs. The USACE entered into an agreement with the NEWTT to develop a report on federal invasive species interests in Florida.

INVASIVE ANIMAL SPECIES IN SOUTH FLORIDA

The effort to address the issue of nonindigenous animals in the Everglades has lagged behind that of invasive plants. While it is relatively easy to determine the extent to which non-native plants invade natural areas, the impact of introduced animals on native communities and on those species with which they compete directly is often less obvious (Schmitz and Brown, 1994). Several existing reports have highlighted this difficulty. According to the Multi-Species Recovery Plan (USFWS, 1999):

> 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) also addresses this 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.

Additionally, in 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 SFERTF Working Group has gathered available information as a basis for an assessment of the problem. In February 1998, the Working Group established an ad hoc interagency team to (1) focus on South Florida and evaluate the status of non-native animals in all habitats (freshwater, marine, and terrestrial), (2) describe efforts underway to deal with them, and (3) identify agency needs and problems (Goodyear, 2000).

The SFERTF established a Florida Invasive Animal Task Team (FIATT) in 2003. This group convened and is developing a non-native animal report to provide a broad picture of the status of exotic animal species in South Florida. It will focus on the agencies, along with their respective departments, that are represented on the SFERTF Working Group. This document is to be used as the basis for the SFERTF 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.

In July 2004, the District and the USDOI jointly convened an Everglades Invasive Species Summit in an effort to increase dialog between and among plant and animal specialists. The group presented new information about various taxa and discussed priority non-native species in the Everglades. The group reconvened in July 2005 and continues to work on sharing cross-taxa information. Through these discussions, at least one valuable – and encouraging – partnership has been initiated between plant and animal managers. Plant managers at the District are now working with wildlife biologists in Everglades National Park (ENP or Park) to survey for and control python populations on remote levees and canal banks in the Everglades region.

The National Park Service (NPS) staff is spearheading an unparalleled effort to develop a species-based management plan for pythons in Everglades National Park and in lands managed by the District in areas along the eastern and northern boundaries of the Park. In July 2005, an international group of specialized herpetologists convened in South Florida to participate in a workshop that focused on the issue of pythons in the Everglades. Team leaders are in the process of drafting a management plan for the Park that will outline specific research needs, educational needs, management needs, and a plan for early detection and rapid response.

MARINE INVASIONS

The extent of nonindigenous species invasions into marine habitats of Florida are not well documented, although the pathways for this invasion are clear. The sources include accidental releases from an expanding aquaculture industry (especially tropical fish), home aquaria releases, live seafood escapes, and shipping ballast and fouling water releases. Marine habitats are less visible, and documenting marine system impacts has been poor. Marine invasions are not a new issue to North America. Shipworms were spread globally by early explorers (pre-Columbus), and green crabs were first reported in the United States waters in the early 1850s. Introduction rates are increasing with the rate of increased ship traffic. It is estimated that ship ballast water transports between 3,000 and 7,000 foreign species daily around the globe. With 80 percent of the world's commodities carried by ship, the probability of new species introductions and subsequent establishment is high. A 2002 report documenting invasive species in Florida's saltwater systems reported 40 species of nonindigenous species as having established populations. Marine scientists believe the actual numbers are much higher (Carlton and Ruckelshaus, 1997). The non-native species established in Florida marine environments include nine fishes, three mollusks, and 12 crustaceans. Since the report's publication, the Florida Marine Research Institute confirmed that the red lionfish (*Pterois volitans*) is established along Florida's Atlantic Coast. A foreign marine algae (*Caulerpa brachypus*), native to the Pacific Ocean, has also established along Florida's southeast Atlantic Coast (see the *Northern Estuaries Module* section).

COYOTES AND CATTAILS

It is important to note that certain organisms are sometimes erroneously grouped with the nonindigenous species discussed in this chapter. Plants like cattail and animals like the coyote are examples of organisms that are sometimes considered "noxious," "aggressive," or "out of place" but a distinction should be made between these species and the nonindigenous species that invade South Florida. Cattail is a native plant and considered a natural component of the Everglades. However, its dense growth habit resulting from human changes to nutrient levels and hydrology in parts of the Everglades is not natural. Similarly, the coyote, native to western North America, has recently spread into Florida. This is thought to be an eastward range expansion, likely facilitated by human manipulations to the natural environment. While many professionals argue coyotes are not indigenous to Florida, they are not considered an invasive exotic species.

Coyotes and cattails are moving and spreading because people have changed the natural environment. If phosphorus is added to the Everglades, then cattails take advantage of it; they grow taller, denser, and spread to wherever the nutrients are present. If large natural predators are removed from the ecosystem, then coyote populations expand and they start moving. It is important to note that unlike coyotes and cattails, exotic species brought to South Florida from other parts of the world do not need an alteration of the natural environment to thrive. Each exotic organism has its own potential to invade and, as they invade, the native environment is altered thereby further exacerbating the problem. While the symptoms may seem similar, the causes are quite different.

MANAGEMENT TOOLS

INVASIVE PLANT MANAGEMENT TOOLS

Many different techniques are used to control exotic invasive plants in South Florida (Langeland and Stocker, 1997). Biological controls, herbicides, manual and mechanical controls, and cultural practices are integrated or used separately to control invasive plants. More detailed descriptions of each of these plant management tools are presented in this section.

Biological Control

Plants are often prevented from becoming serious weeds in their native range by a complex 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 USDA for permission to release into the United States; also, obtain permission from necessary state agencies
7. Culture agents that are approved to have sufficient numbers to release at field sites; 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; 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

Herbicides

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

Herbicide Application Methods

- *Foliar applications* – An 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 non-target vegetation, or broadcast. Broadcast applications are used where damage to non-target vegetation is not a concern or where a selective herbicide is used.
- *Basal bark applications* – An 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, a 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 is 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.

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." A list of USEPA-approved herbicides used by the District is presented in **Table 9-1**.

Table 9-1. The District uses 17 separate herbicides to manage exotic plants in South Florida.

Herbicide Type	Brand Names	Formulation
2,4-D (amine)	Weedar 64, Gladeamine 3.8	Liquid
2,4-D (ester)	---	Granules
Triclopyr (amine)	Garlon 3A, Renovate	Liquid
Triclopyr (ester)	Garlon 4, Pathfinder II	Liquid
Diquat	Reward	Liquid
Endothol (potassium	Aquathol K	Liquid
Endothol (coco-amine)	Hydrothol 191	Liquid
Endothol	Aquathol Super K	Pellets
Glyphosate	Rodeo, Aqua-neat, Glypro,	Liquid
Glyphosate-Pro	Roundup Pro, Glypro Plus,	Liquid
Glyphosate/2,4-D	Campaign	Liquid
Sulfometuron methyl	Oust	Dry flowable
Imazapyr	Arsenal, Habitat, Stalker	Liquid
Imazapic	Plateau	Liquid
Fluridone	Sonar AS, Avast	Liquid
Fluridone	Sonar PR	Pellets
Hexazinone	Velpar L	Liquid
Metsulfuron methyl	Escort	Wettable powder

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 themselves are not toxic to wildlife. A risk assessment to wildlife is conducted as part of the federal herbicide registration procedure. Risk is determined as the product of hazard and exposure. Hazard is measured as the toxicity of the herbicide to test animals and exposure depends on the use and persistence of the compound. 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 LC50 (lethal concentration, 50 percent) of triclopyr ester (0.87 parts per million, or 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 plants. Mechanical removal may not be appropriate in natural areas because of the disturbance to soils and non-target 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 plants entering these communities or about the subsequent management effects of fire on the altered communities.

Understanding the reproductive biology of the target and non-target 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 invasive species flower or set seed at different times than the native species.

Fire is a normal part of most of South Florida’s ecosystems. Native species have evolved varying degrees of fire tolerance or dependence on a regular fire regime. Throughout much of Florida, suppression of fire during this century has altered historical plant communities, such as pine flatwoods, enhancing fire intolerant species, and reducing the coverage of species that possess fire adaptations. Within these communities, less fire-tolerant species have increased while fire-tolerant species have lingered in smaller numbers.

In general, fire can be used to suppress plant growth, and kill both native and exotic plants that are not fire tolerant. Most often, woody species are reduced while effects are less noticeable on herbaceous species. There is some published information on responses of individual Florida plant species, but very little is known about the vast majority of native plant species, and less about invasive exotic species. The invasion of native tree stands by exotic vines such as Old World climbing fern (*Lygodium microphyllum*) has greatly increased the danger of canopy (crown) fires in Everglades tree islands and cypress swamps and has resulted in the death of mature, native trees. Tolerance to fire can sometimes be predicted in both native and exotic plant species. Fire tolerant species are typically plants with thick bark and seeds (either in the soil or held in the canopy) plants that are adapted to fire (either tolerant of high temperature, or requiring fire for seed release or germination), and/or have seeds that are disbursed over wide areas, but it is unclear if fire can play a long-term role in the integrated management of invasive plant species in Southern Florida.

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 invaded habitat, and levels can be avoided that promote invasive species, but rarely are these management options 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.

INVASIVE ANIMAL MANAGEMENT TOOLS

Operational management tools to control invasive animals in Florida's natural areas are poorly developed. There is not a single agency in the state that has a dedicated program to deal with the operational-type control and management of nonindigenous wildlife or marine species (ISWG, 2003). The following list provides a generalized description of available animal control techniques:

- **Exclusion** – Use of barriers (i.e., electrical, hydraulic or sound) in terrestrial or aquatic environments to prevent target species from moving into unaffected areas.
- **Habitat Manipulation** – Removal of food and/or water sources or breeding sites, or preventing the use of habitats by target species to reduce species population growth or tendency to occupy an area.
- **Trapping** – Use of snares, nets, or cage traps to allow individuals of the target species to be caught and relocated or disposed of humanely.
- **Hunting or Fishing** – Use of recreational hunting or fishing as a means to reduce populations of the target species.
- **Biological Control** – The development of biological control agents that can be introduced to reduce target species populations.

- **Chemical Control** – Use of direct chemical application or bait stations to dispatch target species or interrupt breeding.
- **Sterilization** – Use of sterilization to phase populations of the target species out of specific areas.

MONITORING AND TRACKING PROGRAMS FOR INVASIVE SPECIES IN SOUTH FLORIDA

Baseline monitoring programs are important in establishing the extent of a problematic species and can offer valuable benchmarks once operational control programs begin. Similarly, long-term, repeatable monitoring is key to answering questions related to the impacts of invasive species. The general distributions of most invasive exotic plants in South Florida are fairly well understood (Wunderlin, 1995; FLEPPC, 2005). Agency-sponsored programs to track the distribution of certain target exotic plant species regionally are in place. However, the availability of spatial data for most other invasive taxa in natural areas is lacking or not readily available. The Florida Fish and Wildlife Conservation Commission (FWC) maintains a county-level database for reptiles, amphibians, birds and terrestrial mammals (http://www.myfwc.com/critters/exotics/exotics.asp). FWC biologists compiled these data from both published and unpublished sources. The U.S. Geological Survey (USGS) maintains an extensive database for nonindigenous aquatic species by watershed (Pam Fuller, personal communication). These resources are valuable and have been used extensively in this report, but it is difficult to glean information about population dynamics of these species without more detailed specific locations and/or historical spatial data.

Certain animal species distributions are tracked at a higher level of detail in South Florida, but not in a consistent cross-taxa manner, and not by any single agency. These exceptions include varying agency efforts to track detailed distributions of Burmese python (*Python molurus bivittatus*), lobate lac scale (*Paratachardina lobata lobata*), and Mexican bromeliad weevil (*Metamasius callizona*). While these single-species monitoring programs are successful in tracking a specific animal, there is not a coordinated database in the state that spans taxa. Difficulties in monitoring invasive animals may, in part, be “the nature of the beast.” Tracking mobile organisms is inherently more difficult than documenting the occurrences of rooted plants.

ANIMAL MONITORING

Burmese Python

Everglades National Park and District staff track Burmese python occurrences through observations and a “Python Hotline” administered by the Park (Skip Snow, Everglades National Park, personal communication). Park staff maintains a well-coordinated occurrence database for “big snakes” in and around the Park. **Figure 9-1** depicts coordinates for Burmese python observations made by biologists, Park rangers, District field, and contract personnel and the general public. It is a valuable resource in tracking the population and demonstrating the magnitude of the problem.

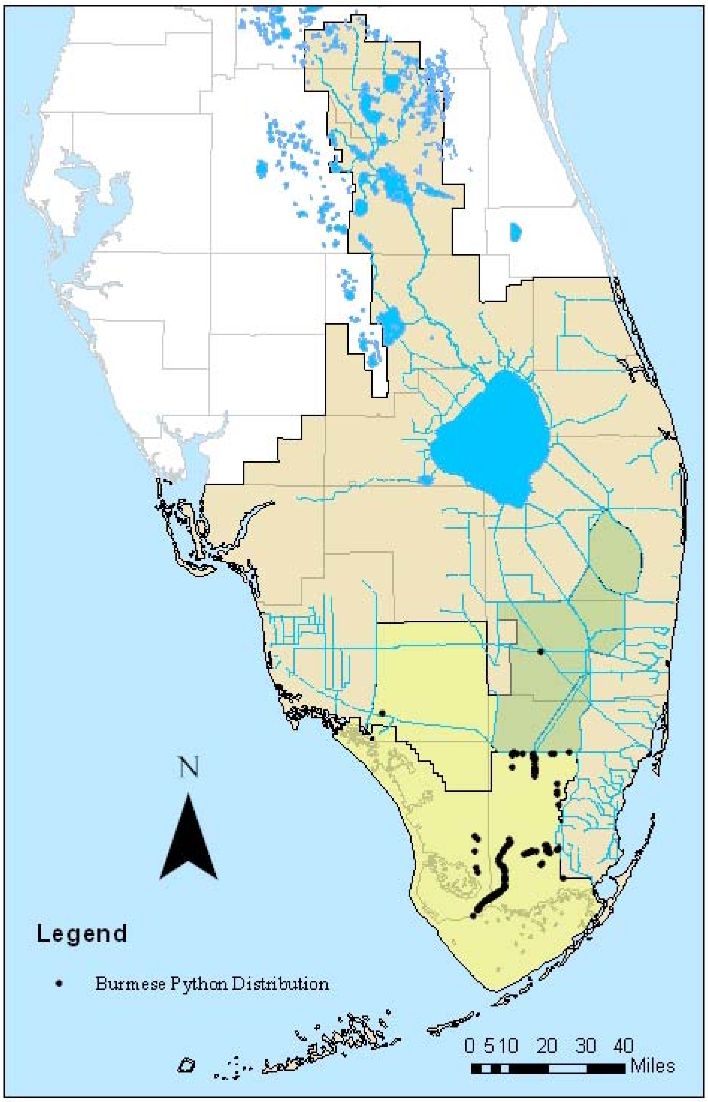

Figure 9-1. Distribution of Burmese python observations in South Florida (source: Skip Snow, Everglades National Park).

Lobate Lac Scale

The Cooperative Agricultural Pest Survey (CAPS) Program is a combined effort by federal and state agricultural organizations to conduct surveillance, detection, and monitoring of agricultural crop pests that have eluded first-line inspections at our ports-of-entry. Surveys include weeds, plant diseases, insects, nematodes, and other invertebrate organisms. While this program is charged with dealing with agricultural pests, certain organisms like lobate lac scale threaten both ornamental plant species and native flora. In this case, the CAPS monitoring program extended into some natural areas, providing valuable information on the distribution of this dangerous insect species, and documented the need to track it in the Everglades (**Figure 9-2**).

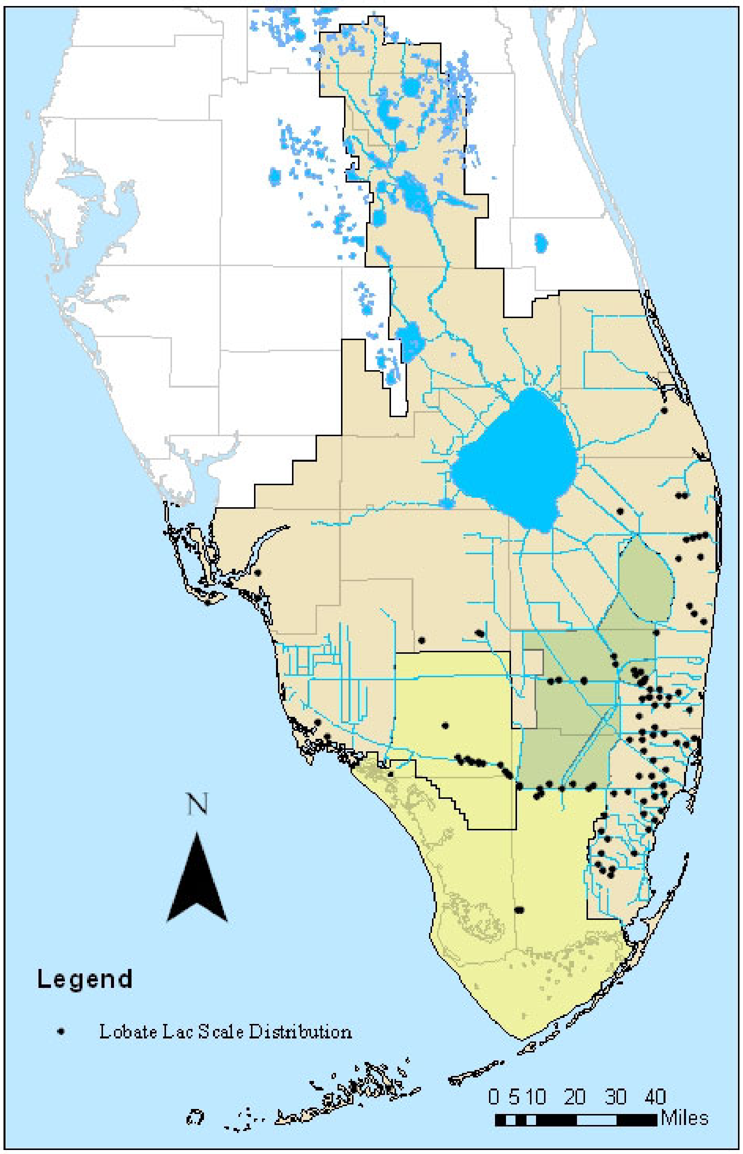

Figure 9-2. Distribution of lobate lac scale in South Florida (source: CAPS Survey).

Mexican Bromeliad Weevil

University of Florida entomologists collect information on the distribution of the Mexican bromeliad weevil in Florida (Howard Frank, University of Florida, personal communication). This database includes occurrence data on the nonindigenous weevil and documents impacts on native Florida bromeliad populations (**Figure 9-3**). Work in tracking this weevil continues in conjunction with work to develop a biological control program.

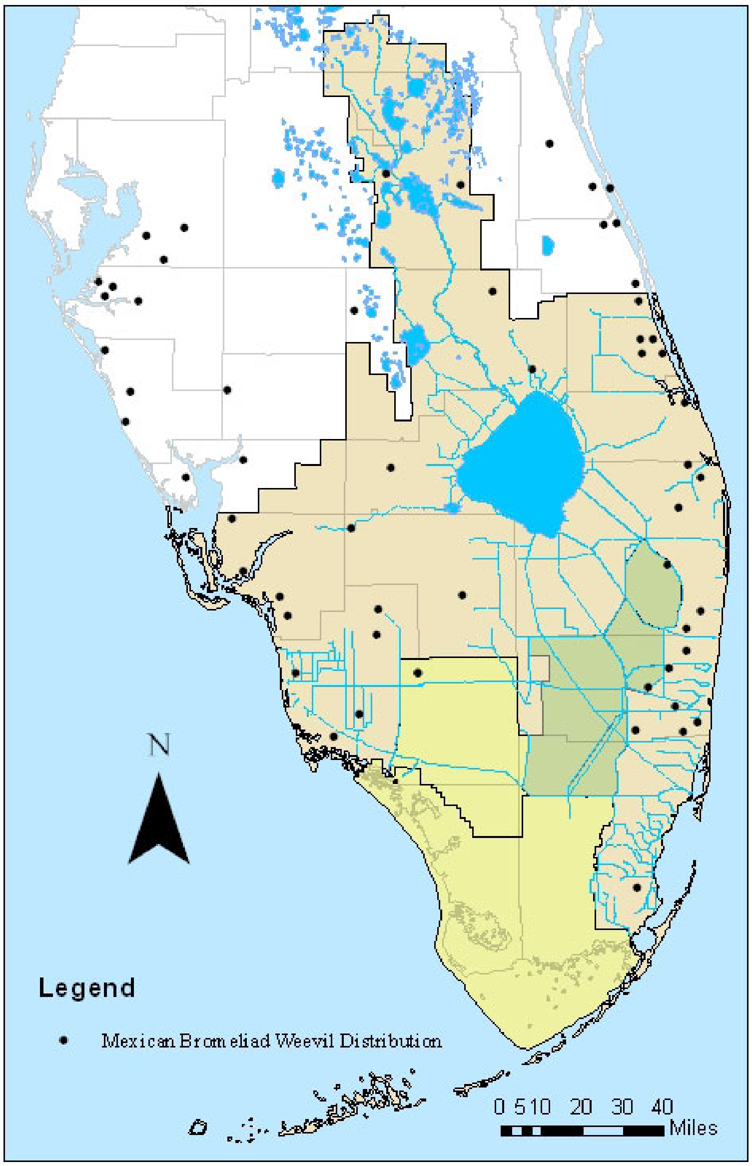

Figure 9-3. Distribution of Mexican bromeliad weevil in South and Central Florida (source: Howard Frank, University of Florida).

Biological Control Agent Releases

The release of biological control agents on nonindigenous species is an important component of plant and animal management. Several agents have been released to control nonindigenous plants in natural areas in Florida. Agents to control melaleuca were first released in 1997. After these agents were released, researchers with the USDA-ARS initiated a monitoring program to establish the spread of the agents and track agent effectiveness against the target species. To date, insect agents have been released for two upland natural area weeds, melaleuca (*Melaleuca quinquenervia*) and Old World climbing fern (*Lygodium microphyllum*). **Figure 9-4** shows release data for each of these biological control agents in South Florida.

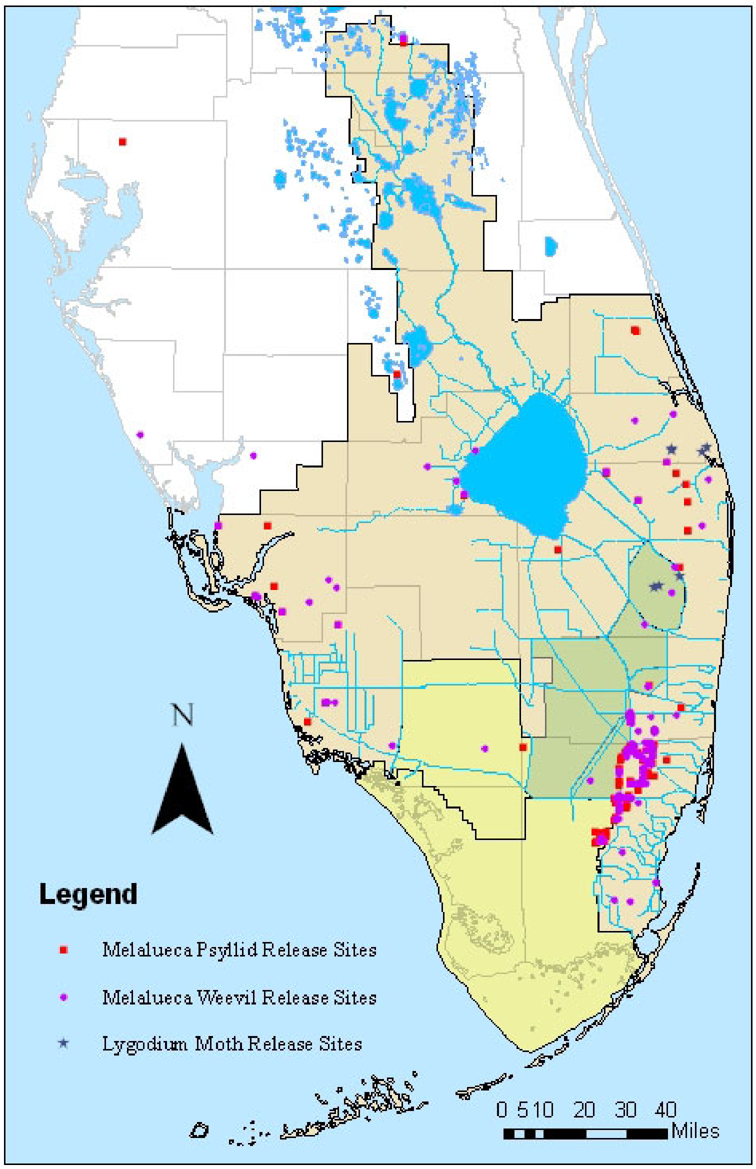

Figure 9-4. Distribution of biological control agents for terrestrial weeds in South and Central Florida (source: Paul Pratt and Bob Pemberton, USDA).

PLANT MONITORING

The extent to which remote sensing technologies have been successfully applied to operational invasive species programs to date is limited. Traditional remote sensing technologies are useful for mapping generalized plant communities, but they can not accurately identify small incipient plant populations, a critical need for invasive plant managers. Additionally, target plants growing under and among the canopy of other plants can not yet be detected consistently with these technologies. A great deal of time and energy is spent ground-truthing data gained from aerial photos and satellite images. Agency-sponsored invasive plant control operations are ongoing throughout Florida, and the coverage of the target invasive plants is changing constantly. Given time and budgetary constraints, resource managers often opt to simply kill the target species and map treatment sites rather than create detailed coverage maps prior to beginning a treatment program. While it is generally accepted that remote sensing technologies can be used successfully to map large invasive plant monocultures, the usefulness of this data to "on the ground" resource managers tasked with controlling these species is limited.

Systematic Reconnaissance Flights

Systematic Reconnaissance Flight (SRF) surveys were initiated to give South Florida's operational resource managers a tool to quickly and affordably assess target plant populations and gauge successes and/or failures. The SRF method is widely used in tracking wildlife (Russell et al., 2002; Dalrymple, 2001; Mauro et al., 1998). It involves flying at a fixed height and speed across a study area on a predetermined transect while observers count targets (plants or animals) in a strip of land on either side of the aircraft.

The U.S. Forest Service (USFS) conducted the initial survey for melaleuca in South Florida in 1980 (Cost and Craver, 1980). This survey was initiated by the USFS to estimate forested and non-forested land cover in the area south of Lake Okeechobee. As part of this work, the researchers measured the extent of melaleuca coverage and densities. This survey was conducted before the use of Global Positioning System (GPS) technology was readily available. Paper maps were used to record information along transect lines. The transects were spaced 2.5 miles apart, east and west across the southern part of Florida. The data derived from this survey was valuable in documenting the problems associated with melaleuca in the Everglades and helped legitimize this issue in the state.

In the early 1990s, the District and the NPS began conducting independent, parallel SRF surveys for exotic plants in the region. The District surveys covered the entire peninsula south of the north rim of Lake Okeechobee. The transects were modeled after the USFS 1980 survey and were spaced at 2.5 mile intervals, east and west across the state. The Park Service surveys focused on National Park lands in the region. The transects were finer (1 km apart) and observers deviated from the transect when they encountered exotic plant populations. Both surveys recorded both plant species and density classifications. In 1999, the District and the NPS began collaborating in conducting the biannual surveys. The surveys are now nested (the District survey uses 4 km transects, and the NPS uses 1 km transects) and the transects overlap on the park lands (**Figure 9-5**).

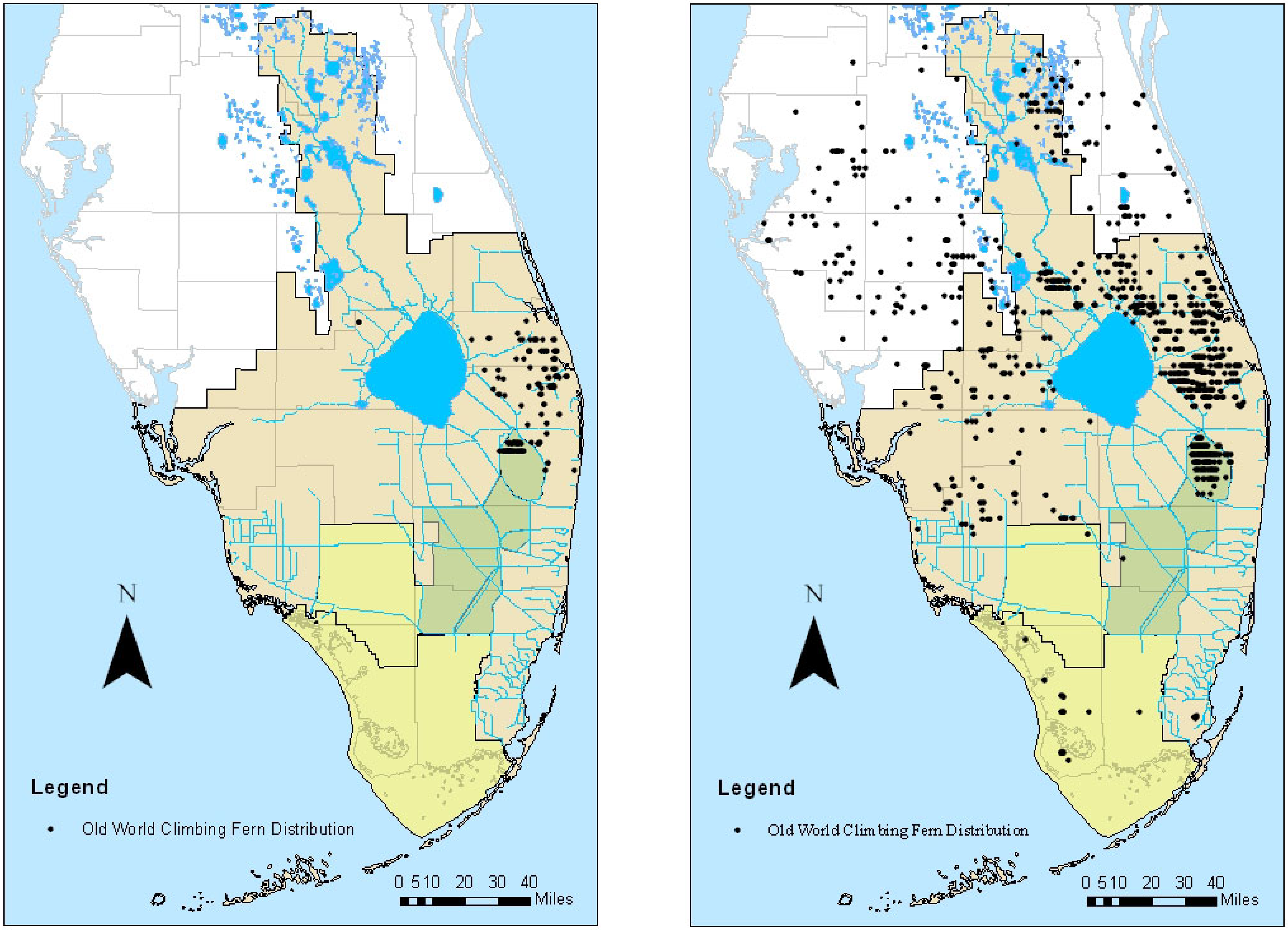

Figure 9-5. Distribution and spread of Old World climbing fern 1993–2005 (source: Amy Ferriter, Boise State University).

Digital Aerial Sketchmapping Pilot Project

In 2005, USDA grant funding (TAME Melaleuca) allowed the District and the NPS to conduct a pilot project to evaluate the use of USFS Digital Aerial Sketchmapping (DASM) technologies to track invasive plants in the Greater Everglades. This technology was developed by the USFS to provide a tool for tracking forest health. It combines the use of trained observers and mobile maps, allowing observers to use high resolution images as a background while they “sketch” target plant observations onto a digital map (**Figure 9-6**). Results of this pilot project are still being field verified and evaluated for future use in lieu of or in conjunction with the ongoing District/NPS SRF program.

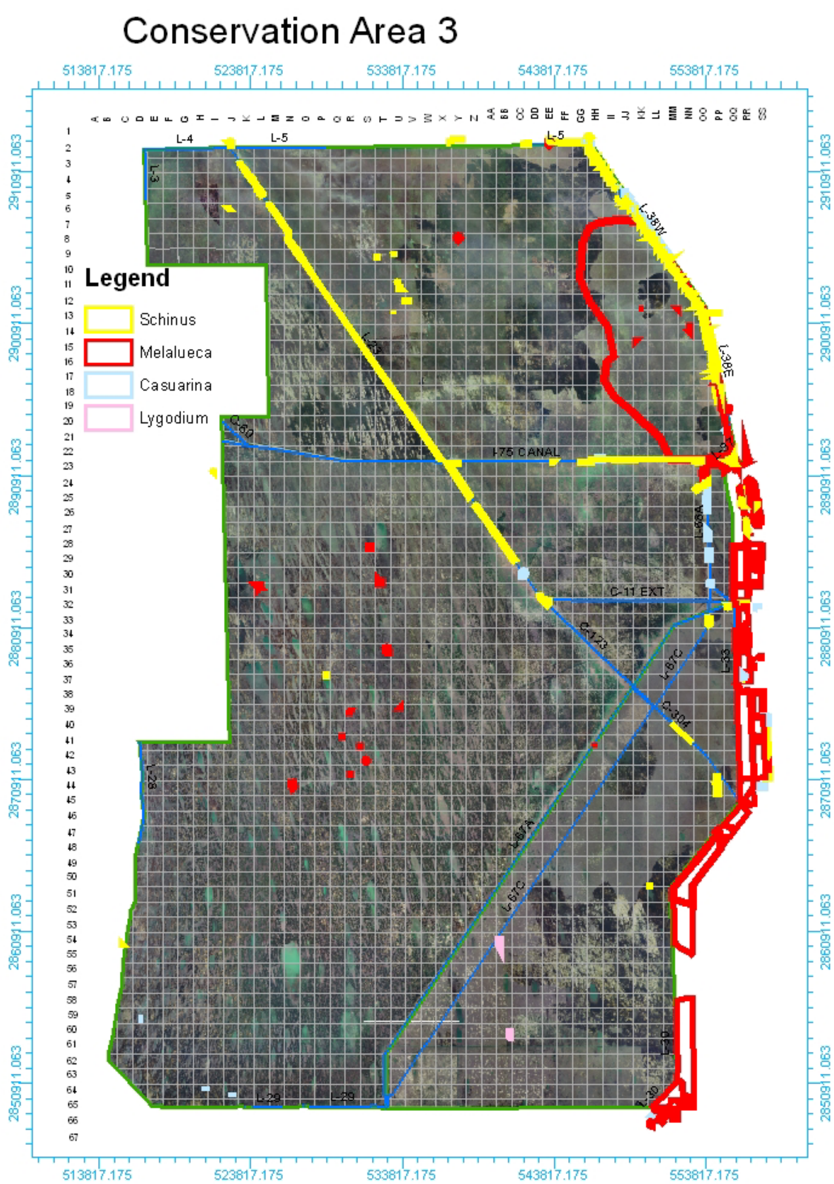

Figure 9-6. Draft Digital Aerial Sketchmapping map of WCA-3 (source: Tony Pernas, National Park Service and Amy Ferriter, Boise State University).

Invasive Species Data Tracking

Agency efforts to track and control invasive species in South Florida vary widely. Without a "clearinghouse" of agency programs, gathering information on invasive plant and animal species activities is challenging. Based on an extensive review of several invasive species programs, NEWTT developed a web-based, database-oriented system (ECOSTEMS) to organize and track agency activities in the Everglades (see www.ecostems.org). ECOSTEMS is intended for use by the agencies working with the South Florida Ecosystem Task Force on Everglades restoration to input, track, and update invasive species project information. This includes a description and title of each task, dates, funding levels by fiscal year, and personnel involved in each task and identifies agency affiliations and interagency partnerships for each task. The system allows users to see tasks as they relate to other agency efforts and within the overall programmatic strategy. Agency staff can also query data for use in developing cross-cut budgets, funding requests, and download the data for use in reports and presentations.

The ultimate goal of this project is to provide a system that agencies can use to coordinate and integrate invasive species research, education, management, and control activities in South Florida. While ECOSTEMS was initiated and developed by NEWTT for tracking invasive plant data, the system is well-suited for tracking information for other taxa.

AN ASSESSMENT OF INVASIVE PLANT AND ANIMAL SPECIES IN THE SOUTH FLORIDA ENVIRONMENT

Within the Central and Southern Florida Restudy Area, just six species of invasive exotic plants have replaced approximately 1.9 million acres of habitat (Doren and Ferriter, 2001). One species alone, Old World climbing fern (*Lygodium microphyllum*) has spread exponentially during the last two years. Its current range covers more than 125,000 acres across seven South Florida counties in Everglades habitat, and model predictions for this species estimates more than 5 million acres covered by 2014.

This chapter covers the entire Central and Southern Florida Restudy area, which encompasses approximately 18,000 square miles from Orlando to the Florida Reef Tract with at least 11 major physiographic provinces: Everglades, Big Cypress, Lake Okeechobee, Florida Bay, Biscayne Bay, Florida Reef Tract, near shore coastal waters, Atlantic Coastal Ridge, Florida Keys, Immokalee Rise, and the Kissimmee River Valley. The Kissimmee River, Lake Okeechobee, and the Everglades are the dominant watersheds that connect a mosaic of wetlands, uplands, coastal areas, and marine areas. This area includes all or part of the following 16 counties: Monroe, Miami-Dade, Broward, Collier, Palm Beach, Hendry, Martin, St. Lucie, Glades, Lee, Charlotte, Highlands, Okeechobee, Osceola, Orange, and Polk.

There is significant scientific evidence and research documenting that invasive exotic plants are degrading and damaging natural ecosystems in South Florida (see Doren and Ferriter, 2001). These species are causing significant ecological harm through crowding out and displacing native vegetation upon which native fish and wildlife are dependent for food and shelter. Other negative impacts of invasive species can include (1) alteration of soil types and soil and water chemistry, (2) alteration of ecosystem functions such as carbon sequestration and nutrient cycling, (3) attenuation of gene pools and genetic diversity, (4) reducing native species diversity and (5) alteration of community composition. Most exotic plants provide little or no habitat value for native wildlife. They can cause changes in hydrology and soil composition, degrade water quality, and decrease the biodiversity of an entire ecosystem. The distribution, magnitude, and impacts of exotic animals in South Florida are poorly understood. If the Everglades is to be restored and preserved and if South Florida's natural environments are to remain intact, then the problem of invasive plant and animal species must be addressed comprehensively and with sufficient resources.

Sixteen different federal and state agencies, numerous local agencies, and two Indian tribes are involved in Everglades' restoration and thus in one or more activities related to the management, regulation, control, interdiction, and prevention of invasive exotic species in Florida. Combined, these agencies have management authority for more than 13.7 million acres (about 21,500 square miles) of Florida's natural lands. Individual agencies have noted 32 out of the 66 priority plant species included in Weeds Won't Wait as particularly serious and specifically targeted for control. The process of documenting the problems associated with exotic animal species in South Florida is just beginning (Goodyear, 2000; Art Roybal, USFWS, personal communication).

The many agencies supporting the Comprehensive Everglades Restoration Plan (CERP) and the broader restoration efforts being coordinated by the SFERTF consider invasive species a serious threat to the Everglades Restoration Initiative and the goals of the restoration program. This is the first report to develop an all-taxa approach to identifying nonindigenous species in a region and attempt to organize these species spatially, thus beginning the process of prioritizing species in relation to the threat they pose to Everglades restoration efforts.

The nonindigenous species information in this report is organized using the terms, geographical references, and structure developed by Restoration Coordination and Verification (RECOVER) – an arm of CERP responsible for linking science and the tools of science to a set of systemwide planning, evaluation and assessment tasks - and the Science Coordination Group (SCG) (see Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan, 2005) (**Figure 9-7**). In addition, RECOVER has identified invasive species as 'drivers' and 'stressors' in the conceptual ecological models (CEM). The CEMs include the Florida Bay, Everglades Ridge and Slough, Southern Marl Prairies, Greater Everglades, Everglades Mangrove Estuaries, Big Cypress Regional, Lake Okeechobee, and Loxahatchee Watershed (see http://www.evergladesplan.org/pm/recover/recover.cfm). These models and the performance measures and ecological indicators derived from them serve as the basis for adaptive management activities and the development of Vital Signs (system-wide ecological indicators) for Everglades restoration by the SFERTF.

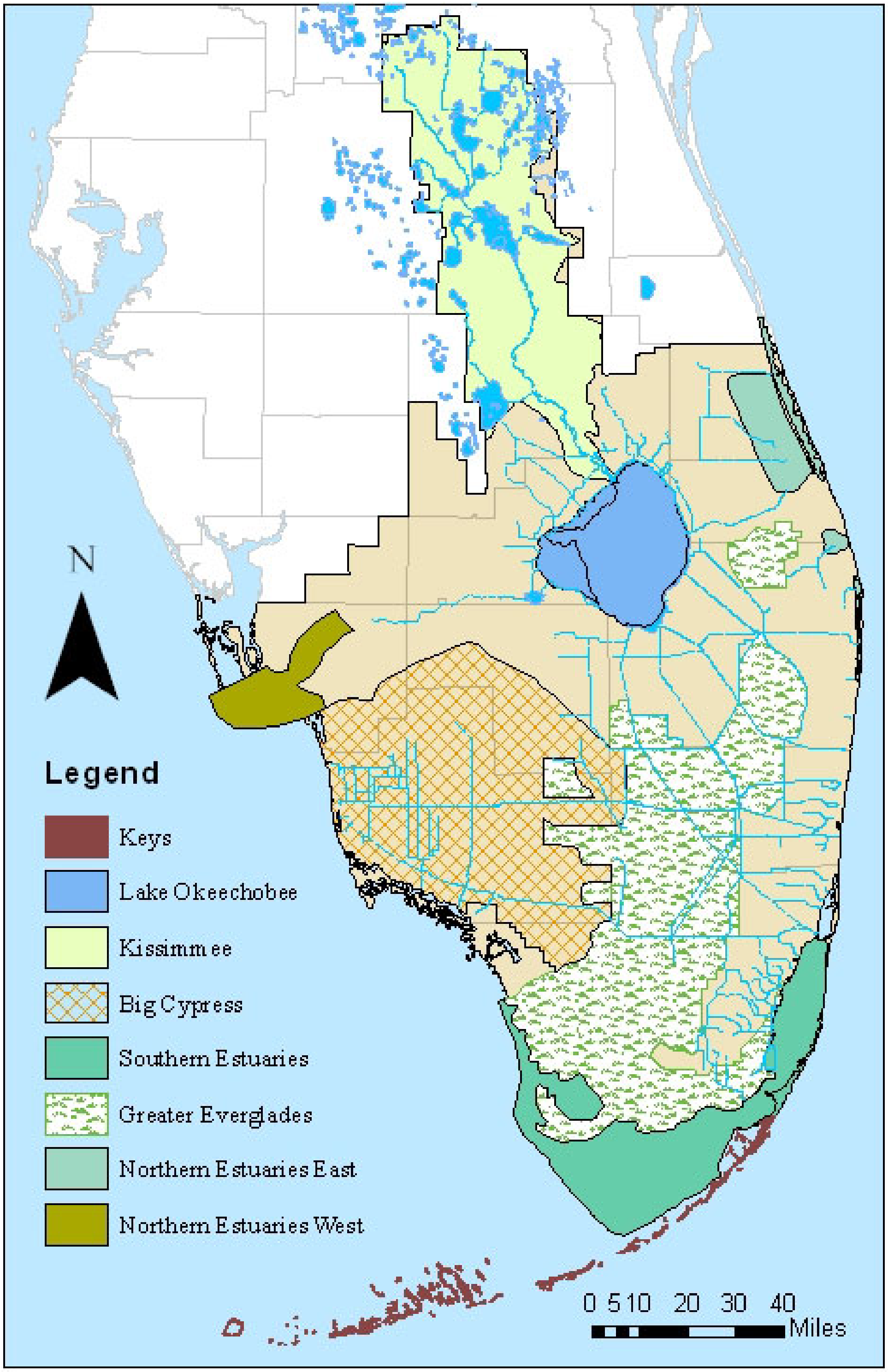

Figure 9-7. The nonindigenous species information in this report is organized using the terms, geographical references, and structure developed by Restoration Coordination and Verification (RECOVER).

Information is organized according to these established formats to maintain consistency among the many different agencies and personnel working on Everglades restoration projects. Nonindigenous species are presented by occurrence within eight geographic divisions (modules) related to the South Florida Restoration and the Kissimmee Basin Restoration programs:

- Florida Keys
- Florida Bay and the Southern Estuaries
- Greater Everglades
- Western Big Cypress
- Lake Okeechobee
- Northern Estuaries - East
- Northern Estuaries – West (Caloosahatchee Estuary)
- Kissimmee River Basin

The individual module species lists were compiled from the FWC exotic animal occurrence data, USGS data, Carole Goodyear's Exotic Animal Report (2000), Florida Exotic Pest Plant Council data (www.fleppc.org), peer review from NEWTT and FIATT members, and interviews with land managers. Within the geographic areas, animal species are divided by broad taxonomic groups: mammals, fish, birds, invertebrates, reptiles, and amphibians. The individual species are then listed within these taxonomic groups. Priority plant species are listed and scored in a separate table for each module.

It is recognized that some of the listed invasive exotic animal species may actually occur outside of the specific module due to limitations in available animal distribution data – often county level data is the most specific location available. Through peer review by various taxonomic experts and land managers, these lists have been refined to reflect regional considerations such as coastal vs. inland habitats. This report attempts to describe the issues of invasive exotic species related to the South Florida Ecosystem Restoration Program. Overall organization and planning for the management and control of these species does however take into account the regional aspects related to invasive species management strategies, logistics and control tactics (see Doren and Ferriter, 2001).

Agency-sponsored efforts to control exotic plants in the Everglades date back to the 1980s, and an effort is made here to provide an account of agency successes and failures for priority species in each regional module. The focus of this evaluation is public lands, although generalized private land data is available in some modules, and is presented in this chapter, if applicable. Priority plant species evaluations are based on the following criteria:

- Are the acres of the species in the region increasing, decreasing, or static?
- Is the regional distribution and basic biology of the species sufficiently understood to develop effective integrated control programs?
- Is there an active and effective systematic control program in place for that species in that region or elsewhere?
- Is there dedicated funding for control and management of the species in the region?

- Are biocontrols released or under development for the species?
- Has a region or species-wide, species-specific management plan been developed and being implemented and/or is the species included in a broader regional or landscape level strategic planning and management program?

Evaluations of animal species were extremely limited due to the paucity of data and information about these taxa. When possible, pertinent localized animal issues will be discussed in the module narrative, but specific evaluations are not possible at this time.

THE MODULES

Each of the eight module sections includes a narrative of relevant nonindigenous species issues. Through the use of the abovementioned scoring criteria, priority plant species are given a "score" for each module. A summary of FY2005 District nonindigenous species expenditures by module is provided in **Table 9-2**.

Table 9-2. Summary of FY2005 District nonindigenous species control expenditures by RECOVER module.

	Lake Okeechobee	Kissimmee	Big Cypress	Greater Everglades	Northern Estuaries East	Northern Estuaries West	System-wide Biocontrol
Australian Pine				$219,800			
Brazilian Pepper	$110,500	$230,000		$1,903,429		$102,000	$75,000
Shoebutton Ardisia				$134,000			
Old World climbing fern		$401,000	$13904	$400,440	$145,000	$102,000	$150,000
Melaleuca	$284,000			$2,423,750	$433,000	$301,000	$150,000
Torpedograss	$840,000						

The scores indicate if agencies are "Winning" (the control program is effective and populations are decreasing in that module) "Losing" (a control program is not in place or not effective for that species in that module) or a "Draw" (not enough information is available to determine the effectiveness of the program or the species population seems to be static in that particular module). These classifications are provided here in an attempt to gauge progress in overall agency-sponsored invasive plant control efforts. The plant species that are "scored" for each module and a listing of animal taxa are highlighted in tables within each module summary.

While animal taxa lists are provided for each module and certain animal species are discussed in the modules, no attempt is made here to prioritize or "score" animal taxa. The animal lists are meant to represent "Nonindigenous Species of Interest" for the respective region. The lists do not imply that the individual species are expanding or negatively impacting the environment. They are presented to provide a baseline list of organisms that occur in the module and have the potential to impact restoration efforts. Key animal species are discussed in modules where agency efforts to deal with the individual species are ongoing, where evidence suggests that these species are causing negative impacts, or to highlight the need for resources or early detection and rapid response efforts.

It is important to note that certain nonindigenous animal species occur in almost every module. These species are listed in the respective module "Nonindigenous Animal Species of Interest" tables, and include the green iguana (*Iguana iguana*), monk parakeet (*Myiopsitta monachus*) (**Figure 9-8**), giant toad (*Bufo marinus*), Cuban treefrog *(Osteopilus septentrionalis*), tokay gecko (*Gekko gecko*), feral dog (*Canis familiaris*), and feral cat (*Felis catus*). Failure to specifically mention these species in the module narrative does not imply that they are not problematic or should not be given priority for control. On the contrary, work is urgently needed to establish distribution and biological data for these organisms given their ubiquitous nature in South Florida.

Figure 9-8. The monk parakeet (*Myiopsitta monachus*) (photo by Kathleen Carr, FDEP).

The Florida Keys Module

The Florida Keys Module was separated from the Southern Estuaries Module because it is a unique and important ecological unit that is part of the South Florida environment, but was not included in the scope of CERP. Unlike virtually every other coastal habitat in Florida, the "invadable" land area is relatively small in the Florida Keys. This allows land managers to effectively prioritize species and deal systematically with relatively small parcels (Alison Higgins, The Nature Conservancy, personal communication). Through the well-coordinated Florida Keys Invasive Exotics Task Force, a list of priority plant and animal species has been developed. Virtually all conservation lands are considered to be under maintenance control for target plant species, and other public lands (military facilities, rights of way, etc.) are beginning to be addressed. Work to assess, prioritize, and control nonindigenous animals in the Florida Keys is just beginning, but this module is perhaps the best organized in an all-taxa approach, and will likely serve as a model for other regions as the issue of managing nonindigenous animals becomes more mainstream.

Although the public lands in the Florida Keys are well-maintained, land managers report that populations of some species (e.g., Australian pine*, Casuarina equisetifolia)* are decreasing on public lands, but increasing on private lands. Although latherleaf (*Colubrina asiatica)* appears to be decreasing on public lands as a result of systematic control efforts, challenges in detecting this sprawling coastal shrub species make it difficult to determine if populations are decreasing overall in the Florida Keys. Ficus (*Ficus microcarpa*) continues to be a priority species in the upper Florida Keys because it grows epiphytically on many native tree species, making control difficult. Other priority species, such as sapodilla (*Manikara zapota)* are problematic in localized areas, and species such as leadtree (*Leucaena leucocephala)* and umbrella tree (*Schefflera actinophylla)* are mainly increasing along roadsides and in disturbed sites (**Table 9-3**). The Nature Conservancy is working to facilitate invasive species control for private lands that are adjacent to conservation areas (Chris Berg, The Nature Conservancy, personal communication).

There are also localized problems associated with relatively new (or previously undetected) plant populations such as sickle bush (*Dichrostachys cinerea).* This African/Indian thorny shrub forms dense, impenetrable thickets, and is a major weed in large areas of Cuba. It was first detected in the Florida Keys on Tavernier in 2002 (Tony Pernas, National Park Service, personal communication). Although not currently listed on the FLEPPC's list of invasive plants in Florida (FLEPPC, 2005), it warrants special attention in the Florida Keys, and is the target of coordinated control measures to prevent its further spread.

Table 9-3. Priority nonindigenous plant species, Florida Keys Module.

Scientific Name	Common Name	Condition
Casuarina spp.	Australian pine	Winning
Colubrina asiatica	Latherleaf	Losing
Dichrostachys cinerea	Sickle bush	Draw
Ficus microcarpa	Ficus	Draw
Leucaena leucocephala	Lead tree	Draw
Neyraudia reynaudiana	Burma reed	Draw
Manilkara zapota	Sapodilla	Draw
Scaevola taccada	Inkberry	Draw
Schefflera actinophylla	Umbrella tree	Draw
Schinus terebinthifolius	Brazilian pepper	Winning
Thespesia populnea	Seaside mahoe	Draw

Nonindigenous Animals – Florida Keys Module

In addition to the priority plant species listed above (**Table 9-3**), a list of "Nonindigenous Animal Species of Interest" is provided for the Florida Keys Module (**Table 9-4**).

Table 9-4. Nonindigenous animals of interest, Florida Keys Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus coqui	Coqui
Eleutherodactylus planirostris	Greenhouse frog
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Agama agama	African redhead Agama
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis sagrei	Brown anole
Apalone ferox	Florida softshell
Gekko gecko	Tokay gecko
Gonatodes albogularis fuscus	Yellowhead gecko
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Phelsuma madagascariensis grandis	Giant day gecko
Ramphotyphlops braminus	Brahminy blind snake
Sphaerodactylus argus argus	Ocellated gecko
Sphaerodactylus elegans elegans	Ashy gecko
Trachemys scripta elegans	Red-eared slider
Birds	
Acridotheres tristis	Common myna
Brotogeris chiriri	Yellow-chevroned parakeet
Cairina moschata	Muscovy duck
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet
Passer domesticus	House sparrow
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove

Scientific Name	Common Name
Mammals	
Canis familiaris	Feral dog
Cricetomys gambianus	Gambian pouch rat
Felis catus	Feral cat
Molossus molossus tropidorhynchus	Pallas's mastiff bat
Mus musculus	House mouse
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Vulpes vulpes	Red fox
Fish	
Belonesox belizanus	Pike killifish
Herichthys cyanoguttatus	Rio grande cichlid
Gramma loreto	Royal gramma
Hemichromis letourneauxi	African jewelfish
Osteoglossum bicirrhosum	Arawana
Platax oribularis	Orbiculate batfish
Invertebrates	
Blattella asahinai	Asian cockroach
Cactoblastis cactorum	Cactus moth
Cittarium pica	West Indian trochid
Glossodoris sedan	Marine nudibranch
Iridomyrmex humilis	Argentine ant
Litopenaeus stylirostris	Pacific white shrimp
Litopenaeus vannamei	Pacific white shrimp
Littorina littorea	Common periwinkle
Monomorium pharaonis	Pharaoh ant
Ozamia lucidalis	Moth
Paratachardina lobata	Lobate lac scale
Paratrechina longicornis	Crazy ant
Plecia nearctica	Love bug
Solenopsis invicta	Imported fire ant
Truncatella subcylinidrica	Snail
Zachrysia provisoria	Cuban garden snail

While several nonindigenous animals are listed here as "Species of Interest" in the Florida Keys (**Table 9-4**), two animal species – an insect and a mammal – are receiving warranted agency attention.

Cactoblastis

Cactoblastis cactorum is a South American moth whose larvae feed exclusively on species of prickly pear cactus (*Opuntia* spp.) (**Figure 9-9**). The moth was first discovered in North America on Big Pine Key in 1989. The insect had become widely established in the Caribbean and was most likely introduced accidentally to Florida through the horticulture trade. Distribution of this species now occurs along the Atlantic coast to Charleston, South Carolina, and westward along the Gulf Coast to Dauphin Island, Alabama. The cactus moth is attacking and destroying native species of prickly pear and represents a substantial threat to the southwestern U.S. and Mexico, areas that are rich in cactus diversity and have substantial industries dependent on prickly pear cacti.

Figure 9-9. *Cactoblastis cactorum* larvae on an Opuntia cactus pad (photo by Ignacio Baez, USDA-ARS).

Figure 9-10. *Cactoblastis cactorum* larvae inside of an Opuntia pad (photo by Ignacio Baez, USDA-ARS).

Caterpillars of this invasive moth feed gregariously inside cactus pads (**Figure 9-10**), destroying the plants. In the Florida Keys, this moth threatens the endemic and endangered *Opuntia* species, *O. corallicola*, and causes negative impacts to populations of the native, common prickly pear cactus and ornamental species. The U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS) has conducted work to track the abundance and location of the moth with development of a female, sex pheromone, baited trap. ARS research is also being aimed at developing a Sterile Insect Technique (SIT) program as a control/exclusion strategy for this moth. The SIT program may serve as a possible means of establishing a barrier that would stop the cactus moth's westward movement or reduce the moth population attacking endangered cactus species (Stephen Hight, Florida A&M University, personal communication). Release of irradiated cactus moths began in March 2005. The long-term management strategy for this species involves the use of complementary tactics such as releasing sterilized moths, sanitation (removal of infested plants, cladodes, eggsticks, and pupae), use of biological pesticides, and increasing public awareness. Until effective control methods are developed, land managers in the Florida Keys are monitoring *Opuntia* spp. populations and manually removing impacted cactus pads.

Gambian Pouch Rat

Figure 9-11. Gambian pouch rat (*Cricetomys gambianus*) (photo by Alison Higgins, TNC).

Gambian pouch rats (*Cricetomys gambianus*) are native to Africa. They were bred in captivity on Grassy Key, where it is believed that eight rats escaped between 1999 and 2002. These eight individuals have since established a reproducing population on Grassy Key. Gambain pouch rats are large, weighing an average of 3 pounds and measuring 20–35 inches from head to tail, which is much larger than the native species including the Key Largo wood rat, cotton rat, and silver rice rat, which are not found in the area of current Gambian pouch rat infestation (**Figure 9-11**). The Gambian pouch rat's unusually large size has made this species popular in the exotic pet trade, although the Food and Drug Administration (FDA) has banned their transport and sale because they are a carrier of monkey pox.

These nonindigenous rodents primarily eat fruit and grains, but are also known to eat invertebrates (Novak and Paradiso, 1991). Conditions on Grassy Key are not optimal for this species, possibly due to a lack of burrowing habitat and a paucity of fresh water as well as potential competition from the abundant raccoon population. Gambian pouch rats have been concentrated in the vicinity of dwellings near the initial release site, apparently relying on refuse and pet food. Scientists fear that this species is poised to move from Grassy Key onto adjacent keys and eventually to the mainland of Florida.

In response to the threat that this species poses to the South Florida environment, a containment and eradication program for the Gambian pouch rat was initiated in June 2005 by the FWC and USDA-APHIS/Wildlife Services, assisted by USFWS and the FDEP. As part of this effort, the FWC has established a phone line and a web site to handle public information requests related to this species. This aggressive project has nearly completed a baseline abundance index survey using 40 motion sensor/infrared cameras in hammock habitats on Grassy Key. Additionally, rodent-specific toxicants have been tested, and a bait station has been fabricated to exclude non-target species. In late 2005, bait stations will be deployed with toxicants, with subsequent re-survey using cameras. To date, cameras deployed at the Long Key garbage transfer station and at the garbage receiving facility in Pompano Beach (Broward County, FL) have not detected Gambian pouch rats. Although trash piles may serve as a dispersal pathway, initial observations suggest that the Gambian rat population will likely be confined to Grassy Key, with some possibility of dispersal southward to Vaca Key (Marathon).

The Florida Bay and Southern Estuaries Module

Invasive plant management efforts in this region focus on coastal areas of Everglades National Park and the islands and mainland of Biscayne National Park. Control operations have been ongoing since the 1980s. Priority plants in this module include coastal species such as Australian pine, agave, inkberry, Brazilian pepper, seaside mahoe, and most notably, latherleaf. Nowhere in Florida are the ecological effects of latherleaf more noticeable than in this region (Jones, 1997) (**Table 9-5**). Latherleaf was first noted as naturalized in the Southern Estuaries by Small (1933), and is now well established and distributed throughout the coastal areas of both Everglades National Park and Biscayne National Park. This species 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.

Figure 9-12. Latherleaf (*Colubrina asiatica*) commonly invades the coastal ridges just above the mean high-tide line (photo by Tony Pernas, National Park Service).

Latherleaf invades 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) (**Figure 9-12**). This species is of particular concern in Florida's coastal hammocks, where it threatens a number of rare, listed native plants such as Florida thatch palm, Keys thatch palm, wild cinnamon, manchineel, cacti, bromeliads, and orchids (Jones, 1996). Fortunately, there is no evidence of long-distance dispersal mechanisms on land that could facilitate its spread inland. Storms and extreme tides appear to be the only dispersal agents (Carlquist, 1966).

Latherleaf is actively managed in Everglades National Park and Biscayne National Park, although there are increased concerns about this species in the Southern Estuaries. Due to difficulties in early detection of this intertwined scandent shrub, resource managers are unable to accurately estimate the distribution of latherleaf in the region, complicating systematic control operations. The National Park Service is also in the process of investigating questions related to seed and seed bank viability. This information is directly related to ongoing operational and maintenance control strategies.

Table 9-5. Priority nonindigenous plant species, Florida Bay and Southern Estuaries Module.

Scientific Name	Common Name	Condition
Agave sisalana	Agave	Losing
Calophyllum antillanum	Mastwood	Losing
Casuarina spp.	Australian pine	Winning
Colubrina asiatica	Latherleaf	Losing
Leucaena leucocephala	Leadtree	Draw
Manilkara zapota	Sapodilla	Draw
Pennisetum setaceum	Fountaingrass	Draw
Phoenix reclinata	Senegal date palm	Draw
Sansevieria hyacinthoides	Bowstring hemp	Losing
Scaevola taccada	Inkberry	Losing
Schefflera actinophylla	Umbrella tree	Losing
Schinus terebinthifolius	Brazilian pepper	Draw
Thespesia populnea	Seaside mahoe	Losing

Nonindigenous Animals – Florida Bay and Southern Estuaries Module

In addition to well-documented problems associated with nonindigenous coastal plant species (**Table 9-5**), Florida Bay and the Southern Estuaries also have many "Nonindigenous Animal Species of Interest," as listed below (**Table 9-6**). Two species, a mammal and a fish, are highlighted here due to recent evidence that populations are expanding and these organisms may be impacting ecologically sensitive areas of Florida Bay and the Southern Estuaries.

Table 9-6. Nonindigenous animals of interest, Florida Bay and Southern Estuaries Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus coqui	Coqui
Eleutherodactylus planirostris	Greenhouse frog
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Agama agama	African redhead agama
Ameiva ameiva	Giant ameiva
Anolis chlorocyanus	Hispaniolan green anole
Anolis cristatellus cristatellus	Puerto Rican crested anole
Anolis cybotes	Largehead anole
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis garmani	Jamaican giant anole
Anolis porcatus	Cuban green anole
Anolis sagrei	Brown anole
Basiliscus vittatus	Brown basilisk
Cnemidophorus lemniscatus	Rainbow lizard
Cnemidophorus motaguae	Giant whiptail
Cosymbotus platyurus	Asian flattail house gecko
Ctenosaura pectinata	Mexican spinytail iguana
Ctenosaura similes	Black spinytail iguana
Gekko gecko	Tokay gecko
Gonatodes albogularis fuscus	Yellowhead gecko
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiocephalus schreibersii schreibersii	Red-sided curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Mabuya multifasciata	Many-lined grass skink

Scientific Name	Common Name
Reptiles *(continued)*	
Phelsuma madagascariensis grandis	Giant Day Gecko
Phrynosoma cornutum	Texas Horned Lizard
Ramphotyphlops braminus	Brahminy Blind Snake
Sphaerodactylus argus argus	Ocellated Gecko
Sphaerodactylus elegans elegans	Ashy Gecko
Tarentola annularis	White-spotted Wall Gecko
Tarentola mauritanica	Moorish Wall Gecko
Trachemys scripta elegans	Red-eared Slider
Varanus niloticus	Nile Monitor
Birds	
Columba livia	Rock Dove
Passer domesticus	House Sparrow
Streptopelia decaocto	Eurasian Collared-Dove
Zenaida asiatica	White-winged Dove
Mammals	
Canis familiaris	Feral Dog
Felis catus	Feral Cat
Lepus californicus	Black-tailed Jackrabbit
Macaca mulatta	Rhesus Monkey
Molossus molossus tropidorhynchus	Pallas's Mastiff Bat
Mus musculus	House mouse
Nasua narica	White-nosed Coati
Rattus norvegicus	Norway Rat
Rattus rattus	Black Rat
Saimiri sciureus	Squirrel Monkey
Sciurus aureogaster	Mexican Red-bellied Squirrel
Vulpes vulpes	Red Fox
Fishes	
Acanthurus sohal	Sohal Surgeonfish
Alosa sapidissima	American Shad
Arusetta asfur	Arabian Angel
Astronotus ocellatus	Oscar
Belonesox belizanus	Pike Killifish
Betta splendens	Siamese Fighting Fish
Brachydanio rerio	Zebra Danio
Carassius auratus	Goldfish
Cephalopholis argus	Peacock Hind
Chaetodon lunula	Racoon Butterfly
Channa marulius	Bullseye Snakehead
Chitala ornata	Clown Knife

Scientific Name	Common Name
Fishes *(continued)*	
Cichla ocellaris	Peacock cichlid
Cichla temensis	Speckled pavon
Cichlasoma bimaculatum	Black acara
Cichlasoma citrinellum	Midas cichlid
Cichlasoma cyanoguttatum	Rio Grande cichlid
Cichlasoma managuense	Jaguar guapote
Cichlasoma meeki	Firemouth cichlid
Cichlasoma nigrofasciatum	Convict cichlid
Cichlasoma octofasciatum	Jack dempsey
Cichlasoma urophthalmus	Mayan cichlid
Clarias batrachus	Walking catfish
Colisa lalia	Dwarf gourami
Colossoma macropomum	Tambaqui
Colossoma or Piaractus sp.	Unidentified pacu
Corydoras sp.	Corydoras
Cromileptes altivelis	Panther grouper
Ctenopharyngodon idella	Grass carp
Cyprinus carpio	Common carp
Danio malabaricus	Malabar danio
Dorosoma petenense	Threadfin shad
Esox niger	Chain pickerel
Geophagus brasiliensis	Pearl eartheater
Geophagus surinamensis	Redstriped eartheater
Gramma loreto	Royal gramma
Helostoma temmincki	Kissing gourami
Hemichromis letourneauxi	African jewelfish
Heros severus	Banded cichlid
Hoplosternum littorale	Brown hoplo
Hypophthalmichthys nobilis	Bighead carp
Hypostomus plecostomus	Suckermouth catfish
Hypostomus sp.	Suckermouth catfish
Labeotropheus sp.	Scrapermouth cichlid
Macrognathus siamensis	Spotfinned spinyeel; Peacock eel
Macropodus opercularis	Paradisefish
Monopterus albus	Asian swamp eel
Morone chrysops x saxatilis	Wiper
Morone saxatilis	Striped bass
Naso lituratus	Unicornfish
Oreochromis aureus	Blue tilapia
Oreochromis mossambicus	Mozambiqua tilapia
Oreochromis mossambicus x hornorum	Hybrid tilapia
Oreochromis, Sarotherodon, Tilapia sp.	Tilapia
Oreochromis, Sarotherodon, Tilapia sp. x sp.	Hybrid tilapia
Osteoglossum bicirrhosum	Arawana

Scientific Name	Common Name
Fishes *(continued)*	
Oxydoras niger	Ripsaw catfish
Piaractus mesopotamicus	Small-scaled pacu
Platax orbicularis	Orbiculate batfish
Poecilia latipinna x velifera	Black molly
Poecilia petenensis	Peten molly
Poecilia reticulata	Guppy
Polypterus delhezi	Bichir
Pomacanthus annularis	Blue ringed angelfish
Pomacanthus imperator	Emperor angelfish
Pomacanthus maculosus	Yellowbar angelfish
Pomacanthus semicirculatus	Semicircle angelfish; Zebra angelfish
Pomacanthus xanthometopon	Bluefaced angel
Pterois volitans	Lionfish
Pterophyllum sp.	Freshwater angelfish
Pterygoplichthys multiradiatus	Orinoco sailfin catfish
Puntius conchonius	Rosy barb
Puntius gelius	Dwarf barb
Puntius schwanenfeldii	Tinfoil barb
Puntius tetrazona	Tiger barb
Pygocentrus nattereri	Red piranha
Rhamdia quelen	Bagre
Rhinecanthus verrucosus	Bursa triggerfish
Salvelinus fontinalis	Brook trout
Sarotherodon melanotheron	Blackchin tilapia
Serrasalmus rhombeus	White piranha
Tilapia mariae	Spotted tilapia
Tilapia zillii	Redbelly tilapia
Trichogaster leerii	Pearl gourami
Trichogaster trichopterus sumatranus	Blue gourami
Trichopsis vittata	Croaking gourami
Xiphophorus helleri	Green swordtail
Xiphophorus maculatus	Southern platyfish
Xiphophorus variatus	Variable platyfish
Zanclus cornutus	Moorish idol
Zebrasoma desjardinii	Sailfin tang
Zebrasoma flavescens	Yellow tang
Zebrasoma veliferum	Sailfin tang
Zebrasoma xanthurum	Yellowtail tang

Scientific Name	Common Name
Invertebrates	
Balanus reticulates	Barnacle
Balanus trigonus	Barnacle
Cactoblastis cactorum	Cactus moth
Callinectes bocourti	Bocourt swimming crab; Red blue crab
Cepolis varians	Caribbean land snail
Chelymorpha cribraria	Tortoise beetle
Corbicula fluminea	Asian clam
Craspedacusta sowerbyii	Freshwater jellyfish
Cuthona perca	Lake Merritt cuthona
Daphnia lumholtzi	Water flea
Glossodoris sedan	Marine nudibranch
Haliplanella luciae	Sea anemone
Iridomyrmex humilis	Argentine ant
Littorina littorea	Common periwinkle
Marisa cornuarietis	Giant rams-horn snail
Melanoides tuberculatus	Red-rim melania
Monomorium pharaonis	Pharaoh ant
Paratrechina longicornis	Crazy ant
Pomacea bridgesii	Spiketop applesnail
Pomacea canaliculata	Channeled applesnail
Solenopsis invicta	Imported fire ant
Sphaeroma terebrans	Wood-boring isopod
Sphaeroma walkeri	Fouling isopod
Tridacna crocea	Giant clam
Tridacna maxima	Giant clam
Truncatella subcylindrica	Snail

Mexican Red-bellied Squirrel

The Mexican red-bellied squirrel (*Sciurus aureogaster*) is native to southern Mexico (reviewed in Koprowski et al., in press). Two pairs of the squirrel were purposefully introduced from eastern Mexico to Elliott Key in 1938. They quickly established a breeding population on the island and were widespread by the 1960s. The species has also been reported on two adjacent islands, Adams Key and Sand Key.

Figure 9-13. Mexican red-bellied squirrel (*Sciurus aureogaster*) nest in a canopy tree on Elliott Key (photo by John L. Koprowski, University of Arizona).

Hurricane Andrew (1992) resulted in losses of island forests (Ogden, 1992; Davis et al., 1993). Many mammal species survived the storm on mainland Miami-Dade County (Ogden, 1992; Davis et al., 1993) but the island populations of red-bellied squirrels were thought to have been extirpated on Elliott, Adams, and Sand keys (Koprowski et al., in press). Recent sightings and conspicuous nests in large trees on Elliott Key (**Figure 9-13**) suggest that this nonindigenous species survived the hurricane and is increasing in number (Tony Pernas, National Park Service, personal communication). The current status of the species on Sand and Adams keys is not known.

The Mexican red-bellied squirrel breeds year-round. They are opportunistic feeders (John Koprowski, University of Arizona, personal communication) with a diet that includes the fruits of many native species including sea grape (*Coccoloba uvifera*), mastic (*Mastichodendron foetidissimum*), gumbo limbo (*Bursera simaruba*), Keys thatch palm (*Thrinax morrissii*), Florida thatch palm (*Thrinax radiata*), and most notably, the endangered Sergeant's Buccaneer palm (*Pseudophoenix sargentii*). They also feed on eggs and invertebrates and pre-Andrew National Park Service assessments of the squirrel on Elliott Key (Tilmant, 1980) suggested that they feed on the declining liguus tree snail (*Liguus fasciatus)*.

The impact and potential impacts of this exotic species on Florida Bay and the Southern Estuaries are poorly understood, although introduced populations of other squirrels in Europe and the western U.S. are known to cause detrimental impacts (Steele and Koprowski, 2001). A National Park Service ranger intercepted a swimming squirrel near Old Rhodes Key (Layne, 1997), suggesting that this species is capable of spreading throughout the Southern Estuaries and onto the Florida Keys where species of endangered rodents such as the Key Largo woodrat (*Neotoma floridana smalli*) and the Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*) would be vulnerable to competition. The invasive potential of the Mexican red-bellied squirrel coupled with the conspicuous number of individuals and increased abundance of nests on Elliott Key suggests that this species warrants further investigation. In response to this threat, the National Park Service has initiated the development of a "Rapid Assessment of the Mexican Red Bellied Squirrel at Biscayne National Park" with the University of Arizona. This work will use nest surveys, live trapping, and radio telemetry to document the status of the nonindigenous squirrel on Elliott, Sand, and Adams keys.

Mayan Cichlid

The Florida population of Mayan cichlid (*Cichlasoma urophthalmus*) was first recorded in 1983 in Snook Creek, a tributary of Joe Bay in northeastern Florida Bay (Loftus, 1987). The source of this introduction is unknown, although scientists suspect one or more accidental or purposeful aquarium releases (Loftus and Kushlan, 1987). The Mayan cichlid is native to the Atlantic slope waters of southeastern Mexico and Central America. It thrives under a wide range of environmental conditions, exhibiting a tolerance to brackish and marine conditions (**Figure 9-14**). Since its discovery in Florida Bay in the early 1980s, this species has expanded its range; it is common throughout the District canal system, freshwater wetlands, and estuarine mangrove swamps of the Southern Estuaries. The Mayan cichlid is an established, introduced species (Loftus, 1987), which is unlikely to be eradicated.

The Mayan cichlid has a varied diet, preying on small fishes and aquatic invertebrates. Given its broad salinity tolerance and aggressive nature, it is likely to continue to impact the Florida Bay and the Southern Estuaries and expand its range in southern Florida (Loftus, 1987). Analysis of recent data from mangrove areas along northern Florida Bay showed that densities of native species varied inversely with densities of Mayan cichlids, indicating strong predation effects (Trexler et al., 2000). Potential impacts of this species could include altering native fish community structure through direct interaction, breeding ground competition, and the predation of juveniles of desirable species such as snook and tarpon (Shafland, 1996).

Figure 9-14. Mayan cichlid (*Cichlasoma urophthalmus*) (photo by Paul Shafland, FFWCC).

The Greater Everglades Module

Before organized state and federal exotic plant control operations were initiated in the Greater Everglades in 1990, melaleuca was widely distributed throughout Water Conservation Areas (WCAs) and Everglades National Park in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) (**Figure 9-15**). Pioneering or "outlier" melaleuca had invaded the interior of the ENP and WCA-2A. Light to moderate infestations occurred in WCA-3 and the western edge of the former East Everglades Acquisition Area (currently known as the northeastern side of the ENP). Moderate to heavy infestations occurred in the Refuge and WCA-2B. It was the widespread nature of this species in the Everglades that galvanized South Florida's biologists and led to the formation of the FLEPPC.

Figure 9-15. Large melaleuca (*Melaleuca quinquenervia*) head in the northern Everglades (photo by SFWMD).

Within the Greater Everglades, the District, NPS, FWC, and USFWS all have management responsibilities for this species on their respective lands. Overall, agency efforts to control melaleuca, are succeeding in containing and reducing its spread in the Greater Everglades. Melaleuca has been systematically cleared from WCA-2A, 3A, and 3B, north and south of Alligator Alley. These areas are now under "maintenance control." (**Table 9-7**) Dense populations of melaleuca in these WCAs no longer occur and scattered populations have been significantly reduced. District operational work now focuses on carefully maintaining previously treated areas. Melaleuca populations in the ENP are also decreasing, with significant populations now limited to the northeasternmost edge of the ENP where crews are working systematically to bring the area under maintenance control. However, melaleuca populations in the northernmost sections of the Greater Everglades Module are increasing, and control operations do not appear to be systematic in approach. Areas of the Refuge and Corbett Wildlife Management Area that had light to medium levels of melaleuca in the early 1990s are now dominated by large stands of the tree.

Figure 9-16. Old World climbing fern (*Lygodium microphyllum*) and Brazilian pepper (*Schinus terebinthifolius*) overtaking a tree island in the northern Everglades (photo by Amy Ferriter, Boise State University).

There is perhaps no other plant species that poses a greater threat to the Everglades than Old World climbing fern (*Lygodium microphyllum)*. This highly-invasive vining fern smothers native vegetation, severely compromising plant species composition, destroying tree island canopy cover and dominating understory communities, all of which are cited as key parameters in measuring Everglades restoration success (**Figure 9-16**).

When surveys for the species began in the early 1990s, Old World climbing fern occurred on limited tree islands in the northern quarter of the Refuge. Today, it dominates the Refuge, and has now expanded into virtually every habitat in the Greater Everglades (Ferriter, 2001). ENP staff discovered thousands of acres of lygodium on the western edge of the ENP in 2000 (Tony Pernas, National Park Service, personal communication) and District field biologists began observing small strands of lygodium in WCA-3 in 2001 (Michael Korvela, SFWMD, personal communication). This species could potentially overtake most of the southern peninsula of Florida (Lott et al., 2003; Volin et al., 2004). Biannual SRF surveys conducted by the District have documented the rapid spread of this species since 1993 (**Figure 9-17**). Based on the documented impacts of this species in the Refuge (Brandt and Black, 2001) and ENP, the District initiated a detailed ground-based tree island survey to estimate the extent to which lygodium occurs in the WCAs. The District has been actively involved in conducting aerial surveys for lygodium since 1993, and conducting operational and field research for *lygodium* control since 1997 (Stocker et al., 1997; Gann et al., 1999; Ferriter, 2001; Langeland and Link, in press), while control operations are ongoing throughout the Greater Everglades.

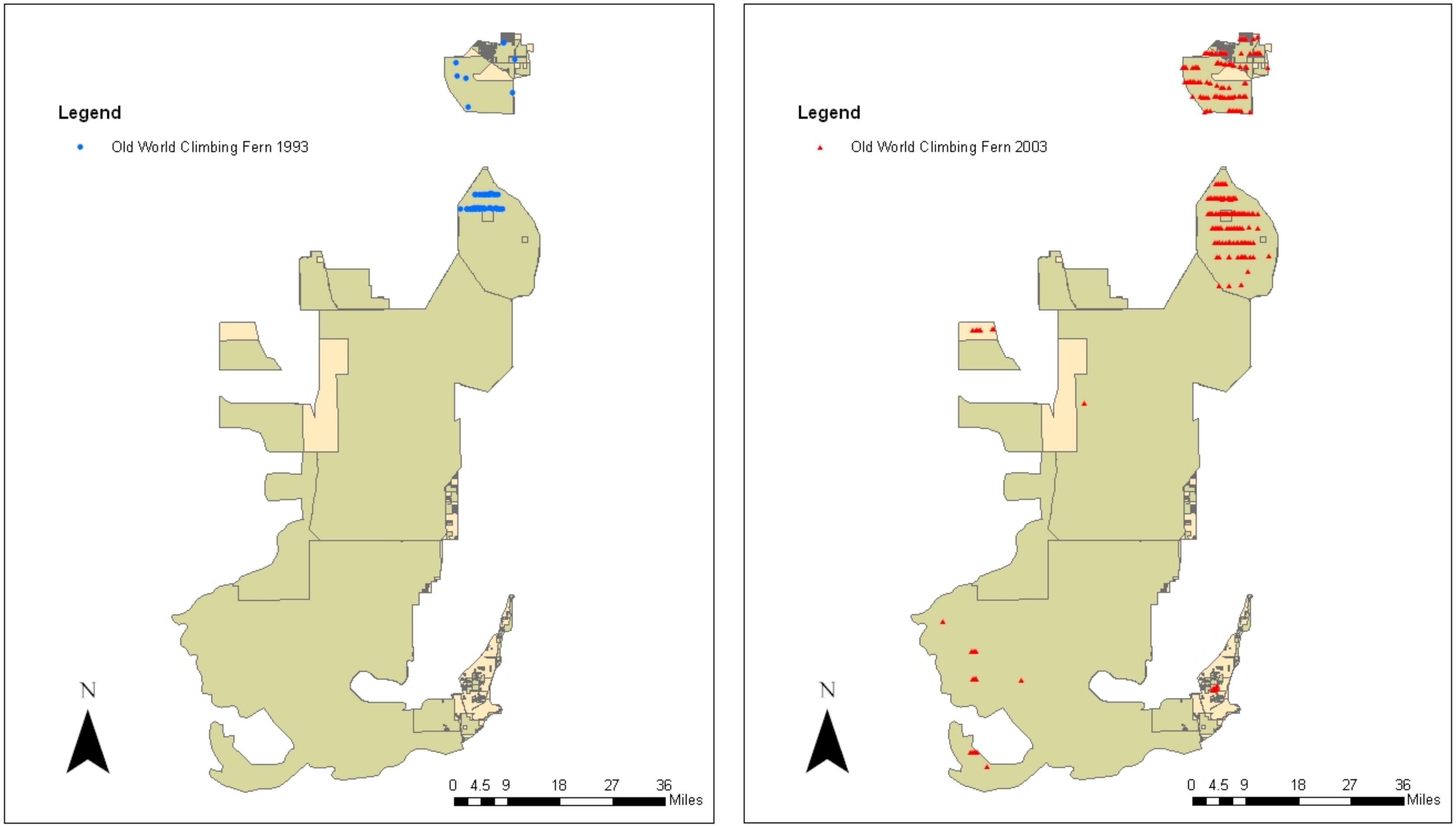

Figure 9-17. Spread of Old World climbing fern (*Lygodium microphyllum*) 1993–2003 in the Greater Everglades Module (source: Boise State University).

Due to the remoteness of the ENP populations, Park staff is limited to using aerial treatments to contain the plant. Park Service staff is working to evaluate non-target damage and assess the effectiveness of these treatments. District contract crews treat *lygodium* as it is encountered on tree islands throughout the Everglades and in the South Dade Wetlands. In an effort to contain its spread in the WCAs, District and FWC biologists regularly report GPS locations of incipient lygodium populations to the District's Operations and Maintenance Department so that crews can be dispatched to specific areas (Francois Laroche, SFWMD, personal communication). At the Refuge, where there is a particularly severe infestation of *Lygodium microphyllum*, the treatments are performed by contract crews and Refuge staff. Additionally there are several ongoing research initiatives including a model of the plant's spread with an "Optimal Control Growth Model" for the Refuge (Brandt, 2005), studies on lygodium spore dispersal and germination, and effects of lygodium on ant diversity in tree islands (Darby et al., 2002).

It is extremely important that the District, as well as other land managers, continue to identify and treat small populations of this exotic climbing fern before they become substantial infestations. Early detection and treatment is crucial to successful and economical management of this plant. Land managers statewide agree that biocontrol holds the key to effective long-term regional management of this species. The USDA released one biocontrol agent, a defoliating moth (*Austromusotima camptozonale),* on this species in 2005 (Buckingham et al., 2003), but it is too early to determine its effectiveness in Florida and overseas searches and rigorous quarantine testing for other agents (Goolsby and Pemberton, 2004) will take many years.

Brazilian pepper (*Schinus terebinthifolius*) is common on levees and tree islands throughout the Greater Everglades. Unlike melaleuca, operational control for this species is not systematic in approach, with the exception of the ENP's "Hole in the Donut" (HID) project, where impenetrable monocultures of Brazilian pepper are being controlled through the complete removal of substrate. This intensive process results in recolonization by native vegetation to the exclusion of Brazilian pepper. In contrast, vast areas of the western edge of the ENP are completely dominated by this species and resource managers face almost insurmountable obstacles in treating these populations due to the scope and remoteness of the sites. This underscores the need for effective biological controls for this species. The University of Florida and the USDA are working to develop biological controls for Brazilian pepper. Several petitions for release have been submitted to the USDA Animal Plant Health Inspection Service - Plant Protection Quarantine (APHIS-PPQ), but to date permission has not been granted for the release of any agents in Florida.

Australian pine (*Casuarina equisetifolia*) grows very fast (1 to 3 meters per year), is salt tolerant, and readily colonizes rocky coasts, dunes, sandbars, islands, and invades far-inland moist habitats (Morton, 1980). It forms dense forests, eventually excluding other plant species. Efforts to control Australian pine in the Greater Everglades are ongoing, but are not systematic in approach. This species is still common along District levee berms, in a large portion of eastern ENP, in the District's southern saline glades (C-111 basin), and many coastal areas of the ENP and mainland Biscayne National Park. The seeds are windblown, carried by birds, and probably moved throughout the Everglades via water flow in canals.

Australian pine threatens key habitat for the endangered Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis),* which needs the short-hydroperiod marl prairies of the southeastern Everglades to nest. This sparsely vegetated community is characteristically dominated by muhly grass (*Muhlenbergia capillaris*) and sawgrass. Australian pine has invaded and forested many of these historically graminoid marsh nesting sites. In response to this threat, the ENP and the USACE initiated a systematic Australian pine control program for the eastern edge of the Park in an effort to restore nesting habitat.

Shoebutton ardisia (*Ardisia elliptica*) is a shade-loving shrub that was originally reported in the HID. It spread into adjacent tropical hardwood hammocks in the Long Pine Key area of the Park (Seavey and Seavey, 1994) and was observed in the Flamingo Bay area in 1995 (Doren and Jones, 1997). Large monotypic stands of this species now occur on District lands adjacent to the ENP. Sporatic District and NPS control operations are ongoing for this species, but recent field observations (Mitchell Blakenship, Applied Aquatics, personal communication) indicate that this highly invasive plant is invading the understory of many tree islands in WCA-3. If this species continues to spread in the WCAs, then it will threaten the integrity of tree island plant communities. Shoebutton ardisia prefers wetlands and in other areas of the Greater Everglades, it forms dense, monotypic populations that completely exclude understory vegetation. Early detection of this species in tree islands will be extremely challenging as it is difficult to discern from the air and a related native, marlberry (*Ardisia escallonioides*), has a very similar form. Birds are the principal seed dispersers although raccoons and opossums also eat the fruit and disperse seeds (Miami-Dade County, 2002).

Table 9-7. Priority nonindigenous plant species, Greater Everglades Module.

Scientific Name	Common Name	Condition
Ardisia elliptica	Ardisia	Losing
Casuarina spp.	Australian pine	Winning
Lygodium microphyllum	Old World climbing fern	Losing
Melaleuca quinquenervia	Melaleuca	Winning
Schinus terebinthifolius	Brazilian pepper	Draw

Nonindigenous Animals – Greater Everglades Module

In addition to the priority plant species listed above (**Table 9-7**), a list of "Nonindigenous Animal Species of Interest" is provided for the Greater Everglades Module (**Table 9-8**). While there are many animal species on this list, several organisms have raised special concerns among scientists in the region and have the potential to impact Everglades restoration initiatives. The Burmese python, lobate lac scale, and swamp eel are discussed here, but recent (2005) field observations by the Florida International University and Everglades National Park scientists indicate that other species such as the channeled applesnail (see the *Kissimmee Basin Module* section) are present in the Greater Everglades. These snails and egg masses were found in an old borrow canal within the northern boundary of Everglades National Park just east of the entrance to Shark Valley (Skip Snow, Everglades National Park, personal communication). Surveys for this nonindigenous species continue in neighboring waterways as well as adjacent freshwater marshes, and work is beginning to explore available control strategies (Skip Snow, Everglades National Park, personal communication).

Table 9-8. Nonindigenous animals of interest, Greater Everglades Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus coqui	Coqui
Eleutherodactylus planirostris	Greenhouse frog
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Agama agama	African redhead agama
Ameiva ameiva	Giant ameiva
Anolis chlorocyanus	Hispaniolan green anole
Anolis cristatellus cristatellus	Puerto Rican crested anole
Anolis cybotes	Largehead anole
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis garmani	Jamaican giant anole
Anolis porcatus	Cuban green anole
Anolis sagrei	Brown anole
Basiliscus vittatus	Brown basilisk
Boa constrictor	Common boa
Caiman crocodiles	Spectacled caiman; Common caiman
Chrysemys picta dorsalis	Southern painted turtle
Cnemidophorus lemniscatus	Rainbow lizard
Cnemidophorus motaguae	Giant whiptail
Cosymbotus platyurus	Asian flattail house gecko
Ctenosaura pectinata	Mexican spinytail iguana

Scientific Name	Common Name
Reptiles *(continued)*	
Ctenosaura similes	Black spinytail iguana
Gekko gecko	Tokay gecko
Gonatodes albogularis fuscus	Yellowhead gecko
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiocephalus personatus scalaris	Green-legged curlytail lizard
Leiocephalus schreibersii schreibersii	Red-sided curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Mabuya multifasciata	Many-lined grass skink
Phelsuma madagascariensis grandis	Giant day gecko
Phrynosoma cornutum	Texas horned lizard
Python molurus bivittatus	Burmese python
Ramphotyphlops braminus	Brahminy blind snake
Sphaerodactylus argus argus	Ocellated gecko
Sphaerodactylus elegans elegans	Ashy gecko
Tarentola annularis	White-spotted wall gecko
Tarentola mauritanica	Moorish wall gecko
Trachemys scripta elegans	Red-eared slider
Varanus niloticus	Nile monitor
Varanus salvator	Water monitor
Birds	
Acridotheres tristis	Common myna
Cairina moschata	Muscovy duck
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet
Passer domesticus	House sparrow
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove
Mammals	
Canis familiaris	Feral dog
Chlorocebus aethiops	Vervet monkey
Felis catus	Feral cat
Lepus californicus	Black-tailed jackrabbit
Macaca mulatta	Rhesus monkey
Molossus molossus tropidorhynchus	Pallas's mastiff bat
Mus musculus	House mouse
Nasua narica	White-nosed coati
Rattus norvegicus	Norway rat

Scientific Name	Common Name
Mammals *(continued)*	
Rattus rattus	Black rat
Saimiri sciureus	Squirrel monkey
Sus scrofa	Feral pig
Vulpes vulpes	Red fox
Fishes	
Alosa sapidissima	American shad
Astronotus ocellatus	Oscar
Belonesox belizanus	Pike killifish
Carassius auratus	Goldfish
Cichla ocellaris	Peacock cichlid
Cichla temensis	Speckled pavon
Cichlasoma bimaculatum	Black acara
Cichlasoma citrinellum	Midas cichlid
Herichthys cyanoguttatus	Rio Grande cichlid
Cichlasoma managuense	Jaguar guapote
Cichlasoma meeki	Firemouth cichlid
Cichlasoma nigrofasciatum	Convict cichlid
Cichlasoma octofasciatum	Jack dempsey
Cichlasoma salvini	Yellowbelly guapote
Cichlasoma urophthalmus	Mayan cichlid
Clarias batrachus	Walking catfish
Colisa lalia	Dwarf gourami
Colossoma macropomum	Tambaqui
Colossoma or Piaractus sp.	Unidentified pacu
Corydoras sp.	Corydoras
Ctenopharyngodon idella	Grass carp
Cyprinus carpio	Common carp
Danio malabaricus	Malabar danio
Dorosoma petenense	Threadfin shad
Esox niger	Chain pickerel
Geophagus brasiliensis	Pearl eartheater
Geophagus surinamensis	Redstriped eartheater
Helostoma temmincki	Kissing gourami
Hemichromis letourneauxi	African jewelfish
Heros severus	Banded cichlid
Hoplosternum littorale	Brown hoplo
Hypostomus plecostomus	Suckermouth catfish
Hypostomus sp.	Suckermouth catfish
Macrognathus siamensis	Spotfinned spinyeel; Peacock eel
Macropodus opercularis	Paradisefish
Monopterus albus	Asian swamp eel
Morone chrysops x saxatilis	Wiper
Morone saxatilis	Striped bass
Oreochromis aureus	Blue tilapia

Scientific Name	Common Name
Fishes *(continued)*	
Oreochromis mossambicus	Mozambiqua tilapia
Oreochromis mossambicus x hornorum	Hybrid tilapia
Oreochromis, Sarotherodon, Tilapia sp.	Tilapia
Oreochromis, Sarotherodon, Tilapia sp. x sp.	Hybrid tilapia
Piaractus mesopotamicus	Small-scaled pacu
Poecilia latipinna x velifera	Black molly
Poecilia latipunctata	Broadspotted molly
Poecilia petenensis	Peten molly
Poecilia reticulata	Guppy
Polypterus delhezi	Bichir
Liposarcus multiradiatus	Orinoco sailfin catfish
Puntius conchonius	Rosy barb
Puntius gelius	Dwarf barb
Puntius schwanenfeldii	Tinfoil barb
Puntius tetrazona	Tiger barb
Pygocentrus nattereri	Red piranha
Rhamdia quelen	Bagre
Sarotherodon melanotheron	Blackchin tilapia
Tilapia mariae	Spotted tilapia
Tilapia zillii	Redbelly tilapia
Trichogaster leerii	Pearl gourami
Trichogaster trichopterus sumatranus	Blue gourami
Trichopsis vittata	Croaking gourami
Xiphophorus helleri	Green swordtail
Xiphophorus maculatus	Southern platyfish
Xiphophorus variatus	Variable platyfish
Invertebrates	
Amblyomma chabaudi	Madagascan tortoise tick
Amblyomma exornatum	Monitor lizard tick
Amblyomma flavomaculatum	Yellow-spotted monitor lizard tick
Amblyomma humerale	Reptilian tick
Amblyomma latum	Snake tick
Amblyomma marmoreum	African tortoise tick
Amblyomma nodosum	Reptilian tick
Amblyomma nuttalli	Small reptile tick
Amblyomma sabanerae	Neotropical tortoise tick
Amblyomma varanense	Asian monitor lizard tick
Apis mellifera scutellata	African bee
Aulacaspis yasumatsui	Armored scale insect
Blattella asahinai	Asian cockroach
Ceroplastes rusc	Fig wax scale
Chaetanophotrips leeuwenia	Thrips
Chelymorpha cribraria	Tortoise beetle

Scientific Name	Common Name
Invertebrates *(continued)*	
Corbicula fluminea	Asian clam
Craspedacusta sowerbyii	Freshwater jellyfish
Crocothemis servilia	Scarlet skimmer
Daphnia lumholtzi	Water flea
Erythemis plebeja	Black pond hawk
Eupristina masoni	Wasp
Glossodoris sedna	Marine nudibranch
Hyalomma aegyptiujm	Reptilian tick
Iridomyrmex humilis	Argentine ant
Marisa cornuarietis	Giant rams-horn snail
Melanoides tuberculatus	Red-rim melania
Metamasius callizona	Mexican bromeliad weevil
Micrathyria aequalis	Spottedtailed skimmer
Micrathyria didyma	Three-striped skimmer
Monomorium pharaonis	Pharaoh ant
Oceanaspidiotus araucariae	Scale
Parapristina varticillata	Wasp
Paratachardina lobata	Lobate lac scale
Paratrechina longicornis	Crazy ant
Plecia nearctica	Love bug
Pomacea bridgesii	Spiketop applesnail
Pomacea canaliculata	Channeled applesnail
Retithrips syriacus	Thrips
Solenopsis invicta	Imported fire ant
Technomyrmex albipes	White-footed ant
Truncatella subcylindrica	Snail
Wasmannia auropunctata	Little fire ant

Swamp Eel

Figure 9-18. Swamp eel (photo by USGS).

During the late 1990s, three reproducing non-native populations of swamp eel (Family: Synbranchidae) were discovered in Florida. Included are large populations in North Miami canals, canal networks near Homestead adjacent to Everglades National Park, and in water bodies near Tampa (Fuller et al. 1999; L.G. Nico, USGS, personal communication). Initially, all populations were identified as *Monopterus albus*, a species widespread in Eastern Asia. However, subsequent genetic analysis of introduced and native populations indicate that introduced swamp eels in Florida represented at least two different Asian forms, presumably both belonging to the genus *Monopterus* but the species not yet determined (Collins et al., 2002) (**Figures 9-18** and **9-19**)). It is believed that wild populations in Florida originated as escapes or releases associated with aquaculture, the pet trade, or live food markets.

These fish are now widespread in District canals in Miami-Dade County. Swamp eels have certain characteristics that concern scientists, setting them apart from most other nonindigenous fish species documented in the Greater Everglades Module. The diverse wetland habitats of the Greater Everglades are presumably ideal for the species. Swamp eels are versatile animals, capable of living in extremely shallow water, traveling over land when necessary, and burrowing into mud to survive periods of drought. The eels, which can grow to more than three feet in length, are predators that feed on invertebrates, frogs, and other fishes. Although swamp eels are not yet known to have spread from canal systems into the interior of the Everglades, their proximity to restoration efforts is a concern.

USGS scientists have been studying swamp eels since their discovery in Florida. Work is focusing on various aspects of swamp eel biology, including changes in distribution and abundance, basic life history (e.g., diet and reproduction), genetics, environmental tolerances (e.g., salinity), and ecological effects. Certain control methods have been investigated (e.g., removal with electroshocking gear and use of rotenone), but these studies are not yet complete. Given the abundance and wide distribution of swamp eels in Florida's canals, elimination is probably impossible and successful containment and control will be difficult.

Figure 9-19. Swamp eel (photo by Don Schmitz, FDEP).

Lobate Lac Scale

Figure 9-20. Lobate lac scale (*Paratachardina lobata)* on native tree island species (photo by SFWMD).

The lobate lac scale insect (*Paratachardina lobata)* is native to India and Sri Lanka and was first discovered in Davie, Florida in 1999, on ornamental hibiscus (*Hibiscus rosa-sinensis*) The scale began spreading at an alarming rate, with new populations reported with increasing frequency throughout urban and natural areas. Host species include many different ornamental shrubs and trees, including fruit trees, and it is known to occur on over 40 native plant species. Some plant families, notably Fabaceae (peas and beans), Myrtaceae (myrtles), and Moraceae (mulberry) seem to have many species that are especially susceptible to the scale. Field observations in the Greater Everglades indicate that the nonindigenous insect occurs on many native plants, and certain native species appear to be highly susceptible, e.g., wax myrtle (*Myrica cerifera*), cocoplum (*Chrysobalanus icaco*), buttonwood (*Conocarpus erectus*), strangler fig (*Ficus aurea*), myrsine (*Myrsine guianensis*), red bay (*Persea borbonia*), and wild coffee (*Psychotria nervosa*) (**Figure 9-20**).

This insect is already seriously impacting native tree islands, aerial surveys indicate that large specimens and populations of wax myrtle and cocoplum have been killed by this insect in areas well within the Everglades. Given the importance of healthy tree islands and associated canopy cover to wading bird nesting and the overall success of Everglades Restoration efforts, and the propensity of some exotic plants to rapidly colonize disturbed sites (such as areas of canopy dieback), immediate research is needed to understand the distribution of this species and steps should be taken to contain its spread into these important Everglades communities.

Surveys for this species are conducted by the Cooperative Agricultural Pest Survey (CAPS) program, but the charge of this agency-sponsored work is to track the species in agricultural and urban areas, and only very limited work has been done in natural areas. The spread of lobate lac scale in the Everglades is of great concern as there are currently no insecticides labeled for use in wetland areas, and selective control of this species with pesticides will be difficult, if not impossible. In addition, the use of pesticides in sensitive natural areas may have other secondary effects especially on native insect populations. The USDA and the University of Florida have initiated overseas searches for natural enemies of lobate lac scale, and biological control agents are currently seen as the only option for controlling this species.

Burmese Python

Hugh Willoughby, explorer of the late 1890s, referred to the mainland along the southern coast of Everglades National Park as the "Land of the Big Snake." In Willoughby's account of an 1896 canoe journey across the Everglades, he noted two different Indian accounts "…of snakes that were at least eighteen feet in length, and evidently belonged to the constrictor family." Reports of "big snakes" in the ENP a century later include regular and increasing sightings of Burmese pythons, and occasional, infrequent sightings of ball pythons, reticulated pythons, and common boas. Untouched photographs depicting alligator versus python appeared in the February 25, 2003, issue of the *National Examiner* under the headline banner, "Mighty beasts grapple for 24 hours as shocked Florida tourists watch!" Remarkably, in February 2004 and June 2005, this event was repeated at two different locations in the Park (**Figure 9-21**). Unlike the rare and infrequent circus animal escapees during Willoughby's time, Burmese pythons in the wild today are a result of unwanted and intentionally released exotic pets.

Figure 9-21. American alligator and Burmese python (*Python molurus bivittatus*) entangled in the Everglades (photo by Lori Oberhofer, Everglades National Park).

The Burmese python (*Python molurus bivittatus*), a native to Southeast Asia, can reach a length greater than 20 feet. This python is a long lived (15–25 years) behavioral, habitat, and dietary generalist, capable of producing large clutches of eggs (8–107). The nonindigenous python's diet in the Everglades includes raccoon, rabbit, muskrat, squirrel, opossum, cotton rat, black rat, cat (kitten), house wren, pied-billed grebe, white ibis, and limpkin. As the Burmese python is known to eat birds, and also known to frequent wading bird colonies in their native range, the proximity of python sightings to the Paurotis Pond and Tamiami West wood stork rookeries is troubling**.**

Observations of pythons exist primarily from three locations in the ENP: (1) along the Main Park Road in the saline and freshwater glades, and mangroves, between Pay-hay-okee and Flamingo, (2) the greater Long Pine Key area (including Hole-in-the-Donut), and (3) the greater Shark Valley area along the Tamiami Trail (including L-67 Ext.). They have also been observed repeatedly on the eastern Park boundary, along canal levees, in the remote mangrove backcountry, and in Big Cypress National Preserve. Since 1995, more than 156 Burmese pythons have been captured and removed or found dead on the road. In recent years (2003–2005) individuals of all size classes have been seen with increasing regularity in and around the ENP. The measured total length for snakes recovered ranged from 2–14 feet, including five hatchling sized animals recovered in the summer 2004, and two hatchlings captured in 2005.

Burmese pythons present a potentially significant threat to the successful ecological restoration of the greater Everglades. Pythons are now established and breeding in South Florida. The Burmese python has the clear potential to occupy the entire footprint of CERP, adversely impacting valued resources across the landscape.Burmese pythons are widely bred in Florida and still imported from Southeast Asia as pets. Proposed management and control actions must include strategies for preventing their intentional release. In July 2005, an Invasive Snake/Reptile Management and Response Workshop was convened, recommendeding strategic actions in three broad areas: (1) python control, (2) rapid response to invasive amphibians and reptiles in South Florida, and 3) public outreach and education. Action plans are currently being drafted and funding is being pursued.

Western Big Cypress Module

The Western Big Cypress Module is made up of Big Cypress National Preserve (BCNP) to the east, a patchwork of public and private lands to the west, and Tribal lands to the north. Melaleuca is being effectively controlled on most public lands such as BCNP and District-managed lands, but appears to be spreading on private lands. The USDA-sponsored melaleuca biological control program is an important component of the overall melaleuca management strategy in this module. The first melaleuca biocontrol agent, a melaleuca weevil (*Oxyops vitiosa*), was introduced in 1997 and subsequently established on melaleuca throughout the region (**Figure 9-22**). The immature stages of the weevil are flush-feeders, attacking the tender new shoots growing at the branch tips. Weevil feeding results in the defoliation of the upper portions of the melaleuca canopy. In response to the defoliation, melaleuca trees produce new leaves to replace those that are destroyed, which in turn are attacked by the weevil. This ongoing game of “cat and mouse” causes melaleuca trees to dedicate nearly all available energy to vegetative growth rather than reproduction. Recent studies by USDA entomologists have determined that weevil attacks suppress reproduction by 80 percent, and the few trees that do reproduce have flowers that are small and contain few seeds.

Figure 9-22. The first melaleuca biocontrol agent, the melaleuca weevil (*Oxyops vitiosa*), was introduced to Florida in 1997 (photo by USDA).

The second agent, the melaleuca psyllid (*Boreioglycaspis melaleucae*), was released in 2002. This agent passes through five immature stages. While all stages of the insect feed on melaleuca sap, the immature stages cause the majority of the damage. The melaleuca psyllid is generally found on newly developed melaleuca leaves but also attacks older leaves and young branches (**Figure 9-23**). Psyllids feed on melaleuca by inserting their straw-like mouthparts through the leaf tissues to gain access to the phloem. As the insects suck the plant sap they inject a phytotoxic saliva that causes the tissue surrounding the feeding site to degrade, causing the leaves to drop prematurely.

Figure 9-23. The second agent, the melaleuca psyllid (*Boreioglycaspis melaleucae*), was released in 2002 (photo by USDA).

USDA entomologists have determined that psyllid feeding on melaleuca seedlings results in 60 percent mortality in less than a year. This type of feeding accelerates the defoliation caused by the weevil and further weakens melaleuca trees.

The combined efforts of these two biological control agents have resulted in thinning of the melaleuca canopy in many areas, which allows more sunlight to reach the forest floor. As a result, native species are beginning to return to some melaleuca-dominated habitats and are able to compete with the exotic tree. To facilitate the distribution of these biological control agents, state and federally supported collection and redistribution efforts have resulted in the release of over 900,000 insects in Florida. A coordinated strategy was used to concentrate insect releases in environmentally sensitive restoration sites or melaleuca-dominated areas that were not currently slated for herbicide treatments. This approach aims to use biological control agents to reduce reinvasion of managed sites and halt continued melaleuca invasion in untreated sites. The effects of these two biocontrol agents are most apparent in the Western Big Cypress Module and will be important in the long-term control of this tree given the large percentage of melaleuca that remains on unmanaged private lands, as shown in **Figure 9-24**.

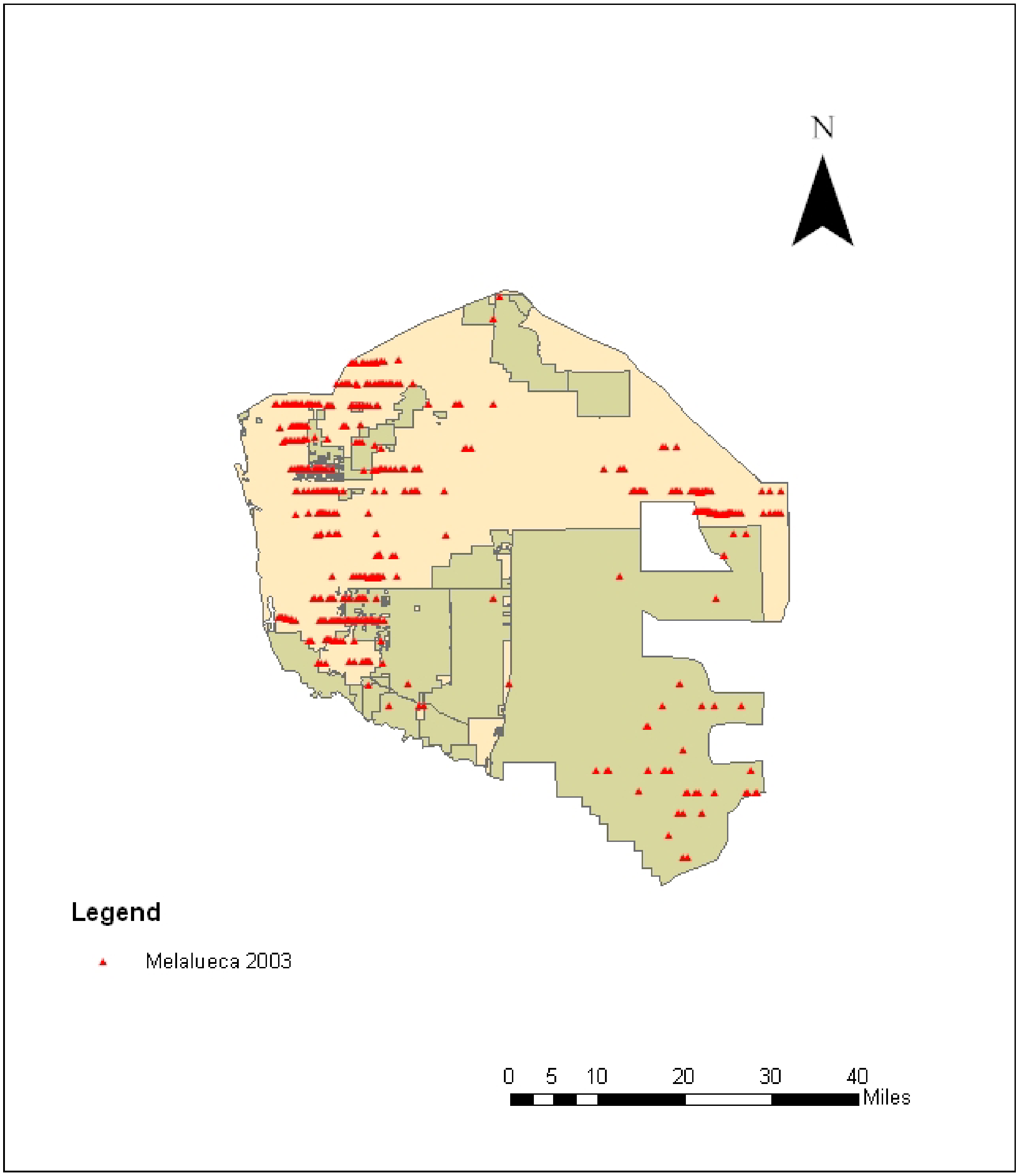

Figure 9-24. Distribution of melaleuca in the Big Cypress Module, 2003 (source: Boise State University).

Lygodium microphyllum is major weed in region and, as in the Greater Everglades Module, it poses a serious threat to restoration initiatives (**Figure 9-25**). The District launched the first large scale operational control program for this species at the CREW property in 1999. District land managers are effectively controlling this species on District lands in the Big Cypress Module, but constant vigilance is necessary as new populations are constantly being found. BCNP employs a "find and treat" contractor that is devoted to scouting for incipient populations of lygodium. This is a responsible strategy given the potential for this species to decimate large areas of the preserve. A closely related nonindigenous species, *Lygodium japonicum,* was recently identified and controlled in the BCNP (Jimi Sadle, National Park Service, personal communication). This species was previously thought to mainly occur north of Lake Okeechobee.

The floating aquatic fern, giant salvinia (*Salvinia molesta*) is a nonindigenous plant species of great concern in this module. It was first reported in Naples (1999) in the Airport Road Canal, and later in the Golden Gate Canal (2004). This species is a notorious weed elsewhere in the world. It quickly forms thick mats on top of the water and prevents light penetration of the water column, shading out native vegetation and degrading habitat for fish and wildlife. Given the threat this species poses to the aquatic and wetland areas of the state, the District initiated a program to treat and maintain this outbreak of giant salvinia in the hopes of containment. The USDA is also studying a biological control agent, the Salvinia weevil (*Cyrtobagous salviniae*) that was introduced (the source of this introduction is unknown) and has been heavily attacking giant salvinia in the Naples area.

Figure 9-25. Old World climbing fern in Big Cypress National Preserve (photo by Big Cypress National Preserve).

Table 9-9. Priority nonindigenous plant species, Western Big Cypress Module.

Scientific Name	Common Name	Condition
Casuarina spp.	Australian pine	Winning
Dioscorea bulbifera	Air potato	Draw
Ficus microcarpa	Ficus	Losing
Hymenachne amplexicaulis	West Indian marsh grass	Losing
Imperata cylindrical	Cogongrass	Losing
Lygodium japonicum	Japanese climbing fern	Winning
Lygodium microphyllum	Old World climbing fern	Winning
Melaleuca quinquenervia	Melaleuca	Winning
Pennisetum purpureum	Napier grass	Losing
Rhodomyrtus tomentosa	Downy rose myrtle	Draw
Salvinia molesta	Giant salvinia	Winning
Schinus terebinthifolius	Brazilain pepper	Winning
Solanum viarum	Tropical soda apple	Winning
Syzigium cumini	Java plum	Losing
Urochloa plantaginea	Creeping signal grass	Losing

Nonindigenous Animals – Western Big Cypress Module

In addition to the priority plant species listed above (**Table 9-9**), a list of "Nonindigenous Animal Species of Interest" is provided for the Western Big Cypress Module (**Table 9-10**). Notably, two animal species pose a direct threat to the Big Cypress ecosystem. They are a mammal (feral hog) and an insect (Mexican bromeliad weevil). Other species, such as the green mussel (see the *Caloosahatchee Estuary Module* section), lobate lac scale (see the *Greater Everglades Module* section), and Mayan cichlid (see the *Southern Estuaries Module* section), are also known to be expanding in this region, but are detailed in other sections of this chapter.

Table 9-10. Nonindigenous animals of interest, Big Cypress Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus planirostris	Greenhouse frog
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Agama agama	African redhead agama
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis sagrei	Brown anole
Basiliscus vittatus	Brown basilisk
Boa constrictor	Common boa
Ctenosaura similis	Black spinytail iguana
Gekko gecko	Tokay gecko
Gonatodes albogularis fuscus	Yellowhead gecko
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Phelsuma madagascariensis grandis	Giant day gecko
Python molurus bivittatus	Burmese python
Ramphotyphlops braminus	Brahminy blind snake
Sphaerodactylus argus argus	Ocellated gecko
Sphaerodactylus elegans elegans	Ashy gecko
Trachemys scripta elegans	Red-eared slider
Varanus niloticus	Nile monitor

Scientific Name	Common Name
Birds	
Cairina moschata	Muscovy duck
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet
Passer domesticus	House sparrow
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove
Mammals	
Canis familiaris	Feral dog
Felis catus	Feral cat
Mus musculus	House mouse
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Saimiri sciureus	Squirrel monkey
Sus scrofa	Feral pig
Vulpes vulpes	Red fox
Fishes	
Astronotus ocellatus	Oscar
Belonesox belizanus	Pike killifish
Cichlasoma bimaculatum	Black acara
Cichlasoma urophthalmus	Mayan cichlid
Clarius batrachus	Walking catfish
Oreochromis aureus	Blue tilapia
Tilapia mariae	Spotted tilapia
Channa marulius	Bullseye snakehead
Hoplosternum littorale	Brown hoplo
Liposarcus multiradiatus	Orinoco sailfin catfish
Invertebrates	
Amblyomma auricularium	Reptilian tick
Amblyomma helvolum	Reptilian tick
Amblyomma marmoreum	African tortoise tick
Amblyomma sabanerae	Neotropical tortoise tick
Iridomyrmex humilis	Argentine ant
Melanoides tuberculata	Red-rimmed melania
Metamasius callizona	Mexican bromeliad weevil
Monomorium pharaonis	Pharaoh ant
Paratachardina lobata	Lobate lac scale
Paratrechina longicornis	Crazy ant
Perna viridis	Green mussel
Plecia nearctica	Love bug
Pomacea bridgesi	Spiketopped applesnail
Solenopsis invicta	Imported fire ant
Technomyrmex albipes	White-footed ant

Feral Hogs

Feral hogs (*Sus scrofa)* are reported in all 67 counties of Florida and are extremely common in the Western Big Cypress Module. They were first introduced, intentionally or accidentally, by the Spanish over 400 years ago (Frankenberger and Belden, 1976). Sporadic introductions of new populations have occurred over time by sportsmen (Tiebout, 1983). Florida's feral hogs consist of feral domestic hogs or hybrids of domestic hogs and wild boars, which readily interbreed (Johnson et al., 1982; Whitaker, 1988).

Feral hogs are omnivorous and their diet varies seasonally. These hogs are known to consume a variety of vegetation, invertebrates, insects, reptiles, frogs, bird eggs, rodents, small mammals, and carrion (Lowery, 1974; Bratton et al., 1982; Laycock, 1984; Baber and Coblentz, 1986; Gingerich, 1994). Although feral hogs are common throughout the Western Big Cypress Module, the greatest population numbers are found in pine flatwood savanna communities with an open canopy of slash pine (*Pinus elliotti* var. *densa*), an understory of palmetto (*Serenoa repens*), and a diverse ground cover of grasses, sedges, and broad-leaved forbs.

The composition and structure of major plant communities is a performance measure developed as a basis for monitoring Big Cypress within the context of RECOVER. The impacts from feral hogs in the Big Cypress Module (and Florida) are not well documented, although it is widely held that hogs damage and alter native plant communities through rooting, compete with native wildlife species for forage, and host diseases and parasites communicable to humans, livestock, and wildlife (Laycock, 1984; Gingerich, 1994). Hogs use their tusks to uproot large areas of soil in search of edible plants, nuts, and acorns. In so doing, they damage natural plant communities, leaving large disturbed areas of bare ground. These "plowed" areas impact water quality and interrupt native vegetation succession, facilitating the establishment and spread of exotic plants (Duever et al., 1986; Layne, 1984; Belden and Pelton, 1975; Laycock, 1984). This widespread activity is undoubtedly resulting in plant community alterations in this region. In addition to the direct physical impacts of feral hog rooting, they are also known to carry many diseases and parasites including pseudorabies, which is fatal in panthers (Gingerich, 1994), hog cholera, brucellosis, tuberculosis, salmonellosis, anthrax, ticks, fleas, lice, and various flukes and worms.

Although the ecological impacts caused by this species in Florida are apparent, proposals for feral hog eradication are controversial since they are a valued game species (Baber and Coblentz, 1987; Laycock, 1984). Feral hogs are viewed as a source of income, recreational opportunities, and food (Belden, 1990) throughout Florida. Complicating the issue further, the endangered panther preys on feral hogs (Maehr et al., 1990) and it has been argued that feral hogs are important to the survival of this endangered species in Florida.

Mexican Bromeliad Weevil

Figure 9-26. Mexican bromeliad weevil (*Metamasius callizona*) (photo by Barbara Larson, University of Florida).

The Mexican bromeliad weevil (*Metamasius callizona*) was first introduced to Florida in 1989 via a shipment of bromeliads imported from Mexico and is now found in 18 counties in South Florida (Frank and Thomas, 1994). The weevil is now attacking epiphytes in Big Cypress National Preserve, Florida Panther National Wildlife Refuge, and Fakahatchee Strand Preserve State Park (**Figure 9-26**).

The weevil attacks native bromeliad species including 10 state-listed threatened and endangered native bromeliads (*Catopsis berteroniana*, *C. floribunda*, *C. nutans*, *Guzmania monostachia*, *Tillandsia fasciculata*, *T. pruinosa*, *T. utriculata*, *T. balbisiana*, *T. flexuosa*, and *T. valenzuelan*) and one endemic species (*T. simulata*). Two bromeliad species, *T. utriculata* and *T. fasciculata*, were listed due to damage done to their populations by the weevil (F.A.C., 2000). The weevil is particularly aggressive on *T. utriculata*, *T. fasciculata*, *T. flexuosa*, *T. paucifolia*, *T. balbisiana*, and *Guzmania monostachia* (Frank and Thomas, 2003).

Figure 9-27. Mexican bromeliad weevil damage to a native bromeliad (photo by University of Florida).

While adult weevils eat the leaves of bromeliads, weevil larvae cause the most damage as they bore deep into the growing tissue of a plant. The plant eventually dies and falls to the ground (**Figure 9-27**). Weevils can eventually destroy entire populations of a species. Bromeliads are important plants to many other native taxa. Capturing water between leaf axils, bromeliads are a source of water and protection for many native insect, worm, frog, snake, and salamander species. In addition, this region of Florida is known for its rich epiphytic plant life. Fakahatchee Strand State Preserve was acquired by the state of Florida in 1972 to protect its unusual collection of rare plants including rare bromeliads.

Pesticides are used to effectively keep these weevils in check in cultivated bromeliads, but the use of insecticides is not feasible in natural areas due to the epiphytic nature of wild bromeliads and the potential for impacting native insects. The University of Florida is working to track the spread of this weevil and develop biological controls for the weevil. A possible biocontrol agent (the fly, *Lixophaga* sp.) has been identified from Honduras and researchers are working on the required non-target testing and rearing at the university's quarantine facility in Ft. Pierce, FL. Given the mounting obstacles in managing this pest with traditional chemical control methods, biological controls hold the only hope in controlling this species in Florida's wildlands.

The Northern Estuaries - West Module

Invasive plant control operations in the coastal Caloosahatchee Estuary are largely carried out by local governments such as Lee County and the city of Sanibel. A town-sponsored program eliminated melaleuca from Sanibel Island in the 1980s. Work to control Brazilian pepper is ongoing, with several mechanical removal projects under way throughout the region. Efforts to control well-established Australian pine on the coastal islands of the estuary have met with public resistance in the past. That changed on August 13, 2004 when major Hurricane Charley made a near direct hit on Sanibel and Captiva islands. Many of the large Australian pine trees toppled and effectively barricaded access to the islands for post-storm relief. The tall trees also snapped powerlines and were responsible for extensive structural damage (Rob Loflin, City of Sanibel, personal communication; Ferriter et al., 2005). In light of the problems encountered as the result of the hurricane, city leaders have now embraced the effort to control Australian pine on these coastal islands and much-needed FEMA funding is making broad scale control of this species possible (see the *Hurricanes and Invasive Species* section).

In addition to these species, several grasses were cited by land managers as problematic in the Caloosahatchee Estuary. Guinea grass (*Panicum maximum*), cogongrass (*Imperata cylindrica*), Burma reed (*Neyraudia reynaudiana*), itch grass (*Rottboellia cochinchinensis*), West Indian marsh grass (*Hymenachne amplexicaulis*) and para grass (*Urochloa mutica*) were cited as spreading and difficult control in areas such as dredged spoil along the Caloosahatche River (**Table 9-11**). They are a management challenge because they occur in wetland areas, and the biology of these species is not sufficiently understood to effectively manage them in wetland areas (also, see the *Lake Okeechobee Module* section).

Table 9-11. Priority nonindigenous plant species, Northern Estuaries - West Module.

Scientific Name	Common Name	Condition
Melaleuca quinquenervia	Melaleuca	Winning
Casuarina spp.	Australian pine	Winning
Schinus terebinthifolius	Brazilian pepper	Winning
Dioscorea bulbifera	Air potato	Draw
Panicum maximum	Guinea grass	Losing
Syzygium cumini	Java plum	Draw
Leucaena leucocephala	Lead tree	Draw
Scaevola taccada	Inkberry	Losing
Lygodium microphyllum	Old World climbing fern	Winning
Imperata cylindrical	Cogongrass	Losing
Neyraudia reynaudiana	Burma reed	Losing
Rottboellia cochinchinensis	Itch grass	Losing
Solanum tampicense	Wetland nightshade	Draw
Solanum viarum	Tropical soda apple	Winning
Hymenachne amplexicaulis	West Indian marsh grass	Losing
Urochloa mutica	Para grass	Losing
Ardisia elliptica	Shoebutton ardisia	Losing
Eugenia uniflora	Surinam cherry	Losing

Nonindigenous Animals – Northern Estuaries - West Module

In addition to the plant species listed above (**Table 9-11**), a list of "Nonindigenous Animal Species of Interest" is provided for the Northern Estuaries - West Module (**Table 9-12**). Notably, two species of animal are spreading quickly in the Caloosahatchee Estuary. One is a large nonindigenous lizard (monitor lizard), and the other is a small marine invertebrate (green mussel). Both have the potential to seriously impact this coastal ecosystem.

Table 9-12. Nonindigenous animals of interest, Northern Estuaries - West Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Osteopilus septentrionalis	Cuban Treefrog
Reptiles	
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis extremus	Barbados anole
Anolis garmani	Jamaican giant anole
Anolis sagrei	Brown anole
Chamaeleo calyptratus	Veiled chameleon
Cosymbotus platyurus	Asian flattail house gecko
Ctenosaura similes	Black spinytail iguana
Gekko gecko	Tokay gecko
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Phelsuma madagascariensis grandis	Giant day gecko
Ramphotyphlops braminus	Brahminy blind snake
Tarentola annularis	White-spotted wall gecko
Tarentola mauritanica	Moorish wall gecko
Trachemys scripta elegans	Red-eared slider
Varanus niloticus	Nile monitor
Birds	
Brotogeris chiriri	Yellow-chevroned parakeet
Cairina moschata	Muscovy duck
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet
Nandayus nenday	Black-hooded parakeet
Passer domesticus	House sparrow

Scientific Name	Common Name
Birds *(continued)*	
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove
Mammals	
Canis familiaris	Feral dog
Felis catus	Feral cat
Mus musculus	House mouse
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Sus scrofa	Feral pig
Vulpes vulpes	Red fox
Fishes	
Cichlasoma urophthalmus	Mayan cichlid
Clarius batrachus	Walking catfish
Hemichromis letourneauxi	African jewelfish
Hoplosternum littorale	Brown hoplo
Oreochromis mossambicus	Mozambique tilapia
Piaractus mesopotamicus	Pacu
Tilapia mariae	Spotted tilapia
Invertebrates	
Amblyomma exornatum	Monitor lizard tick
Amblyomma fimbriatum	Reptilian tick
Amblyomma flavomaculatum	Yellow-spotted monitor lizard tick
Amblyomma latum	Snake tick
Amblyomma marmoreum	African tortoise tick
Amblyomma nuttalli	Small reptile tick
Balanus trigonus	Barnacle
Ceroplastes rusci	Fig wax scale
Corbicula fluminea	Asiatic clam
Crocothemis servillia	Dragonfly
Haliplanella luciae	Sea anemone
Iridomyrmex humilis	Argentine ant
Marisa cornuarietis	Giant rams-horn
Metamasius callizona	Mexican bromeliad weevil
Monomorium pharaonis	Pharaoh ant
Paratachardina lobata	Lobate lac scale
Paratrechina longicornis	Crazy ant
Perna viridis	Green mussel
Plecia nearctica	Love bug
Solenopsis invicta	Imported fire ant
Sphaeroma terebrans	Wood-boring isopod

Monitor Lizard

The African Nile monitor lizard (*Varanus niloticus*) has been observed in several areas of Florida, but the only confirmed breeding population is in Cape Coral (Enge et al., 2004). This species was first noted in Cape Coral in 1990 and has rapidly colonized the region. The Cape Coral population is now estimated as 1,000 individuals of various size classes. The median size for an adult male is 5 feet, but they can reach lengths of more than 7 feet (Faust, 2001). Although this large reptile species is an ill-suited pet, it is a popular novelty in the exotic pet trade. The source of the Cape Coral population is undocumented, but researchers believe that several monitor lizards were either intentionally or accidentally introduced.

The rapidly expanding Southwestern Florida Nile monitor lizard population is of concern for several reasons. Cape Coral is situated between Matlacha Pass and the Caloosahatchee River. It has more than 400 miles of canals and is fringed with ecologically important mangrove communities, tidal creeks, and marshes of the Charlotte Harbor State Buffer Preserve and the Matlacha Pass State Aquatic Preserve. These habitats have proven to be ideal for this semi-aquatic reptile, which is poised to become a top predator. In its native range, the Nile monitor lizard preys or scavenges on a variety of snails, clams, oysters, crabs, fishes, lizards, turtles, snakes, young crocodiles, birds, eggs, and small mammals (**Figure 9-28**).

Figure 9-28. Nile monitor lizard (*Varanus niloticus*). (Photo by Todd Campbell, University of Tampa).

Cape Coral has the largest population of burrowing owls in Florida, and a Nile monitor lizard was recently observed killing a young owl. Monitors could impact populations of other listed species such as the brown pelican, gopher tortoise, sea turtle, and American crocodile (Enge et al., 2004). The Nile monitor lizard may also prey on the native mangrove tree crab, which is cited as an indicator species for measuring the increase or loss of functionality of the mangrove system in the Caloosahatchee Estuary Module.

Data indicates that this agile climber and swimmer has dispersed to nearby islands and the mainland, and has recently been observed in isolated areas elsewhere in Florida, including the sawgrass prairies along Card Sound Road in extreme southern Miami-Dade County (Kenneth Krysko, Florida Museum of Natural History, personal communication). Researchers fear that it is only a matter of time before the species begins to breed in other estuarine and freshwater swamps, marsh edges, river banks, canals, and lakes, which are all suitable habitats (Enge et al., 2004). In response to the threats associated with this species in Southwest Florida (and beyond), the University of Tampa has initiated an aggressive trapping program on Cape Coral. Associated research at the University of Tampa and the University of Florida aims to understand the basic biology—feeding habits, activity patterns, and reproductive cycle—of the species. This information is critical in developing an effective management plan for this reptile, which appears to be approaching an exponential rate of expansion in Southwest Florida.

Green Mussel

The green mussel (*Perna viridis*) was first discovered in 1999 by maintenance divers inspecting a jammed intake valve at the Big Bend powerplant in Tampa Bay, Florida. Larvae-infested commercial ballast water releases are believed to have been the source of this introduction. A native to the Indo-Pacific region, this species is now well established in Tampa Bay, fouling bridges, piers, buoys, and decimating oyster beds (**Figure 9-29**). From Tampa Bay, currents dispersed green mussel larvae south along the Gulf Coast to Boca Grande outside of Charlotte Harbor (Benson et al., 2001), and the mussel now occurs as far south as Naples (Fajans and Baker, 2004).

Figure 9-29. Green mussel (*Perna viridis*) (photo by Patrick Baker, University of Florida).

Prior to 2002, the species was believed to be confined to man-made structures. However, recent surveys show that green mussels are establishing in a wider variety of habitats (Baker, 2003). Of particular concern is the evidence that green mussels are becoming abundant on eastern oyster (*Crassostrea virginica*) beds (Baker and Benson, 2002) (**Figure 9-30**). Densities can be very high in these areas, and this nonindigenous species is replacing the biomass formerly produced by oysters. Baker (2003) found that the oyster reef matrix and structure remain, but over 90 percent of adult oysters are recently dead (shells still articulated by the ligament).

Figure 9-30. Green mussel invading an oyster bed (photo by Patrick Baker, University of Florida).

Several factors make this species a threat to the Caloosahatchee Estuary. It disperses easily, grows fast, and reproduces quickly. Fajans and Baker (2004) found high densities of approximately 4,000 individuals per square meter in Tampa Bay. The green mussel appears to have a lack of local predators and high tolerance of environmental conditions. Researchers expect the mussel population to expand in Gulf Coast and Atlantic habitats until it reaches its thermal limits. Unfortunately, there is little that can be done if green mussels overtake the oyster beds of the Caloosahatchee Estuary. Non-native marine invertebrates are challenging to manage. Intensive mechanical and chemical (continuous high-level chlorination) control is possible in closed systems such as power plants, but these methods are not feasible in a natural ecosystem, making selective control and eradication of this species in oysterbeds virtually impossible.

Healthy oysterbeds are a key ecological performance measure in restoration efforts, but to date the invasion of this nonindigenous invertebrate has not been considered in restoration models. Important work is under way by the University of Florida and the USGS to understand the spread and environmental impacts of this species in coastal ecosystems.

Northern Estuaries - East

The Northern Estuaries - East Module is made up of a strip of coastal estuaries along the eastern coast of South Florida. Priority species for this region include mainly coastal species. The majority of the work is done by the FDEP, local governments, and volunteer groups.

The construction and maintenance of the Intracoastal Waterway channel and barrier island inlets resulted in the formation of a chain of spoil islands in this area. These islands, formed by the deposition of the dredged material (spoil), generally parallel the channel alignment. They are often dominated by exotic vegetation, such as Brazilian pepper and Australian pine. Australian pine was most likely planted on these islands in an effort to stabilize them. The other coastal systems in this module are also highly prone to invasion by Brazilian pepper and Australian pine. East coast populations of mangroves are near their northernmost range in this module, and are subject to being killed by periodic freezes. Because damaged mangrove communities reestablish slowly, they can be replaced by these faster growing exotic species. Mangroves stabilize shorelines by trapping sand in their roots, providing homes to countless birds and fish, and providing the food base for almost every species living in the estuaries.

Agency control efforts spearheaded by the FDEP are ongoing to restore mangrove, salt marsh, and upland habitat along the shoreline and a coalition of volunteer groups is active in working to remove Brazilian pepper and replant native shoreline vegetation.

Figure 9-31. Caulerpa (*Caulerpa brachypus*) (photo by FDEP).

In addition to the plants discussed above and presented in the priority plant species table (**Table 9-13**), the occurrence of a nonindigenous marine plant (an alga) in the coastal areas of this region is alarming. In 2001, an invasive non-native macroalga was identified growing on underwater reefs located off the coast in Palm Beach County. *Caulerpa brachypus*, a native of Pacific waters and commonly sold marine aquarium plant, has now been found as far north at Fort Pierce and is expected to continue spreading north and south from Palm Beach County, although the acreage area it currently covers has not been determined (**Figure 9-31**). Anecdotal information gathered from dive operators and fisherman have reported that the species is now becoming so thick it is forcing fish and lobster away from reefs. Scientists have speculated that besides forming a dense canopy or blanket over a coral reef and killing it, the macroalga is reducing the food source for many fish species.

Current thinking within the scientific community suggests that excess nutrients, particularly nitrogen from septic seepage and offshore outfalls, may be responsible for the rapid colonization of Palm Beach County's underwater reefs by *Caulerpa brachypus* and two other native macroalgae species. Studies by Harbor Branch Oceanographic Institution personnel are under way to determine if excess nutrients are fueling macroalgae blooms along South Florida's coastline.

Since 1984, a related nonindigenous species, *C. taxifolia* has invaded broad areas of the Mediterranean and is documented in a San Diego, California lagoon and in the harbor of Sydney, Australia. In California, a $6 million chlorine treatment controlled an infestation in 2000. To date, this species affects thousands of acres of Mediterranean reef causing at least $1 billion in damages. Also, internal toxins of *C. taxifolia* have been found to repel herbivory as well as inhibit the proliferation of several phytoplankton. At this time, it is unclear whether *C. brachypus* will have the same impacts (Lemée et al., 1997) in South Florida's marine systems, but given the potential of this plant species to spread in coastal environments, it is clear that if it does become established, it will impede key restoration performance indicators such as healthy native submersed aquatic vegetation communities, fish communities, oyster beds, and an healthy nearshore reefs.

In response to these macroalgae blooms along the coast, the Florida Harmful Algal Bloom Task Force was created by the Florida legislature in 1999 to review information, prioritize research needs, and recommend plants to predict, mitigate, and control harmful algal blooms. Panel members include representatives from the FDEP, St. Johns River Water Management District, Florida Fish and Wildlife Conservation Commission, Harbor Branch Oceanographic Institution, National Undersea Research Center, Smithsonian Institution, and the Indian River Lagoon Estuary Program.

Table 9-13. Priority nonindigenous plant species, Northern Estuaries - East Module.

Scientific Name	Common Name	Condition
Casuarina spp.	Australian pine	Draw
Caulerpa brachypus	Mini caulerpa	Losing
Eugenia uniflora	Surinam cherry	Draw
Lygodium microphyllum	Old World climbing fern	Draw
Melaleuca quinquenervia	Melaleuca	Winning
Rhodomyrtus tomentosa	Downy rose myrtle	Draw
Sansevieria hyacinthoides	Bowstring hemp	Draw
Scaevola taccada	Inkberry	Draw
Schinus terebinthifolius	Brazilian pepper	Winning

Nonindigenous Animals – Northern Estuaries - East Module

In addition to the plant species listed above (**Table 9-13**), a list of "Nonindigenous Animal Species of Interest" is provided for the Northern Estuaries - East Module (**Table 9-14**). Several of these species are discussed in other modules, and are of special concern to the east coast estuaries. The green mussel (see the *Northern Estuaries - West Module* section) was recently found on the eastern coast of Florida and threatens to decimate oyster beds in this area. The Mexican bromeliad weevil (see the *Western Big Cypress Module* section) is impacting the inland areas of this region, killing bromeliads in the Savannas State Preserve in St. Lucie County. Two animal species – a fish and a marine invertebrate – have been found in the Northern Estuaries - East Module and could threaten the diversity of fish species in the estuary.

Table 9-14. Nonindigenous animals of interest, Northern Estuaries - East Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus planirostris	Greenhouse frog
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Agama agama	African redhead agama
Ameiva ameiva	Giant ameiva
Anolis chlorocyanus	Hispaniolan green anole
Anolis cybotes	Largehead anole
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis garmani	Jamaican giant anole
Anolis sagrei	Brown anole
Basiliscus vittatus	Brown basilisk
Calotes versicolor	Oriental garden lizard
Gonatodes albogularis fuscus	Yellowhead gecko
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Phrynosoma cornutum	Texas horned lizard
Ramphotyphlops braminus	Brahminy blind snake

Scientific Name	Common Name
Birds	
Acridotheres tristis	Common myna
Cairina moschata	Muscovy duck
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet
Passer domesticus	House sparrow
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove
Mammals	
Canis familiaris	Feral dog
Felis catus	Feral cat
Lepus californicus	Black-tailed jackrabbit
Mus musculus	House mouse
Nasua narica	White-nosed coati
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Sus scrofa	Feral pig
Vulpes vulpes	Red fox
Fishes	
Alosa sapidissima	American shad
Cichlasoma bimaculatum	Black acara
Herichthys cyanoguttatus	Rio Grande cichlid
Cichlasoma octofasciatum	Jack dempsey
Clarius batrachus	Walking catfish
Oreochromis aureus	Blue tilapia
Oreochromis mossambicus	Mozambique tilapia
Piaractus brachypomus	Pirapatinga
Poecilia reticulata	Guppy
Pomacanthus semicirculatus	Koran angelfish
Sarotherodon melanotheron	Blackchin tilapia
Tilapia mariae	Spotted tilapia
Xiphophorus helleri	Green swordtail
Xiphophorus maculates	Southern platyfish
Xiphophorus variatus	Variable platyfish
Zebrasoma veliferum	Sailfin tang
Invertebrates	
Aethina tumida	Small hive beetle
Balanus trigonus	Barnacle
Blattella asahinai	Asian cockroach
Cactoblastis cactorum	Cactus moth

Scientific Name	Common Name
Invertebrates *(continued)*	
Charybdis helleri	Indian Ocean portunid crab
Cryptosula pallasiana	Bryozoan
Iridomyrmex humilis	Argentine ant
Lyrodus mediolobatus	Indo-Pacific shipworm
Metamasius callizona	Mexican bromeliad weevil
Monomorium pharaonis	Pharaoh ant
Paratrechina longicornis	Crazy ant
Perna viridis	Green mussel
Phyllorhiza punctata	Australian spotted jellyfish
Pinctada margaritifera	Black-lipped pearl oyster
Plecia nearctica	Love bug
Pomacea canaliculata	Channeled applesnail
Solenopsis invicta	Imported fire ant
Sphaeroma walkeri	Fouling isopod
Styela plicata	Sea squirt
Sundanella sibogae	Bryozoan
Technomyrmex albipes	While-footed ant
Victorella pavida	Bryozoan
Watersipora subovoidea	Bryozoan

Spotted Jellyfish

The Australian spotted jellyfish (*Phyllorhiza punctata*) was first documented in the Gulf of Mexico in 2000 and was discovered on Florida's east coast in the Banana River and the Indian River Lagoon in 2001 (Graham et al., 2003). It is believed to have been accidentally introduced through bilge water of ships passing through the Panama Canal. The population just north of the Indian River lagoon was estimated to be 300–500 jellies.

Figure 9-32. The Australian spotted jellyfish (*Phyllorhiza punctata*) (photo by USGS).

The spotted jellyfish is typically a translucent milky color with spots on the bell and 6 to 8 inches in diameter (**Figure 9-32)**. The jellies are frequently found in clusters. The spotted jellyfish has a voracious appetite and feeds on fish eggs, larvae, and microzooplankton. The spotted jellyfish typically hosts symbiotic photosynthetic algae, zooxanthallae. Specimens found in the Gulf of Mexico were environmentally stressed and did not carry these algae; those found in Indian River Lagoon did host the algae suggesting that the lagoon may be a better environment than the Gulf for the jellies (Graham et al., 2003). Offshore drilling platforms and artificial reefs may contribute to the occurrence of the jellyfish by providing hard substrates for attached organisms like jellyfish polyps. Over-harvesting of competitor fish such as menhaden, nutrient runoff, and hypoxia may also be contributing factors (Graham et al., 2003).

The spread of this species poses a threat this estuarine ecosystem and its commercial fisheries. Indian River Lagoon is recognized as the most biologically diverse estuary in North America, and healthy fish communities are cited as an important ecological performance measure for the RECOVER ecological model. A spotted jellyfish is capable of consuming up to 2,400 fish eggs per day. If this nonindigenous species continues to spread into the southeastern estuaries and becomes established, then fish community richness and diversity could be directly impacted.

Lionfish

Native to the Indo-Pacific, the lionfish (*Pteoris volitans*) has been observed in Florida's offshore waters since 1992 when Hurricane Andrew damage reportedly led to an accidental release into Biscayne Bay from a broken aquarium (Courtenay, 1995). In the same timeframe, diver reports were made off Palm Beach and Boca Raton. Sightings have since come from near shore waters of Georgia and North and South Carolina, and juvenile fish have been collected from Bermuda and Long Island, New York. From 2000–2003, at least 49 lionfish were reported at 19 different locations off the coast of North Carolina. Numbers appear to be increasing along the southeastern U.S. coastline (Hare and Whitfield, 2003).

The lionfish has distinctive red, maroon, and white stripes; fleshy appendages above the eyes and below the mouth; and fan-like pectoral fins and long dorsal spines with trailing feathery maroon and white banded membranes (**Figure 9-33**). Although northern distribution is limited by colder temperate waters, the Gulf Stream influence enables northward survival. Body and fin patterns reported from the Atlantic most closely resemble those of lionfish populations in the Phillipines and Indonesia. These areas have been the primary lionfish collection areas for the aquarium trade, implicating aquarium commerce as the primary source of Atlantic lionfish introduction (Basleer, 1994).

Figure 9-33. The Indo-Pacific lionfish (*Pteoris volitans*) (photo by NOAA).

This species can give a painful, venomous sting from its dorsal, anal, and pelvic spines. The lionfish frequents reefs, shipwrecks, and other structures over hard bottom habitat. It is an ambush predator feeding on a variety of fish and crustaceans. This feeding habit is shared by native grouper, snapper, and scorpionfish. The impacts of lionfish interactions with these predators and prey species have not been evaluated. In freshwater settings, fish introductions have been implicated in the displacement and decline of native species. Also, potential predators (e.g., shark, grouper) of lionfish have no experience feeding on prey armed with poisonous spines; envenomations will likely occur.

The introduced lionfish populations are hypothesized to be increasing along the eastern coast, and few management options exist for a marine fish. Population estimates from reports from the public are being collected by NOAA http://www.noaa.gov/). As this nonindigenous population increases, ecological interactions may become more noticeable along with human stings, most likely as SCUBA divers encounter the species in greater numbers.

Lake Okeechobee Module

Figure 9-34. Floating aquatic plants in Lake Okeechobee Module (photo by SFWMD).

Lake Okeechobee is approximately 450,000 acres of open water, vast marshes, and numerous islands, with an average depth of 9 feet. More than 80 non-native plant species have been identified in the Lake Okeechobee Module. Of these, eight have been or are considered invasive and potentially threatening to the Lake Okeechobee ecosystem. The lake is a highly regulated and managed system with all of these invasive plant species of concern having dedicated funding and control programs currently in place. Even with this dedicated funding and continual monitoring, some species have proven difficult to control. The current status of invasive species, although improving in many areas, is not optimal. The lake has an interagency group lead by representatives from the FDEP, FWC, SFWMD, and USACE. This group meets every second month to discuss the state of invasive plants and control activities on the lake. The purpose is this group is to coordinate treatments, prioritize activities, and recommend actions for the lake. There are more than 100 invasive animals in and around the lake, and there is currently little understanding of their impacts to native species or the ecosystem. No control programs are presently in place to address these invaders.

Figure 9-35. Water hyacinth (*Eichhornia crassipes*) (photo by SFWMD).

Water hyacinth *(Eichhornia crassipes)* and water lettuce *(Pistia stratiotes)* are currently managed by the USACE (**Figure 9-34**). The USACE program started in the 1920s with mechanical removal of hyacinth and continues today principally with chemical and biocontrol methods (**Figure 9-35**). The goal of the program is to keep the plants at a maintenance level as stated under Chapter 369.22, F.S. In the past 15 years, the lake has averaged about 240 acres of combined hyacinth and lettuce, with an average of over 5,000 acres being treated each year. Without continued control of these plants, they would quickly expand and cause severe environmental damage. Even with the current control program in place damage to natives occasionally occurs with the displacement and uprooting of bulrush and the accidental treatment of other non-target plants during chemical treatments.

Hydrilla (*Hydrilla verticillata*) has been in Lake Okeechobee for about 20 years, but it has not been a consistent problem. Its acreage varies annually with water clarity, wind, wave action, water level, and substrate conditions. In some years, hydrilla has expanded rapidly to cover thousands of acres and required mechanical harvesting to open up boat trails. Wave and wind from hurricanes, including Hurricane Irene (1999) and the 2004 hurricanes, have kept populations of hydrilla low for the past 10 years. However, the exponential growth rate and new water regulation schedules could allow for hydrilla to be a major concern in the future.

Alligator weed *(Alternanthera philoxeroides),* has not been a major problem since the 1960s due to a successful biocontrol program. Thousands of acres of alligator weed were treated annually by chemical and mechanical means prior to the introduction of the biocontrols. Presently, three insects [alligatorweed flea beetles (*Agasicles hygrophila*), alligatorweed thrips (*Amynothrips andersoni*), and alligatorweed stem borer (*Vogtia/ Arcola malloi)]* are all present on the lake and keep populations of alligator weed at acceptable levels (**Figure 9-36**). Barring any situation that would negatively impact the biocontrol agents, alligator weed is not expected to cause any measurable impacts in the near future, but serves as a good example of what a successful biocontrol program can accomplish.

Figure 9-36. Alligatorweed flea beetle (*Alternanthera philoxeroides*) (photo by USDA).

Three species of exotic trees have been controlled to a great extent on Lake Okeechobee during the period from 1993–2005. The most environmentally threatening of these was melaleuca (*Melaleuca quinquenervia*), which had developed significant coverage in the lake's 100,000 acres of emergent marsh. By 1993, large monospecific heads were common and outlier seedlings were rapidly expanding the tree's coverage. Control efforts ultimately costing $10 million have now brought melaleuca under "maintenance control." The maps below (**Figure 9-37**) show the decrease in coverage of this species on the lake from the SRF survey results. The release and establishment of the melaleuca snout beetle (*Oxyops vitiosa*) and melaleuca psyllid *(Boreioglycaspis melaleucae)* throughout the South Florida region hold promise for limiting future melaleuca seed production and seedling establishment (see the *Western Big Cypress Module* section).

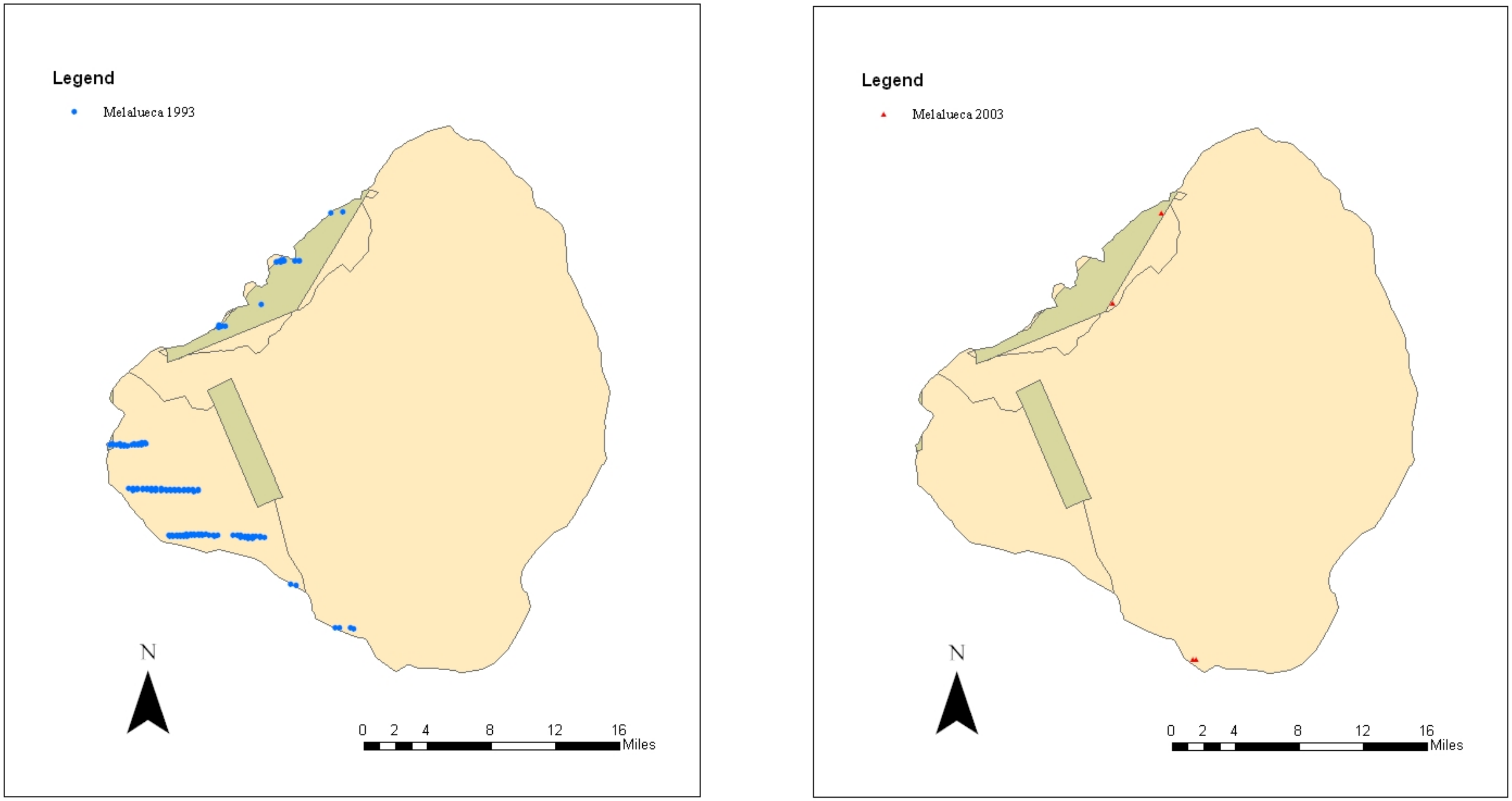

Figure 9-37. Distribution of melaleuca on Lake Okeechobee 1993–2003 (source: Boise State University).

Two other exotic trees, Australian pine (*Casuarina* spp.) and Brazilian peppertree (*Schinus terebinthifolius*) had established sizeable populations mainly on artificially elevated sites in the lake's watershed including spoil deposits and the lake's levees. In the 1995–2005 timeframe, these trees have been eliminated to a great degree through efforts of the USACE and the District. However, ongoing maintenance will be needed to achieve and extend maintenance control levels as no biological controls have been released in Florida for the control of either species (**Table 9-15**).

West Indian marsh grass (*Hymenachne amplexicaulis*) is a perennial, stout semi-aquatic grass native to Central and South America. Invading tropical seasonally wet waterways, wetlands, and drainage systems, it impedes flood protection and water management. It has overwhelmed riparian systems in many locations worldwide. In Lake Okeechobee, it is increasing its range, particularly in Fisheating Bay. Upstream of the lake, in Fisheating Creek, *H. amplexicaulis* has established dense populations along the edge of the creek and in the cypress forest understory. Reproduction is reported to occur by seed germination on moist soils and by aquatic transport of rhizome segments. To date, very little control has been exerted in the lake. However, estimates of its population already range to 100 acres (Mike Bodle, SFWMD, personal communication). The District has committed to initiate herbicidal control in 2005 within the FDEP aquatic plant control funding program.

Torpedograss (*Panicum repens*) has been the target of extensive control in the lake's 100,000-acre western marsh during the period from 1999–2005. Torpedograss had invaded more than 16,000 acres by 1996. Subsequently its spread was exacerbated the by lake's record low water level in April 2001. It is estimated that the plant expanded its range to more than 20,000 acres by 2002 (Mike Bodle, SFWMD, personal communication). Torpedograss tolerates deep flooding without significant growth or expansion, but may spread rapidly and broadly when waters recede. Spread is apparently by vegetative means; floating plant sections serve as propagules and rhizomes spread broadly from sites of initial establishment. No fertile torpedograss seed production has been found in Lake Okeechobee (Smart, in press).

More than 20,000 acres of torpedograss have been aerially treated Lake Okeechobee from 2002–2005. However, large areas remain to be treated by both aerial and surface applications. The District continues to treat torpedograss in the lake, and winter time trials show promise for selective treatments that will kill torpedograss and spare native species.

Table 9-15. Priority nonindigenous plant species, Lake Okeechobee Module.

Scientific Name	Common Name	Condition
Alternanthera philoxeroides	Alligatorweed	Winning
Melaleuca quinquenervia	Melaleuca	Winning
Casuarina ssp.	Australian pine	Winning
Eichhornia crassipes	Hyacinth	Draw
Panicum repens	Torpedograss	Draw
Pistia stratiotes	Water lettuce	Draw
Hydrilla verticillata	Hydrilla	Draw
Hymenachne amplexicaulis	West Indian marsh grass	Losing

Nonindigenous Animals – Lake Okeechobee Module

In addition to the plant species listed above (**Table 9-15**), a list of "Nonindigenous Animal Species of Interest" is provided for the Lake Okeechobee Module (**Table 9-16**). Due to the aquatic nature of this module, fishes are the majority of the problemmatic nonindigenous animal species within the lake.

Table 9-16. Nonindigenous animals of interest, Lake Okeechobee Module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus planirostris	Greenhouse frog
Eleutherodactylus coqui	Coqui
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Agama agama	African redhead agama
Ameiva ameiva	Giant ameiva
Anolis chlorocyanus	Hispaniolan green anole
Anolis cybotes	Largehead anole
Anolis distichus	Bark anole
Anolis equestris equestris	Knight anole
Anolis garmani	Jamaican giant anole
Anolis sagrei	Brown anole
Basiliscus vittatus	Brown basilisk
Caiman crocodilus	Common caiman
Calotes mystaceus	Indochinese tree agama
Hemidactylus frenatus	Common house gecko
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Iguana iguana	Green iguana
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Phrynosoma cornutum	Texas horned lizard
Ramphotyphlops braminus	Brahminy blind snake
Varanus niloticus	Nile monitor
Varanus salvator	Water monitor
Birds	
Acridotheres tristis	Common myna
Cairina moschata	Muscovy duck
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet

Scientific Name	Common Name
Birds *(continued)*	
Passer domesticus	House sparrow
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove
Mammals	
Canis familiaris	Feral dog
Felis catus	Feral cat
Lepus californicus	Black-tailed jackrabbit
Mus musculus	House mouse
Nasua narica	White-nosed coati
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Sus scrofa	Feral pig
Vulpes vulpes	Red fox
Fishes	
Cichlasoma bimaculatum	Black acara
Cichlasoma urophthalmus	Mayan cichlid
Clarias batrachus	Walking catfish
Ctenopharyngodon idella	Grass carp
Cyprinus carpio	Common carp
Dorosoma petenense	Threadfin shad
Hoplosternum littorale	Brown hoplo
Hypophthalmichthys nobilis	Bighead carp
Oreochromis aureus	Blue tilapia
Liposarcus multiradiatus	Orinoco sailfin catfish
Tilapia zillii	Redbelly tilapia
Invertebrates	
Corbicula fluminea	Asian clam
Crocothemis servillia	Dragonfly
Daphnia lumholtzi	Water flea
Iridomyrmex humilis	Argentine ant
Monomorium pharaonis	Pharaoh ant
Paratrechina longicornis	Crazy ant
Plecia nearctica	Love bug
Solenopsis invicta	Imported fire ant

Sailfin Catfish

The sailfin catfish (*Pterygoplichthys* spp.) has been observed in the lake since the early 1990s (**Figure 9-38**). These numbers are increasing as evidenced by FWC electroshocking surveys and anecdotal evidence from commercial fishermen in the lake that have seen dramatic increases in the catches since the mid-1990s. This species is suspected to have been introduced by aquarist releases into canals and other water bodies (Hoover et al., 2004). These fish appear to reproduce easily in South Florida and have spread into Lake Okeechobee and throughout the region via the District's extensive canal system. Numerous burrows are found on the lake and the surrounding canal banks, dikes, and levees (**Figure 9-39**). Environmental impacts of the sailfin catfish are potentially significant and include displacement of native fishes, mortality of shorebirds, disruption of aquatic food webs, and shoreline erosion (Hoover et al., 2004). In Florida, sailfin catfish tunneling is believed to damage canals and levees and result in increased siltation. (Hill, 2002; King, 2004).

Figure 9-38. Sailfin catfish (*Pterygoplichthys* sp.) (photo by USACE).

Other Nonindigenous Fishes

In addition to the sailfin catfish, there are other fish species of concern in Lake Okeechobee, and these species could have a direct or cumulative impact on the lake ecosystem. Populations of oscar (*Astronotus ocellatus*), Mayan cichlid (*Cichlasoma urophthalmus*), and blue tilapia (*Oreochromis aureus*) have all also increased in the lake. Not enough is known about population dynamics, reproduction, feeding habits, and biology of these species in the lake to determine what impacts they may be having. Largemouth bass (*Micropterus salmoides*) and black crappie (*Pomoxis nigromaculatus*) populations are decreasing on the lake, and their recruitment has been poor for several years (FWC, personal correspondence). Agency fishery biologists have linked high and extreme fluctuations of Lake Okeechobee water levels and resultant reduced and degraded habitat as having a negative impact on the bass and crappie populations. However, no links between invasive fishes and the declining habitat and falling native fish populations have been studied to date.

Figure 9-39. Sailfin catfish tunneling is believed to damage canals and levees and result in increased siltation (photo by USACE).

Kissimmee Basin Module

Water hyacinth and water lettuce are the most pervasive nonindigenous aquatic plants in the Kissimmee Basin Module (**Table 9-17**). The District manages these species in the Kissimmee Chain of Lakes (KCOL) and in the Kissimmee River/C-38 portion of the system. Water hyacinth and water lettuce coverage in the KCOL has increased significantly during the past year due to flushing of plants from adjoining watersheds during fall hurricanes and heavy spring rains. Increased flow in restored portions of the river provides less conducive conditions for these species, and populations these floating plants are reduced in about 14 miles of the Kissimmee River channel. Conversely, new open water habitat has been (at least temporarily) created by restoration efforts on the reflooded floodplain, providing suitable areas for growth of water hyacinth and water lettuce on this section of floodplain.

During the past several years, the District has increased herbicide applications to control the potential source of floating plants in the adjacent river channel and downstream canal (C-38). As native wetland plant communities reestablish, the amount of open water and associated coverage of floating exotic plants is expected to decrease. However, given the magnitude of recent required control efforts, it is expected that extensive herbicide treatments of water hyacinth and water lettuce on the reflooded floodplain will continue for at least several more years. There is a similar concern for increased coverage of water hyacinth in isolated wetlands within the boundaries of the adjacent Kissimmee Prairie Preserve. Another mat-forming species, Cuban bulrush (*Scirpus cubensis*), is periodically spot-treated in both the lakes and river/canal system. This species has been eliminated from the section of river channel with restored flow.

Hydrilla continues to be a priority nonindigenous aquatic plant species in the lakes of the Kissimmee basin. Hydrilla infestations cover approximately 52,500 acres in lakes Tohopekaliga, Cypress, Hatchineha, Kissimmee, and Istokpoga and account for more than half of the hydrilla in all of Florida's public waterways. As a result of management efforts and effects of the 2004 hurricanes, including uprooting by winds and persistent turbidity that limits regrowth, hydrilla in the KCOL is at the lowest level in the last four years. Like water hyacinth and water lettuce, hydrilla also has colonized open water habitats on the reflooded portion of the Kissimmee River floodplain. Established beds are presently localized and are being monitored to evaluate if potential treatments are warranted.

Although torpedograss and para grass have colonized the backfilled canal and locations where former spoil mounds have been degraded within the Kissimmee River restoration project area, existing growths of these species do not appear to be impacting the recovery of wetland communities on these highly disturbed areas. Both of these species are found on the spoil mounds within the remaining channelized river, and torpedograss is reportedly spreading in disturbed seasonal wetlands on and adjacent to the Lake Wales Ridge. Localized patches of West Indian marsh grass (*Hymenachne amplexicaulis*) have been found on the floodplain in the northern end of the restoration project area but have been treated successfully.

Restoration of former wetland communities on the Kissimmee River floodplain appears to be most severely threatened by the establishment and continuing spread of limpograss (*Hemarthria altissima*). Limpograss is an introduced forage grass that has invaded the floodplain from adjacent upland pastures and is thriving in the hydrologic regimes provided by the restoration project. It presently forms monospecific stands over approximately 2,000 acres of the east-central portion of the reflooded floodplain and is colonizing to the north and west. Potential control methods for this species are currently being evaluated, with large scale treatments on the floodplain tentatively planned for the 2006 dry season.

Old World climbing fern is the primary nonindigenous plant species of concern in riparian and upland habitats in the Kissimmee valley. Control efforts on the Kissimmee River floodplain have involved aerial and ground treatments, and have been successful in reducing cover density of Old World climbing fern on a localized scale. This includes the lygodium within the mesophytic shrub community in the lower portion of the restoration project area, where regrowth following several annual aerial herbicides applications appears to have been inhibited by prolonged inundation. Similarly, as a result of intensive control efforts, cover of Old World climbing fern has decreased on the Avon Park Air Force Range. The reduction/thinning of tree and shrub canopy by the 2004 hurricanes has increased the visibility of lygodium cover during aerial surveys and will facilitate more thorough treatments of distributions of this species in the Kissimmee basin.

Though presently not as widely distributed as Old world climbing fern, a population of Japanese climbing fern (*L. japonicum*) has spread from the lower end of Pool D into Pool E of the channelized Kissimmee River. Japanese climbing fern also has been found on Avon Park Air Force Range, where staff has expressed concern about the effectiveness of available herbicides for this species.

Other exotic vines of concern in upland tree and/or shrub habitats in the valley include air potato (*Dioscorea bulbifera*), rosary pea (*Abrus precatorius*), and flame vine (*Pyrostegia venusta*), which have been observed by staff at Archbold Biological Station to spread aggressively after initial establishment. Herbicide treatments have decreased the population of air potato in Pools D and E of the channelized river. However, this species is reportedly spreading along the Lake Wales Ridge.

Infestations of Brazilian pepper and melaleuca are somewhat scattered and are generally targeted for control by the natural resource managers in the valley. Brazilian pepper has been largely eliminated by inundation within the reflooded portion of the Kissimmee River floodplain, and melaleuca appears to be decreasing due to control efforts by Highlands County and to lakeshore development.

Avon Park and Archbold Biological Station staff have indicated that natal grass (*Rhynchelytrum repens*) and cogon grass (*Imperata cylindrica*) are continuing to spread, particularly in disturbed upland habitats, throughout the region. Cogon grass is presently the exotic species of greatest concern on Kissimmee Prairie Preserve, where it is increasing in leased cattle pasture and along roads. Cogon grass also is commonly found on the spoil mounds of channelized river.

Tropical soda apple (*Solanum viarum*) is another pervasive exotic species of concern in the pastures of the Kissimmee valley. Cover of this species is reportedly increasing on private lands neighboring Avon Park Air Force Range. Other exotic plants that have been locally treated in the valley include strawberry guava (*Psidium littorale*), caesarweed (*Urena lobata*), star grass (*Cynodon nlemfuensis*), and bahia grass (*Paspalum notatum*). Bahia grass is the most pervasive exotic grass on the drained Kissimmee River floodplain, but along with Bermuda grass (*Cynodon dactylon*), has been largely eliminated from the reflooded portion of the floodplain.

Table 9-17. Priority nonindigenous plant species, Kissimmee Basin Module.

Scientific Name	Common Name	Condition
Abrus precatorius	Rosary pea	Draw
Cynodon dactylon	Burmuda grass	Draw
Cynodon nlemfuensis	Star grass	Draw
Dioscorea bulbifera	Air potato	Losing
Eichhornia crassipes	Water hyacinth	Winning
Hemarthria altissima	Limpograss	Losing
Hydrilla verticillata	Hydrilla	Winning
Hymenachne amplexicaulis	West Indian marsh grass	Winning
Imperata cylindrica	Cogongrass	Losing
Lygodium japonicum	Japanese climbing fern	Draw
Lygodium microphyllum	Old World climbing fern	Draw
Melaleuca quinquenervia	Melaleuca	Winning
Panicum repens	Torpedograss	Draw
Paspalum notatum	Bahia grass	Draw
Pistia stratiotes	Water lettuce	Winning
Psidium littorale	Strawberry guava	Draw
Pyrostegia venusta	Flame vine	Losing
Rhynchelytrum repens	Natal grass	Losing
Schinus terebinthifolius	Brazilain pepper	Winning
Scirpus cubensis	Cuban bulrush	Draw
Solanum viarum	Tropical soda apple	Draw
Urena lobata	Ceasarweed	Draw
Urochloa mutica	Para grass	Draw

Nonindigenous Animals – Kissimmee Basin Module

In addition to the plant species listed above (**Table 9-17**), a list of "Nonindigenous Animal Species of Interest" is provided for the Kissimmee Module (**Table 9-18**). The feral hog is the most ubiquitous exotic animal of concern for potential impacts to natural habitats in the Kissimmee valley (also, see the *Western Big Cypress Module* section). Although the current population of feral hogs within the Avon Park Air Force Range is reportedly lower than previous years (possibly due to wetter climatic conditions), the population is apparently increasing on Kissimmee Prairie Preserve and of major concern for impacts to the dry prairie habitat. Current levels of hunting and trapping have not had any significant effect on feral hog populations, so an increase in the length of the hunting season has been proposed to attempt to reduce the abundance of this species.

Similarly, although the population of Asian clam (*Corbicula fluminea*) has increased in the section of Kissimmee River channel with restored flow, its potential threat to reestablishment of native invertebrate fauna has not been determined. Avon Park staff has expressed concern about potential impacts of the broadly distributed populations of walking catfish (*Clarias batrachus*) in aquatic habitats and Kissimmee Prairie staff is alarmed about increasing populations of European starlings (*Sturnus vulgaris*). White winged doves (*Zenaida asiatica*) appear to be locally common in at least Highlands County and have observed roosting in large numbers in upland habitats adjacent to the Kissimmee River.

Table 9-18. Nonindigenous animals of interest, Kissimmee module.

Scientific Name	Common Name
Amphibians	
Bufo marinus	Giant toad
Eleutherodactylus planirostris	Greenhouse frog
Osteopilus septentrionalis	Cuban treefrog
Reptiles	
Anolis equestris equestris	Knight anole
Anolis sagrei	Brown anole
Calotes mystaceus	Indochinese tree agama
Hemidactylus garnotii	Indo-Pacific gecko
Hemidactylus mabouia	Tropical house gecko
Hemidactylus turcicus	Mediterranean gecko
Leiocephalus carinatus armouri	Northern curlytail lizard
Leiolepis belliana belliana	Butterfly lizard
Phrynosoma cornutum	Texas horned lizard
Ramphotyphlops braminus	Brahminy blind snake
Trachemys scripta elegans	Red-eared slider
Varanus niloticus	Nile monitor

Scientific Name	Common Name
Birds	
Brotogeris chiriri	Yellow-chevroned parakeet
Columba livia	Rock dove
Myiopsitta monachus	Monk parakeet
Passer domesticus	House sparrow
Streptopelia decaocto	Eurasian-collared dove
Sturnus vulgaris	European starling
Zenaida asiatica	White-winged dove
Mammals	
Canis familiaris	Feral dog
Capra hircus	Feral goat
Felis catus	Feral cat
Mus musculus	House mouse
Mustela putorius	Ferret
Nasua narica	White-nosed coati
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Saimiri sciureus	Squirrel monkey
Sus scrofa	Feral pig
Vulpes vulpes	Red fox
Fishes	
Cichlasoma bimaculatum	Black acara
Clarias batrachus	Walking catfish
Ctenopharyngodon idella	Grass carp
Cyprinus carpio	Common carp
Dorosoma petenense	Threadfin shad
Hoplosternum littorale	Brown hoplo
Oreochromis aureus	Blue tilapia
Oreochromis, Sarotherodon, Tilapia sp.	Tilapia
Pterygoplichthys disjunctivus	Vermiculated sailfin catfish
Tilapia zillii	Redbelly tilapia
Invertebrates	
Aedes albopictus	Asian tiger mosquito
Amblyomma fimbriatum	Reptilian tick
Amblyomma latum	Snake tick
Cipangopaludina japonica	Japanese mysterysnail
Corbicula fluminea	Asian clam
Craspedacusta sowerbyii	Freshwater jellyfish
Crocothemis servillia	Dragonfly
Daphnia lumholtzi	Water flea
Iridomyrmex humilis	Argentine ant
Monomorium pharaonis	Pharaoh ant
Paratrechina longicornis	Crazy ant
Pomacea canaliculata	Channeled applesnail
Solenopsis invicta	Imported fire ant

Channeled Apple Snail

The channeled apple snail (*Pomacea canaliculata*) is a large (up to 10 cm) South American freshwater mollusk established in North America (California, Texas, and Florida) through the aquarium trade (**Figure 9-40**). At maturity, it is about 50 percent larger than the native Florida apple snail (*P. paludosa*) with a prominently ridged shell, as opposed to smooth. *P. canaliculata* produces more offspring than the Florida apple snail and produces numerous egg masses, which are bright pink and appear in great density on aerial structures over water (seawalls, plant stems, etc.) (**Figure 9-41**).

Figure 9-40. Channeled apple snail (*Pomacea canaliculata*) (photo by Bob Hill, SFWMD).

This species has been nominated as one of the "100 World's Worst Invaders." Since its establishment in Southeast Asia and Hawaii in the 1980s, it has become the number one rice and taro pest, causing large economic losses. It has also been implicated in the decline of native apple snails in Southeast Asia. Likely impacts in Florida include destruction of native aquatic vegetation and serious habitat modification along with competition with native aquatic fauna. The snail serves as a vector for disease and parasites. Spread has commonly occurred as intentional introductions to wetlands, as discards from aquaria or, as reported in Asia, as releases to establish a food crop.

Figure 9-41. The channeled apple snail produces numerous egg masses which are bright pink and appear in great densities on structures such as seawalls. (photo by Mike Bodle, SFWMD).

In Florida, the species is reported from Hillsborough, Collier, Palm Beach, and Osceola counties. In the KCOL, the channeled apple snail is now common in northern Lake Tohopekaliga and particularly in the lake's northeastern Gobblett's Cove. In 2005, the federally endangered Florida snail kites (*Rostrhamus sociabilis*) nested for the first time in recent history in unusually large numbers in northern sections of the lake, including the cove. While the birds are feeding on the channeled apple snails, it remains unclear whether the snail's presence, and presumed large populations, has induced the kites to nest in this area. The USFWS has contracted for snail populations to be monitored in the future, although little work has been done to outline a control strategy for this nonindigenous species.

HURRICANES AND INVASIVE SPECIES

NONINDIGENOUS PLANTS AND HURRICANES

Resource managers in Miami-Dade County frequently refer to post-Hurricane Andrew (1992) disturbance as the cause for an explosion of nonindigenous plant species in natural areas. The storm decimated the canopy of many native plant communities, and the open nature of the storm-ravaged forests may have made them more prone to the invasion of invasive exotic plant species. Everglades National Park staff suspects that the storm blew melaleuca seeds deep into the Park since even-aged saplings were found 2 to 3 years after the storm in previously un-infested areas in the path of Andrew (Tony Pernas, National Park Service, personal communication). Given the uncertainties in exotic plant invasion biology and related post-storm effects, invasion events and rates are almost impossible to correlate directly to a single event such as a hurricane. However, these storms undoubtedly impact native plant community and exotic invasion dynamics through increases in propagule pressure, and by creating massive physical disturbance of large areas of native vegetation (Armentano et al., 1995).

Hurricane Andrew was perhaps the seminal storm event in southern Florida. However, numerous major hurricanes have affected a number of forested habitats throughout North, Central and South America. A number of post-hoc studies have documented the extensive level of damage to forest canopies—including mangrove, hardwood hammock, coastal hardwood, and tropical hardwood—caused by major storms (Armentano et al., 1995; Basnet et al., 1992; Bellingham, 1991; Bellingham et al., 1992 and 1994; Boucher et al., 1990; Horvitz et al., 1995; Lugo and Wade, 1993; Reilly, 1991; Weaver 1986 and 1989; Yih et al., 1991). In hardwood forests these effects are usually short-lived as rapid resprouting of the damaged trees results in re-formation of a closed canopy within a few years (Armentano et al., 1995; Horvitz et al., 1995; Yih et al., 1991). Effects of hurricanes on pine and cypress — major components of the Everglades flora — are however less well documented or known (Platt et al., 1999).

Surveys of forest damage after hurricane Andrew revealed previously undocumented information about the kinds and levels of damage sustained by different forest communities in South Florida. Mortality and severe damage were greatest in mangrove forests where 60–85 percent of trees were killed (Armentano et al., 1995). Red mangrove forests sustained the worst damage and in some cases forested areas were simply blown away or covered by a few meters of mud. However, propagule recruitment of red mangroves and resprouts of black and white mangrove were evident weeks after the storm and evidence of damage today is difficult to find. Cypress forests on the other hand had little damage with only 4 percent mortality. Slash pine stands sustained over 80 percent damage but mortality was directly related to tree size and prior burn regimes of trees (Platt et al., 2002). Mortality in large stands of summer burned trees ranged from 17–24 percent, but was near 100 percent in small winter burned stands (Platt et al., 2002). Tropical hardwood hammocks suffered extensive canopy damage but mortality averaged 11.5 percent (Armentano et al., 1995). However, tropical hardwood hammocks seemed particularly susceptible to nonindigenous plant invasion – especially vines – and regrowth of the canopy, while vigorous, was often not of the same species that characterized the pre-storm community (Horvitz et al., 1995). Stands of invasive exotic trees were also damaged by the hurricane but recovered quickly because of resprouting (Armentano et al., 1995).

HURRICANE WINDS AND TREE DAMAGE: A PRELIMINARY EVALUATION OF THE 2004 HURRICANE SEASON

With the exception of Hurricane Andrew in 1992, major storms have been relatively uncommon in Florida for the past few decades. The 2004 hurricane season, however, was very active with four hurricanes striking Florida in a criss-cross pattern. This provided an opportunity to gather data about the effects of high winds on different species of resident trees. Data from the three southernmost storms was gathered and is presented here as a preliminary look at changes to tree communities. Trees were evaluated at several hundred locations within 100 miles of hurricane landfalls and these changes to trees were compared with estimated sustained maximum wind speeds at each location (wind field estimates from NOAA, 2005).

Generally trees withstood winds less than hurricane strength (74 mph) with some broken branches and occasional trunk failure. Category Two hurricane winds (96–110 mph) or stronger caused damage to nearly all trees, with significant branch loss, snapped trunks, or uprooting. Native slash pine (*Pinus elliottii*) trees were encountered most often in this examination. These trees lost branches of consistent diameter regardless of wind speed. This suggests that *Pinus* branches are lost in winds with relatively low energy and do not break further because most of their leaf area has been removed. This was common with many trees and may illustrate an adaptive strategy found in many native trees.

In this preliminary evaluation, native and nonindigenous trees were noted, and the reactions of these trees to high winds were compared (**Table 9-19**). The objective was to collect data about these major categories of trees, and to understand possible hazards related to trees common in inhabited areas. Australian pine is a nonindigenous tree that was very common on Sanibel Island, near the landfall of Hurricane Charley (see the *Northern Estuaries - West Module* section). Much of this island received relatively light winds, but hundreds of Australian pine trees were uprooted or snapped off during the storm (Ferriter et al., 2005). As previously mentioned, this interrupted power, blocked roads, compromised emergency services, and cost significant revenue to remove fallen trees and overcome associated damage.

Table 9-19. Damage to native and exotic trees (percent) from the 2004 hurricanes: Charley, Frances, and Jeanne. (Preliminary data source: Jim Burch, National Park Service)

Storm	Tropical Storm	Category One	Category Two +
Branches Broken			
Natives	51.1	73.8	95.3
Exotics	48.7	81.4	97.6
Trunks Snapped			
Natives	3.6	7.4	20.3
Exotics	9.8	11.8	26.2
Uprooted			
Natives	3.1	2.2	5.6
Exotics	6.7	5.3	9.5
No Apparent Damage			
Natives	48.9	26.2	4.7
Exotics	51.3	18.6	2.4

Overall, nonindigenous trees reacted differently from native trees in high winds. Native coastal hardwood trees had slightly greater branch loss frequency and lost larger branches than exotics in winds less than hurricane strength. This suggests a general weakness of native trees, but may actually indicate an advantage for living in storm-prone areas (**Figure 9-42**). When branches and their associated surface areas are lost, the rest of the tree is less likely to be torn out of the ground by high energy winds. This can allow the trunk and roots to produce new shoots and branches, and become reestablished in the forest community quickly after the storm. Non-native trees in coastal areas are more likely to retain branches, but become uprooted in high winds.

Figure 9-42. Surveys conducted on coastal barrier islands one week after Hurricane Charley revealed that native tree species – such as gumbo limbo and sea grape – lost branches, but rarely toppled, perhaps indicating an advantage for living in storm-prone areas. (photo by Amy Ferriter, Boise State University)

As noted earlier, invasion biology and post-storm conditions make understanding post-storm-related invasion events complex and difficult. In addition, no research has been established to develop an understanding of the effects of major storms on the invasion rate or potential spread of invasive exotic species. Until careful studies are designed and implemented to help understand invasion dynamics related to these disturbance events that occur throughout the Everglades, these relationships will continue to be speculative at best.

NONINDIGENOUS ANIMALS AND HURRICANES

Hurricanes are often cited as a factor in the unintended release or escape of nonindigenous animals. After Hurricane Andrew, Miami-Dade County officials were charged with controlling various monkey, bird, mammal, and reptile species, but these escapes were largely undocumented. The spread of invertebrate species is less obvious, but hurricane winds undoubtedly carry small organisms to new environments where they establish populations.

INFORMATION GAPS AND NEEDS

The elements of a comprehensive nonindigenous plant management strategy – legislation, coordination, planning, research, education, training, and resource input – have been in place in Florida for many years. The majority of plants identified as priority species in this document are all being controlled on public lands by local, state, or federal agencies. Unfortunately, there are dozens of other nonindigenous organisms in South Florida with unknown distributions and invasive potentials. The threat of nonindigenous animals is becoming a recognized issue for many agencies in Florida, and certain species are beginning to be addressed. Funding and coordination for a comprehensive nonindigenous animal management plan are badly needed in the state. There is also a need to set priorities for animal management in South Florida. The sheer number of nonindigenous animals is overwhelming and agencies charged with managing natural systems have a responsibility to understand the distribution and impacts of these species and either initiate control operations or accept their occurrence in natural areas.

Resource managers charged with controlling nonindigenous plants in Florida have recognized for almost a decade that single-species management is not effective. The control of one plant species often leads to reinvasion by another nonindigenous plant. Similarly, the time has come to consider that single-taxa management is not an effective long-term strategy. Melaleuca serves as a preferred host for lobate lac scale. The remaining large populations of melaleuca in South Florida harbor large populations of lobate lac scale, effectively serving as a reservoir for this nonindigenous insect species. An integrated management approach is needed for these types of species.

Given the impacts of nonindigenous organisms in South Florida, scientists are obliged to begin to factor these species into restoration models, and research must be carried out to understand the distribution, biology, and impacts of these nonindigenous organisms. The idea of dealing with nonindigenous organisms in an all-taxa approach is a nascent study, but it is sure to emerge as an important field of science given global trade and the virtual "open barn" situation. Organisms will continue to arrive and will continue to establish breeding populations in South Florida. The abundance of nonindigenous plants in South Florida may be accelerating this process, as animals are arriving not only without their natural enemies but also into a hospitable environment that includes plant species from their native range. It is probably no coincidence that the Burmese python prefers levees covered with Burma reed in the Everglades.

Irrespective 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, hurricane, long-term commercial availability, or other factors. Resource managers need to recognize these species during the early incipient phase in order to maximize available operational resources. As part of this effort, there is a need to establish an "applied monitoring" program and a project tracking system for nonindigenous plant and animal species before, during and after control operations have taken place.

It is tempting to assume that when CERP restoration goals are achieved, results will include a reduced need to control nonindigenous plants and animals. Although it is true that the spread of some invasive 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 nonindigenous species throughout the system. Nutrient enrichment studies have looked at changes to native flora but have virtually excluded the study of invasive species. The Mexican bromeliad weevil, lobate lac scale, green mussel, Old World climbing fern, and Brazilian pepper have successfully invaded areas with few apparent human alterations, including the mangrove zones of Southwest Florida and remote areas of Big Cypress National Preserve. A more comprehensive approach needs to be taken when looking at the long-term restoration process with regard to the nonindigenous species composition response. It is also necessary to educate the public and policy makers that invasive species will always require some level of maintenance and that new introductions need to be recognized and prevented early in order to avoid future costs.

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