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 only vestiges of a once vast Everglades, hinges on the ability to reverse the environmental degradation chiefly caused by human activities over the last 100+ years and to prevent further degradation. While the Comprehensive Everglades Restoration Plan (CERP) efforts and Restoration Coordination and Verification (RECOVER) programs have made it clear that restoration involves numerous factors (e.g., water quantity, water quality, and abundance of flora and fauna), the potential impact of invasive species has emerged as a high priority for CERP planning. Invasion of South Florida's natural habitats by nonindigenous (non-native or exotic) plant and animal species has significantly changed the ecosystem, particularly by displacing native species.

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 an "all-taxa" format for understanding and presenting an inclusive picture of the magnitude of the far-reaching invasive species threats that exist in South Florida. While detailed information on many nonindigenous species is still unknown, this document provides a complete listing with species annotations for those species either known, or considered to be, serious threats to Everglades restoration. The species are presented using the RECOVER and Science Coordination Group (SCG) Modules for Everglades restoration. Species impacts also are discussed by region, as available. Supporting

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background information, including management tools used to control invasive exotic species in South Florida, is presented in the 2006 SFER – Volume I, Chapter 9.

Key activities occurring or culminating in Fiscal Year 2006 (FY2006) also are detailed in this report. Notably:

- In FY2006, the District spent over $21 million for invasive plant prevention, control`, and management efforts in South Florida
- Vegetation control efforts carried out during FY2006 included the treatment of more than 69,635 acres within lands and waters managed by the South Florida Water Management District (SFWMD or District).
- To date, more than one million acres of Melaleuca trees (*Melaleuca quinquenervia*) have been cleared in CERP project areas, and over 5,000 acres of Old World climbing fern (*Lygodium microphyllum)* have been treated in the Everglades.
- Research on invasive species controls continues, with advances such as the successful use of a leaf-eating moth species as a biological agent to control the spread of *L. microphyllum*.
- Exceptional interagency efforts have been undertaken, for instance, to develop a management plan that addresses the alarming increase in Burmese python (*Python molurus bivittatus*) populations in the Greater Everglades.

In addition to providing a comprehensive look at nonindigenous species across taxa, this document takes an important step toward trying to determine what, if any, control or management has been initiated for targeted species. This progress assessment technique has been established along with the development of the SCG systemwide ecological indicators for invasive plants through coordination among the SCG, the Noxious Exotic Weed Task Team (NEWTT), and the Florida Invasive Animal Task Team (FIATT) of the South Florida Ecosystem Restoration Task Force (SFERTF). Continued collaboration is expected to set in place a coherent and integrated method for evaluating progress on controlling invasive plants. It is anticipated that a parallel system for exotic animals will be developed within the next two to three years.

NONINDIGENOUS SPECIES AND EVERGLADES RESTORATION

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 these documents support an "all-taxa" approach. The 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 SFERTF in 1993. One of the tasks in the 1993 charter for the former Management Subgroup (December 16, 1993) was to develop a restoration strategy that addressed the spread of invasive exotic plants and animals.

The U.S. Fish and Wildlife Service (USFWS) was designated as the lead agency for this strategy and submitted a brief report (Carroll, 1994). Among issues highlighted in the report are:

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

The USFWS report indicated the greatest obstacle to combating invasive non-native species is the lack of sufficient funding and manpower.

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 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 efforts is the SFERTF Scientific Information Needs Report (SSG, 1996), which 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 serious consideration of achieving true restoration of the natural system, one in which nonindigenous species are not present. The report 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, may help to 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 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 organisms such as fish, amphibians, and snails. Other components involve removal or partial removal of canals, processes 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 (*Python molurus bivittatus*). The U.S. Department of the Interior (USDOI) also recommended establishment of the FIATT to work on the issue as part of CERP. For the planned Water Preserve Areas 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). USACE and SFWMD (1999) responded that in CERP this recommendation [team] should be presented to the SFERTF.

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 addresses 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).

In 2002, the USACE authorized the Melaleuca Eradication and Other Exotic Plants project. This project was listed in the Central and Southern Florida Comprehensive Review Study (Restudy) as an "other project element," but funding was not initially authorized for it under CERP in the 1999 Water Resources Development Act. 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, Florida. This facility was designed and constructed by the University of Florida without federal cost-sharing participation. An additional facility was designed and constructed by USACE at Davie, Florida with 100 percent USDOI funding.
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, Florida. This component was not pursued due to funding constraints.
3. A cost-share agreement with the SFWMD for the "controlled release" of biological agents. In July 2004, a CERP Design Agreement amendment was approved 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 was completed in January 2005. Work began on the Project Implementation Report (PIR) in July 2005. 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 (*Melaleuca quinquenervia*) and Old World climbing fern (*Lygodium microphyllum)* biocontrol projects [and hopefully Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (*Casuarina equisetifolia*) 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 over 15 years with a federal cost of about $4 million.
4. The Special Reconnaissance Report on invasive species to determine federal interest and future federal involvement in invasive species projects in South Florida was completed in December 2005. This report incorporates the NEWTT's "Weeds Won't Wait strategy" and recommends federal involvement in developing a comprehensive plan for management of invasive species in South Florida in collaboration with other federal, state, and local agencies. A Project Delivery Team is being assembled to develop the Program Management Plan for the Invasive Species Master Plan to implement the recommendations from the report.

In July 2001, the Florida Department of Environmental Protection (FDEP) formed an Invasive Species Working Group (ISWG) comprising representatives from nine state agencies and one state university. Charged by former Florida governor Jeb Bush with developing a comprehensive invasive species strategic plan for all state agencies, the ISWG has since completed the plan, which was 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 complementary 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 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 working groups’ recommendations. 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.).

Public awareness of invasive species and their impacts to Florida's natural resources is an important component of successful invasive species prevention and management efforts. Promoting behavioral changes of individuals and industries can help curtail the introduction of potentially invasive non-native species. A 2006 FWC-funded invasive species awareness study found that roughly 50 percent of Floridians have some knowledge of invasive species issues and most strongly agree that invasive species represent a significant threat to Florida's natural resources and human welfare.

State and federal agencies involved in natural resource protection have a variety of programs to educate the public and industries. These agencies regularly produce and distribute at outreach events printed media such as weed identification cards and flyers. For instance, the FWC collaborated with other agencies to publish an eight-page insert on invasive species in a 2006 Sunday edition of the *Orlando Sentinel*. The insert reached approximately 600,000 readers. A South Florida edition is planned for publication in the *Miami Herald* during 2007.

The ISWG website at http://iswgfla.org/ includes news, education, and other resources promoting public awareness. Likewise, other state and federal agencies have continually expanded invasive species educational content on their websites and improved cross-agency website linking to further facilitate access to invasive species information.

Despite these education and outreach programs, the FWC survey suggests that more effort is needed to raise invasive species awareness among Floridians. Additional funding and improved interagency coordination are needed to adequately reach the growing and often transient Florida population. The Statewide Invasive Species Strategic Plan for Florida, recognizing the importance of public education, called on the ISWG to make recommendations for a coordinated public awareness campaign. Consequently, the ISWG established a public education sub-working group composed of communications professionals from member agencies charged with providing specific recommendations for implementing a public awareness campaign. The sub-working group also is cooperating with a new interagency invasive species awareness effort being coordinated by the FWC.

BIOLOGICAL MONITORING FOR NONINDIGENOUS 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 nonindigenous plants in South Florida are fairly well understood (Wunderlin, et al., 1995; FLEPPC, 2005), although detailed information on distributions and expansion rates are lacking. Agency-sponsored programs are in place that track the regional distribution of certain target exotic plant species, yet spatial data for most other invasive taxa in natural areas is lacking or not readily accessible. The 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 (P. Fuller, personal communication). This report makes extensive use of these valuable resources, but it is difficult to glean information about species population dynamics without more detailed location 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. For instance, varying agencies track detailed distributions of Burmese python, lobate lac scale (*Paratachardina lobata lobata*), and Mexican bromeliad weevil (*Metamasius callizona*). While these single-species monitoring programs do successfully track specific animals, the state has no coordinated database that spans taxa. Moreover, obstacles to monitoring invasive animals are considered in part “the nature of the beast,” as tracking mobile organisms is inherently more difficult than documenting the occurrences of plants.

Remote sensing (RS) technologies have been applied to operational invasive species programs to date with only limited success. RS technologies useful for mapping generalized plant communities cannot accurately identify small incipient plant populations, a critical need for invasive plant managers. Additionally, RS technologies cannot yet consistently detect target plants growing under and among the canopy of other plants; researchers must spend considerable time and energy 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 changes constantly. Given time and budgetary constraints, resource managers often opt to kill the target species and map treatment sites rather than create detailed coverage maps prior to beginning a treatment program. RS technologies are therefore acknowledged as successful for mapping large invasive plant monocultures, but the usefulness of resulting data to on-the-ground resource managers tasked with controlling species is limited.

The Everglades Forever Act (EFA) requires the SFWMD to conduct surveys to measure the extent of exotic plants in the Everglades Protection Area (EPA). Systematic Reconnaissance Flight (SRF) surveys were initiated to give operational resource managers a tool to quickly and affordably assess target plant populations and gauge successes or failures. The SRF method is widely used in tracking wildlife (Russell et al., 2001; 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. The data derived from this survey was valuable in documenting the problems associated with melaleuca in the Everglades and helped to legitimize melaleuca spread as an issue in the state of Florida.

In the early 1990s, the SFWMD and the National Park Service (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 (8 million acres). The transects, modeled after the USFS 1980 survey, were spaced at 2.5-mile intervals east and west across the state. The NPS surveys focused on national park lands in the region. NPS transects were finer (at 1-km intervals), and observers deviated from the transect when exotic plant populations were encountered. Both surveys recorded both plant species and density classifications. In 1999, the District and the NPS began to conduct the biannual surveys collaboratively. The surveys are now nested, with the District survey using 4-km transects, and the NPS using 1-km transects) and the transects overlap federal lands (Ferriter and Pernas, 2005).

The SFWMD conducts surveys of the EPA biannually as required by the EFA, but has expanded the scope of the survey in recent years to include the entire District (2005) and the entire range of several key species (2006). Due to its geographical extent (almost 20 million acres) and the fact that the survey is only flown in the winter months to optimize plant detection, the survey has been compartmentalized. Portions of the state are flown each year in an alternating regional design to allow for complete coverage of the study area. Past survey results (1993–2005) are available for viewing at http://maps.google.com/ and download in shapefile format at http://tame.ifas.ufl.edu/ (Ferriter and Pernas, 2005). Results from the most recent surveys (2006) and acreage estimates for priority species are provided in this document and shapefiles of the 2006 data will be available on the website in March 2007.

The 2006 SRF survey aimed to cover the entire range of melaleuca in Florida as part of the TAME Melaleuca project (**Table 9-1**). Survey teams flew east-west transects up the peninsula to the area just south of Gainesville. It is generally considered that this expanded study area includes the entire range of melaleuca, Old World climbing fern, and Australian pine in Florida. Distribution of these four species is depicted in **Figures 9-1** through **9-4**. Occurrences of the species did not continue northward throughout the expanded study area. However, occurrences of Brazilian pepper were recorded along the east coast of Florida throughout the expanded survey area, indicating that its range extends northward in coastal areas of the state.

Table 9-1. Exotic plant acreage estimates based on results of 2006 aerial SRF survey. Survey area includes Florida peninsula south of Gainesville.

Species	Acres
Melaleuca *(Melaleuca quinquenervia)*	355,200
Old World climbing fern *(Lygodium microphyllum)*	205,720
Brazilian pepper *(Schinus terebinthifolius)*	805,675
Australian pine *(Casuarina equisetifolia)*	261,775

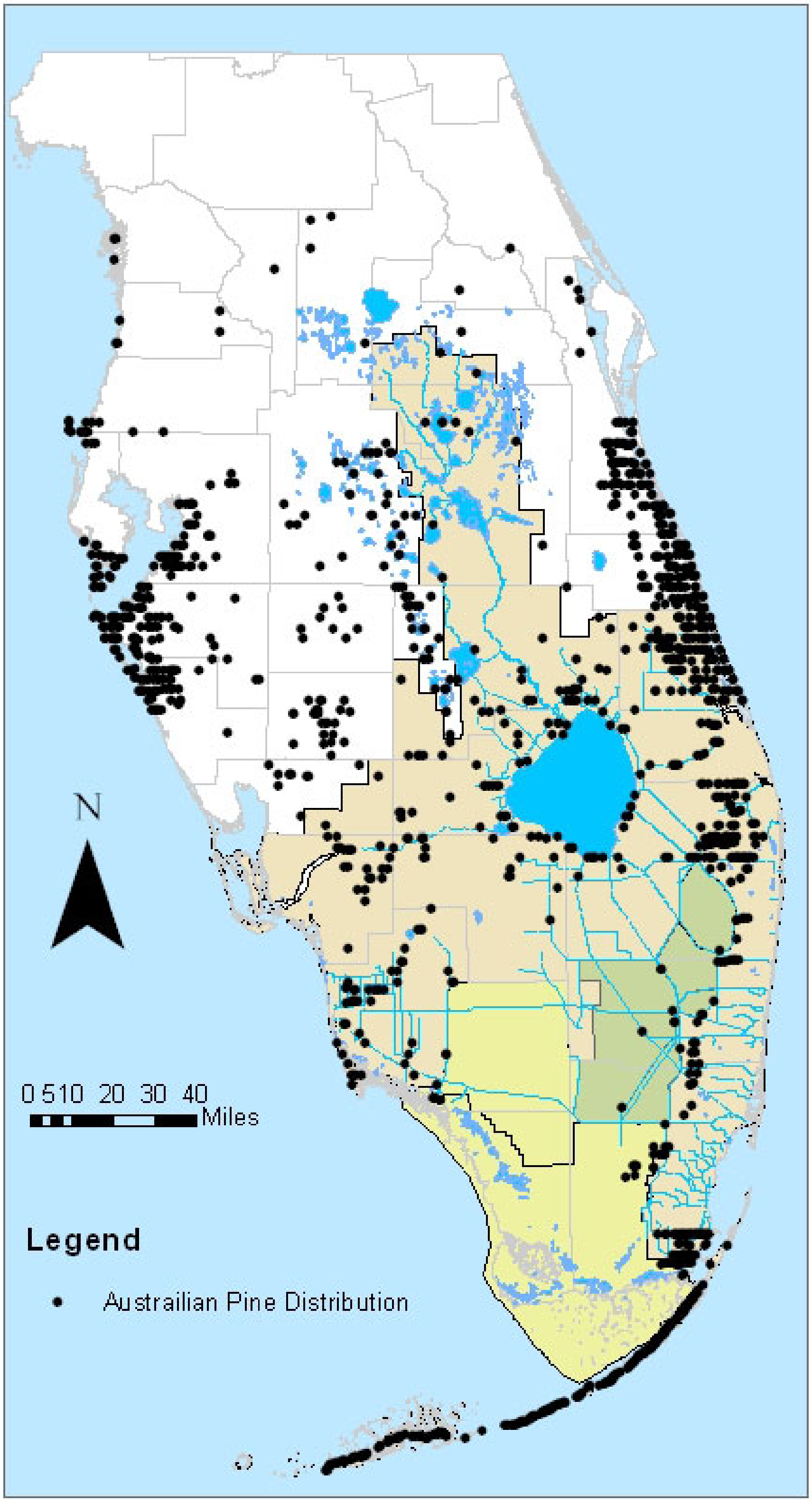


Figure 9-1. Distribution of Australian Pine *(Casuarina equisetifolia)* across South Florida (October 2006).

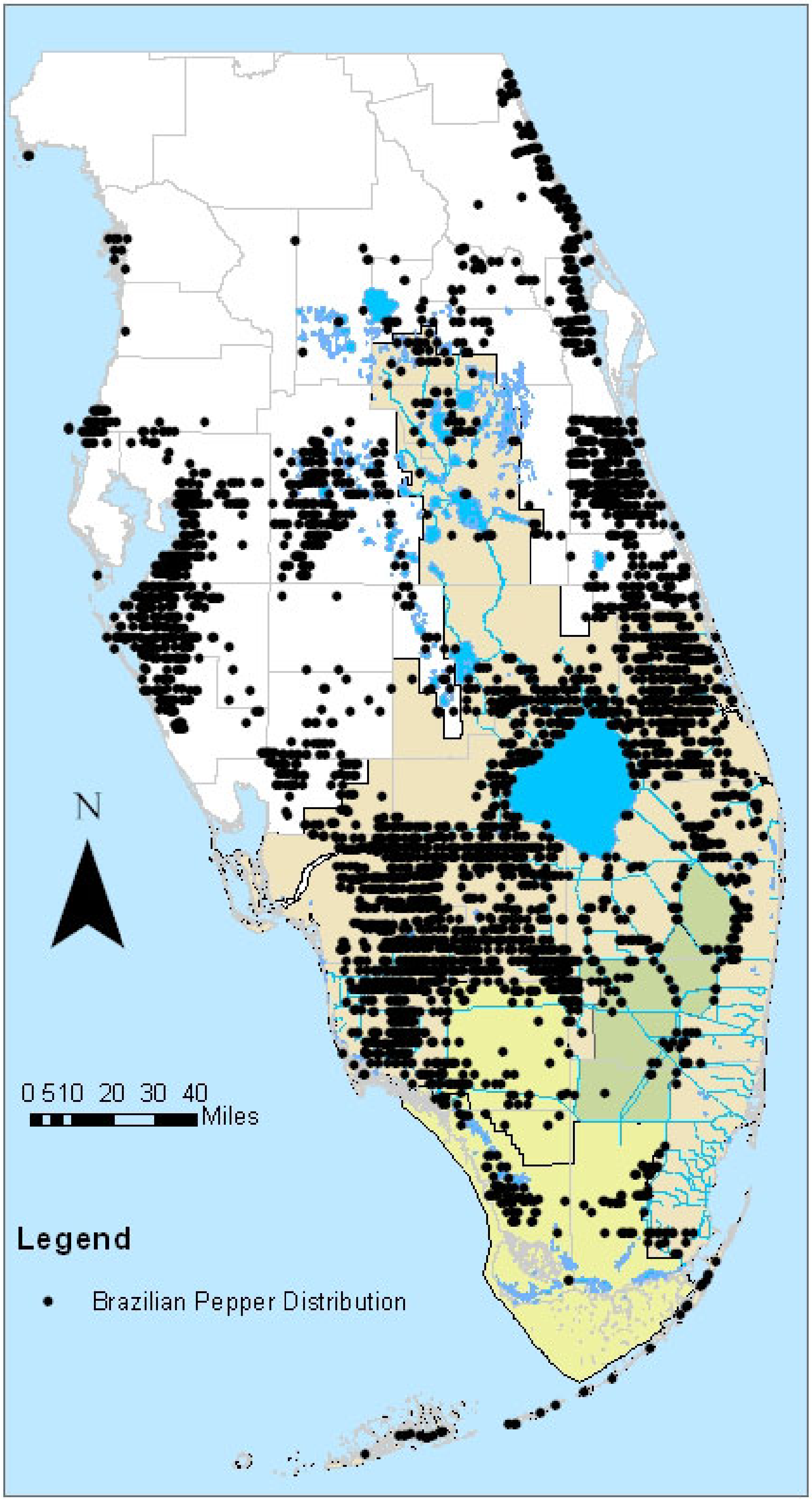


Figure 9-2. Distribution of Brazilian pepper *(Schinus terebinthifolius)* across South Florida (October 2006).

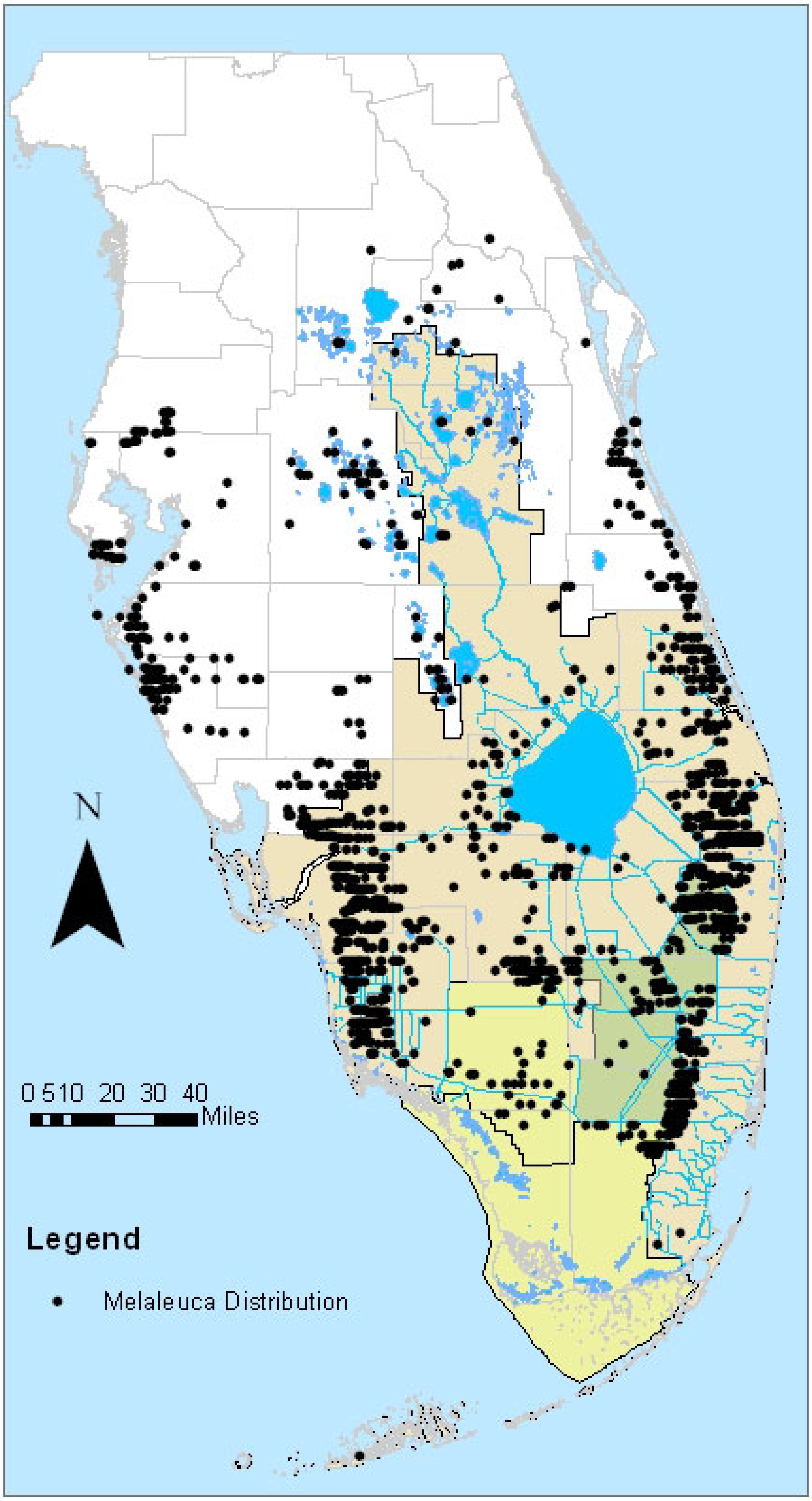


Figure 9-3. Distribution of melaleuca *(Melaleuca quinquenervia)* across South Florida (October 2006).

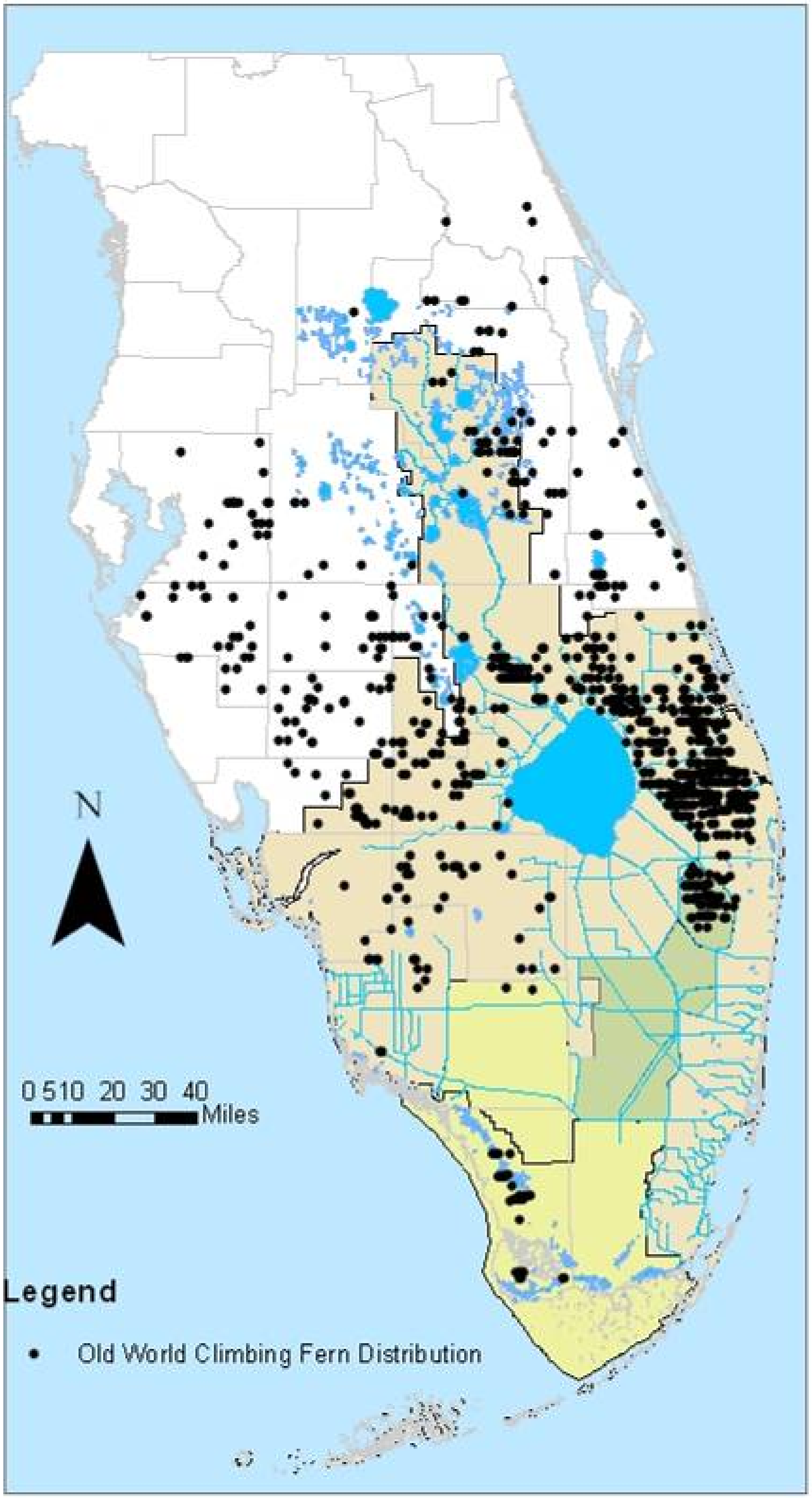


Figure 9-4. Distribution of Old World climbing fern *(Lygodium microphyllum)* across South Florida (October 2006).

AN ASSESSMENT OF NONINDIGENOUS SPECIES IN SOUTH FLORIDA

This chapter covers the entire Central and Southern Florida Restudy area, which encompasses approximately 18,000 square miles (sq mi) from Orlando to the Florida Reef Tract with at least 11 major physiographic provinces:

Everglades	Biscayne Bay	Florida Keys
Big Cypress	Florida Reef Tract	Immokalee Rise
Lake Okeechobee	Near-shore coastal waters	Kissimmee River Valley
Florida Bay	Atlantic Coastal Ridge	

The Kissimmee River, Lake Okeechobee, and the Everglades are the dominant watersheds, connecting a mosaic of wetlands, uplands, coastal areas, and marine areas. This area includes all or part of 16 counties: Monroe, Miami-Dade, Broward, Collier, Palm Beach, Hendry, Martin, St. Lucie, Glades, Lee, Charlotte, Highlands, Okeechobee, Osceola, Orange, and Polk.

Significant scientific evidence and research reveals that invasive exotic plants are degrading and damaging natural ecosystems in South Florida (see Doren and Ferriter, 2001). These species cause significant ecological harm by crowding out and displacing native vegetation upon which native fish and wildlife depend for food and shelter. Other negative impacts of invasive species can include the (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) reduction of native species diversity and (5) alteration of community composition. Most exotic plants provide little or no habitat value for native wildlife, yet they can change 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. Collectively, these agencies have management authority for more than 13.7 million acres (about 21,500 sq mi) of Florida's natural lands. Individual agencies have identified 32 of the 66 priority plant species named in *Weeds Won't Wait* as particularly serious and specifically targeted for control (Doren and Ferriter, 2001). Nevertheless, the process of documenting problems associated with exotic animal species in South Florida began only recently (Goodyear, 2000; A. Roybal, USFWS, personal communication).

The many agencies supporting CERP and the broader restoration efforts coordinated by the SFERTF target invasive species as a serious threat to the Everglades Restoration Initiative and to restoration program goals. This is the first report to use an all-taxa approach to identify nonindigenous species by region and organize these species spatially, thus launching the process of prioritizing species in terms of threat posed to Everglades restoration.

This report organizes nonindigenous species data 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 (**Figure 9-5**). The Science Coordination Group (SCG) 2005 Recommendations for Interim Goals and Interim Targets for CERP also are considered. 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). CEMs and the performance measures and ecological indicators derived from them serve as the basis for adaptive management activities and the development of "Vital Signs" (systemwide ecological indicators) for Everglades restoration by the SFERTF. Additional information on CERP and RECOVER is presented in Chapters 7A and 7B of this volume, respectively.

Information in this chapter 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, or modules, related to the South Florida restoration programs:

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

The species lists for each module presented in **Table 9-2** were compiled from the FWC exotic animal occurrence data, USGS watershed data, the Exotic Animal Report (Goodyear, 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 — amphibians, reptiles, birds, mammals, fish, and invertebrates. In addition, the table indicates whether a species is widely or locally distributed (i.e., occurring in all modules or all but one module, or in only one module). This distribution information indicates the problem scope and in the future may help agencies to prioritize animal species for control and management in the region.

Due to limited availability of animal distribution data, lists in **Table 9-2** may not be comprehensive or entirely precise. For instance, some nonindigenous species listed for a module may actually occur outside of the module noted in **Table 9-2**, because the listing relies on incomplete county data as the most specific location data available. The lists have been refined through peer review by taxonomic experts and land managers to reflect regional considerations (such as coastal versus inland habitats), but should be used with the knowledge that animal distribution data — especially across taxa — is deficient in Florida.

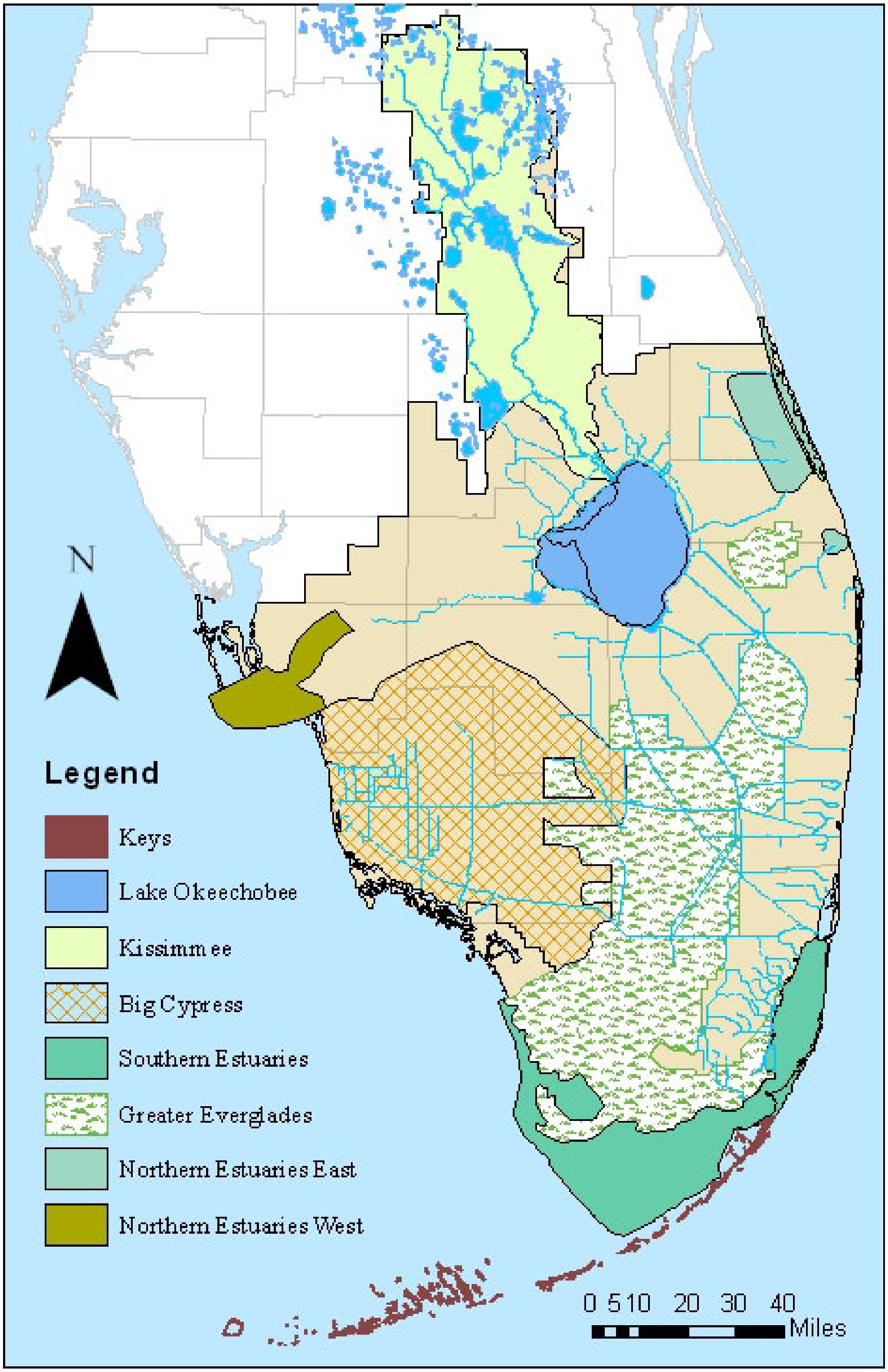


Figure 9-5. The nonindigenous species information in this report is organized using the terms, geographical references, and structure developed by Restoration Coordination and Verification (RECOVER).

Table 9-2. Summary of South Florida's nonindigenous animal species by RECOVER module.[10]

		KY	SE	GE	BC	NW	NE	LO	KR
Amphibians									
Bufo marinus	Giant toad	x	x	x	x	x	x	x	x
Eleutherodactylus planirostris	Greenhouse frog	x	x	x	x		x	x	x
Osteopilus septentrionalis	Cuban treefrog	x	x	x	x	x	x	x	x
Eleutherodactylus coqui	Coqui	x	x	x				x	
Reptiles									
Agama agama	African redhead agama	x	x	x	x		x	x	
Ameiva ameiva	Giant ameiva		x	x			x	x	
Anolis chlorocyanus	Hispaniolan green anole		x	x			x	x	
Anolis cristatellus cristatellus	Puerto rican crested anole		x	x					
Anolis cybotes	Largehead anole		x	x			x	x	
Anolis distichus	Bark anole	x	x	x	x	x	x	x	
Anolis equestris equestris	Knight anole	x	x	x	x	x	x	x	x
Anolis extremus	Barbados anole					x			
Anolis garmani	Jamaican giant anole		x	x		x	x	x	
Anolis porcatus	Cuban green anole		x	x					
Anolis sagrei	Brown anole	x	x	x	x	x	x	x	x
Basiliscus vittatus	Brown basilisk		x	x	x		x	x	
Boa constrictor	Common boa			x	x				
Caiman crocodilus	Common caiman			x				x	
Calotes mystaceus	Indochinese tree agama							x	x

Table Key

KY = Keys
SE = Southern Estuaries
GE = Greater Everglades
BC = Big Cypress
NW = Northern Estuaries West
NE = Northern Estuaries East
LO = Lake Okeechobee
KR = Kissimmee River

Green	Found in one module
Orange	Found in all modules
Blue	Found in all but one module

Table Summary

Found in 1 Module	Found in All Modules	Found in All but 1 Module
0 amphibians	2 amphibians	1 amphibian
7 reptiles	6 reptiles	5 reptiles
3 birds	4 birds	2 birds
5 mammals	6 mammals	0 mammals
15 fish	0 fish	1 fish
41 invertebrates	5 invertebrates	0 invertebrates

[10] Due to limited availability or animal distribution data, species lists presented in table are not comprehensive, but are considered representative of the most dominant species within modules.

Table 9-2. Continued.

		KY	SE	GE	BC	NW	NE	LO	KR
Reptiles *(continued)*									
Calotes versicolor	Oriental garden lizard						x		
Chamaeleo calyptratus	Veiled chameleon					x			
Chrysemys picta dorsalis	Southern painted turtle			x					
Cnemidophorus lemniscatus	Rainbow lizard		x	x					
Cnemidophorus motaguae	Giant whiptail		x	x					
Cosymbotus platyurus	Asian flattail house gecko		x	x		x			
Ctenosaura pectinata	Mexican spinytail iguana		x	x					
Ctenosaura similis	Black spinytail iguana		x	x	x	x			
Gekko gecko	Tokay gecko	x	x	x	x	x			
Gonatodes albogularis fuscus	Yellowhead gecko	x	x	x	x		x		
Hemidactylus frenatus	Common house gecko	x	x	x	x	x	x	x	
Hemidactylus garnotii	Indo-pacific gecko	x	x	x	x	x	x	x	x
Hemidactylus mabouia	Tropical house gecko	x	x	x	x	x	x	x	x
Hemidactylus turcicus	Mediterranean gecko	x	x	x	x	x	x	x	x
Iguana iguana	Green iguana	x	x	x	x	x	x	x	
Leiocephalus carinatus armouri	Northern curlytail lizard	x	x	x	x		x	x	x
Leiocephalus personatus scalaris	Green-legged curlytail lizard			x					
Leiocephalus schreibersii schreibersii	Red-sided curlytail lizard		x	x					
Leiolepis belliana belliana	Butterfly lizard	x	x	x	x		x	x	x
Mabuya multifasciata	Many-lined Grass Skink		x	x					
Phelsuma madagascariensis grandis	Giant day gecko	x	x	x	x	x			
Phrynosoma cornutum	Texas horned lizard		x	x			x	x	x
Python molurus bivittatus	Burmese python			x	x				
Ramphotyphlops braminus	Brahminy blind snake	x	x	x	x	x	x	x	x
Sphaerodactylus argus argus	Ocellated gecko	x	x	x	x				
Sphaerodactylus elegans elegans	Ashy gecko	x	x	x	x				
Tarentola annularis	White-spotted wall gecko		x	x		x			
Tarentola mauritanica	Moorish wall gecko		x	x		x			
Trachemys scripta elegans	Red-eared slider	x	x	x	x	x			x
Varanus niloticus	Nile monitor		x	x	x	x			
Varanus salvator	Water monitor			x					

Table 9-2. Continued.

		KY	SE	GE	BC	NW	NE	LO	KR
Birds									
Acridotheres tristis	Common myna	x		x			x	x	
Brotogeris chiriri	Yellow-chevroned parakeet	x				x			x
Cairina moschata	Muscovy duck	x		x	x	x	x	x	
Columba livia	Rock dove	x	x	x	x	x	x	x	x
Myiopsitta monachus	Monk parakeet	x		x	x	x	x	x	x
Nandayus nenday	Black-hooded parakeet					x			
Passer domesticus	House sparrow	x	x	x	x	x	x	x	x
Porphyrio porphyrio	Purple swamphen			x					
Streptopelia decaocto	Eurasian collared-dove	x	x	x	x	x	x	x	x
Sturnus vulgaris	European starling	x		x	x	x	x	x	x
Threskironis aethiopicus	Sacred ibis			x					
Zenaida asiatica	White-winged dove	x	x	x	x	x	x	x	x
Mammals									
Canis familiaris	Feral dog	x	x	x	x	x	x	x	x
Capra hircus	Feral goat								x
Chlorocebus aethiops	Vervet monkey			x					
Cricetomys gambianus	Gambian pouch rat	x							
Felis catus	Feral cat	x	x	x	x	x	x	x	x
Lepus californicus	Black-tailed jackrabbit		x	x			x	x	
Macaca mulatta	Rhesus monkey		x	x					
Molossus molossus tropidorhynchus	Pallas's mastiff bat	x	x	x					
Mus musculus	House mouse	x	x	x	x	x	x	x	x
Mustela putorius	Ferret								x
Nasua narica	White-nosed coati		x	x			x	x	x
Rattus norvegicus	Norway rat	x	x	x	x	x	x	x	x
Rattus rattus	Black rat	x	x	x	x	x	x	x	x
Saimiri sciureus	Squirrel monkey		x	x	x				x
Sciurus aureogaster	Mexican red-bellied squirrel		x						
Sus scrofa	Feral pig			x	x	x	x	x	x
Vulpes vulpes	Red fox	x	x	x	x	x	x	x	x

Table 9-2. Continued.

		KY	SE	GE	BC	NW	NE	LO	KR
Fishes									
Acanthurus sohal	Sohal surgeonfish		x						
Arusetta asfur	Arabian angel		x						
Astronotus ocellatus	Oscar		x	x	x				
Belonesox belizanus	Pike killifish	x	x	x	x				
Cephalopholis argus	Peacock hind		x						
Chaetodon lunula	Racoon butterfly		x						
Channa marulius	Bullseye snakehead		x						
Chitala ornata	Clown knife		x						
Cichla ocellaris	Peacock cichlid		x	x					
Cichlasoma bimaculatum	Black acara		x	x	x		x	x	x
Cichlasoma citrinellum	Midas cichlid			x					
Cichlasoma managuense	Jaguar guapote			x					
Cichlasoma salvini	Yellowbelly guapote			x					
Cichlasoma urophthalmus	Mayan cichlid		x	x	x	x		x	
Clarias batrachus	Walking catfish		x	x	x	x	x	x	x
Colossoma macropomum	Tambaqui		x	x					
Colossoma or Piaractus sp.	Unidentified pacu		x	x					
Cromileptes altivelis	Panther grouper		x		x				
Ctenopharyngodon idella	Grass carp		x	x				x	x
Cyprinus carpio	Common carp		x	x				x	x
Geophagus surinamensis	Redstriped eartheater		x	x					
Hemichromis letourneuxi	African jewelfish	x	x	x	x	x			
Heros severus	Banded cichlid		x	x					
Hoplosternum littorale	Brown hoplo		x	x	x	x		x	x
Hypophthalmichthys nobilis	Bighead carp							x	
Hypostomus plecostomus	Suckermouth catfish		x	x					
Liposarcus disjunctivis	Vermiculated sailfin catfish								x
Macrognathus siamensis	Spotfinned spiny eel		x	x					
Monopterus albus	Asian swamp eel		x	x					
Naso lituratus	Unicornfish		x						
Oreochromis aureus	Blue tilapia		x	x	x		x	x	x
Oreochromis mossambicus	Mozambiqua tilapia		x	x		x	x		
Oreochromis mossambicus x hornorum	Hybrid tilapia		x	x					
Oreochromis, Sarotherodon, Tilapia sp.	Tilapia		x	x					x
Osteoglossum bicirrhosum	Arawana	x							
Piaractus brachypomus	Pirapatinga						x		
Piaractus mesopotamicus	Small-scaled pacu		x	x		x			
Platax oribularis	Orbiculate batfish	x	x						
Pterygoplichthys multiradiatus	Orinoco sailfin catfish		x	x				x	
Tilapia mariae	Spotted tilapia		x	x	x	x	x		
Xiphophorus helleri	Green swordtail						x		
Xiphophorus maculatus	Southern platyfish						x		
Xiphophorus variatus	Variable platyfish						x		

Table 9-2. Continued.

		KY	SE	GE	BC	NW	NE	LO	KR
Invertebrates									
Aedes albopictus	Asian tiger mosquito	x	x	x	x	x	x	x	x
Aethina tumida	Small hive beetle						x		
Amblyomma auricularium	Reptilian tick				x				
Amblyomma chabaudi	Madagascan tortoise tick			x					
Amblyomma exornatum	Monitor lizard tick			x		x			
Amblyomma fimbriatum	Reptilian tick					x			x
Amblyomma flavomaculatum	Yellow-spotted monitor lizard tick			x		x			
Amblyomma helvolum	Reptilian tick				x				
Amblyomma humerale	Reptilian tick			x					
Amblyomma latum	Snake tick			x		x			x
Amblyomma marmoreum	African tortoise tick			x	x	x			
Amblyomma nodosum	Reptilian tick			x					
Amblyomma nuttalli	Small reptile tick			x		x			
Amblyomma sabanerae	Neotropical tortoise tick			x	x				
Amblyomma varanense	Asian monitor lizard tick			x					
Apis mellifera scutellata	African bee			x					
Aulacaspis yasumatsui	Armored scale insect			x					
Balanus reticulatus	Barnacle		x						
Balanus trigonus	Barnacle		x			x	x		
Blattella asahinai	Asian cockroach	x		x			x		
Cactoblastis cactorum	Cactus moth	x	x				x		
Callinectes bocourti	Bocourt swimming crab,		x						
Cepolis varians	Caribbean land snail		x						
Ceroplastes rusc	Fig wax scale			x		x			
Chaetanophotrips leeuwenia	Thrips			x					
Charybdis helleri	Indian ocean portunid crab						x		
Chelymorpha cribraria	Tortoise beetle		x	x					
Cipangopaludina japonica	Japanese mysterysnail								x
Cittarium pica	West Indian trochid	x							
Corbicula fluminea	Asian clam		x	x		x		x	x
Craspedacusta sowerbyii	Freshwater jellyfish		x	x					x
Crocothemis servilia	Scarlet skimmer			x		x		x	x
Cryptosula pallasiana	Bryozoan						x		
Cuthona perca	Lake merritt cuthona		x						
Daphnia lumholtzi	Water flea		x	x				x	x
Erythemis plebeja	Black pond hawk			x					
Eupristina masoni	Wasp			x					

Table 9-2. Continued.

		KY	SE	GE	BC	NW	NE	LO	KR
Invertebrates *(continued)*									
Glossodoris sedna	Marine nudibranch	x	x						
Haliplanella luciae	Sea anemone		x			x			
Hyalomma aegyptiujm	Reptilian tick			x					
Iridomyrmex humilis	Argentine ant	x	x	x	x	x	x	x	x
Litopenaeus stylirostris	Pacific white shrimp	x							
Litopenaeus vannamei	Pacific white shrimp	x							
Littorina littorea	Common periwinkle	x	x						
Lyrodus mediolobatus	Indo-pacific shipworm						x		
Marisa cornuarietis	Giant Rams-horn Snail		x	x		x			
Melanoides tuberculatus	Red-rim melania		x	x	x				
Metamasius callizona	Mexican bromeliad weevil			x	x	x	x		
Micrathyria aequalis	Spottedtailed skimmer			x					
Micrathyria didyma	Three-striped skimmer			x					
Monomorium pharaonis	Pharaoh ant	x	x	x	x	x	x	x	x
Mytella charruana	Mussel						x		
Oceanaspidiotus araucariae	Scale			x					
Ozamia lucidalis	Moth	x							
Parapristina varticillata	Wasp			x					
Paratachardina lobata	Lobate lac scale	x		x	x	x	x		
Paratrechina longicornis	Crazy ant	x	x	x	x	x	x	x	x
Perna viridis	Green mussel				x	x	x		
Phyllorhiza punctata	Spotted jellyfish						x		
Pinctada margaritifera	Black-lipped pearl oyster						x		
Pomacea bridgesii	Spiketop applesnail		x	x	x				
Pomacea insularum	Channeled applesnail			x			x	x	x
Retithrips syriacus	Thrips			x					
Solenopsis invicta	Imported fire ant	x	x	x	x	x	x	x	x
Sphaeroma terebrans	Wood-boring isopod		x			x			
Sphaeroma walkeri	Fouling isopod		x				x		
Styela plicata	Sea squirt						x		
Sundanella sibogae	Bryozoan						x		
Technomyrmex albipes	White-footed ant			x	x		x		
Tridacna crocea	Giant clam		x						
Tridacna maxima	Giant clam		x						
Truncatella subcylindrica	Snail	x	x	x					
Victorella pavida	Bryozoan						x		
Wasmannia auropunctata	Little fire ant			x					
Watersipora subovoidea	Bryozoan						x		
Zachrysia provisoria	Cuban garden snail	x							

PILOT EXOTIC PLANT INDICATORS

The SFERTF directed the SCG to develop a suite of ecological indicators to help determine whether CERP restoration is being achieved. This suite is intended to reflect systemwide ecological indicators and restoration compatibility indicators for "built system" projects. The ecological indicators are to incorporate important "cross-scale features" of the Everglades, including biogeographic regions (see module names in **Figure 9-1**), vegetation mosaic and exotic interactions, landscape characteristics, and numerous physical and biological properties.

The indicator for invasive exotic plants is not similar in nature or context to other RECOVER indicators because nonindigenous species are inherently ill-suited to indicate ecological function, process, or structure, especially in the context of restoration. In addition, measurements of their biological "performance" do not reflect how they may or may not impact restoration. While the spread of nonindigenous plants may change ecological function and structure, it does not necessarily indicate anything of the overall ecological condition (or restoration) except as it pertains to the level of invasion and resultant adverse impacts to the ecosystem. However, restoration efforts could fail without active control and management of nonindigenous species, because these species have the capacity to drastically alter the natural environment (Mack et al., 2000). Therefore, the invasive exotic plant indicator is being developed to allow regular reporting on the status, progress, and outlook of nonindigenous plants in the context of the South Florida ecosystem restoration initiative.

It is important to note that this assessment only synthesizes existing sources of information to allow evaluation of and reporting on the status of invasive plant species. This constraint underlies the design and application of indicator questions; pilot indicators cannot be used to answer questions outside of available parameters. Each module is assessed and within the module, each priority species is assessed based on six parameters:

1. Number of different invasive exotic plant species present
2. Number, abundance, and frequency of new exotic plant species in the ecosystem
3. Number and abundance of extant invasive exotic plant species found in new locations
4. Location and density of invasive exotic plants, particularly in relation to native plant communities
5. Rate of invasive exotic plant spread, especially in relation to restoration activities (e.g., removal of canals or levees)
6. Effectiveness of control actions/programs for invasive exotic plants, generally measured as a decrease in spatial extent of a species

The individual responses are collated into a single response in the "stop-light" tables found within each module. While the development of an assessment/monitoring program specifically designed for this purpose would be ideal, the exotic plant indicator is currently constrained to using existing monitoring/research programs that collect information on nonindigenous plants. For the purposes of this Report, the use of the Exotic Plant Indicator should be viewed as a "Pilot" for evaluating priority plant species within the context of RECOVER, and this pilot indicator may be improved and refined as appropriate in future documents.

MODULES OVERVIEW

For each of eight modules, this report includes a narrative of relevant nonindigenous species issues, and lists priority plant species in an indicator-based stop-light table (in which a red "stop-light" indicates a severe negative condition). Pilot exotic plant indicator tables are also provided to introduce the use of the indicator tool in gauging progress in overall agency-sponsored invasive plant control efforts as related to the restoration initiatives.

In **Table 9-3**, the District's FY2006 expenditures on nonindigenous species control are summarized by module. The District spent over $21 million in FY2006 for overall invasive plant prevention, control, and management efforts in South Florida. Distribution of the four species for which systemwide control efforts are under way is presented in **Figures 9-1** through **9-4**.

Table 9-3. Summary of invasive plant species control expenditures by RECOVER module by the District in Fiscal Year 2006 (FY2006). District FY2006 expenditures for overall invasive plant prevention, control, and management efforts in South Florida totaled more than $21 million.

	Lake Okeechobee	Kissimmee	Big Cypress	Greater Everglades	Northern Estuaries East	Northern Estuaries West	Systemwide Biological Control
Australian Pine *(Casuarina equisetifolia)*	--	--	--	$113,411	--	--	$20,000
Brazilian Pepper *(Schinus terebinthifolius)*	$164,372	$16,919	$65,003	$586,888	$620,630	$12,832	$30,000
Shoebutton Ardisia *(Ardisia elliptica)*	--	--	--	$87,567		--	--
Old World Climbing Fern *(Lygodium microphyllum)*	--	$358,377	$35,266	$357,367	$91,993	--	$150,000
Melaleuca *(Melaleuca quinquenervia)*	$281,522	$21,973	$502,413	$2,393,532	$4,620	--	$150,000
Torpedograss *(Panicum repens)*	$816,385	--	$17,608	$142,560	$28,680	--	--

While overall animal taxa lists have been provided for each module (**Table 9-2**) and certain animal species are discussed as priorities in the individual modules, no attempt is made to "score" animal taxa as part of an indicator. It should be noted that the table does not imply that the individual species are expanding or negatively impacting the respective modules. This table, representing nonindigenous species of interest in a geographic framework, provides a baseline list of organisms that occur in the modules and have the potential to impact restoration efforts.

Priority 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. While most agencies strive to use scientific data to support the management of these priority species, these data are most often unavailable. Consequently, agency managers must use their best judgment in initiating control programs for these animal species.

Figure 9-6. The monk parakeet (*Myiopsitta monachus*) (photo by Kathleen Carr, FDEP).

It is important to note that certain nonindigenous animal species occur in almost every module. These species include the monk parakeet (*Myiopsitta monachus*) (**Figure 9-6**), giant toad (*Bufo marinus*), Cuban treefrog (*Osteopilus septentrionalis*), feral dog (*Canis familiaris*), and feral cat (*Felis catus*). Omitting specific mention of these species in module narratives does not imply that the species are not problematic or should not be controlled. On the contrary, work is urgently needed to establish distribution and biological data for these organisms, given their ubiquitous nature in South Florida.

FLORIDA KEYS MODULE

The Florida Keys Module was created as a separate 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 land area available to invasion is relatively small in the Florida Keys. This allows land managers to prioritize species effectively and deal systematically with relatively small parcels (A. Higgins, The Nature Conservancy [TNC], 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 listed conservation lands are considered to be under maintenance control for target plant species, and other public lands (military facilities, rights of way, etc.) are being addressed. As work to assess, prioritize, and control nonindigenous animals in the Florida Keys has begun, this module is perhaps the best organized for an all-taxa approach to management and control of invasive plant and animal species and is likely to serve as a model for other regions in South Florida.

Figure 9-7. Ficus *(Ficus microcarpa)* growing on limestone (photo by Kenneth Langeland, Univ. of Florida).

Nonindigenous Plants

Although the public lands in the Florida Keys are well maintained, land managers report that populations of some species (e.g., Australian pine) 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 whether 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 (**Figure 9-7**).

Other priority species such as sapodilla (*Manikara zapota)* and half flower (*Scaevola taccada*) are problematic in localized areas (**Figure 9-8**). Species such as leadtree (*Leucaena leucocephala)* and umbrella tree (*Schefflera actinophylla)* are increasing chiefly along roadsides and in disturbed sites (**Figure 9-9**).

Figure 9-8. Half flower *(Scaevola taccada)* (photo by Kenneth Langeland, Univ. of Florida).

Figure 9-9. Umbrella tree *(Schefflera actinophylla)* (photo by Kenneth Langeland, Univ. of Florida).

Localized problems have developed also 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 (T. Pernas, NPS, personal communication). Although not currently listed on the FLEPPC's list of invasive plants in Florida (FLEPPC, 2005), the shrub warrants special attention in the Florida Keys and is the target of coordinated control measures to prevent its further spread.

Nonindigenous Animals

In addition to the priority plant species listed in **Table 9-4**, the following nonindigenous animal species are considered a priority in the Florida Keys Module.

CACTOBLASTIS

Cactoblastis cactorum is a South American moth whose larvae feed exclusively on species of prickly pear cactus (*Opuntia* spp.) (**Figure 9-10**). 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 9-10. *Cactoblastis cactorum* larvae on an Opuntia cactus pad (photo by Ignacio Baez, USDA-ARS).

Table 9-4. Stoplight table for priority plant species in the Florida Keys Module.

	2006 STATUS	1-2 YEAR PROGNOSIS
FLORIDA KEYS MODULE (Results in this row reflect module-level questions, not species-level questions)	Restoration efforts have been under way in this module for several years and much progress has been made on Australian pine and Brazilian pepper; however, systematic monitoring of the Keys has been insufficient to determine the distributions of all the species present or their locations in natural areas	This module has had a significant control program effort under way for several years; progress on many species is evident, but continued monitoring and control efforts will be needed to prevent serious reinvasions of the many species still threatening this region and new species that may arrive
Australian Pine (*Casuarina* spp.)	Effective removal program is in place and Australian pine is not currently a serious problem in the natural areas of the Keys	Chemical control effective with most natural areas clear or clearable with modest effort; biocontrol research under way
Latherleaf (*Colubrina asiatica*)	Little known about its spread or distribution throughout the region; it is not included in Indicator systematic monitoring program	Increases in spread and distribution are occurring but not well documented; may become a serious pest moving into areas where other exotics have been controlled; a potentially serious pest of the Crocodile Refuge in north Key Largo
Sickle Bush (*Dichrostachys cinerea*)	A relatively new species; little known about its spread or distribution throughout the region; it is not included in Indicator systematic monitoring program	Increases in spread and distribution may be occurring but unable to confirm; may become a serious pest moving into areas where other exotics have been controlled; a known and serious pest in Cuba.
Laurel Fig (*Ficus microcarpa*)	Limited distribution throughout the region; it is not included in Indicator systematic monitoring program	Problematic because it grows epiphytically on native tree species, making control difficult; biological control probably not an option given native *Ficus* species
Sapodilla (*Manilkara zapota*)	Know little about its spread or distribution throughout the region; it is not included in Indicator systematic monitoring program	Localized problem; may become a serious pest moving into areas where other exotics have been controlled; invades natural forests and difficult to control
Half Flower (*Scaevola taccada*)	Coastal species, distributed throughout this module; it is not included in Indicator systematic monitoring program, although it is fairly easy to detect	Seeds float, making long-term management of this coastal species problematic; biological control probably not an option given closely related native *Scaevola* species
Brazilian Pepper (*Schinus terebinthifolius*)	Invades most habitats and very destructive; chemical control ineffective in reducing systemwide spread so far; however, local control programs are proving effective in the Keys	Control programs effective in the Keys, with most populations limited; new biocontrol agents under study for future release in 2007-2008

Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Figure 9-11. *Cactoblastis cactorum* trap developed by the USDA-ARS (photo by Stephen Hight, USDA-ARS).

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's 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 (**Figure 9-11**). This research has lead to an improved trap that is being used to evaluate the spread of this invasive species. USDA-ARS research is also aimed at developing a Sterile Insect Technique (SIT) program as a control/exclusion strategy for this moth. The SIT program may serve as a means of establishing a barrier to stop the moth's westward movement or reduce the moth population attacking endangered cactus species (S. Hight, ARS, personal communication). The SIT validation study continued for a second year at sites along the Florida panhandle and southern Alabama.

Year-long sanitation efforts (removal of infested pads and cactus moth eggsticks, larvae, and pupae) reduced the densities of invading moths, but did not keep the moth population from rebounding. Combining sanitation with sterile insect releases, however, did substantially reduce the population of wild cactus moths. Sterile insects released in the wild were shown to be highly competitive against wild moths. Wild moth populations were drastically reduced in areas where sterile insects were released over 1.5 years. Population reduction was also measured in 2006 in areas that received sterile insects for only the first two of three annual wild-moth generations. Continued released and evaluation of sterile cactus moths at SIT validation sites was planned through 2006. 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

Gambian pouch rats (*Cricetomys gambianus*) are native to Africa (**Figure 9-12**). 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. Gambian 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

Figure 9-12. Gambian rat (*Cricetomys gambianus*) (photo from FWC).

wood rat, cotton rat, and silver rice rat. The Gambian rat's unusually large size has made this species popular in the exotic pet trade, although the Food and Drug Administration has banned their transport and sale because they are a carrier of monkey pox.

These nonindigenous rodents primarily eat fruits and grains, but also are 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, a paucity of fresh water, and potential competition from the abundant raccoon population. Gambian rats have been concentrated in the vicinity of dwellings near the initial release site, although there has been some dispersal to an adjacent key. The population apparently relies on refuse, pet food, and water from homeowners. Scientists are concerned that this species is poised to move from Grassy Key onto adjacent keys and eventually to Florida's mainland.

A baseline abundance index survey using 40 motion-sensor/infrared cameras in hammock habitats on Grassy Key was completed in July 2005. Data analyzed by the USDA Animal Plant Health Inspection Service (APHIS) National Wildlife Research Center indicated that an eradication plan should follow protocols established for black rats (*Rattus rattus*) on islands. Specifically, bait stations should be deployed on a 40-m grid in all Gambian rat habitat (tropical hammock).

In November 2005, Hurricane Wilma inundated Grassy Key. Subsequent hurricane debris was stockpiled at Knight's Key (the extreme west end of Marathon), prior to being transported to Broward County via a caravan of trash haulers. Informational Gambian rat posters were distributed to all truck drivers throughout the city of Marathon. USDA APHIS Wildlife Services (WS) staff traveled immediately to Knight's Key and deployed remote cameras. No photographs were taken of Gambian rats, but transport of this species cannot be completely ruled out. Cameras deployed on Grassy Key confirmed post-storm survival of Gambian rats.

In February 2006, a $20,000 grant from the Wildlife Foundation of Florida, Inc., with matching funds from the USDA APHIS WS, funded a pilot project on Crawl Key, a 360-acre uninhabited key (due west of Grassy Key) where Gambian rat photographs were recorded in three out of four camera locations in 2005. In June 2006, USDA APHIS WS deployed 94 bait stations on a 40-m grid system. For 3 days, stations were pre-baited with peanut butter and horse feed but no toxicant, followed by 10 days of baiting with toxicant (zinc phosphide) added. Supplemental trapping occurred to obtain rats for radio telemetry. Bait stations were monitored daily, and bait was weighed upon evidence of disturbance. Of the 94 stations, 37 had been visited by wildlife that consumed some of the bait. During this project, no photographs were taken of Gambian rats, and no Gambian rats were trapped. Some raccoons likely died, although no fresh carcasses were found. As Hurricane Wilma essentially eliminated freshwater sources on Crawl Key and severely impacted vegetation, Gambian rats may have immigrated from the key or suffered mortality prior to the project; indeed, one Gambian rat carcass was discovered while setting bait stations. Regardless of the reason, the FWC concluded that no Gambian rats remain on Crawl Key. Based on the pilot project, the consistency of the bait was modified to avoid removal by raccoons along with subsequent non-target mortality.

Concurrent with the pilot eradication project, six Gambian rats (three males) were trapped on Grassy Key and fitted with radio collars. GPS locations were obtained nightly, weather permitting, for the final six days of the project. Movement and location data will be used to refine the eradication project for Grassy Key.

Figure 9-13. The green iguana (*Iguana iguana*) (photo by Tony Pernas, NPS).

GREEN IGUANA

Green iguana (*Iguana iguana*) are native to Central and South America and some Caribbean islands but have become well established in South Florida (**Figure 9-13**). The range of the green iguana appears to be expanding in South Florida, having being found initially in Dade County in 1966 and observed later in Broward, Lee, Monroe, Palm Beach, and St. Lucie counties. Breeding populations have been established in all but one of these counties.

Green iguanas were first reported in Monroe County around 1995 and are now common on several of the Florida Keys. These large lizards are popular in the pet trade and frequently escape or are released, although it is illegal to release iguanas in Florida per Chapter 39-4.005, Florida Administrative Code (F.A.C.). They are generally found in low-density suburban areas, in peripheral areas of urban locales, agricultural areas, and rockland hammock communities. Iguanas bask in open areas including sidewalks, docks, seawalls, and open mowed areas.

Adult green iguanas are generally herbivorous, feeding on foliage, flowers, and fruit, though they occasionally eat insects, lizards, nestling birds, and eggs. Juveniles tend to consume insects and other invertebrates more than adults do. Iguanas consume both native and ornamental plant species in South Florida, however, they have also been found to prey on tree snails, especially *Drymaeus multilineatus* in Key Biscayne. In the Florida Keys, iguana feeding could have serious implications for populations of other snail species, such as the stock island tree snail (*Orthalicus reses*), federally designated as a threatened species, and the Florida tree snail (*Liguus fasciatus*), a state-listed species of special concern.

Damage caused by green iguanas includes eating valuable landscape plants, orchids, many other flowers, fruits and berries, and native vegetation. Droppings of green iguanas are a possible source of salmonella bacteria, which could cause deleterious effects to humans. Furthermore, adult green iguanas are powerful animals that can bite and scratch, and aggressively slap with their tail. Although green iguanas normally avoid people, they will defend themselves if cornered or threatened.

Green iguanas are listed for protection in their native range in the Convention on International Trade in Endangered Species (http://www.cites.org/eng/app/appendices.shtml), because they are economically valued in their range and are often rare due to over-collection for the pet trade. There are currently no agency-sponsored, coordinated control efforts for the nonindigenous green iguana in South Florida (including the Keys). The controls likely will be implemented, given the region's expanding green iguana populations, impacts to water management operations (see the *Greater Everglades Module* section), and potential impacts of this nonindigenous species on native species.

FLORIDA BAY AND SOUTHERN ESTUARIES MODULE

Nonindigenous Plants

Invasive plant management in this region focuses on Florida Bay, the bay's keys, coastal areas of Everglades National Park (ENP or 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, Brazilian pepper, half-flower, sapodilla, seaside mahoe, and latherleaf. The ecological effects of latherleaf have been most prevalent in this region (Jones, 1997). Latherleaf, first noted as naturalized in the module by Small (1933), is now well established and distributed throughout the coastal areas of ENP 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 9-14. Latherleaf (*Colubrina asiatica*) commonly invades the coastal ridges just above the mean high-tide line (photo by Tony Pernas, NPS).

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) (**Figure 9-14**). 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 vegetation including trees (Langeland, 1990; Jones, 1996). This species is of particular concern in Florida's coastal hammocks, where it threatens a number of rare habitats and 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 primary dispersal agents (Carlquist, 1966).

Latherleaf is actively managed in ENP and Biscayne National Park, although there are increased concerns about this species in the Southern Estuaries and its movement into the natural reserves in north Key Largo. 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 NPS is 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.

The NPS has been controlling Australian pine in this module since the 1970s. Regular treatments are effective, and the species is considered to be under maintenance control, but there is a constant (floating) seed source from surrounding areas of the coastal mainland and islands to the south, making long-term control impossible without a continuous, active treatment program.

A biological control feasibility project is being conducted for *Casuarina* by the USDA that focuses on the development of cone/flower feeding biocontrol agents to reduce propagule pressure and spread by seeds. Australian pine is of special concern in the Southern Estuaries because it threatens the habitat of the endangered crocodile (*Crocodylus acutus).* Australian pine's shallow root system has been observed to interfere with both sea turtle nests on beaches and crocodile nests in northeastern Florida Bay (**Figure 9-15**).

Figure 9-15. Crocodile (*Crocodylus acutus)* nest on a *Casuarina*-impacted island in northeastern Florida Bay (photo by Tony Pernas, NPS).

Other problematic species in the southern coastal estuaries include half flower (*Scaevola taccada*) and seaside mahoe (*Thespesia populnea*). Like Australian pine, the seeds of these species float, and there is constant seed pressure from surrounding natural areas and ornamental plantings in coastal urban communities, making perpetual control necessary. The sapodilla tree (*Manilkara zapota*) is interspersed with tropical hardwood communities throughout some coastal islands, making on-the-ground control tedious as herbicide applicators are forced to canvass the forested area on foot looking for the nonindigenous tree among native tree species (**Figure 9-16**).

Figure 9-16. Sapodilla (*Manikara zapota)* interspersed along the southern coastline (photo by Tony Pernas, NPS).

The priority plant species for the Florida Bay and Southern Estuaries Module are listed in **Table 9-5**.

Table 9-5. Stoplight table for priority plant species in the Florida Bay and Southern Estuaries Module.

	2006 STATUS	1-2 YEAR PROGNOSIS
FLORIDA BAY & SOUTHERN ESTUARIES MODULE (Results in row reflect module-level questions, not species-level questions)	Australian pine and Brazilian pepper control programs under way for many years have achieved significant control; however, many species have invaded in recent years and their possible effects are unclear; Most of Florida Bay is not included in any monitoring program for invasive plants	Some species, such as Latherleaf, have been serious invaders of rare habitats along the southern coast of the Park; other new species are simply off the radar as far as their inclusion in a systematic control or monitoring program and are serious unknowns
Australian Pine (*Casuarina* spp.)	Effective control program is in place in the southern and western coastal areas of the Park; surrounding seed sources make continuous long-term management necessary in these areas; impacts endangered species	Chemical control effective and most coastal habitats are clear but ongoing control still needed in coastal areas due to (floating) seed pressure from other areas; biocontrol research under way
Latherleaf (*Colubrina asiatica*)	The spread of latherleaf has been documented for over a decade; overall, distribution and impacts in coastal habitats are increasing; it is difficult to detect remotely and especially problematic to rare coastal habitats; not part of a systematic monitoring program	This species has been spreading north along the Park's west coast, east along Florida Bay, and south into the Keys; poses a serious threat to the natural areas of north Key Largo; herbicidal control logistically challenging; seed viability poorly understood; no biological control programs under way
Sapodilla (*Manilkara zapota*)	It is scattered throughout coastal hardwood habitats; it is difficult to detect remotely and is not included in an Indicator systematic monitoring program	Because it is intermixed in native tropical hardwood communities, its detection and control are difficult and logistically challenging; likely spread by animals; no biological control program under way
Half Flower (*Scaevola taccada*)	This species is limited to coastal habitats; it is easy to detect but is not part of an Indicator systematic monitoring program	Effectively controlled along beaches in most locations in the module, but surrounding seed sources from ornamental plantings make long-term control problematic; no biological control program under way; Prospects poor, given native *Scaevola* species
Brazilian Pepper (*Schinus terebinthifolius*)	Invades most habitats, including coastal communities, and very destructive; chemical control ineffective in reducing ecosystemwide spread so far; however, localized control programs are proving effective in the module	Control programs in southern Park areas have been effective in reducing local populations; most Brazilian pepper populations limited so far in this region but coastal mangroves still threatened; new biocontrol agents under study for future release in 2007-2008
Seaside Mahoe (*Thespesia populnea*)	Invades coastal habitats and forms dense monocultures; not part of a systematic monitoring program	Control of this species is ongoing in Elliot Key and scattered locales in Florida Bay; surrounding seed sources from wild populations and ornamental plantings; floating seeds are spread into natural areas with high tide, and make long-term control difficult

Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Nonindigenous Animals

In addition to well documented problems associated with nonindigenous coastal plant species (**Table 9-5**), the Florida Bay and Southern Estuaries Module also has several priority nonindigenous animals, highlighted in this chapter because recent evidence indicates that populations are expanding and may be impacting ecologically sensitive areas in this region.

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.

Hurricane Andrew (1992) resulted in losses of island forests (Ogden, 1992; Davis et al., 1994). Many mammal species survived the storm on mainland Miami-Dade County (Ogden, 1992; Davis et al., 1994), 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 suggest that this species survived the hurricane and is increasing in number (T. Pernas, NPS, personal communication). The status of the species on Sand and Adams keys is not known.

The Mexican red-bellied squirrel breeds year-round. They are opportunistic feeders (J. 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 Sargent's buccaneer palm (*Pseudophoenix sargentii*). They also feed on eggs and invertebrates, and pre-Andrew NPS assessments of the squirrel on Elliott Key suggested that they feed on the declining liguus tree snail (*Liguus fasciatus)* (Tilmant, 1980).

The potential and actual 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). An NPS ranger intercepted a swimming squirrel near Old Rhodes Key (Layne, 1997), suggesting that this species could spread throughout the Southern Estuaries and into the Florida Keys, where endangered rodent species such as the Key Largo woodrat (*Neotoma floridana smalli*) and the Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*) would be vulnerable to competition.

This 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 NPS has begun 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 this nonindigenous squirrel on Elliott, Sand, and Adams keys. Population surveys of Elliott Key completed in March 2006 identified 129 squirrel nests (**Figure 9-17**). Following these surveys, an Environmental Assessment will be prepared that recommends whether an NPS-sponsored control program for this species should be initiated.

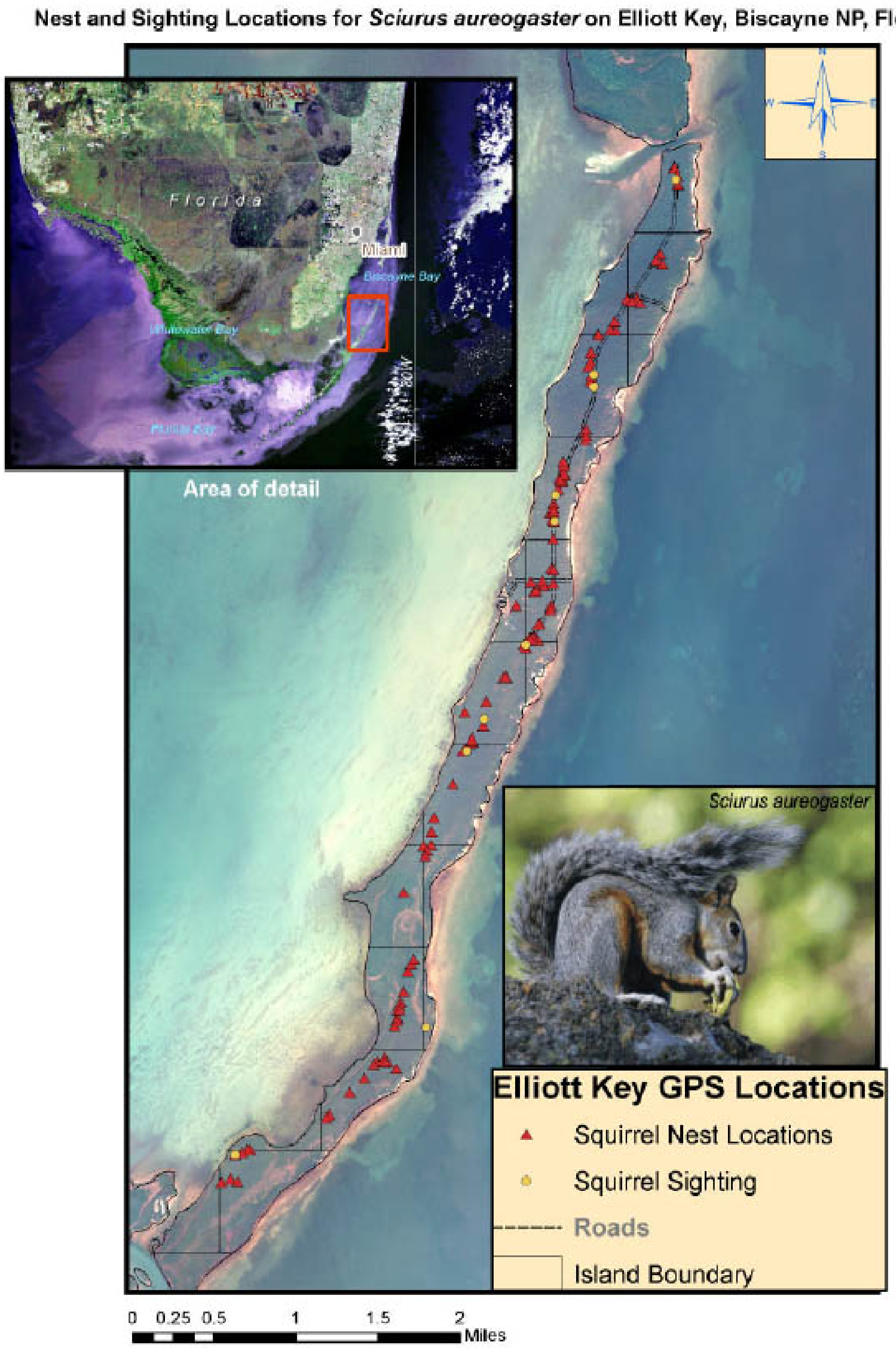


Figure 9-17. Location map of Mexican red-bellied squirrel (*Sciurus aureogaster*) population surveys on Elliot Key by the National Park Service, March 2006 (figure from NPS).

MAYAN CICHLID

The Florida population of the Mayan cichlid (*Cichlasoma urophthalmus*) was first recorded in 1983 in Snook Creek, a tributary of Joe Bay in northeastern Florida Bay (Loftus, 1987). Although the source of this introduction is unknown, 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 9-18**). 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.

Figure 9-18. Mayan cichlid (*Cichlasoma urophthalmus*) (photo by Paul Shafland, FWC).

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 (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).

GREATER EVERGLADES MODULE

Nonindigenous Plants

Before organized state and federal exotic plant control operations were initiated in 1990, melaleuca (*Melaleuca quinquenervia*) was widely distributed throughout the Water Conservation Areas (WCAs), ENP and Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). 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.

Within the Greater Everglades Module, 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. These areas are now under maintenance control. Dense melaleuca populations no longer occur in the WCAs 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 where crews are working methodically to bring the area under maintenance control (**Figure 9-19**). However, melaleuca populations in northernmost sections of the Greater Everglades Module are increasing, and control operations do not appear to have been 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, dense stands.

Figure 9-19. Field crews controlling melaleuca in the Everglades (photo by NPS).

Perhaps no other individual plant species poses a greater threat to the Everglades than Old World climbing fern. As depicted in **Figure 9-20**, this highly invasive vining fern smothers native vegetation, severely compromising plant species composition, destroying tree island canopy cover, and dominating understory communities, which are all cited as key parameters in measuring Everglades restoration success. 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 (Ferriter and Pernas, 2006). Today, it dominates Refuge tree islands, and now occurs, at various levels of density, in virtually every habitat in the Greater Everglades Module (Ferriter, 2001).

Figure 9-20. Old World climbing fern and Brazilian pepper overtaking a tree island in the northern Everglades (photo by Amy Ferriter, Boise State University).

ENP staff discovered thousands of acres of Old World climbing fern on the Park's western edge in 2000 (T. Pernas, NPS, personal communication) and District field biologists began observing small strands in WCA-3 in 2001 (M. Korvela, SFWMD, personal communication) (**Figure 9-21**). 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. Based on the documented impacts of this species in the Refuge (Brandt and Black, 2001) and the Park, the District initiated a detailed ground-based tree island survey to estimate the extent to which Old World climbing fern occurs in the WCAs. The District has conducted aerial surveys for this species since 1993 and is conducting ongoing operational and field research to effectively control the species and determine environmental factors that affect its growth and spread. (Stocker et al., 1997; Gann et al., 1999; Ferriter, 2001; Langeland and Link, in press).

Figure 9-21. *Lygodium* survey in WCA-3B (photo by Mike Korvela, SFWMD).

Due to the remoteness of the Old World Climbing Fern populations in the Park, Park staff is limited to using aerial treatments for containment. Park staff is evaluating non-target damage and assessing the effectiveness of these treatments. District contract crews treat this species as it is encountered on tree islands throughout the Everglades. Over the last year, District and FWC contractors have conducted intensive ground-based tree island surveys in the WCAs to locate remote, incipient Old World climbing fern populations. Based on preliminary results from a random survey of 80 tree islands, roughly 9 percent of the tree islands surveyed had at least one Old World climbing fern infestation. The occurrence of infestations did not correlate with site conditions such as island size, island elevation, or species richness, suggesting that most islands are susceptible to invasion by this plant. The District is entering an operational phase of the tree island surveys, which increases survey frequency and improves coordination between surveyors and vegetation management contractors. Once populations are discovered by field biologists, the coordinates and infestation characteristics are transferred to the District's Vegetation Management Division, which then dispatches control contractors.

Aerial and follow-up ground treatments have been initiated at the Refuge in areas that have particularly severe infestations of Old World climbing fern. Additionally, several ongoing research initiatives are underway at the Refuge to (1) determine the effects of fire as a posttreatment strategy on tree islands, (2) assess post-fire recruitment of Old World climbing fern, a model of the plant's spread with an "Optimal Control Growth Model" (Brandt, 2005), and (3) study Old World climbing fern spore dispersal and germination as well as the effects of Old World climbing fern on ant diversity on Refuge tree islands (Darby et al., 2002).

Land managers statewide agree that biocontrol may be the key to effective long-term regional management of Old World climbing fern. Financial and logistical support from the District and other stakeholders is provided to the USDA-ARS for research on host specificity testing and to support release and monitoring efforts of approved biocontrol agents. The only agent currently permitted for release is the pyralid moth (*Austromusotima camptozonale*); the moth's caterpillars defoliate Old World climbing fern plants. During 2005, *A. camptozonale* was successfully reared, and a total of 12,000 adult moths was released at locations in the Refuge, Jonathan Dickinson State Park, and on private land in Martin County. To date, there is no evidence that these releases resulted in successful establishment of *A. camptozonale* at any of the sites. In 2006, on the supposition that *A. camptozonale* caterpillars would be a more resilient life stage for transportation and release, a total of 16,000 caterpillars were released at the same sites. Early monitoring indicated that this release method holds promise, as the caterpillars had survived and reproduced at several of the release sites (R. Pemberton, USDA-ARS, personal communication, 2006). Approval of the federal release permit for a second agent, a leaf-gall mite (*Floracarus perrepae*) was expected in late 2006. A third agent, another species of pyralid moth (*Neomusotima conspurcatalis*), was approved for release by the Technical Advisory Group for Biological Control of Weeds, and researchers are awaiting issuance of a federal release permit from USDA-APHIS-Plant Protection Quarantine (APHIS-PPQ) (R. Pemberton, USDA-ARS personal communication).

Brazilian pepper 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 controlled through the complete removal of previously farmed and rock-plowed substrate. This intensive process results in recolonization by native wetland vegetation to the exclusion of Brazilian pepper. In contrast, vast areas of the western coastal mangroves and marshes of the Park are being dominated by Brazilian pepper, and resource managers face almost insurmountable obstacles in treating these populations due to the breadth and remoteness of the sites. This underscores the need for effective biological controls for this species. The University of Florida and USDA are working to develop biological controls for Brazilian pepper. Several petitions for release have been submitted to USDA APHIS-PPQ, but no permissions were granted in 2006 for the release of any agents.

Figure 9-22. Dead Brazilian pepper along the western edge of the ENP following the 2005 hurricanes (photo by Tony Pernas, NPS).

ENP staff observed large areas of dead or dying Brazilian pepper along the western edge of the Park after Hurricane Katrina/Wilma in late 2005 (**Figure 9-22**). Although it was thought that this Brazilian pepper mortality might have resulted from increased salinity caused by storm surge, soil samples taken in the area revealed no significant differences in salinity levels in areas where the Brazilian pepper had died (T. Pernas, NPS, personal communication). The Park staff will continue to monitor this area.

Australian pine (*Casuarina equisetifolia*) grows quickly; is salt tolerant; fixes nitrogen; readily colonizes rocky coasts, dunes, sandbars, islands; and invades far-inland, moist habitats (Morton, 1980) (**Figure 9-23**). It forms dense forests, eventually excluding other plant species. Efforts to control Australian pine in the Greater Everglades are ongoing, but are not yet systematic in approach. This species still is 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 ENP and mainland Biscayne National Park. The seeds are windblown, carried by birds, and probably moved throughout the Everglades via water flow in canals.

Figure 9-23. Australian pine threatens the habitat of the endangered Cape Sable seaside sparrow in the East Everglades (photo by Kenneth Langeland, Univ. of Florida).

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 large areas of these historically graminoid marsh nesting sites. To restore sparrow nesting habitat, the ENP and USACE began a ground-based, systematic program to control Australian pine along the eastern edge of the Park that still is ongoing.

Figure 9-24. Shoebutton ardisia *(Ardisia elliptica)* is becoming frequent in the understory of many Everglades tree islands (photo by Kenneth Langeland, Univ. of Florida).

Shoebutton ardisia (*Ardisia elliptica*) is a shade-loving shrub that was originally reported in the HID (**Figure 9-24**). 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 Park. Sporadic District and NPS control operations are ongoing for this species, but recent field observations by District contract crews (M. Blankenship, Applied Aquatics, personal communication) indicate that this plant is invading the understory of many tree islands and bayheads in WCA-3. If this species continues to spread in the WCAs, 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 stands that completely exclude understory vegetation. Early detection on tree islands and bayheads will be extremely challenging, as this species is difficult to detect remotely, and a closely related native, marlberry (*Ardisia escallonioides*), has a very similar form. While birds are the principal dispersers of the seed, raccoons and opossums also eat the fruit and disperse seeds (Miami-Dade County, 2002).

The priority plant species for the Greater Everglades Module are listed in **Table 9-6**.

Table 9-6. Stoplight table for priority plant species in the Greater Everglades Module.

	2006 STATUS	1-2 YEAR PROGNOSIS
GREATER EVERGLADES MODULE (Results in this row reflect module-level questions, not species-level questions)	Old World climbing fern and Brazilian pepper are still widespread and serious threats to module; continued rapid spread of these two species with little results from control efforts; still several other species present with little or no control effort or effectiveness	Good control of melaleuca and Australian pine, biocontrol for melaleuca effective; first biocontrol releases for Old World climbing fern, new biocontrol for Brazilian pepper under study; other species still localized, no new serious invaders detected
Shoebutton Ardisia (*Ardisia elliptica*)	Was a localized problem in the Park but now infests tree islands and bayheads throughout the WCAs; difficult to detect and not part of a systematic monitoring program	No significant control program and no biocontrol effort under way; now found in WCA tree islands and bayheads, posing a serious threat; may be entering exponential spread phase; difficult to monitor remotely and resembles several native species making detection and control difficult
Australian Pine (*Casuarina* spp.)	Still common in northeast portions of the Park and on District canal banks	Chemical control effective; most natural areas clear with the exception of northeast part of the Park where significant control is still needed; biocontrol research under way
Old World Climbing Fern (*Lygodium microphyllum*)	Serious invader, rapidly spreading throughout module; invades most habitats and very destructive; long-term management difficult given the variety of habitats it infests	No effective control yet but biocontrol release made with additional release expected in 2006; chemical control studies continuing
Melaleuca (*Melaleuca quinquenervia*)	Large portions of the module are under maintenance control and biocontrols showing promising results; however, some areas in the east Everglades, Refuge, and Corbett WMA still need significant work	Chemical control effective on most public lands; biocontrol agents effective and additional spread of existing agents and new agents expected in 2006
Brazilian Pepper (*Schinus terebinthifolius*)	Serious invader, with rapid spread throughout the module; invades most habitats and very destructive; chemical control effective in limited areas but ineffective in reducing overall spread; significant portions of the Park, particularly the mangroves are seriously impacted	No effective regionwide controls yet; chemical control programs effective in limited areas where significant resources can be applied; new biocontrol agents under study for possible release in 2007-2008

Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Nonindigenous Animals

In addition to the priority plant species listed in **Table 9-6**, many nonindigenous animal species occur in the Greater Everglades Module. The priority animal species discussed below have raised special concerns among agency scientists in the region and have the potential to impact Everglades restoration initiatives.

LOBATE LAC SCALE

The lobate lac scale insect (*Paratachardina lobata)* native to India and Sri Lanka and was first discovered in 1999, on ornamental hibiscus (*Hibiscus rosa-sinensis*) in Davie, Florida 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 insect occurs on many native plants, and certain native species appear to be highly susceptible, such as the 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 9-25**).

Figure 9-25. Lobate lac scale (*Paratachardina lobata)* on native tree island species (photo by SFWMD).

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 within the Everglades. Given the importance of healthy tree islands in Everglades restoration, the value of canopy cover for wading bird nesting, and the propensity of some exotic plants to rapidly colonize disturbed sites (such as areas of canopy dieback), both research to understand the distribution of this invasive species and steps to contain its spread are warranted.

Surveys for this species are conducted by the Cooperative Agricultural Pest Survey Program, but because the role of this program is tracking the species in agricultural and urban areas, very limited tracking has been done in natural areas. The spread of lobate lac scale in the Everglades is of great concern, as no available insecticides are labeled for use in wetland areas and selective control of this species with pesticides would be difficult, if not impossible. In addition, using pesticides in sensitive natural areas may have secondary effects, especially on native insect populations.

As biological control agents are seen as the only option for controlling this species, the USDA and the University of Florida have begun overseas searches for natural enemies of lobate lac scale. After several years of searching its native range, the USDA found populations of the scale in southern India in August 2005 (R. Pemberton, USDA, personal communication). Infested twigs were brought back to the USDA quarantine facility in Davie, where several parasitoids from the scales have been reared. Regular shipments of infested twigs from the same site are now being shipped to the quarantine facility. Early indications are good that three parasitoids from the India collections will attack the Florida populations of lobate lac scale, although developing colonies in quarantine has been difficult.

Potential differences between the Florida populations and the Indian scale might influence USDA's ability to successfully develop cultures. To examine this possibility, DNA from the invasive scale collected in Florida and the Bahamas will be compared with the scale collected in India. Despite this progress, it will be many years before a safe, effective biological control for lobate lac scale is available in Florida. (R. Pemberton, USDA, personal communication).

BURMESE PYTHON

The Burmese python (*Python molurus bivittatus*), a native to Southeast Asia, can reach a length greater than 20 feet. This long-lived (15–25 years) python is a behavioral, habitat, and dietary generalist, capable of producing large clutches of eggs (8–107). The python's diet in the Everglades includes alligator, raccoon, rabbit, muskrat, squirrel, opossum, cotton rat, black rat, cat, 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) in the greater Long Pine Key area (including Hole-in-the-Donut), and (3) in the greater Shark Valley area along the Tamiami Trail (including L-67 Ext.) (**Figure 9-26**). The pythons also have been observed repeatedly on the eastern Park boundary, along canal levees, in the remote mangrove backcountry, and in Big Cypress National Preserve. 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 to 14 feet, including five hatchling-sized animals recovered in the summer 2004 and two hatchlings captured in 2005.

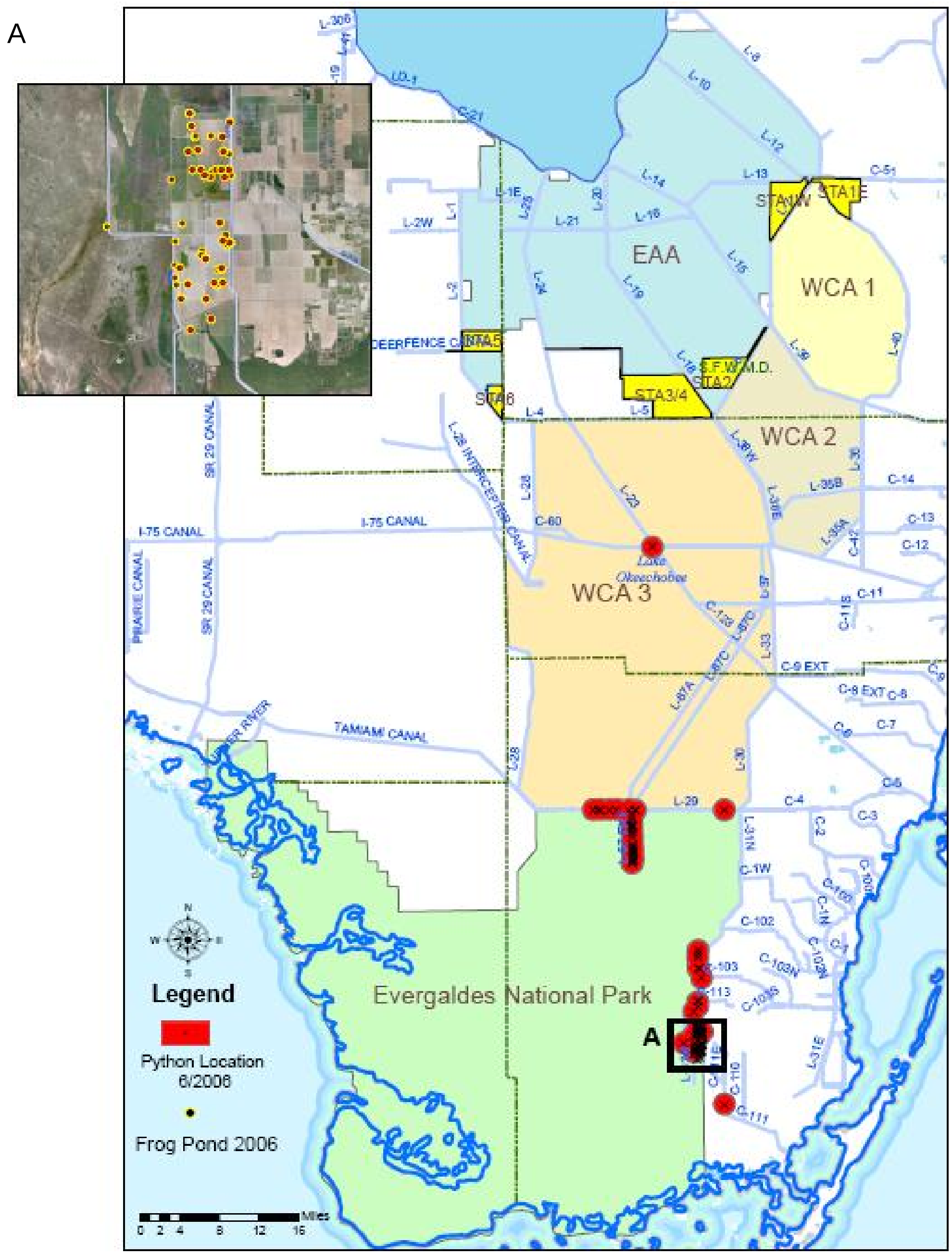


Figure 9-26. General distribution of Burmese python across South Florida based on available data, October 2006.

Figure 9-27. Everglades National Park staff releasing radio-tagged Burmese python (*Python molurus bivittatus*) (photo by Lori Oberhofer, ENP).

The non-native Burmese python populations are continuing to expand at an alarming rate in the Greater Everglades, as documented in previous SFERs. In 2006, approximately 160 pythons were removed from the ENP and surrounding areas, representing a twofold increase from last year. A Park-sponsored workshop was held in July 2005 to address this growing issue. Park staff continues on-the-ground control and research in the Greater Everglades Module (**Figure 9-27**).

Burmese pythons present a potentially significant threat to the successful ecological restoration of the Greater Everglades. Established and breeding in South Florida, the populations have the clear potential to occupy the entire footprint of CERP, adversely impacting valued resources across the landscape. Increasing observations of Burmese python/ American alligator conflicts are troubling, particularly because the alligator is widely considered the top predator in the Greater Everglades region (**Figure 9-28**).

Figure 9-28. Alligator consuming Burmese python in the Everglades National Park (photo by Lori Oberhofer, ENP).

The pathway of invasion for the Burmese python is through the pet industry, as pythons are still commonly sold in pet stores. Roughly 6,000 Burmese pythons were imported through the Port of Miami in the last three years alone. In an attempt to "cork the bottle," the SFWMD Governing Board requested that the director of the USFWS regulate the Burmese python as an injurious species under the Lacey Act (42 U.S.C. § 18). The USFWS regulates international wildlife trade and addresses threats to native wildlife resources. A 1981 amendment to the Lacey Act allows for the regulation of importation or shipment of animals that have been determined to be injurious to human beings or to wildlife resources of the U.S. No decision on this request has yet been made.

CHANNELED APPLESNAIL

Recent (2005) field observations by the Florida International University and ENP scientists indicate that other species such as the channeled applesnail (see the *Kissimmee Basin Module* section for species-specific information) are present in the Greater Everglades Module. 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 (S. Snow, ENP, 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 (S. Snow, ENP, personal communication).

GREEN IGUANA

The green iguana (*Iguana iguana*) (see the *Florida Keys Module* section for species-specific information) is a widespread nonindigenous reptile species in Southern Florida. District field observations of large groups of this species have increased dramatically in the last two years and many canals and levees in and around the Greater Everglades are now peppered with green iguana burrows. This extensive burrowing along canal and levee banks may present a maintenance liability to surface water infrastructure important to the Everglades restoration effort. Waterways and water structures with notably high numbers of green iguanas include the C-7, C-11 and C-1 West canals. Iguanas burrow into canal banks, leading to bank instability and bank erosion. District and NPS biologists have completed preliminary surveys of burrow characteristics to evaluate their impact on bank stability (**Figure 9-29**). Burrow measured at the S-13 structure in Broward County tended to extend horizontally into the banks, ranging from 0.3 to 2.4 meters deep and generally from 10 to 20 centimeters in diameter. While further evaluations may provide a fuller understanding of the effect of the burrows on bank integrity and maintenance costs, it is clear that moderate densities of green iguanas have some impact on bank stability.

Figure 9-29. An NPS scientist surveys a green iguana burrow on an Everglades canal bank (photo by LeRoy Rodgers, SFWMD).

SACRED IBIS

The sacred ibis (*Threskironis aethiopicus*), a large, long-legged wading bird native to parts of Africa and Iraq, escaped captivity and became a serious pest in parts of Europe, and is considered a major threat to European tern colonies. The physical appearance of the sacred ibis is similar to the native and federally threatened wood stork (*Mycteria americana)*. Overall, coloration is white with black plumes composing the tail. During flight, scarlet patches are noticeable under the wings near the arm pit and on the sides of the breast. The head and neck are bare, scaly and gray in color. The bill is curved and is similar to native white, glossy and scarlet ibis. This nonindigenous ibis is much larger than any other native ibis, but slightly smaller than the protected wood stork.

The sacred ibis prefers marshes, moist soil wetlands, flooded agricultural fields, coastal estuaries, and lagoons (**Figure 9-30**). It shares communal roosting and nesting areas with other native wading and water birds, and has life cycle requirements similar to those of native wading birds such as egrets, herons, and wood storks. The diet consists primarily of mollusks, frogs, and aquatic insects, but this opportunistic species has been reported to prey upon the eggs and young of other wading birds.

Figure 9-30. Sacred ibis (*Threskironis aethiopicus*) on a tree island in the Refuge interior (photo by USFWS).

Although not confirmed, it is believed that populations in South Florida came from a breeding population that escaped the Miami Metrozoo following Hurricane Andrew in August 1992. This species appears well suited to Everglades habitats including the WCAs and surrounding agricultural lands. State and federal agencies view this nonindigenous species as a potential threat to native water bird populations. The sacred ibis could impact native wading and water bird populations due to its opportunistic feeding nature, and the bird may compete with native wading birds for food and nesting space.

District biologists observed six to eight individuals nesting in the southern Refuge interior during the 2005 wading bird nesting season. In May 2006, sacred ibis were reported nesting among active wading bird colonies in the Refuge (W. Calvert, USFWS, personal communication, 2006). A rapid response control measure was initiated by the USFWS Region 4 Invasive Species Strike Team following a 2006 District report of a single nesting pair located in an active wading bird rookery. Both individuals were dispatched. Since treatment, no additional sacred ibis have been observed at this colony.

PURPLE SWAMPHEN

The purple swamphen (*Porphyrio porphyrio*), a large rail from which there are known to be six or more subspecies, is native to Europe, Africa, Asia, Australasia, Indonesia, and the Philippines. This species is very similar in coloration to the native purple gallinule (*Porphyrula martinica)* but is much larger, approximately the size of a domestic chicken. The European subspecies is purplish-blue in color and appears to be the stock that has escaped in South Florida. The species has huge feet, red legs and a characteristic bright red bill and red frontal shield that extend onto the crown of the head. They may have been released from Miami Metrozoo after Hurricane Andrew in 1992 or by avicultural hobbyists (Pranty et al., 2000).

Purple swamphens breed prolifically in wetlands dominated by sedges, rushes, and reeds. The bird has opportunistically adapted to Everglades habitats, particularly man-constructed impoundments and Stormwater Treatment Areas (STAs). By nature, purple swamphens are communal and social. Multiple females share incubation and parental nurturing duties, with more than one female often laying (three–six speckled eggs each) in one nest. Nest structures are often covered for sheltering purposes and protection from the elements. Purple swamphens feed on tender shoots and reeds, invertebrates, and small mollusks. However, they have been reported to feed on the eggs and young of native water birds including native waterfowl.

The original South Florida purple swamphen population appears to have established in Pembroke Pines in 1996 (S. Hardin, FWC, personal communication). This population has been reported on varied bird-watching websites, including that of the Broward County Audubon Society (http://www.browardaudubon.org/BirdingHotspots05.html). In recent years, purple swamphens have been sighted adjacent to the Greater Everglades Module in STA-1 West (STA-1W), STA-1E, STA-5 (**Figure 9-31**), and possibly in an impoundment of the Refuge (unconfirmed). STA-5 is thought to harbor a population of 100 or more birds (E. Donlan, SFWMD, personal communication). The birds in STA 1W appear to have disappeared, and it is hypothesized that they could have moved into the Refuge. A single bird was reported in Orlando following the active 2005 hurricane season (S. Hardin, FWC, personal communication) but is not believed to have survived.

Figure 9-31. An FWC scientist captures a purple swamphen (*Porphyrio porphyrio*) during a recent survey in the WCAs (photo by Ellen Donlan, SFWMD).

The purple swamphen seems to prefer the edges of manmade ponds, lakes, or impoundments, including STAs, and often uses levees and dikes for feeding and travel to, from, and within the STAs. Birds escaped in South Florida are reported to be somewhat tame and easily approached by humans. Large concentrations of the purple swamphen could impact native water birds through competition for food and space and through direct predation. The consensus among land management agencies in Florida is that this species could be effectively controlled and possibly eradicated as part of an Early Detection and Rapid Response Program, pending appropriate funding and expeditious implementation of a management and control program. Most state and federal agencies view this non-native bird species as a potential threat to native water bird populations. Sightings and control of purple swamphens in the Refuge is coordinated through the USFWS Region 4 Invasive Species Strike Team. While no control has yet been performed , the FWC has conducted a survey to document the absence/presence of this species on Florida's conservation lands, and has produced a combination identification/fact sheet as a component of the initial survey package.

Purple swamphens are being considered for addition to the Migratory Bird Treaty Act (MBTA) since they are native to American Samoa, where there is a concern for protecting them. The MBTA does not have a history of making geographic distinctions and subsequently provides protection to a species throughout all of the holdings and interests of the U.S., including trusts, territories, etc. This federal protection could become effective as early as January 2007. USFWS staff, aware that this species is not native to North America (and is considered potentially invasive in Florida), is evaluating the need for geographic distinctions in these types of cases. The USFWS currently recommends elimination of as many birds as possible in Florida before any implementation of MBTA protections.

SWAMP EEL

During the late 1990s, three reproducing populations of non-native swamp eel (Family: Synbranchidae) were discovered in Florida. Included are large populations in North Miami canals, canal networks near Homestead adjacent to ENP, 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 represent at least two different Asian forms, presumably both belonging to the genus *Monopterus* but with the species not yet determined (Collins et al., 2002) (**Figures 9-32** and **9-33**). It is believed that wild populations in Florida originated as escapes or releases associated with aquaculture, the pet trade, or live food markets.

Figure 9-32. Swamp eel (*Monopterus albus)*(photo by USGS).

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 3 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.

Since the discovery of swamp eels in Florida, USGS scientists have studied 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 9-33. Swamp eel (photo by Don Schmitz, FDEP).

OTHER NONINDIGENOUS FISH

At least 36 nonindigenous fish species have become established in South Florida through anthropogenic introductions (USGS, 2005), and many species are now abundant within the canal system that surrounds and dissects the Greater Everglades (USGS, 2004). Nonindigenous fish are often detrimental to their host communities (Ogutu-Ohwayo, 1993; Clavero and García-Berthou, 2005) and may have the potential to significantly impact aquatic communities of the Everglades. This concern led CERP to set nonindigenous fish population levels in the EPA as an ecological performance measure (RECOVER, 2003).

Most nonindigenous fish in South Florida are tropical in origin, and their populations are considered to be regulated by annual minimum temperatures, which restrict their range to tropically warm or deep-water refugia (Trexler et al., 2000). Scientific consensus suggests that thermal constraints and the difficulty associated with migrating within the ridge and slough landscape limit their distribution to within approximately 1 km of canals. As such, their impact on the marsh communities to date is considered minimal (Shafland, 1996). A number of nonindigenous fish species have been recorded in low relative abundance within certain marshes of the Greater Everglades (e.g., Chick et al., 2004; Kobza et al., 2004; Dunker, 2003; Trexler et al., 2000), but no extensive, long-term systematic surveys have specifically targeted nonindigenous fish, and the sampling methods employed to date have biases that potentially under-sample nonindigenous fish (Loftus, 1987). These findings indicate that the distribution, abundance, and species diversity of nonindigenous fish in the Greater Everglades may be considerably underestimated, and that little is understood of nonindigenous fish species in the marsh or of any impacts associated with these species.

The District investigated nonindigenous fish diversity in WCA-3A and examined whether these species are established in the marsh or restricted in distribution by proximity to a canal. To determine establishment, the nonindigenous fish relative abundance was evaluated in relation to distance from the L-67A canal. A species was considered established if its relative abundance beyond 1 km of the canal was equal to or greater than that within 1 km of the canal.

The nonindigenous fish captured in this study included three species of cichlid and a catfish. These species were an important component of the marsh fish community, accounting for 16 percent of the species count, 5 percent of the total biomass, but less than one percent of the total fish count.

The black acara (*Cichlasoma bimaculatum*) was found at distances beyond 1 km from the canal, suggesting it is established in the marsh. Moreover, juveniles were captured 3 to 4 km from the canal, providing further evidence of establishment in the marsh. It is notable that this species was caught only 3ºC above its stated minimum lethal temperature (P. Shafland, personal communication).

The Mayan cichlid (*C. urophthalmus*) was the eighth most abundant fish of the entire marsh fish community in terms of biomass. Mayan cichlids were distributed equally among the three distance categories, juveniles were captured 3 to 4 km from the canal, and it is likely that this species is established in the marsh. Notably, it was captured up to 2ºC above its stated minimum lethal temperature (P. Shafland, personal communication).

A single juvenile spotted tilapia (*Tilapia mariae*) was captured within 1 km of the canal. This species is widespread in South Florida (Fuller et al., 1999), but its establishment outside of the canals, lakes, and ponds surrounding WCA-2A is unknown.

A single juvenile brown hoplo (*Hoplosternum littorale*) was captured 2 to 3 km from the canal. While a single individual reveals little about possible establishment, its capture 2 to 3 km from the canal and observations of bubble nests in other areas of WCA-3A suggest that this species is established and warrants further investigation.

Although this survey was unable to statistically determine establishment for these nonindigenous fish species, it suggests that at least two species are established in the interior of the Central Everglades. A similar study examined the community structure of fishes and invertebrates along transects originating at canals in the central and southern Everglades but did not report nonindigenous fishes (Rehage and Trexler, 2006). However, localized canal effects attributable to nutrient enrichment were found, and those authors call for further study of predatory fish movements within canals and experimental analysis of their impacts. Future studies are needed to examine ecological factors affecting distribution of nonindigenous species and to reevaluate species-specific physiological tolerances to seasonal minimum temperature.

BIG CYPRESS MODULE

Nonindigenous Plants

The 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 a particularly important component of the overall melaleuca management strategy in this module because some of the first releases were made here, and the biocontrol insects are showing marked effects in this area.

The first melaleuca biocontrol agent, a melaleuca weevil (*Oxyops vitiosa*), was introduced in 1997 and subsequently established on melaleuca throughout the region. 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 9-34. Melaleuca biocontrol psyllid (*Boreioglycaspis melaleucae*) (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 9-34**). Psyllids feed on melaleuca by inserting their straw-like mouthparts through the leaf tissues to access the phloem. As the insects suck plant sap, a phytotoxic saliva is injected, which causes the tissue surrounding the feeding area to degrade and the leaves to drop prematurely. 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 1.9 million insects at 319 locations across 15 counties in South 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 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.

A recently-released bud-gall fly is the third insect species to be distributed against melaleuca. An obligate mutualistic relationship between the bud-gall fly and a nematode makes this release a milestone in biological control; this is the first mutualism approved for release as a natural enemy pair in the USA. This fly deposits its eggs, along with a nematode symbiont (*Fergusobia quinquenerviae*), in the interior of young melaleuca buds via an elongated ovipositor. The nematode appears to cause a proliferation of cell growth to occur within the bud. The resulting gall prohibits normal growth of leaf or flower tissues from the bud and provides the necessary food source for developing nematodes and fly larvae. Nematodes re-invade the ovaries of female flies during the fly's pupal stage, and adult flies emerge through "windows" which appear on the gall surface during fly pupation. The USDA Animal and Plant Health Inspection Service (USDA-APHIS) has issued a permit for the release of *F. turneri (+ F. quinquenerviae)*, and releases have now been made at six sites in South Florida.

Figure 9-35. Old World climbing fern in Big Cypress National Preserve (photo by BCNP).

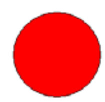
Old World climbing fern is a major weed in this module and, as in the Greater Everglades Module, it poses a serious threat to restoration initiatives (**Figure 9-35**). The District launched the first large scale operational control program for this species at the Corkscrew Regional Ecosystem Watershed 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 Old World climbing fern. This is a responsible strategy given the potential for this species to dominate many different habitats over large areas of the Preserve. A closely related nonindigenous species, Japanese climbing fern (*Lygodium japonicum),* was recently found and controlled in the BCNP (J. Sadle, NPS, personal communication) (**Figure 9-36**). This species was previously thought to mainly occur north of Lake Okeechobee, and its possible invasion into southern Florida is of concern.

Figure 9-36. Japanese climbing fern *(Lygodium japonicum)*, previously thought to occur only north of Lake Okechobee, was recently found and treated in the Big Cypress Module (photo by Kenneth Langeland, Univ. of Florida).

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 in other parts of 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. So far, the control programs including the biocontrol effort seem to be quite effective in South Florida, partly because the Salvinia weevil is a tropical species.

The priority plant species for the Big Cypress Module are presented in **Table 9-7**.

Table 9-7. Stoplight table for priority plant species in the Big Cypress Module.

	2006 STATUS		1-2 YEAR PROGNOSIS	
BIG CYPRESS MODULE (Results in this row reflect module-level questions, not species-level questions)	While much progress has been made with melaleuca, Brazilian pepper, and giant salvinia, other species seem to be gaining a foothold and most are not included in any monitoring programs for exotics		Good control of melaleuca and Australian pine ; biocontrol for melaleuca showing effectiveness; first biocontrol releases for Old World climbing fern; new biocontrol for Brazilian pepper under study; other species still localized, but one new and potentially serious invader has been documented by NPS	
Australian Pine (*Casuarina* spp.)	Remnant populations exist along canals and a few natural sites, but removal program is in place and effective		Chemical control effective; most natural areas clear or clearable with modest effort; biocontrol research under way	
Air Potato (*Dioscorea bulbifera*)	Know little about its spread or distribution; not included in Indicator systematic monitoring program.		Treated as encountered by contract crews in some areas of the module such as BCNP, but no coordinated control programs in the module and no biocontrol effort under way	
Cogon Grass (*Imperata cylindrica*)	Mainly distributed along roadsides, canals, and levees; not part of a systematic monitoring program		Treated as encountered in BCNP; no significant coordinated control efforts in place for the module and no biocontrol effort under way	
Old World Climbing Fern (*Lygodium microphyllum*)	Serious invader, rapid spread throughout module; invades most habitats and very destructive; chemical control in module so far effective due to small localized populations but concern over rate of spread still serious		Contract crews are treating populations as part of "find and treat" operations in some areas; module-wide controls are not coordinated; biocontrol release made with additional release expected 2006; chemical control studies continuing	
Japanese Climbing Fern (*Lygodium japonicum*)	Southernmost extent of species so far; little is known about its impacts in the module		Populations have been controlled in the module so far; however, distribution and spread are unknown and no biological control is program under way	

 Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

 Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

 Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

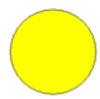
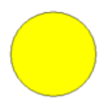
 Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

 Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

 Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

 Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Table 9-7. Continued.

	2006 STATUS		1-2 YEAR PROGNOSIS	
Melaleuca (*Melaleuca quinquenervia*)	Coordinated efforts to control species but is still abundant on private lands; biocontrol reducing cover and spread and agents establishing throughout module		Chemical control effective on most public lands; biocontrol agents effective and additional spread of existing agents and new agents expected in 2007-2008	
Downy Rose-myrtle (*Rhodomyrtus tomentosa*)	Little known about its spread or distribution within the module; not included in Indicator systematic monitoring program		No fully coordinated control efforts in module, although local populations are being controlled; no biological control programs under way	
Giant Salvinia (*Salvinia molesta*)	Small populations but seems to be under control in module; not included in Indicator systematic monitoring program		Serious aquatic weed in many parts of the world and southern US; module populations do not appear to present a serious threat at this time due to active control efforts and presence of effective biological control agent	
Brazilian Pepper (*Schinus terebinthifolius*)	Serious invader with rapid spread throughout module; invades most habitats and very destructive; chemical control ineffective in reducing module-wide spread so far; however, local control programs are proving effective where resources are available		BCNP control program effective; most populations limited or slated for control. New biocontrol agents under study for future release in 2007-2008	
Tropical Soda Apple (*Solanum viarum*)	Little known about its spread or distribution; not included in Indicator systematic monitoring program		Controlled when encountered in BCNP; distribution poorly understood; it has been introduced in contaminated sod and is widespread on some tribal lands; biological control program is under way	

Nonindigenous Animals

In addition to the priority plant species listed above, several nonindigenous animal species are considered priorities in the Big Cypress Module. Recent studies have collected several new records of nonindigenous fish for this region, and also indicate range expansions of several species northward from Everglades National Park. The African jewelfish (*Hemichromis letourneauxi*) is a new record for the Big Cypress area, and is expanding its range northward after becoming abundant in solution holes of the Rocky Glades in southern Miami-Dade County. This species displays several characteristics that make it successful, including being extremely aggressive, saltwater-tolerant and guarding young from predation. The walking catfish (*Clarias batrachus*) is probably the most well known exotic fish in South Florida after becoming established in the late 1980s and sparking a heated debate about the impact of exotic species. Some of the adaptations that make this fish successful include the ability to emerge from water and move short distances across land, resistance to very low oxygenated water, a cosmopolitan diet and the ability to produce many young.

FERAL HOGS

Feral hogs (*Sus scrofa)* are reported in all 67 counties of Florida and are extremely common in the 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, 1966; Baber and Coblentz, 1986; Gingerich, 1994). Although feral hogs are common throughout the 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 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 rooting, feral hogs 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

The Mexican bromeliad weevil (*Metamasius callizona*) originally was introduced to Florida via a shipment of bromeliads imported from Mexico. It was first detected in 1989, 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 9-37**).

Figure 9-37. Mexican bromeliad weevil (*Metamasius callizona*) (photo by Barbara Larson, University of Florida).

The weevil attacks native bromeliad species including 10 state-listed threatened and endangered native bromeliads (*Tillandsia fasciculata*, *T. utriculata*, *T. balbisiana*, *T. flexuosa*, and *T. variabilis*) 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).

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 9-38**). Weevils can eventually destroy entire populations of a species. Bromeliads are important to many 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.

Figure 9-38. Mexican bromeliad weevil damage to a native bromeliad (photo by University of Florida).

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 insect and develop biological controls for the weevil. A possible biocontrol agent (a fly, *Lixadmontia franki*) 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, Florida. 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.

NORTHERN ESTUARIES – WEST MODULE

Nonindigenous Plants

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 Hurricane Charley impacted Sanibel and Captiva islands. Many of the large Australian pine trees toppled and barricaded access to the islands for post-storm relief efforts (**Figure 9-39**). The tall trees also snapped powerlines and were responsible for extensive structural damage (R. 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. Federal Emergency Management Agency funding made broad scale control of this species possible.

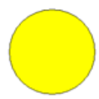
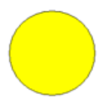
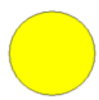
Figure 9-39. Tall Australian pine trees blocked roads, snapped powerlines, and were responsible for extensive structural damage on the coastal islands after Hurricane Charley (photo by SFWMD).

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 to control, particularly in areas such as dredged spoil along the Caloosahatche River (**Figure 9-40**). 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).


Figure 9-40. Para grass *(Urochloa mutica)*, left, and West Indian marsh grass *(Hymenachne amplexicaulis)*, right, are spreading in the Northern Estuaries – West Module (photo source: Langeland and Craddock Burks, 1998).

The priority plant species for the Northern Estuaries Module – West Coast are listed in **Table 9-8**.

Table 9-8. Stoplight table for priority plant species in the Northern Estuaries – West Module.

	2006 STATUS		1-2 YEAR PROGNOSIS	
NORTHERN ESTUARIES – WEST MODULE (Results in row reflect module-level questions, not species-level questions)	While much progress has been made with melaleuca, Brazilian pepper, and Australian pine, other species seem to be gaining a foothold and most of these species are not included in any of the Indicator monitoring programs; little known about the large majority of invaders and are not able to assess their status in an objective or repetitive way to determine trends		Good control of melaleuca, Brazilian pepper and Australian pine; biocontrol for melaleuca showing effectiveness; first biocontrol releases for Old World climbing fern; new biocontrol for Brazilian pepper under study; other species still localized, but numerous, and potentially serious invaders exist for which little is known about their biology or spread	
Australian Pine (*Casuarina* spp.)	Populations exist along roadsides, canals, and a few natural sites, but removal programs are in place and are considered effective		Chemical control effective, most natural areas clear or clearable with modest effort; biocontrol research under way	
Air Potato (*Dioscorea bulbifera*)	Little known about its spread or distribution; not included in Indicator systematic monitoring program		Control efforts are not coordinated; no biocontrol effort under way	
West Indian Marsh Grass (*Hymenachne amplexicaulis*)	Distributed in wet areas; not included in Indicator systematic monitoring program		Species problematic because it is difficult to control with herbicides in wetlands; no biocontrol effort under way	
Cogon Grass (*Imperata cylindrica*)	Little known about its spread or distribution beyond roadside-type infestations; not included in Indicator systematic monitoring program		Species problematic because it is difficult to control with herbicides; no biocontrol effort under way	
Old World Climbing Fern (*Lygodium microphyllum*)	Serious invader; rapid spread throughout module; invades most habitats; very destructive		No significant and population-wide effective controls yet, but biocontrol release made with additional release expected in 2006; chemical control studies continuing	

 Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

 Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

 Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

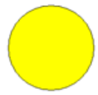
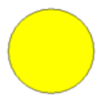
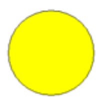
 Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

 Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

 Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

 Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Table 9-8. Continued.

	2006 STATUS	1-2 YEAR PROGNOSIS
Melaleuca (*Melaleuca quinquenervia*)	Still abundant on private lands but biocontrol reducing cover and spread and agents establishing throughout module 	Chemical control effective on most public lands, biocontrol agents effective and additional spread of existing agents and new agents expected in 2006 
Burma Reed (*Neyraudia reynaudiana*)	Little known about its spread or distribution in the module; not included in Indicator systematic monitoring program 	Species problematic because it is difficult to control with herbicides; no biocontrol effort under way 
Guinea Grass (*Panicum maximum*)	Little known about its spread or distribution in the module; not included in Indicator systematic monitoring program 	Species problematic because it is difficult to control with herbicides; no biocontrol effort under way 
Itch Grass (*Rottboellia cochinchinensis*)	Spreading in wetland areas; not included in Indicator systematic monitoring program 	Species problematic because it is difficult to control with herbicides in wetlands; in tropical America, a serious invader of agricultural and abandoned or disturbed lands often leading to land abandonment for agricultural use 
Half-flower (*Scaevola taccada*)	Coastal species; easy to detect; not included in Indicator systematic monitoring program 	Control efforts effective where implemented; seed source from surrounding ornamental plantings makes long-term control necessary; no biocontrol effort under way; prospects limited due to native *Scaevola* species 
Brazilian Pepper (*Schinus terebinthifolius*)	Serious invader, with rapid spread throughout module; invades most habitats and is very destructive; local control programs are proving effective where resources are available 	Control programs in the module are effective in natural areas where management programs are under way; new biocontrol agents under study for future release in 2007-2008 
Para grass (*Urochloa mutica*)	Distributed in wetland areas; not included in Indicator systematic monitoring program 	No coordinated control efforts in place for the module; no biocontrol effort under way although local populations can be eliminated 

Nonindigenous Animals

This area has experienced coastal and inland development pressure and also receives freshwater releases from Lake Okeechobee. While marine fisheries monitoring appears to be adequate, additional freshwater fish monitoring may be necessary in this region to quickly detect new introductions and impacts. The Mozambique tilapia (*Oreochromis mossambicus*) is a well known food fish, has been aquacultured extensively, is an aquarium trade species and has become a popular sport fish. Some successful adaptations include tolerance to low oxygen, a non-specific diet and the ability to modify breeding behavior. The spotted tilapia (*Tilapia mariae*) has a broad tolerance to salt water and shows biparental protection of young which may contribute to its success. In fact, this species was so successful that it served as the primary justification for the release of the exotic peacock cichlid (*Cichla ocellaris*) to act as a control in Miami-Dade County. In addition to the fish species listed above, several animal species are considered priorities in the Northern Estuaries – West Module and could seriously impact this coastal ecosystem.

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 9-41**).

Figure 9-41. 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.

BLACK SPINY-TAILED IGUANA

The black spiny-tailed iguana (*Ctenosaura similis*) (**Figure 9-42**) and Mexican spiny-tailed iguana (*C. pectinata*) are large, primarily herbivorous reptiles that are established in South Florida. The spiny-tails are recognized to have a somewhat more aggressive nature than green iguanas (*I. iguana*) and, although also introduced by the pet trade, are even less suitable as pets than the green iguana.

Figure 9-42. Black spiny-tailed iguana (*Ctenosaura similis*) (photo by Ellen Donlan, SFWMD).

Adult spiny-tailed iguanas reach 4 feet in length and feed primarily on leaves, fruit and flowers, but occasionally eat insects, small animals, bird eggs, and hatchling sea turtles. Juveniles reportedly eat more animal matter.

Black spiny-tailed iguanas were introduced to Northern Estuaries West Module in the mid-1970s. They now occur on Gasparilla Island, Cape Haze, Gulf Cove, Cayo Costa, Keewaydin Island, and Little Marco Island and on the mainland at Placida (Krysko et al., 2003). This species endangers the threatened least tern (*Sterna antillarum*), Wilson's plovers (*Charadrius wilsonia*), and snowy plovers (*C. alexandrinus*) and could impact nesting loggerhead sea turtles (*Caretta caretta*) (Krysko et al., 2003). Spiny-tailed iguanas could also contribute to burrowing owl impacts (see the *Monitor Lizard* section in this module) if they spread to Cape Coral. They would likely compete for burrows and could prey on nestlings (Krysko et al., 2003).

In addition to impacts to native species, the reptiles actively dig extensive burrows along and under cement walls, seawalls, or pavement and, most troubling, in the dunes along beaches. These burrows can weaken natural dunes and lead to structural erosion, undermining, and collapse of manmade features. Their droppings are possible sources of salmonella contamination as are their bites. When cornered, their bites and claws can cause serious lacerations, and tail slaps can deliver powerful blows.

Native predators control young iguanas to some degree. Raccoons and feral hogs dig up nests while raptors, alligators, wading birds and snakes take immature iguanas. However, once mature, few Florida animals serve as natural enemies, unlike the large cats and snakes resident in the iguanas' native range.

Mature black spiny-tailed iguanas are faster than green iguanas making noose capture techniques difficult. Snares, trapping and hunting may be effective control methods but are subject to state and local regulations. One of the most troublesome aspects of iguana control in the area is how to dispose of the dead animals. Chapter 39-4.005, F.A.C., prohibits non-native animal releases, but the animals can be sold or given to pet stores, often exacerbating the problem.

In response to this threat in the module's coastal communities, Boca Grande property owners will soon pay a special tax ($46 per home, on average) to cover the costs of black spiny-tailed iguana assessment and control. Lee County has also developed a brochure to educate tourists and residents about discouraging iguanas and impacting their breeding habits. The brochure, "Do Not Feed the Iguanas," shows photographs and factual information about iguanas, including ways to stress them enough to reduce their population.

Figure 9-43. Green mussel (*Perna viridis*) (photo by Patrick Baker, University of 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 9-43**).

Figure 9-44. Green mussel invading an oyster bed (photo by Patrick Baker, University of Florida).

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).

Prior to 2002, the species was believed to be confined to manmade 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 9-44**). 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).

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 oyster beds 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

Nonindigenous Plants

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. Several other species are considered priorities in the module. Torpedograss (*Panicum repens*), is becoming a major problem in low-lying areas in the module's floodplains. At Savannas Preserve and areas along the St. Lucie River, torpedograss is spreading quickly, but little is being done to manage this species. Shoebutton ardisia (*Ardisia elliptica*) is a major understory problem in many areas around the North Fork and in wetland areas along or adjacent to the Indian River. Air potato (*Dioscorea bulbifera*) is a continual problem in several areas of the module and the plant is persistent in treated areas (**Figure 9-45**).

Figure 9-45. Air potato *(Dioscorea bulbifera)* is a vining species that is a continual management problem in the Northern Estuaries - East Module (photo by Kenneth Langeland, Univ. of Florida).

Figure 9-46. Caulerpa (*Caulerpa brachypus*) (photo by FDEP).

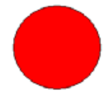
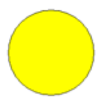
In addition to the plants discussed above and presented in **Table 9-9**, the occurrence of a nonindigenous marine plant (an alga) in the region's coastal areas concerns many scientists and managers (**Figure 9-46**). In 2001, an invasive non-native macroalga was identified growing on underwater reefs located off the coast in Palm Beach County. *Caulerpa brachypus*, a commonly sold marine aquarium plant native to Pacific waters, has now been found as far north at Fort Pierce and it is likely that it will continue to spread north and south from Palm Beach County. Because this species has not been carefully monitored, its actual distribution has not been determined. 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 macroalga 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. This is a potentially serious problem for the reefs along the Florida Keys as nutrient run-off from the keys already has been documented as a problem for the reefs (Lapointe & Clark, 1992; Leichter et al., 2003).

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 reefs 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 species of 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 healthy near-shore 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 plans to predict, mitigate, and control harmful algal blooms. Panel members include representatives from the FDEP, FWC, St. Johns River Water Management District, Harbor Branch Oceanographic Institution, National Undersea Research Center, Smithsonian Institution, and the Indian River Lagoon Estuary Program.

Table 9-9. Priority plant species in the Northern Estuaries – East Module.

	2006 STATUS		1-2 YEAR PROGNOSIS	
NORTHERN ESTUARIES MODULE – EAST COAST (Results in row reflect module-level questions, not species-level questions)	While much progress has been made with melaleuca, Brazilian pepper and Australian pine, other species seem to be increasing and most are not included in Indicator monitoring programs; little is known about the large majority of invaders; unable to assess status in an objective or repetitive way to determine trends		Good control of melaleuca, Brazilian pepper, and Australian pine; biocontrol for melaleuca showing effectiveness; first biocontrol releases for Old World climbing fern; new biocontrol for Brazilian pepper under study; other species still localized but numerous, and potentially serious invaders exist for which little is known about their biology or spread	
Shoebutton Ardisia (*Ardisia elliptica*)	May be entering exponential spread phase in this module; moving into floodplain communities and dominating understory; not included in Indicator systematic monitoring program; difficult to monitor remotely		No coordinated, significant control efforts or biocontrol efforts under way	
Australian Pine (*Casuarina* spp.)	Remnant populations exist along canals and a few natural sites, but removal program is in place and effective		Chemical control effective, most natural areas clear or clearable with modest effort; biocontrol research under way	
Caulerpa (*Caulerpa brachypus*)	Little known about its spread or distribution; not included in Indicator systematic monitoring program		The marine alga Caulerpa, an extreme problem in other parts of the world, now is spreading rapidly across Florida's coral reefs and has the potential to eliminate most other species on Florida's "hard bottom" coastal areas; no significant control efforts or effectiveness and no biocontrol effort under way	
Air Potato (*Dioscorea bulbifera*)	Little known about its spread or distribution; known populations appear to be increasing despite some control efforts; not included in Indicator systematic monitoring program		Control programs in the module have limited success in natural areas; no biocontrol effort under way	

 Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

 Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

 Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

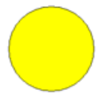
 Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

 Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

 Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

 Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Table 9-9. Continued.

	2006 STATUS		1-2 YEAR PROGNOSIS	
Old World Climbing Fern (*Lygodium microphyllum*)	Serious invader; rapid spread throughout module; invades most habitats; very destructive		No effective module-wide control programs yet, but biocontrol release made and additional release expected in 2006; chemical control studies continuing	
Melaleuca (*Melaleuca quinquenervia*)	Still abundant on private lands but biocontrol reducing cover and spread and agents establishing throughout module		Chemical control effective on most public lands; biocontrol agents effective and additional spread of existing agents and new agents expected in 2006	
Torpedograss (*Panicum repens*)	Little known about its spread or distribution, but appears to be increasing in several managed natural areas; not included in Indicator systematic monitoring programs		No coordinated control efforts in place; no biocontrol efforts under way	
Brazilian Pepper (*Schinus terebinthifolius*)	Serious invader with rapid spread throughout module; invades most habitats; chemical control ineffective in reducing systemwide spread so far; however, local control programs in module are proving effective where resources are available		Control programs in the module are effective; new biocontrol agents under study for future release in 2007-2008	

Nonindigenous Animals

In addition to the plant species listed in **Table 9-9**, several nonindigenous animal species are considered a priority for the Northern Estuaries – East Module. 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 *Big Cypress Module* section) is impacting the inland areas of this region, killing bromeliads in the Savannas State Preserve in St. Lucie County. In addition, several nonindigenous fish species such as the brown hoplo, Mayan cichlid, walking catfish, sailfin catfish and the chanelled applesnail have all been found in or near the District's C-24 canal.

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 9-47. The Australian spotted jellyfish (*Phyllorhiza punctata*) (photo by USGS).

The spotted jellyfish is typically a translucent milky color with spots on the bell and is 6 to 8 inches in diameter (**Figure 9-47**). 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 for these jellyfish than the Gulf (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 to 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.

LAKE OKEECHOBEE MODULE

Nonindigenous Plants

Lake Okeechobee is a 450,000 acre lake with an average depth of only 9 feet. It also contains approximately 100,000 of acres of littoral zone with herbaceous marshes, other emergent wetlands, and numerous islands. More than 80 non-native plant species have been identified in the Lake Okeechobee Module. Of these, eight have been or are considered serious, invasive, and potentially threatening to the Lake Okeechobee ecosystem. The lake is a highly regulated and managed system that has serious nutrient enrichment problems (Havens et al., 1996). Fortunately, the invasive plant species of concern in the lake all have dedicated funding and effective control programs in place. However, even with 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 led 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 of this group is to coordinate treatments, prioritize activities, and recommend actions for the lake. There are also more than 100 invasive animal species 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 exotic animal invaders.

Figure 9-48. Water hyacinth (*Eichhornia crassipes*) (photo by SFWMD).

Floating aquatic plants, such as water hyacinth *(Eichhornia crassipes)* (**Figure 9-48**) and water lettuce *(Pistia stratiotes)* are currently managed by the USACE. The USACE program started in the 1920s with mechanical removal of hyacinth and continues today principally with chemical and biocontrol methods. 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, however, they would quickly expand and have severe environmental consequences for the lake. 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, appears to be partially responsible for keeping populations of hydrilla low for the past several 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 beetle (*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 low levels. 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 successful biocontrol programs can accomplish.

Extensive control programs from 1993 to 2006 have brought three species of exotic trees under virtually complete control in Lake Okeechobee. The most environmentally threatening of these was melaleuca, 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 release and establishment of the melaleuca snout weevil (*Oxyops vitiosa*) and the melaleuca psyllid *(Boreioglycaspis melaleucae)* throughout the South Florida region are showing significant effects on large areas of melaleuca. As the weevils spread throughout South Florida, they are expected to limit future melaleuca seed production and seedling establishment (see the *Big Cypress Module* section).

Figure 9-49. Dense populations of West Indian marsh grass *(Hymenachne amplexicaulis*) are common upstream of Lake Okeechobee (photo by Mike Bodle, SFWMD).

Two other exotic trees, Australian pine and Brazilian peppertree 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 essentially been eliminated primarily through the efforts of the USACE and the District. However, ongoing control and maintenance programs are needed to ensure and retain maintenance control levels as no biological controls have yet been released in Florida for the control of either of these two species.

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 (**Figure 9-49**). 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 of West Indian marsh grass has occurred in the lake, and estimates of its population already range to 100 acres (Mike Bodle, SFWMD, personal communication). The District initiated a herbicide control program for this species in 2005 within the FDEP aquatic plant control 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 through 2005. Torpedograss had invaded more than 16,000 acres by 1996. Subsequently, its spread was exacerbated by the lake's record low water level in April 2001. It is estimated that the plant expanded its range to more than 25,000 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. More than 25,000 acres of torpedograss have been aerially treated in 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 (**Figure 9-50**).

Figure 9-50. Selective control efforts are being used to control torpedograss and spare native species, such as buttonbush (photo by Mike Bodle, SFWMD).

In 2004–2005, the paths of four major hurricanes impacted Lake Okeechobee. Information regarding impacts during the 2004 hurricane season are presented in the 2006 SFER – Volume I, Chapter 9. Hurricane Wilma crossed the southern lake region in October 2005 with recorded winds of 112 miles per hour. Wilma's storm surge height was measured at 30.6 feet above sea level with the lake's then-water level at 15.5 feet. This 15-foot surge scoured vegetation from broad areas of the lake, and boats, campers, and building materials from the Belle Glade marina and campground were swept into the adjacent Rim Canal and onto the Herbert Hoover Dike. As depicted in **Figure 9-51,** these storms scoured vegetation, suspending sediments and increasing dissolved nutrients in concentrations, in turn causing an algal bloom that significantly prevented light penetration and submersed plant growth. This has led to two consecutive years of nearly complete eradication of submerged vegetation — native and non-native — due to storm action and persistent high turbidity.

Figure 9-51. 2005 hurricane storm surges scoured vegetation from broad areas of Lake Okeechobee (photo by Mike Bodle, SFWMD).

Nonindigenous plant species considered a priority in the Lake Okeechobee Module are listed in **Table 9-10**. It should be noted also that in late July 2006, the first population of Old World climbing fern was reported along the north shore of the lake, although its arrival cannot be attributed solely to storm-related influences. A rapid control response is being mounted by state and federal agencies.

Table 9-10. Stoplight table for priority plant species in the Lake Okeechobee Module.

	2006 STATUS	1-2 YEAR PROGNOSIS
LAKE OKEECHOBEE MODULE (Results row reflect module-level questions, not species-level questions)	Restoration efforts have been under way in this module for some time and much progress has been made, including on exotic species; however, several serious species occur in this module and continued disturbance of the littoral zone may increase chances of new invasions	Module has had a significant and well funded control program effort under way for many years; progress on many species is evident, but continued monitoring and control efforts will be needed to prevent serious reinvasions of the many species threatening region
Alligator Weed (*Alternanthera philoxeroides*)	Effective biocontrol program has been under way for many years; control programs have achieved complete control in most areas	Biocontrol and monitoring programs are in place and have been achieving good results
Australian Pine (*Casuarina* spp.)	Effective removal program is in place and Australian pine is not currently a serious problem in this module	Chemical control has been effective with most natural areas clear or clearable with modest effort; biocontrol research under way
Water Hyacinth (*Eichhornia crassipes*)	Chemical and biocontrol control programs have been under way for several years; maintenance control (<300 acres of treatable plants lake-wide) is program goal; however, this goal has not been consistently met due to FY2006 funding shortfalls and very active 2004 and 2005 hurricane seasons	Ongoing control and monitoring programs are in place; maintenance control is expected to be maintained
Hydrilla (*Hydrilla verticillata*)	Although control programs are in place, no control activities have been necessary in recent years; hurricanes, hydrologic conditions, and flocculent substrate have prohibited widespread expansion	Effective control and monitoring programs are in place and have been achieving good results
West Indian Marsh Grass (*Hymenachne amplexicaulis*)	Little known about its spread or distribution throughout the system; not included in Indicator systematic monitoring program	Increases in spread and distribution may be occurring but unable to confirm; may become a serious pest moving into areas where other exotics have been controlled
Melaleuca (*Melaleuca quinquenervia*)	Effective chemical control program under way for several years with excellent effectiveness	Chemical control effective, biocontrol agents becoming effective and additional spread of existing agents and new agents expected in 2006
Torpedograss (*Panicum repens*)	It covers almost 20,000 acres of lake wetlands; spread seems to be increasing; not included in Indicator systematic monitoring program	While control efforts are under way and appear to be effective, lake management and drawdowns may increase spread despite program
Water Lettuce (*Pistia stratiotes*)	Chemical and biocontrol control programs have been under way for several years; maintenance control (<300 acres of treatable plants lake-wide) is program goal; however, this goal has not been consistently met due to FY2006 funding shortfalls and very active 2004 and 2005 hurricane seasons	Ongoing control and monitoring programs are in place; maintenance control is expected to be maintained

Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Nonindigenous Animals

In addition to the plant species listed in **Table 9-10**, several nonindigenous animal species are considered a priority for the Lake Okeechobee Module. Due to the aquatic nature of this module, fishes are the majority of the problematic nonindigenous animal species within the lake. Besides nonindigenous fish, a variety of non-native reptiles, mammals, and birds inhabit marshes and levees of Lake Okeechobee.

SAILFIN CATFISH

Since the early 1990s, the sailfin catfish (*Pterygoplichthys* spp.) has been observed in the lake (**Figure 9-52**). 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 fish 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 9-53**). 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 9-52. Sailfin catfish (*Pterygoplichthys* spp.) (photo by USACE).

Figure 9-53. Sailfin catfish tunneling is believed to damage canals and levees and result in increased siltation (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, 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.

OTHER NONINDIGENOUS ANIMALS

In addition to nonindigenous fish, Lake Okeechobee has documented populations of many other nonindigenous animals including feral hogs (see *Big Cypress Module* section), green iguanas (see *Florida Keys* and *Greater Everglades Modules* sections), brown anoles, Cuban treefrog, and channeled applesnails (see *Kissimmee* and *Greater Everglades Modules* sections). Any of these species could have negative impacts on the lake. Feral hogs are ominvores noted for foraging on roots of native trees and impacting native birds. Populations of brown anoles (*Anolis sagrei*) and Cuban treefrogs (*Osteopilus septentrionalis*) have increased around the lake, and the channeled apple snail has been documented in Lake Okeechobee. The purple swamphen (see the *Greater Everglades Module* section for species-specific information) was observed in the marshes around Torry Island during 2005 and 2006. The species is suspected to be expanding its range through canal systems of South Florida. The purple swamphen could be a species of concern to the native marsh and wading birds, as it has been noted in other locations to forage on other birds' eggs and on baby birds, including ducklings. Not enough is known about the population dynamics, reproduction, feeding habits, or biology of any of these nonindigenous animal species to make evaluations of their current and future potential impacts to the Lake Okeechobee region.

KISSIMMEE BASIN MODULE

Nonindigenous Plants

Water hyacinth and water lettuce are the most pervasive nonindigenous aquatic plants in the Kissimmee Basin Module. 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 of these floating plants are reduced in about 14 miles of the restored sections of the Kissimmee River channel. However, new open water habitat created by restoration efforts on the reflooded floodplain seem to provide suitable areas for growth of water hyacinth and water lettuce on this section of floodplain, at least temporarily.

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 restored sections 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. New open water habitat created by restoration efforts on the reflooded floodplain of the Kissimmee River has provided new areas for hydrilla growth. To date, these sites have been flooded only seasonally, and hydrilla's impacts appear to be negligible at this time.

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 successfully treated.

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 (**Figure 9-54**). It presently forms monospecific stands covering approximately 2,000 acres of the east-central portion of the reflooded floodplain and is spreading to the north and west. Initial limpograss chemical control test plots were established in the Kissimmee River floodplain in 2006 to help define best management practices. Funding is available from the FDEP for future operation control work.

Figure 9-54. Limpograss *(Hemarthria altissima)* has invaded the Kissimmee floodplain from adjacent pastures (photos by Mike Bodle, SFWMD).

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, because 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 observed distributions of this species in the Kissimmee basin.

Though not widely distributed as Old World climbing fern, a Japanese climbing fern (*L. japonicum*) population 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.

The somewhat scattered Brazilian pepper and melaleuca infestations are generally targeted for control by the module's natural resource managers. 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 local lakeshore development activities. Chinese tallow (*Sapium sebiferum*) is a serious invader of wetlands in this region (**Figure 9-55**). Dense stands are able to develop rapidly because wildlife transport abundant seeds quickly and over long distances. Shallow marshes, lake edges, swales, and riparian sites develop dense impenetrable monocultures. No biocontrol is available. Chemical control is readily achieved, but no systematic control has begun.

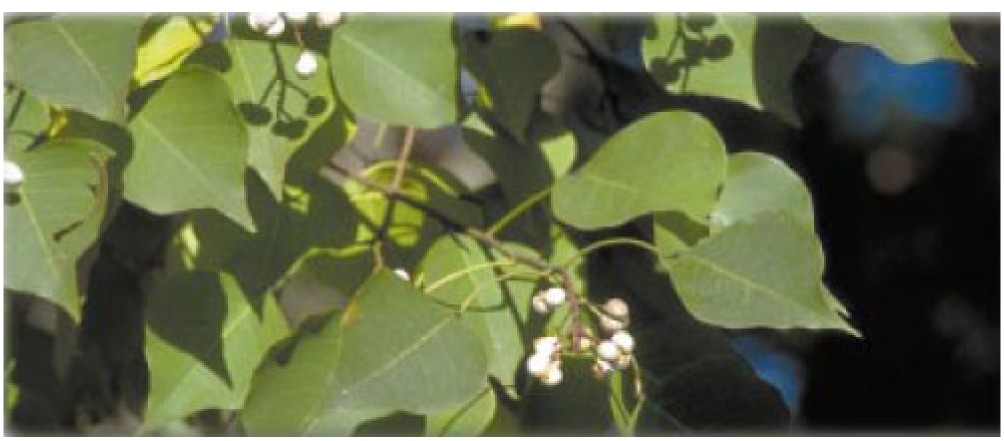


Figure 9-55. Dense stands of Chinese tallow *(Sapium sebiferum)* have developed in the Kissimmee Basin wetlands (photo by Kenneth Langeland, Univ. of Florida).

Avon Park and Archbold Biological Station staff have indicated that natal grass (*Rhynchelytrum repens*) and cogon grass (*Imperata cylindrica*) are continuing to spread throughout the region, particularly in disturbed upland habitats (**Figure 9-56**). Cogon grass is presently the exotic species of greatest concern on Kissimmee Prairie Preserve, where it is increasing on leased cattle pastures and along roads. Cogon grass also is commonly found on the spoil mounds of channelized river.

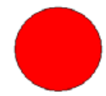
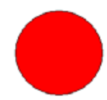
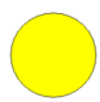
Figure 9-56. Cogon grass *(Imperata cylindrica)* is the exotic species of greatest concern on the Kissimmee Prairie Preserve (photo source: Kenneth Langeland, Univ. of Florida).

Tropical soda apple (*Solanum viarum*) is another pervasive exotic species of concern in the pastures of the Kissimmee valley (**Figure 9-57**). 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 module include strawberry guava (*Psidium littorale*), caesarweed (*Urena lobata*), and star grass (*Cynodon nlemfuensis*).

Nonindigenous plant species considered a priority in the Kissimmee Basin Module are listed in **Table 9-11**.

Figure 9-57. Soda apple *(Solanum viarum)* (photo source: Langeland and Craddock Burks, 1998).

Table 9-11. Stoplight table for priority plant species in the Kissimmee Basin Module.

	2006 STATUS		1-2 YEAR PROGNOSIS	
KISSIMMEE MODULE (Results in this row reflect only the three module-level questions, not species-level questions)	Restoration efforts have been under way in this module for many years and much progress has been made; however, many very serious nonindigenous species occur in this region for which little is known about how invasive they may become		Many of the species occur only in this region of the Everglades and little is known about their biology, yet some of them are very serious weeds in other parts of the world; rehydrated wetlands are providing new habitat for some aquatic species including hydrilla	
Water Hyacinth (*Eichhornia crassipes*)	Significant control efforts and biocontrol programs have been under way for many years; control programs are achieving good results		Systematic control and monitoring programs are in place and have been achieving good results	
Limpograss (*Hemarthria altissima*)	Little known about its spread or distribution; observations indicate this species is increasing in scope; included in FDEP aquatic plant surveys		No significant control efforts or effectiveness; no biocontrol effort under way	
Hydrilla (*Hydrilla verticillata*)	Limited control efforts and biocontrol programs have been under way for many years; control programs have mixed results		Systematic control and monitoring programs are in place and have been achieving good results, but recent herbicide resistance is creating new control problems along with increased habitat on the rehydrated floodplain	
West Indian Marsh Grass (*Hymenachne amplexicaulis*)	Little known about its spread or distribution throughout the system; included in FDEP aquatic plant surveys		Control efforts in this module have been good and most populations in natural areas appear to be under reasonable control	

 Red = Severe Negative Condition, or one is expected in near future, with out-of-control situation that merits serious attention

 Yellow/Red = Problem was previously localized or not too severe but is or appears to be progressing toward a Severe Negative Condition generally due to inaction; without attention and resources the situation may develop or become Red

 Red/Yellow = Currently a Negative Condition but there are reasonable control efforts under way; however, without continued or improved efforts, this species may revert to a severe situation or become a future serious invader and revert to Yellow/Red or Red

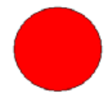
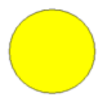
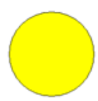
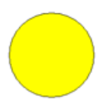
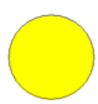
 Yellow = Situation is improving due to reasonable control program and either is stable or moving toward stabilizing, or the species is still very localized but is expected to spread if sufficient resources or actions are not continued or provided; the situation could still reverse

 Green/Yellow = Situation is generally good and under control but still needs regular, even if low-level, attention to continue progress to Yellow/Green or Green

 Yellow/Green = Significant progress is being made and situation is moving toward good maintenance control and is expected to continue improving as long as resources are maintained

 Green = Situation is under control has remained under control for several years, particularly where biocontrol is found to be effective; where chemical maintenance control is in place, continuation of control efforts is essential to maintain Green status

Table 9-9. Continued.

	2006 STATUS		1-2 YEAR PROGNOSIS	
Cogon Grass (*Imperata cylindrica*)	Little known about its spread or distribution; not included in Indicator systematic monitoring program		Has been controlled to varying degrees on public lands in the module; no biocontrol effort under way	
Old World Climbing Fern (*Lygodium microphyllum*)	Serious invader with rapid spread throughout module; invades most habitats and very destructive		Chemical control has brought populations to maintenance control on public land; biocontrol release made with additional release expected in 2006; chemical control studies continuing	
Japanese Climbing Fern (*Lygodium japonicum*)	Little known about its potential impacts in module		Populations being controlled so far; however, distribution and spread unknown and no biological control program under way	
Melaleuca (*Melaleuca quinquenervia*)	Still abundant on private lands but biocontrol reducing cover and spread and agents establishing throughout module		Chemical control effective on most public lands; biocontrol agents effective and additional spread of existing agents and new agents expected in 2006	
Torpedograss (*Panicum repens*)	Little known about its spread or distribution; included in FDEP aquatic plant surveys		No significant control efforts or effectiveness; no biocontrol effort under way although local populations can be eliminated	
Water Lettuce (*Pistia stratiotes*)	Significant control efforts and biocontrol programs have been under way for several years; control programs are achieving good results; included in FDEP aquatic plant surveys		Systematic control and monitoring programs are in place and have been achieving good results	
Chinese Tallow (*Sapium sebiferum)*	Distributed along many lake edges in the Kissimmee Chain of Lakes; not included in Indicator systematic monitoring program		Problematic wetland tree species that forms dense monocultures; no significant control efforts or effectiveness; no biocontrol effort under way although local populations can be eliminated	
Brazilian Pepper (*Schinus terebinthifolius*)	Serious invader, with rapid spread throughout South Florida; invades most habitats, very destructive; chemical control ineffective in reducing systemwide spread so far; however, local control programs are proving effective where resources are available		Control programs effective in natural areas where management programs are under way; new biocontrol agents under study for future release in 2007-2008	
Tropical Soda Apple (*Solanum viarum*)	Little known about its spread or distribution; not included in Indicator systematic monitoring program		Control efforts limited, although local populations can be eliminated; biological control under way	

Nonindigenous Animals

In addition to the plant species listed in **Table 9-11**, several nonindigenous animal species are considered a priority for the Kissimmee Module. The feral hog is the most ubiquitous exotic animal of concern for potential impacts to natural habitats in the Kissimmee valley (see the *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 is 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.

ASIAN CLAM

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 been observed roosting in large numbers in upland habitats adjacent to the Kissimmee River.

FISHES

Extensive fish sampling programs have been conducted throughout this module and have provided current records about nonindigenous fish distribution in the Kissimmee River and floodplains. The brown hoplo (*Hoplosternum littorale*) is an armored catfish that has been reported to occur in abundance within the river and some floodplain pools. This species has achieved a nearly cosmopolitan distribution throughout the fresh and saltwater habitats of mid- to southern Florida. This fish is both an aquarium and food fish, with many of these fish released and harvested as a cultural food source. The vermiculated sailfin catfish (*Pterygoplichthys disjunctivis*) is also common in the module. It is a very popular aquarium fish, commonly called "algae eater." This fish is one of the most resilient exotic species in Florida. Although little is known about habitat preferences, its thick scales, venomous spines, and ability to breathe air and use teeth to scrape algae for nutrition are some of the adaptations that make this species problematic.

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 9-58**). 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 9-59**).

Figure 9-58. 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 in addition to 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.

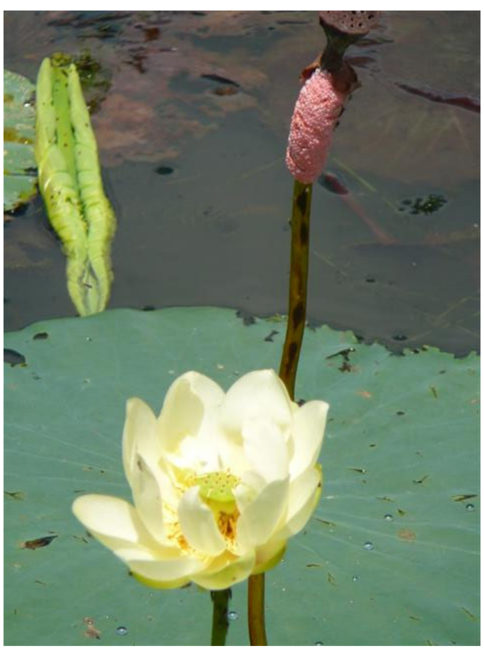


Figure 9-59. Channeled apple snail eggs on American lotus (photo by Mike Bodle, SFWMD).

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.

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.

Species like the purple swamphen in the Greater Everglades and the Gambian pouch rat in the Keys illustrate the need for agencies to act quickly to contain and attempt to eradicate animals that have the potential to become widespread and difficult to control. While it is acknowledged that definitive research is lacking to support the immediate management of these particular species, it is widely accepted in the invasive species literature that catching a species in its incipient phase is advantageous. The use of an early detection and rapid response (EDRR) program increases the likelihood that invasions will be controlled while the species is still localized and population levels are so low that eradication is possible (National Invasive Species Council, 2003). Once populations of an invasive species are widely established, eradication becomes virtually impossible and perpetual control is the only option. In addition, implementing an EDRR program is typically much less expensive than a long-term invasive species management program. Given the risks associated with waiting for research and long-term monitoring to “catch up,” some agencies have opted to initiate control programs concurrently with biological and ecological research programs. In the future, biological risk assessments may be developed to allow agencies to determine which species are most likely to become problems, but this work is many years away from being developed and there are some questions as to how effective they will be in practice.

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 nonindigenous 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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