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 efforts of the Comprehensive Everglades Restoration Plan (CERP) 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 annotations for those species considered serious threats to Everglades restoration. The species are presented using the

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RECOVER and Science Coordination Group (SCG) Modules for Everglades restoration. Species impacts are also discussed by region, as available. Supporting background information, including management tools used to control invasive exotic species in South Florida, is presented in the 2006 South Florida Environmental Report – Volume I, Chapter 9. Numerous groups and agencies are involved with nonindigenous species management. A summary of these agencies and their corresponding tasks and responsibilities as they pertain to nonindigenous species can be found on the Environmental Law Institute website in a report entitled *Filling the Gaps: Ten Strategies to Strengthen Invasive Species Management in Florida*.

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 put 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.

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.

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.

One such group (the Everglades Cooperative Invasive Species Management Area, or CISMA) is working to improve coordination, control, and management of invasive species through the designation of an Everglades invasive species management area. The group is modeled after very successful partnerships in western states known as Cooperative Weed Management Areas (IWCC, 2005). Representatives from the USNPS, USFWS, South Florida Water Management District (SFWMD or District), Florida Fish and Wildlife Conservation

Commission (FWC, formerly the Florida Game and Fresh Water Fish Commission), Florida Department of Environmental Protection (FLDEP), Florida Department of Transportation (FLDOT), Florida Power & Light (FP&L), U.S. Army Corps of Engineers (USACE), the Seminole Indian Tribe of Florida, and the Miccosukee Tribe of Indians of Florida have met several times to develop a Memorandum of Understanding, which will be distributed for signature this year. Additionally, the group has worked to enhance the District's treatment database (WEEDAR) into a multi-agency system to track invasive species treatment throughout the region. This will allow participating agencies to store, compile, and analyze treatment data from all agencies. Other activities will involve developing an expert's directory, coordinating control and monitoring activities through a region-wide strategy, developing early detection and rapid response programs, and identifying research priorities. To facilitate coordination on these activities, the District and the U.S. Department of the Interior (USDOI) co-sponsored the 4th Annual Everglades Invasive Species Summit in July 2007. Land managers from each entity provided operational updates on their invasive plant and/or animal control programs, shared lessons learned, and participated in workshops intended to improve coordination and identify needs and gaps. During the meeting, participants developed a framework for a multi-agency program, which included a reporting system, identified experts for taxonomic confirmation, risk assessment tools, and rapid-response teams to eradicate new populations.

Reinforcing all 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 the following priority questions: (1) How will water management alterations affect introduced plants and animals? (2) What are the principal controls on expansion of a species? (3) What are the impacts of invasive nonindigenous species on native species and ecosystems? (4) What makes a natural area susceptible to invasion? and (5) 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 CERP 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 (*Solenopsis invicta*) and Burmese python (*Python molurus bivittatus*). The 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, techniques that are more effective 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 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, 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 USDOI and SFWMD 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 District and 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 benefit melaleuca (*Melaleuca quinquenervia*), Old World climbing fern (*Lygodium*

microphyllum), Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (*Casuarina equisetifolia*) biocontrol projects. The PIR is scheduled for completion in 2008, with the first appropriation expected in FY2010. Implementation of the project is anticipated to span 17 years with a federal cost of about $5.5 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 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. 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, 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.). Additionally, DEP provides leadership to Florida's Invasive Species Working Group (ISWG). The ISWG is an interagency group comprised of federal, state, local government agencies and other interested parties. It strives to coordinate invasive species activities and provide policy direction within state government.

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* in February of 2008. Figure 9-1 depicts a sign produced by the District and National Park Service as part of outreach efforts pertaining to animal releases on canal and levee right-of-way.

The ISWG web site 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 efforts are needed to raise invasive species awareness among Floridians. Additional funding and improved interagency coordination are both needed to adequately reach the growing and often transient Florida population. The Statewide Invasive Species Strategic Plan for Florida 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 *Miami Herald* newspaper insert mentioned above is a result of this sub-working group. The sub-working group is also cooperating with a new interagency invasive species awareness effort being coordinated by the FWC.

Figure 9-1. Sign posted throughout the southern part of the District as part of a public awareness campaign.

BIOLOGICAL MONITORING FOR NONINDIGENOUS SPECIES IN SOUTH FLORIDA

Monitoring programs are important in establishing the extent of a problematic species and can offer valuable spatial information for ecological purposes, control purposes and 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 occurrence 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 at (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.

The distributions of several animal species 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 (*Python molurus bivittatus*), lobate lac scale (*Paratachardina lobata lobata*), and Mexican bromeliad weevil (*Metamasius callizona*). While these single-species monitoring programs do successfully track individual species, 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, and are often unable to provide precise spatial coordinates of exotic species presence, both critical needs 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. Therefore, RS technologies are 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 in order 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 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; the transects overlap on federal lands (Ferriter and Pernas, 2005).

The SFWMD conducts surveys of the EPA biannually as required by the Everglades Forever Act, 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 through 2005) are available for viewing at http://maps.google.com/ and able to be downloaded in shapefile format at http://tame.ifas.ufl.edu/ (Ferriter and Pernas, 2005). Results from the most recent surveys (2006 through 2007) and acreage estimates for priority species are provided in this document and shapefiles of the 2006/2007 data will be available on the website in August 2007.

The 2007 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, Brazilian pepper, and Australian pine in Florida. Distribution of these four species is depicted in **Figures 9-2** through **9-5**. This study area was expanded even further and mapped for the occurrence of cogongrass (**Figure 9-6**). Occurrences of melaleuca, Old World climbing fern, and Australian pine 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 as does that of cogongrass.

Table 9-1. Nonindigenous plant acreage estimates based on results of 2007 SRF survey. Note that survey area includes the Florida peninsula south of Gainesville, but acreage estimes are for the District only.

SPECIES	ACRES
Melaleuca *(Melaleuca quinquenervia)*	273,014
Old World climbing fern *(Lygodium microphyllum)*	159,220
Brazilian pepper *(Schinus terebinthifolius)*	695,202
Australian pine *(Casuarina equisetifolia)*	207,197
Cogongrass (*Imperata cylindrica*)	6,897

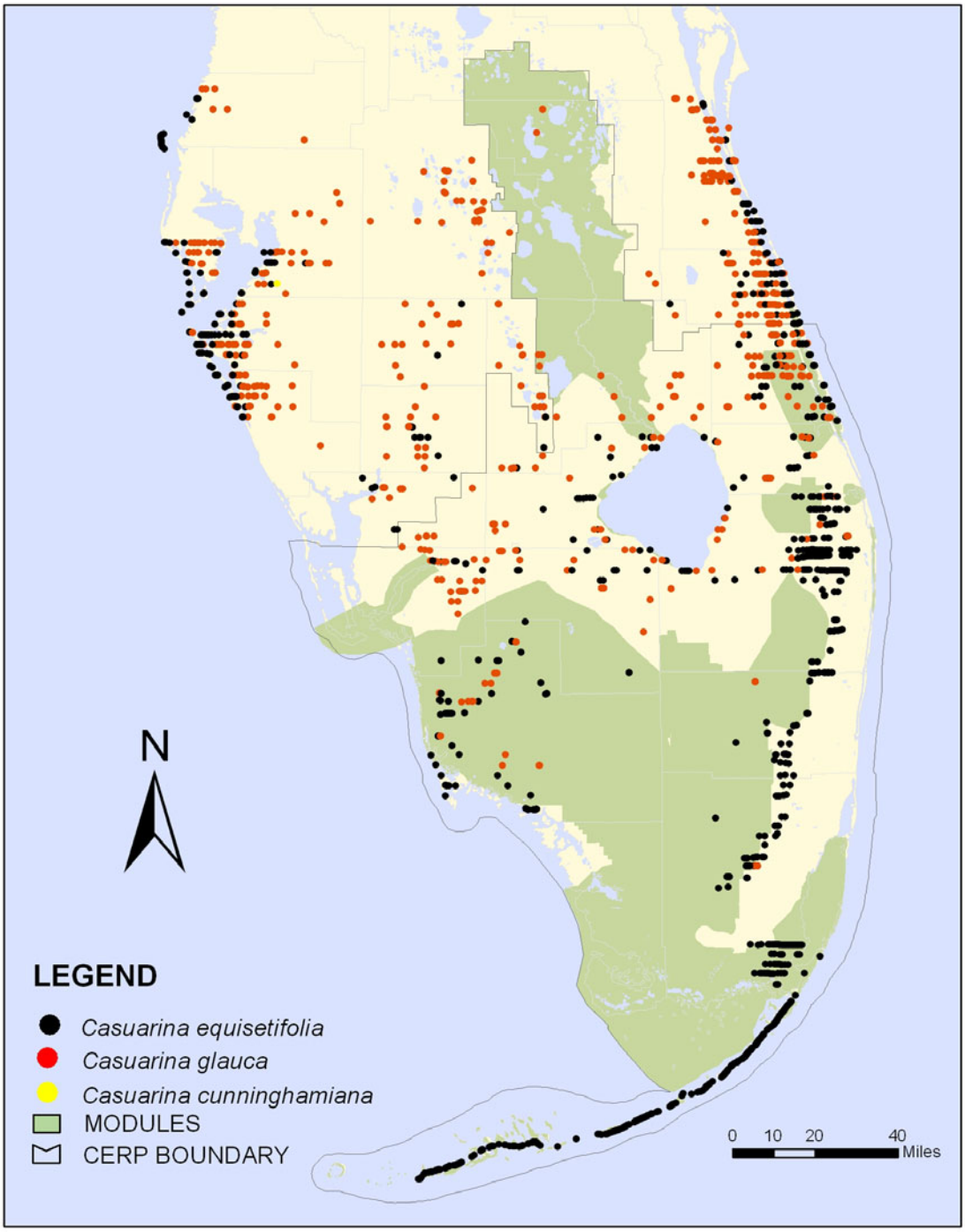


Figure 9-2. Distribution of Australian pine *(Casuarina* spp.*)* across South Florida (2007).

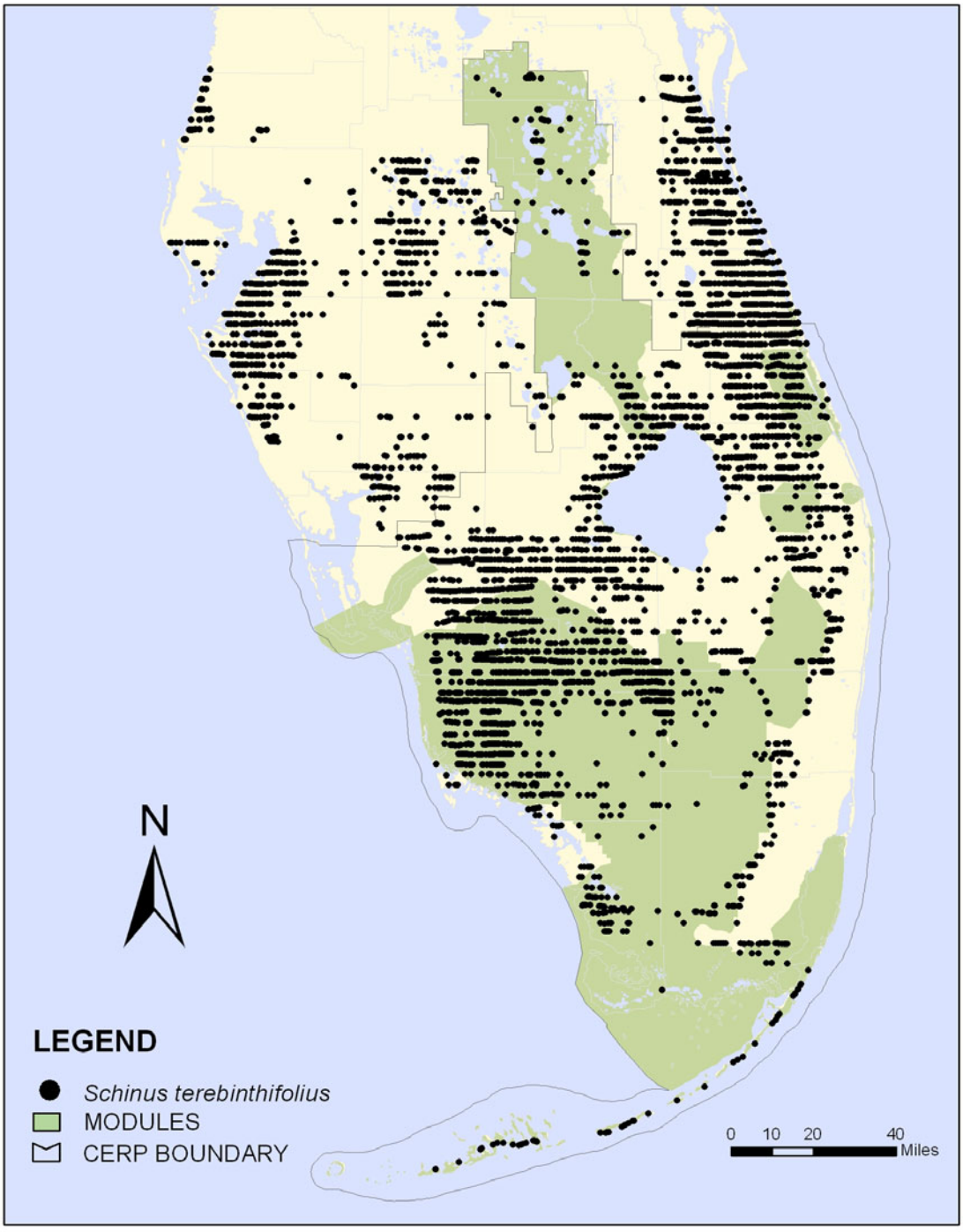


Figure 9-3. Distribution of Brazilian pepper (*Schinus terebinthifolius*) across South Florida (2007).

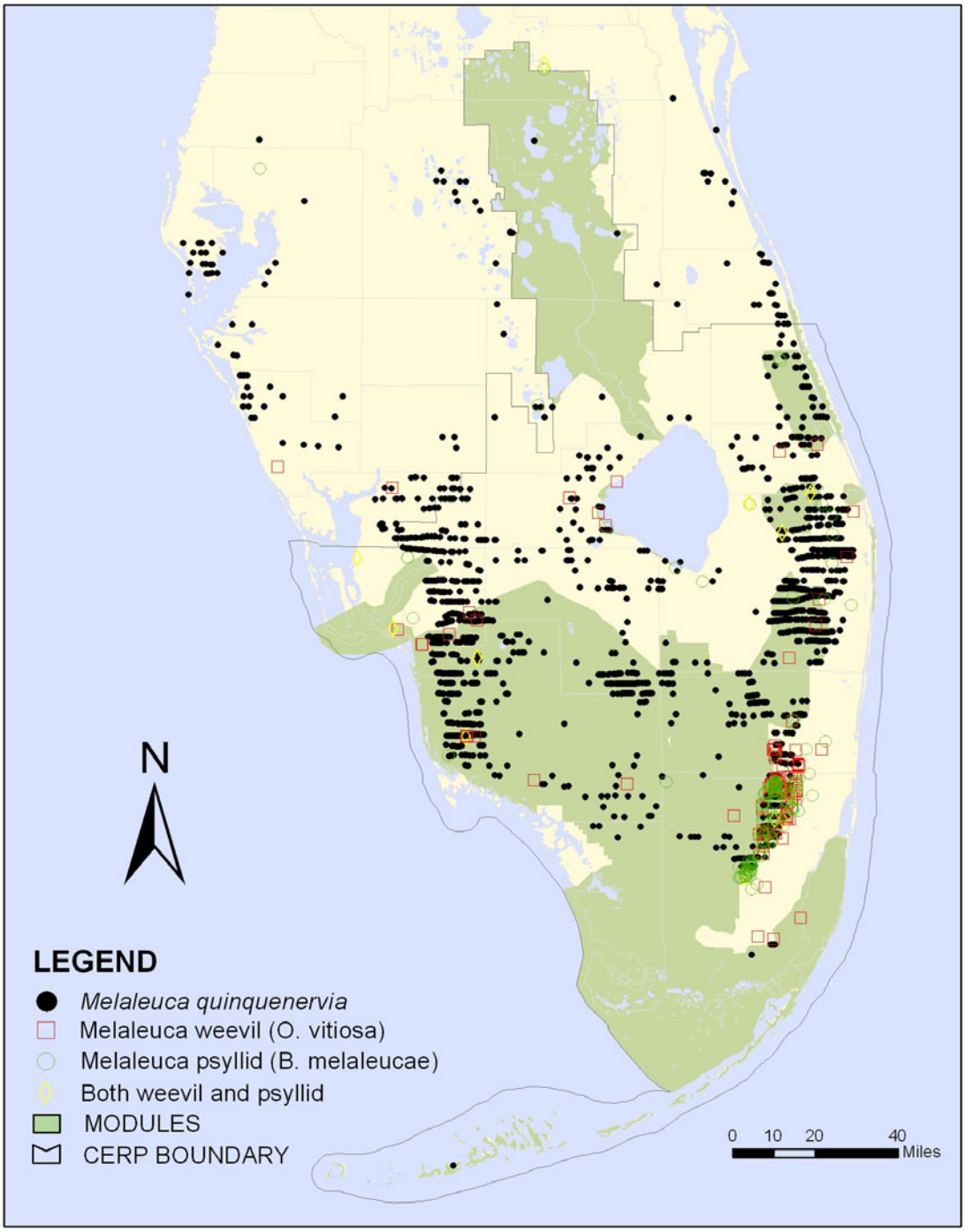


Figure 9-4. Distribution of melaleuca *(Melaleuca quinquenervia)* across South Florida (2007) and sites of original biocontrol agent releases since 1997. (Release site data courtesy of P. Pratt, USDA-ARS.)

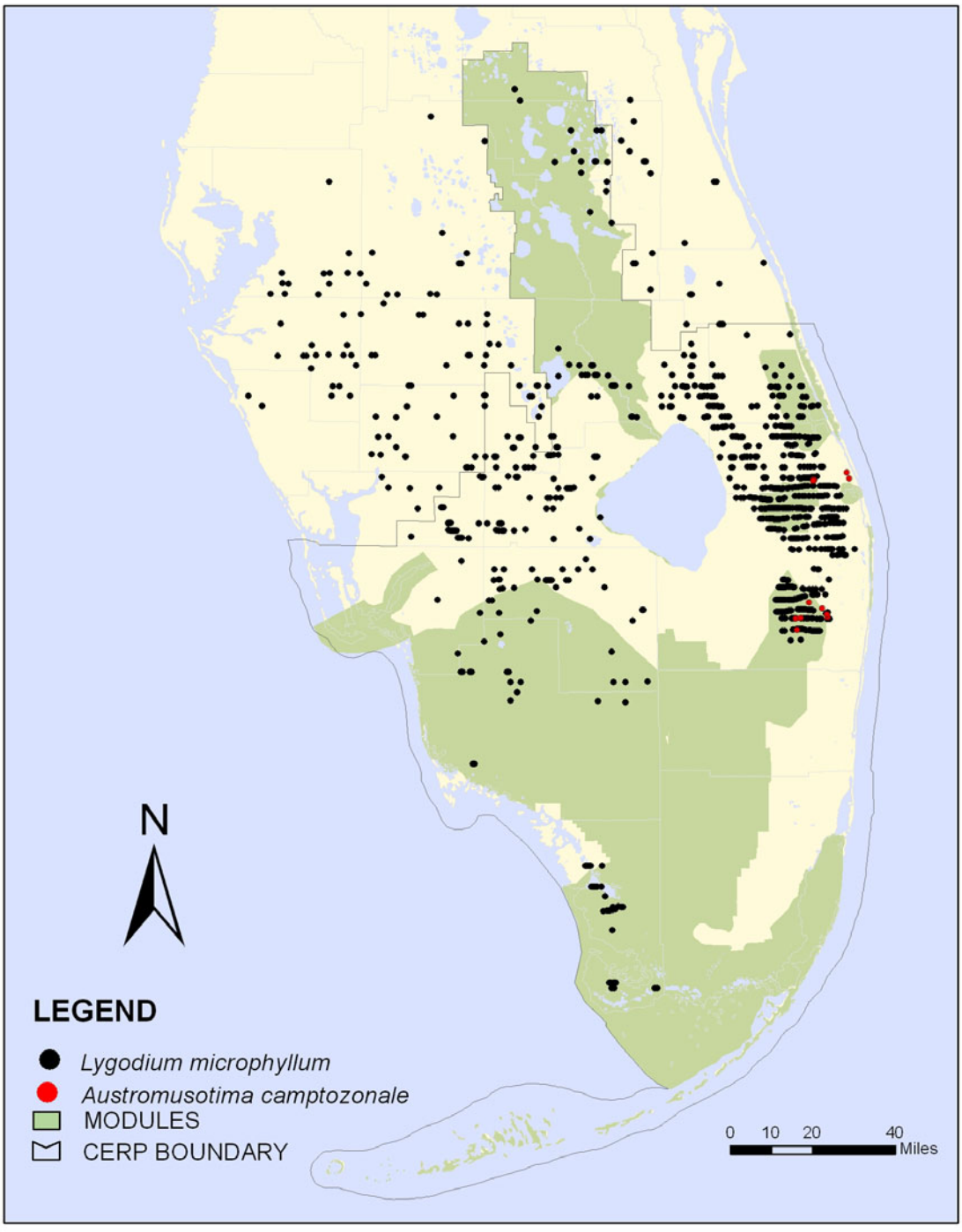


Figure 9-5. Distribution of Old World climbing fern *(Lygodium microphyllum)* across South Florida (2007) and biocontrol (*Austromusotima camptozonale*) release sites from 2006.
(Release site data courtesy R. Pemberton, USDA-ARS).

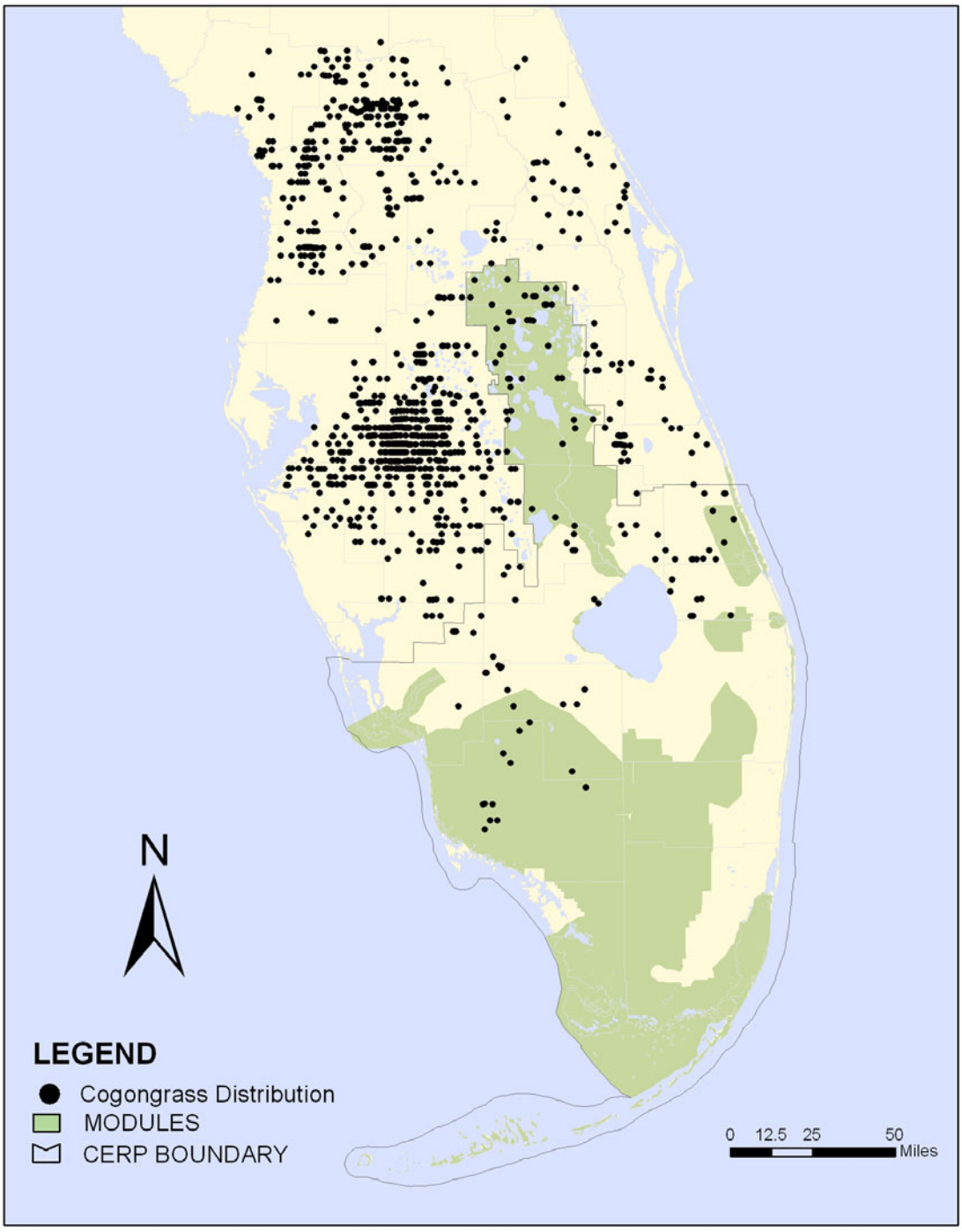


Figure 9-6. Distribution of cogongrass (*Imperata cylindrica)* across South Florida (2007).

AN ASSESSMENT OF NONINDIGENOUS SPECIES IN SOUTH FLORIDA

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 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 9-7**). 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 (CEMs). The CEMs include Florida Bay, Everglades Ridge and Slough, Southern Marl Prairies, Greater Everglades, Everglades Mangrove Estuaries, Big Cypress Regional, Lake Okeechobee, and Loxahatchee Watershed (at 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 plant and animal species lists for each module presented in **Tables 9-2** and **9-4** through **Table 9-11** 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 animal 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 scope of the problem 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 accurate. 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 developed and 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.

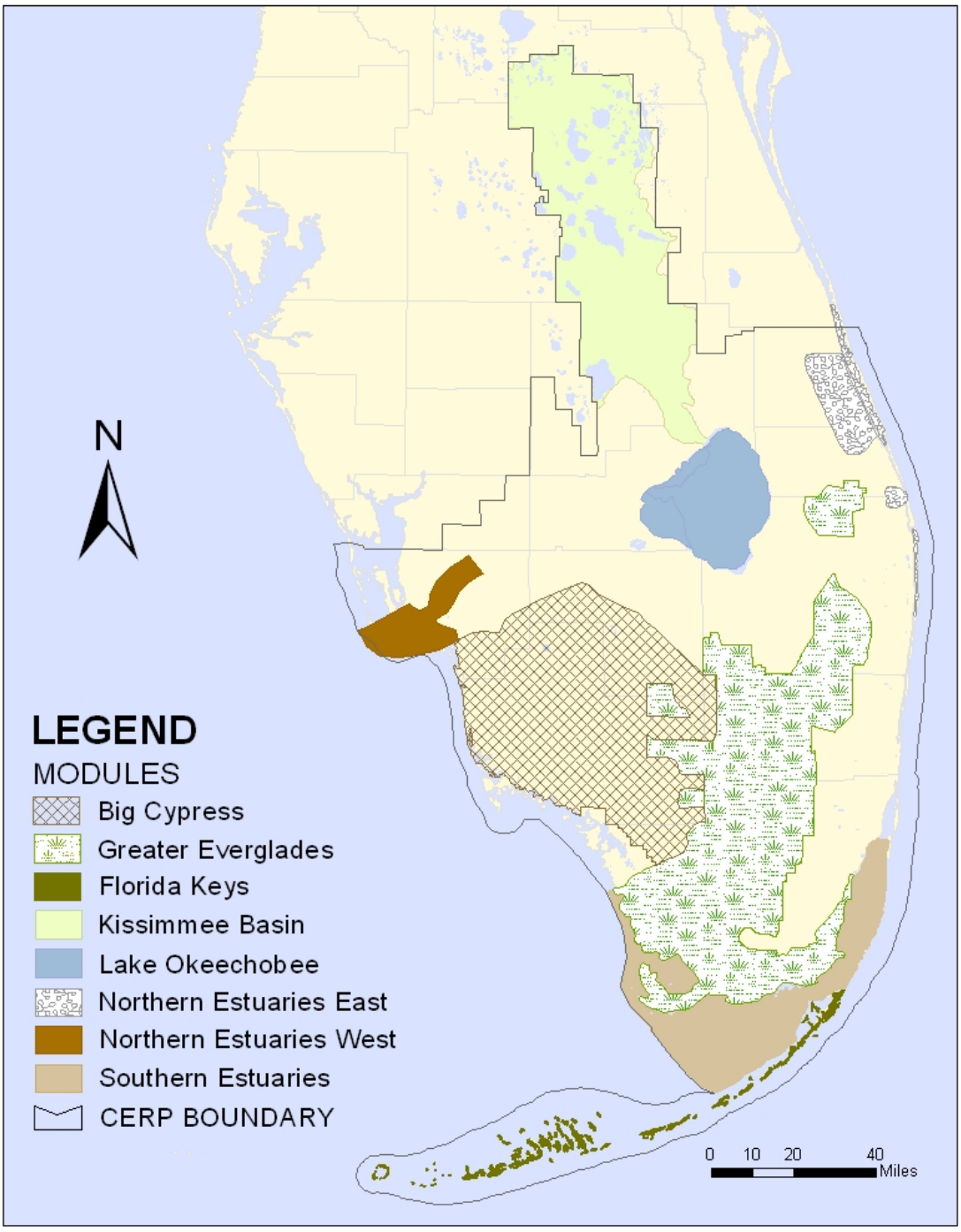


Figure 9-7. The nonindigenous species information in this report is organized using the terms, geographical references, and structure developed by Restoration Coordination and Verification (RECOVER).

Table 9-2. Summary of South Florida's nonindigenous animal species by RECOVER module.[11]

		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 septentrionallis	**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				
*BOIGA IRREGULARIS**	BROWN TREE SNAKE								
Caiman crocodiles	Common caiman			x				x	
Calotes mystaceus	Indochinese tree agama							x	x

Table Key		
KY = Keys	NW = Northern Estuaries West	Green Found in one module
SE = Southern Estuaries	NE = Northern Estuaries East	
GE = Greater Everglades	LO = Lake Okeechobee	Orange Found in all modules
BC = Big Cypress	KR = Kissimmee River	
		Blue Found in all but one module

***** Species designated for Early Detection and Rapid Response
Species entries in bold indicate they are discussed in Modules
Species entries in red indicate new additions to the Report
SPECIES ENTRIES IN CAPITAL LETTERS NOT PRESENT IN SOUTH FLORIDA BUT REPRESENT EXTREME RISK (FIATT, 2007)

Table Summary		
Found in 1 Module	Found in All Modules	Found in All but 1 Module
0 amphibians	2 amphibians	1 amphibian
6 reptiles	6 reptiles	5 reptiles
3 birds	4 birds	2 birds
5 mammals	6 mammals	0 mammals
18 fish	0 fish	1 fish
42 invertebrates	5 invertebrates	0 invertebrates

[11] Due to limited availability of animal distribution data, species lists presented in table are not comprehensive, but are considered representative of the species found within the 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			
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**			
Eunectes notaeus	**Yellow anaconda**				**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**	**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**			**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 decaocta	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.[12]

		KY	SE	GE	BC	NW	NE	LO	KR
Fishes									
Astronotus ocellatus	**Oscar**		**x**	**x**	**x**			**x**	**x**
Belonesox belizanus	Pike killifish	x	x	x	x				
Callichthys callichthys	Cascarudo								x
Channa marulius	Bullseye snakehead		x						
Chitala ornata	Clown knife		x						
Cichla ocellaris	**Butterfly peacock cichlid**		**x**	**x**					
Cichlasoma bimaculatum	**Black acara**		**x**	**x**	**x**		**x**	**x**	**x**
Cichlasoma citrinellum	Midas cichlid			x					
Cichlasoma managuense	Jaguar guapote			x	x				
Cichlasoma festae	**Guayas cichlid**					**x**			
Cichlasoma octofasciatum	Jack Dempsey						x		
Cichlasoma salvini	Yellowbelly cichlid			x					
Cichlasoma urophthalmus	**Mayan cichlid**		**x**	**x**	**x**	**x**	**x**	**x**	
Clarias batrachus	**Walking catfish**		**x**	**x**	**x**	**x**	**x**	**x**	**x**
Dorosoma petenense	Threadfin shad								x
Geophagus surinamensis	Redstriped eartheater			x					
Hemichromis letourneuxi	**African jewelfish**	**x**		**x**	**x**	**x**			**x**
Heros severus	Banded cichlid			x					
Hoplosternum littorale	**Brown hoplo**			**x**	**x**	**x**	**x**	**x**	**x**
Hypostomus plecostomus	Suckermouth catfish			x					
Macrognathus siamensis	**Spotfinned spiny eel**			**x**					
Monopterus albus	**Asian swamp eel**			**x**					
Oreochromis aureus	**Blue tilapia**		**x**	**x**	**x**		**x**	**x**	**x**
Oreochromis mossambicus	**Mozambique tilapia**			**x**		**x**	**x**		
Pterygoplichthys disjunctivus	**Vermiculated sailfin catfish**								**x**
Pterygoplichthys multiradiatus	**Orinoco sailfin catfish**			**x**				**x**	**x**
Sarotherodon melanotheron melanotheron	Blackchin tilapia						x		
Tilapia mariae	**Spotted tilapia**		**x**	**x**	**x**	**x**	**x**		
Tilapia zillii	Redbelly tilapia						x		
Xiphophorus hellerii	Green swordtail						x		
Xiphophorus maculatus	Southern platyfish						x		
Xiphophorus variatus	Variable platyfish						x		

[12] This list contains only established records of nonindigenous fish according to the USGS definition (reproducing and overwintering population). Comprehensive exotic fish lists were reviewed by USGS experts (Bill Loftus and Pam Fuller), and FWC experts (Shafland, 1996) with unique knowledge of the subject. The FWC lab uses a more conservative listing of established fishes (permanent populations so widespread no elimination is possible). The USGS listing was chosen primarily because it provides an indication of species present and capable of expansion in the future. However, any FWC occurrences not listed by USGS are included here. There were some differences between USGS listings, so Loftus occurrences were authoritative for KY, SE, GE and BC; Fuller for NW, NE, LO and KR; as agreed by those reviewers.

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		
*AGRILUS PLANIPENNIS**	EMERADL ASH BORER								
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
*DREISSENA POLYMORPHA**	ZEBRA MUSSEL								
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
Myllocerus undatus	**Sri Lanka Mimic Weevil**						**x**		
Mytella charruana	**Charru 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	**Island applesnail (= Channeled applesnail)**			**x**			**x**	**x**	**x**
*RAOIELLA INDICA**	RED PALM MITE								
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		
*XYLEBORUS GLABRATUS**	REDBAY AMBROSIA BEETLE								
Zachrysia provisoria	Cuban garden snail	x							

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 9-7**), 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 affect 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 — and each priority species within each module — are 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 "stoplight" 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.

MODULES OVERVIEW

For each of eight modules, this report includes a narrative of relevant nonindigenous species issues. Priority plant species are presented in an indicator-based stoplight table (in which a red "stoplight" indicates a severe negative condition). Pilot exotic plant indicator tables are also provided to demonstrate 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 Fiscal Year (FY) 2007 expenditures on nonindigenous plant control are summarized by module. The District spent over $23.8 million in FY2007 for overall invasive plant prevention, control, and management in South Florida. Distribution of the five species for which systemwide control efforts are under way is presented in **Figures 9-2** through **9-6**.

Table 9-3. Summary of invasive plant species control expenditures by module by the District in FY2007.

	Lake Okeechobee	Kissimmee	Big Cypress	Greater Everglades	Northern Estuaries East	Northern Estuaries West	Systemwide Biological Control
Australian Pine *(Casuarina equisetifolia)*	--	$742	$584	$307,720	--	--	$20,000
Brazilian Pepper *(Schinus terebinthifolius)*	$279,328	$88,664	$31,031	$591,062	$386,119	--	$49,000
Shoebutton Ardisia *(Ardisia elliptica)*	--	--	--	$222,619		--	--
Old World Climbing Fern *(Lygodium microphyllum)*	--	$254,164	--	$955,015	$125,658	--	$150,000
Melaleuca *(Melaleuca quinquenervia)*	$362,235	--	$159,999	$4,723,739	--	--	$150,000
Torpedograss *(Panicum repens)*	$2,658,657	100,633	--	$1,484	--	--	--
Cogongrass (*Imperata cylindrica*)	--	--	--	--	$6,576	--	--

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 influencing 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 often unavailable. Consequently, agency managers must use their best judgment in initiating control programs for these animal species.

Figure 9-8. Giant toad (*Bufo marinus*) (Photo by Craig G. Morley, Global Invasive Species Database).

It is important to note that certain nonindigenous animal species occur in almost every module. These species (32 total) include the giant toad (*Bufo marinus*, **Figure 9-8**), Cuban brown treefrog (*Osteopilus septentrionallis*), green iguana (*Iguana iguana*), monk parakeet (*Myiopsitta monachus*), and feral dog (*Canis familiaris*). Not all of these species are described in detail because they cannot all be adequately covered in this chapter. Omitting specific mention of some of these species in module narratives does not imply that the species are not problematic, or that they 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. For additional information on those organisms not discussed in detail herein, readers may refer to extension documents put out by the University of Florida, or visit the links listed on this University of Florida extension site at http://pcb2441.ifas.ufl.edu/list%20of%20species.htm (as of November 6, 2007).

Many nonindigenous plant species, too, are problematic in multiple modules, though their biology, ecological impact, and the control efforts put forth against them may be described in detail in only one module.

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 it was not included in the scope of CERP. Unlike virtually every other habitat in Florida, the invadable land area is relatively small in the Florida Keys. This allows land managers to prioritize species effectively and deal systematically with relatively small parcels. Through the well-coordinated Florida Keys Invasive Exotics Task Force, a list of priority animal and plant species has been developed. The updated priority animal species list is expected to be complete by 2008 and will include a ranking of priority animals along with suggested eradication methods. Land managers are currently inventorying all the land within this module, documenting the presence of priority plant species on both public and private holdings. The maps resulting from this effort are expected to be finished by the close of 2007 (A. Higgins, The Nature Conservancy [TNC], personal communication). Virtually all listed conservation lands are considered to be under maintenance control for target plant species, and other public lands are being addressed. As work to assess, prioritize, and control nonindigenous animals in the Florida Keys has begun, this module is 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.

Nonindigenous Plants

Although public lands in the Florida Keys are well maintained, land managers report that populations of some species (e.g., seaside mahoe, and half-flower) are decreasing on public lands but increasing on private lands because of continued horticultural landscape use. 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. In the past, localized problems developed with sickle bush (*Dichrostachys cinerea)* and laurel fig (*Ficus microcarpa,* **Figure 9-9**). However, both were targets of coordinated control measures that resulted in their eradication. Both species are still actively searched for, but neither inhabits the Keys at this time.

Figure 9-9. Laurel fig *(Ficus microcarpa)* (Photo by Vic Ramey, Univ. Florida).

Figure 9-10. Leadtree *(Leucana leucocephala)* (Photo by Ann Murray, Univ. Florida).

Other priority species such as sapodilla (*Manikara zapota)* are problematic in localized areas, especially hardwood hammocks and old homesteads. Species such as leadtree (*Leucaena leucocephala)* and umbrella tree (*Schefflera actinophylla)* are increasing chiefly along roadsides and in disturbed sites (**Figure 9-10**). Resource managers in the Keys note that leadtree is particularly difficult to control with herbicides. Priority plant species are listed in **Table 9-4**.

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

	2006 STATUS	2007 STATUS		1-2 YEAR PROGNOSIS	
FLORIDA KEYS MODULE (Results in this row reflect module-level questions, not species-level questions)	Y	Restoration efforts under way for several years; much progress made on most species; still some use of invasive species in private landscapes	Y	Significant control program for several years; progress on many species evident, continued monitoring and control needed to prevent serious reinvasions of species still threatening this region and new species	Y G
Australian Pine (*Casuarina* spp.)	Y G	Effective program in place and Australian pine not currently a problem in natural areas of Keys, decreasing on private	Y G	Chemical control effective with most natural areas clear or clearable with modest effort; biocontrol research under way	G
Latherleaf (*Colubrina asiatica*)	Y	Little known about spread throughout region; actively removed in coordinated manner	Y	Removal needed constantly, but coordinated control programs expected to keep populations at easily maintained levels	Y G
Sickle Bush (*Dichrostachys cinerea*)	Y	Actively searched for but effectively removed from module	G	Actively searched for but effectively removed from module	G
Laurel Fig (*Ficus microcarpa*)	Y	Actively searched for but effectively removed from module	G	Actively searched for but effectively removed from module	G
Leadtree (*Leucana leucocephala)*		Not new to module but considered new priority; controlled on public lands; increasing on private; prolific seedbank; resistant to chemicals	Y R	Control efforts increasing; control techniques being perfected	Y
Sapodilla (*Manilkara zapota*)	Y	Know little about spread throughout region; actively removed in coordinated manner	Y R	Localized problem; difficult to detect, may become serious pest in areas where other exotics controlled; invades natural forests; difficult to control	Y R
Half Flower (*Scaevola taccada*)	Y	Fairly easy to detect; actively removed from public land in coordinated manner; still popular for landscape on private land	Y R	Seeds float, long-term management difficult; biocontrol probably not option given closely related native *Scaevola* species	Y R
Brazilian Pepper (*Schinus terebinthifolius*)	Y	Invades most habitats, very destructive; chemical control ineffective in systemwide spread; local control programs proving effective in Keys	Y	Control programs effective in the Keys, with most populations limited; new biocontrol agents under study for future release in 2007-2008	Y
Seaside Mahoe (*Thespesia populnea*)		Not new to module, new to table; removed from public land in coordinated manner; still popular on private land; spreads easily;	Y	Active control program maintains populations; requires constant effort	Y

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 underway. 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 and 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 problems associated with nonindigenous plant species, this module also has several priority nonindigenous animals which threaten ecosystem function in the Florida Keys.

Cactoblastis

Cactoblastis cactorum is a South American moth whose larvae feed exclusively on species of prickly pear cactus (*Opuntia* spp.) (**Figure 9-11**). The moth was first discovered in North America on Big Pine Key in 1989. It was most likely introduced to Florida accidentally 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 9-11. *Cactoblastis cactorum* larvae on *Opuntia* (Photo by Stephen Davis, USDA-APHIS).

In the Florida Keys, this moth threatens the endemic and endangered *O. corallicola* and other native prickly pear cacti, as well as populations of 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 9-12**). USDA-ARS has also developed a Sterile Insect Technique (SIT) program as a control/exclusion strategy for this moth (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. Continued release and evaluation of sterile cactus moths at SIT validation sites is planned through 2007.

Figure 9-12. *C. cactorum* eggsticks (Photo by Ignacio Baez, USDA-ARS).

Although laboratory tests of insecticides show positive results for controlling the cactus moth, widespread use of pesticides may not be suitable for the Florida Keys due to the occurrence of rare and endangered *Lepidoptera* (e.g., Schaus swallowtail, Florida leaf-wing, and Bartram's scrub-hairstreak; M. Barett, USFWS, personal communication). Until effective control methods are developed, land managers in the Florida Keys are monitoring *Opuntia* spp. populations and manually removing impacted cactus pads. Fortunately, since the original infestation in early 2000, cactus moth outbreaks have occurred less frequently.

Gambian Pouch Rat

Gambian pouch rats (*Cricetomys gambianus*), native to Africa, were bred in captivity on Grassy Key. It is believed eight rats escaped between 1999 and 2002 and established a reproducing population. Gambian rats weigh an average of three pounds and measure

20–35 inches from head to tail, which is much larger than native species, including the Key Largo wood rat, the cotton rat, and silver rice rat. Its large size makes 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 rodents primarily eat fruits and grains, but are also known to eat invertebrates (Novak and Paradiso, 1991). Gambian rats are concentrated in the vicinity of dwellings near the initial release site on Grassy Key, although there has been dispersal to the adjacent Crawl Key. The population relies on refuse, pet food, and water from homeowners. Scientists are concerned this species is poised to move from Grassy Key onto adjacent keys, and then to Florida's mainland.

In February 2006, a pilot eradication project was initiated on Crawl Key where Gambian rat photographs were recorded in 2005. In June 2006, USDA-APHIS WS deployed 94 bait stations. Supplemental trapping was done to obtain rats for radio telemetry. It was determined that the combined effects of the eradication effort, along with impacts from Hurricane Wilma, eliminated this sub-population. Using previous trapping and radio telemetry, a bait-station grid was established for Grassy Key using a 40-meter grid in the "core" area. On the periphery, bait stations were placed 50 meters apart. Lot owners in the affected areas were contacted to seek access to their property for placing bait stations (**Figure 9-13**).

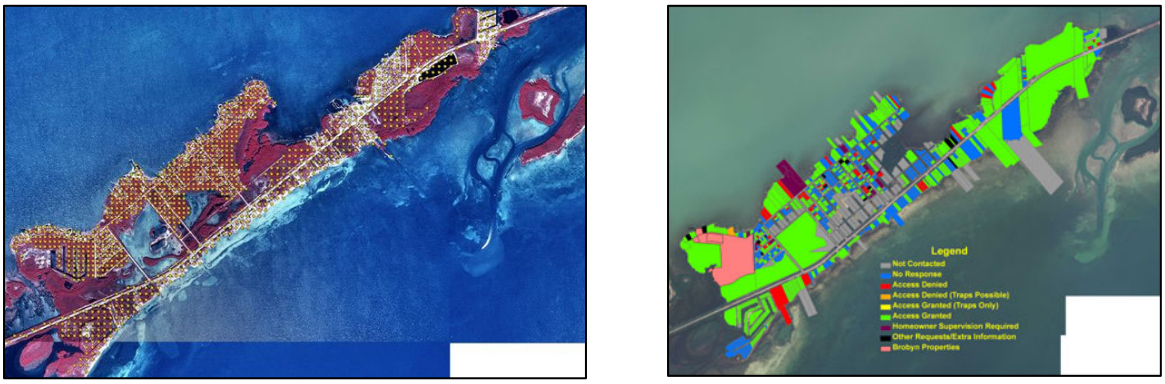


Figure 9-13. Bait station grid (left) and property owner permission status of Gambian pouch rat project (Figures by Scott Hardin, FWC).

From January to May, 2007, 1,000 bait stations were placed throughout Grassy Key hammock and residential areas. In March 2007, 20 Gambian pouched rats were trapped for the USDA APHIS National Wildlife Research Center (NWRC) for studies of more effective attractants and third generation rodenticides (**Figure 9-14**). As an indication that the pouched rat population was recovering from the impacts of Hurricane Wilma in late 2005, three of 11 females transported to the NWRC lab in Fort Collins, Colorado, had litters either in flight or shortly after arrival.

On May 21, the eradication effort commenced with the pre-baiting of roughly 600 stations around the periphery of the core area; actual toxic bait was removed from all stations by June 15. A high level of public awareness throughout the project resulted in no adverse public reactions during the active eradication phase. Two dead Gambian pouched rats were observed by residents, and several dead black rats were observed by WS staff.

Figure 9-14. Gambian pouch rat to be transported to NWRC lab (Photo by Scott Hardin, FWC).

Intensive surveys using remote cameras and trapping will be conducted in July and September, 2007, to detect and eliminate any surviving Gambian pouch rats.

Funding for the project is provided by the Wildlife Foundation of Florida, Inc.; FWC; USDA-APHIS, Wildlife Services and National Wildlife Research Center; U.S. Fish and Wildlife Service, National Wildlife Refuges and Partners in Wildlife; and the District.

Green Iguana

Green iguanas (*Iguana iguana*) are native to Central and South America and some Caribbean islands, but have become well established in South Florida (Meshaka et al., 2004) (**Figure 9-15**). The range of the green iguana appears to be expanding in South Florida, having been initially limited to Dade County in 1966 and later expanding to Broward, Lee, Monroe, Palm Beach, Highlands, Hillsborough, Alachua, Indian River, Collier, Martin and St. Lucie counties. Breeding populations are established in seven of these counties (Meshaka et al., 2004).

Figure 9-15. Green iguana (*Iguana iguana*) (Photo by Stacey Sekscienski).

Green iguanas are popular in the pet trade and frequently escape or are released, although it is illegal to release iguanas and other non-native wildlife in Florida per Chapter 39-4.005, Florida Administrative Code (F.A.C.). They are generally found in suburban areas (especially with canals), agricultural areas, and hammock communities where they bask in open areas including sidewalks, docks, mowed regions, and exposed branches of trees. This long-lived species produces clutches of up to 49 eggs (Meshaka et al., 2004) and quickly reaches sexual maturity (males in 20 months, females in 31 months) (Smith et al., in press). Both traits have greatly contributed to its colonization success. High densities (up to 626 iguanas/km^2 have been reported for managed natural areas in South Florida (Smith et al., 2006; Smith et al., 2007; Smith et al., in press).

Adult green iguanas are generally herbivorous, feeding on foliage, flowers, and fruit, though they occasionally eat invertebrates. Iguanas consume both native and ornamental plant species in South Florida, and have also been found to prey on tree snails, especially *Drymaeus multilineatus* in Key Biscayne (Townsend, 2005). 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.

In addition to eating valuable native and landscape plants, droppings of green iguanas are unsightly and unhygienic and a possible source of *salmonella* bacteria. Green iguanas weaken canals and levees with their extensive burrowing (see the *Greater Everglades Module* section, page 9-49), creating a maintenance liability to surface water infrastructure. They can contribute to weed seed dispersal through ingested seed and provide potential collision hazards on airport runways (Smith et al., in press). Furthermore, adult green iguanas are powerful animals that can bite and scratch, and aggressively whip with their tail (Smith et al., 2006). Although green iguanas normally avoid people, they will defend themselves if threatened, with males becoming more aggressive during mating season.

Green iguanas are a protected species in their native range because they are economically valued there and are often rare due to over-collection for the pet trade (at

http://www.cites.org/eng/app/appendices.shtml). There are currently no agency-sponsored, coordinated control efforts for the nonindigenous green iguana in South Florida (including the Keys), though small-scale removal projects are in place (e.g., through a "Parknership" collaboration with the USDA-WS and Florida Park Service). Future controls likely will be implemented, however, given the region's expanding green iguana populations, impacts to water management operations and potential impacts of this nonindigenous species on native species such as the Florida burrowing owl (Makie et al., 2005; Smith et al., in press).

Feral Cat

FWC estimates populations of feral cats (*Felis catus*) to be between 6.3 and 9.6 million in the state of Florida (at http://www.floridaconservation.org). Worldwide, feral cats feed heavily on small birds, reptiles, and mammals, and have led to the extinction of numerous species. Feral cats (**Figure 9-16**) also spread diseases and parasites. In Florida, feral cats are known to prey upon the green sea turtle, roseate tern, least tern, Florida scrub-jay, Choctawhatchee beach mouse, Anastasia Island beach mouse, Key Largo cotton mouse, Southeastern beach mouse, Perdido Key beach mouse, Key Largo woodrat, Lower Keys marsh rabbit, and rice rat — all federally listed species.

Figure 9-16. Feral cat (Photo by Rex Williams, Chatham Island Taiko Trust, Global Invasive Species Database).

Although feral cats are problematic in all Modules, they are recently of particular concern in the Florida Keys. They have contributed to a 50 percent decline in populations of Hugh Hefner's rabbits (*Sylvilagus palustris hefneri*, an endangered subspecies of marsh rabbit named for Hefner's contributions to their research) on Big Pine Key (CNN.com, accessed May 20, 2007). Numerous trap-neuter-release programs that have been in place on the Keys and throughout South Florida for many years have proven ineffective. Consequently, wildlife officials began trapping the animals in May 2007, with the intent of removing and transporting them to animal shelters. Because escaped and abandoned cats continuously supplement feral cat populations, increased public awareness is needed to ultimately decrease populations of feral cats in the Keys and throughout South Florida.

Figure 9-17. Park biologist Jim Duquesnel, Joanne Potts and Clay DeGayner (left to right) (Photo by Britta Muizenieks, USFWS).

Burmese python

On Friday, April 13, 2007, graduate student Joann Potts and volunteer Clay DeGayner discovered the invasive Burmese python (described in detail in the *Greater Everglades Module,* page 9-47) inhabiting the Keys (**Figure 9-17**). This alarming find on Key Largo was compounded by the discovery of two woodrats, a federally listed endangered species, in the digestive tract of the captured python (J. Duquesnel, FDEP). This validates the concern that these invasive snakes pose an immediate threat to the ecological health and function of South Florida's ecosystem. It is unlikely that this was the only individual living in the Keys. Monitoring efforts will estimate python populations in the Keys and an eradication plan will follow.

FLORIDA BAY AND SOUTHERN ESTUARIES MODULE

The Florida Bay and Southern Estuaries Module is made up of the coastal estuaries, coastal mangroves and islands of the southern Everglades. It is bordered by the Florida Keys Module to the southeast and the Greater Everglades Module to the north. This Module is a gradual transition between freshwater flowing from the mainland Everglades, and the open ocean. Nonindigenous species 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.

Nonindigenous Plants

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 the 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.

Latherleaf invades coastal ridges just above the mean high-tide line (Russell et al., 1982), tropical hammocks, buttonwood and mangrove forests, and tidal marshes (Schultz, 1992). It also forms thickets on disturbed coastal roadsides. Latherleaf can invade disturbed and undisturbed forest sites (Olmsted et al., 1981; Jones, 1996), forming thick mats of entangled stems up to several feet deep, and growing over and shading out 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).

Figure 9-18. Vegetation communities in the lower Ten Thousand Islands were severely damaged first by Hurricane Rita and then by Hurricane Wilma. This time-series of photos demonstrates the ability of Latherleaf (*Colubrina asiatica*) to rebound following a major storm event relative to native species. Turkey Key (top), Wood Key (center), and Plover Key (bottom) are shown. Photos in each column were taken on the same date (Photos by Tony Pernas, NPS).

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

Land Managers have long speculated that the success of latherleaf in South Florida is the result of latherleaf's having high seed germination success, a long lived seed bank, and possible allelopathy. The NPS contracted with the UF to study the seed ecology and allelopathy of latherleaf. The study (McCormick and Langeland, 2007) concluded that latherleaf seeds have very low germination success and that seed viability is typically less than one year. However, field observations during the study showed strong evidence that latherleaf is more resilient than native species following severe hurricanes. It is the first species to flush with growth following storm events and is then able to thrive due to removal of canopy and the influx of light, water, and nutrients (**Figure 9-18**). Latherleaf in its native range is well adapted to regular cyclonic activity. In South Florida, latherleaf seeds are moved by ocean currents; flooding events such as storm surge move seeds inland.

The NPS, SFWMD and Miami-Dade County have been working together on invasive plant control through the South Biscayne Bay Exotic Plant Working Group. A primary focus of the group is Australian pine (*Casuarina* spp.), represented by three unique species in South Florida. In Biscayne National Park, this species is considered to be under maintenance control. This year, the District began initial treatment of approximately 80 acres within the Biscayne Bay Coastal Wetlands (BBCW) project area bordering the entrance to Biscayne National Park (**Figure 9-19**). While primarily targeting Australian pine and Brazilian pepper, crews also discovered several pockets of *Lygodium*, which they quickly treated. As acquisitions of adjacent properties for the Acceler8 BBCW project continue, these areas will undergo the incremental process of controlling invasive species and the seed banks they generate. However, 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.

Figure 9-19. Treated *Casuarina* spp. (Photo by Jason Smith, SFWMD).

Biological control research is actively being pursued for Australian pine. However, the program may face limitations resulting from conflicts with agricultural interests. Australian pine is frequently planted as an ornamental or for wind protection around citrus groves. This conflict of interest between those planting Australian pine and those trying to control it has led researchers to target seed-feeding agents that leave the adult plants intact while preventing them from reproducing (G. Wheeler, USDA-ARS, personal communication). This program is in the early stages; the majority of work currently entails field explorations for potential seed-feeding biocontrol candidates in the plant's native range. Only one species of *Casuarina* in Florida reproduces solely by seed, so seed-feeding insects are not projected to have a large impact on the remaining two species.

Figure 9-20. Crocodile nest on *Casuarina*-impacted island in northeastern Florida Bay (Photo by Tony Pernas, NPS).

Australian pine is of special concern in the Southern Estuaries because it threatens the habitat of the endangered crocodile (*Crocodylus acutus*) and nesting sea turtles. 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 9-20**).

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 9-21**).

Figure 9-21. Sapodilla (*Manilkara zapota)* fruit, and interspersed along the southern coastline (Photos by Ann Murray, Univ. Florida and 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 Southern Estuaries Module.

	2006 STATUS	2007 STATUS		1-2 YEAR PROGNOSIS	
FLORIDA BAY & SOUTHERN ESTUARIES MODULE (Results in row reflect module-level questions, not species-level questions)	Y	Control programs under way for many years, achieve significant control; however, many species invaded in recent years and their possible effects unclear; most Florida Bay not included in any monitoring program for invasive plants	Y	Some species, e.g. Latherleaf, have been serious invaders of rare habitats along the southern coast of the Park; other new species simply off the radar as far as inclusion in a systematic control or monitoring program and are serious unknowns	Y R
Australian Pine (*Casuarina* spp.)	Y	Effective control program in place in southern and western coastal areas of Park; surrounding seed sources make continuous long-term management necessary in these areas; impacts endangered species	Y	Chemical control effective and most coastal habitats clear but ongoing control still needed in coastal areas due to (floating) seed pressure from other areas; biocontrol research under way	Y G
Latherleaf (*Colubrina asiatica*)	Y R	Spread of latherleaf documented for over a decade; overall, distribution and impacts in coastal habitats increasing; difficult to detect remotely,; especially problematic to rare coastal habitats; not part of systematic monitoring program	Y R	Spreading north along Park's west coast, east along Florida Bay, and south into Keys; poses serious threat to natural areas of north Key Largo; herbicidal control logistically challenging; seed viability poorly understood; no biocontrol programs under way	R
Old World Climbing Fern (*Lygodium microphyllum*)		Small population discovered in module in 2006; treatments made, although likelymore widespread than previously thought	Y	Careful monitoring key to successful control; populations currently small, but can spread extremely rapidly in undistrurbed and remote areas; biocontrol releases made	Y
Sapodilla (*Manilkara zapota*)	Y	Scattered throughout coastal hardwood habitats; difficult to detect remotely; not included in Indicator systematic monitoring program	Y	Because intermixed in native tropical hardwood communities, detection and control difficult and logistically challenging; likely spread by animals; no biocontrol program under way	Y R
Half Flower (*Scaevola taccada*)	Y	Limited to coastal habitats; easy to detect but not part of Indicator systematic monitoring program	Y	Effectively controlled along beaches in most locations, but surrounding seed sources from ornamental plantings make long-term control problematic; no biocontrol program under way; Prospects poor, given native *Scaevola* species	Y R
Brazilian Pepper (*Schinus terebinthifolius*)	Y	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	Y	Control programs in southern Park areas effective in reducing local populations; most populations limited so far in this region but coastal mangroves still threatened; new biocontrol agents under study, releases 2007/2008	Y
Seaside Mahoe (*Thespesia populnea*)	Y	Invades coastal habitats and forms dense monocultures; not part of systematic monitoring program	Y	Control ongoing in Elliot Key and scattered locales in Florida Bay; surrounding seed sources from wild populations and ornamental plantings; floating seeds spread into natural areas with high tide, make long-term control difficult	Y

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 underway. 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 and 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*, **Figure 9-22**) is native to southern Mexico (reviewed in Koprowski et al. in review). Two pairs of squirrels 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.

Firgure 9-22. Mexican red-bellied squirrel (*S. qureogaster*) (Photo by NPS).

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 review). 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 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 have 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 (e.g. 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, and Old Rhodes Keys. Population surveys of Elliott Key conducted from 2005 through 2007 identified over 200 squirrel nests (**Figure 9-23**). Of concern was the observation of this squirrel on Old Rhodes Key, just a few hundred yards from Key Largo, indicating that the squirrel has managed to cross water barriers and it is plausible that the species can reach Key Largo in the future.

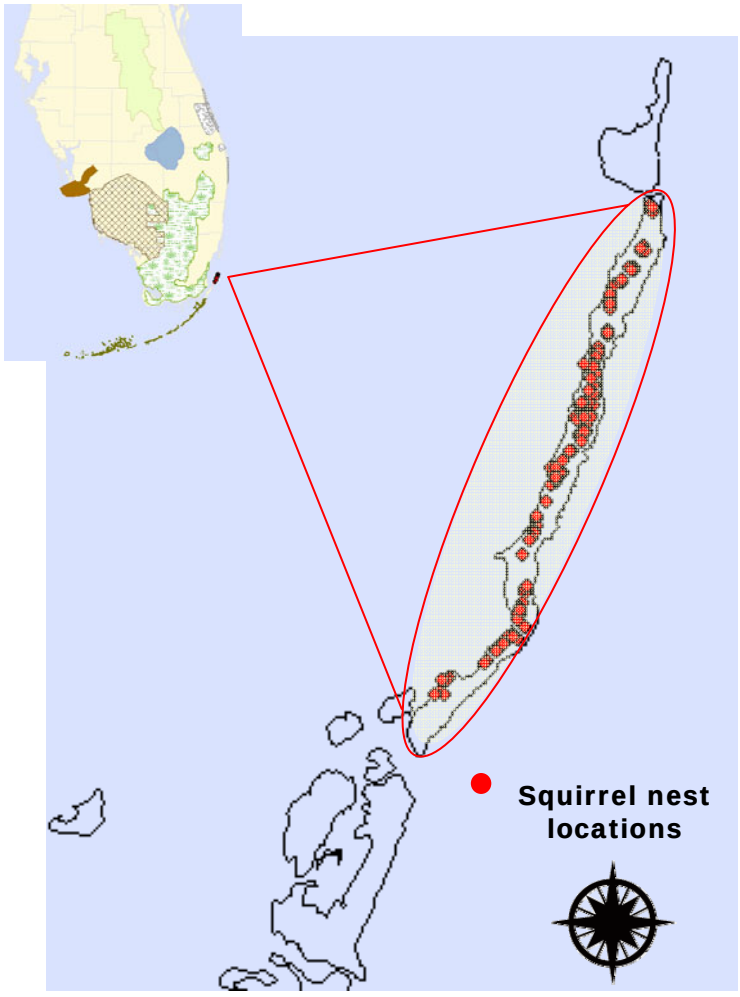


Figure 9-23. Mexican red-bellied squirrel (*Sciurus aureogaster*) population surveys by the NPS and Univ. of Arizona, 2005–2007 (data from NPS and Univ. Arizona).

Mayan Cichlid

Figure 9-24. Mayan cichlid (*Cichlasoma urophthalmus*) (Photo by Paul Shafland, FWC).

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 9-24**). Since its discovery in Florida Bay in the early 1980s, this species has expanded its range; it is common throughout the District canal system, freshwater wetlands, and estuarine mangrove swamps of the Southern Estuaries. The Mayan cichlid is an established, introduced species (Loftus, 1987), which is unlikely to be eradicated.

The Mayan cichlid has a varied diet, preying on small fishes and aquatic invertebrates. Given its broad salinity tolerance and aggressive nature, it is likely to continue to impact the Florida Bay and the Southern Estuaries, expanding 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 (Shafland, 1996).

Figure 9-25. Cuban treefrog feeding on native green treefrog (Photo by Brent Anderson, Univ. Florida IFAS Extension UW259).

Cuban Treefrog

The Cuban treefrog (*Osteopilus septentrionalis*) is native to Cuba, the Cayman Islands, and the Bahamas. It was introduced to the Keys as early as 1920, likely as a ship stowaway. It has since invaded the mainland, its invaded range now stretching to the panhandle and the Georgia coast. This species infests a wide range of habitats including pine forests, hardwood hammocks, swamps, homes and buildings, and gardens. Cuban treefrogs vary in color from yellow to green to dark brown, but are frequently a dull or light brown. They are discernable from native treefrogs by distinctive warts, larger eyes and larger size. This species feeds upon snails, millipedes, spiders, a vast array of insects, lizards, and native frogs (**Figure 9-25**). Their propensity to compete with and/or prey upon native frogs has resulted in Cuban treefrogs becoming the most common frog species in Florida. In addition, Cuban treefrogs are a nuisance to plumbing infrastructure and yard aesthetics and can cause power outages due to short circuits. They also exude a sticky secretion that is irritating to the mucous membranes of people. This species spreads rapidly both with prolific reproduction and with frequent hitchhiking on automobiles, boats, and landscape plants. The University of Florida maintains a database logging the spread of this species, although its impacts are still not fully understood.

GREATER EVERGLADES MODULE

The Greater Everglades Module is made up of a mosaic of historically interconnected wetlands. It includes the Water Conservation Areas, Everglades National Park, the Loxahatchee National Wildlife Refuge and the J.W. Corbett/Pal Mar Wildlife Management Area.

Nonindigenous Plants

Melaleuca

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

Figure 9-26. Controlling melaleuca (Photo by Albert Mayfield, FDACS).

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. Melaleuca populations in the northeasternmost area of the ENP are also decreasing. Operational work is currently focused on methodically treating the remaining 7,000 gross infested acres (**Figure 9-26**). Unfortunately, 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. With technical and fiscal support from the District and Florida DEP, the Refuge has recently seen results from its efforts to control melaleuca. Many acres of infested lands in the southern Refuge have been treated (**Figure 9-27**), and efforts to control northern Refuge infestations are underway (G. Martin, USFWS, personal communication). See the *Big Cypress Module* (page 9-54) for information on the biological control program of melaleuca.

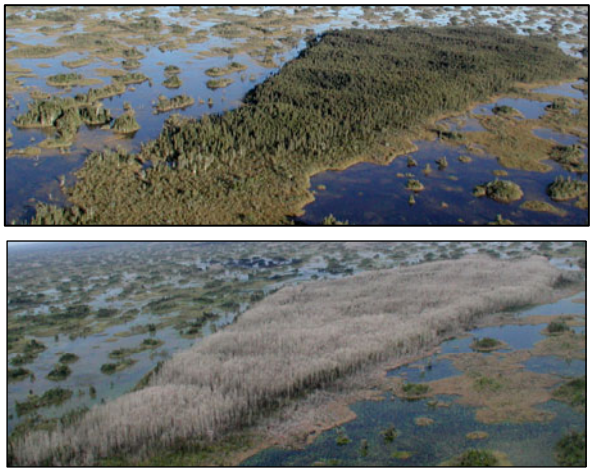


Figure 9-27. Pre (above) and post views following aerial melaleuca treatments in the Refuge (Photos by SFWMD).

Old World Climbing Fern

Perhaps no other individual plant species poses a greater threat to the Everglades than Old World climbing fern (*Lygodium* spp.). As depicted in **Figure 9-28**, 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 9-28. Old World climbing fern (Photo by Peggy Greb, USDA-ARS).

ENP staff first discovered hundreds of acres of Old World climbing fern on the Park's western edge in 1999; by 2000 it had spread to thousands of acres (T. Pernas, NPS, personal communication), and District field biologists observed small strands in WCA-3 beginning in 2001 (M. Korvela, SFWMD, personal communication). This species could potentially overtake most of the southern peninsula of Florida (Lott et al., 2003; Volin et al., 2004). 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 biannual SRF surveys documenting the rapid spread of 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, 2006).

Due to the remoteness of the Old World climbing fern populations in the Park, Park staff is limited to using helicopters to conduct aerial treatments, evaluate non-target damage, and assess the effectiveness of these treatments. District contract crews treat this species as they encounter it 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 into an operational phase of tree island surveys, which increases survey frequency and improves coordination between surveyors and vegetation management contractors. Once field biologists discover populations, the coordinates and infestation characteristics are transferred to the District's Vegetation Management Division, which then dispatches control contractors.

Figure 9-29. Pre (above) and post views showing effects of aerial herbicide treatment on *Lygodium* infested tree islands in the Refuge (Photo by L. Rodgers, SFWMD).

The USFWS has had resource management responsibilities for WCA-1 since 1951 when it was designated as the Arthur R. Marshall Loxahatchee National Wildlife Refuge. Since 2002, the Refuge has worked to implement an integrated plan for the control of its worst invasive plants — Old World climbing fern, melaleuca, Brazilian pepper,

and Australian pine. The Refuge plan utilized a containment strategy — working from the less-infested areas in the southern Refuge towards the dense infestations in the north. By 2005, it was clear that the Refuge had insufficient resources to implement the containment strategy quickly enough to curb the explosive spread of Old World climbing fern that was infesting nearly all tree islands in the northern half.

Recognizing that the biological integrity of the Refuge was quickly being lost to these aggressive weeds, the Refuge, the District and FDEP came together in early 2007 to implement an accelerated invasive plant management plan. Utilizing financial resources from the FDEP, and technical and logistical resources from the District and Refuge staff, this collaborative effort aims to complete a first-pass treatment of all invasive plant infestations within the Refuge by September 2008. Invasive plant managers from each of the three agencies drafted the plan in early March 2007, and began implementing the work later that month. Dense infestations of invasive plants were treated aerially (primarily melaleuca and Old World climbing fern, **Figures 9-27** and **9-29**), followed by the deployment of ground crews to treat small or sparse infestations where non-target damage from aerial treatments would be unacceptable. All aerial treatments of dense infestations were completed on May 20, 2007, with an estimated 11,800 combined acres of melaleuca and Old World climbing fern treated. Ground-based efforts were initiated in mid-March 2007, but low water levels prevented access to the Refuge interior by early April. Surface water levels returned to navigable levels in mid-July. Roughly 7,120 acres of the Refuge have been canvassed by ground applicators.

The success of the plan is dependent upon future resource allocations to follow-up treatments. Given the scale of the problem in the Refuge, invasive-plant managers estimate that an annual allocation of $3 million for the next five years will be necessary to bring the worst weeds within the Refuge under reasonable levels of control.

In addition to the efforts outlined above, several ongoing research initiatives are underway at the Refuge. These include (1) determining the effects of fire as a post-treatment strategy on tree islands, (2) assessing post-fire recruitment of Old World climbing fern, and (3) monitoring the effects of repeated aerial herbicide applications on *Lygodium microphyllum* and native vegetation (B. Miller, USFWS, personal communication).

Figure 9-30. *A. camptozonale* (Photo by Christine Bennett, USDA-ARS).

Land managers statewide agree that biocontrol may be the key to effective long-term regional management of Old World climbing fern. There are only two agents currently permitted for release: the pyralid moth, *Austromusotima camptozonale,* (**Figure 9-30**) and the leaf-gall mite (*Floracarus perrepae*). During 2005, 12,000 adult *A. camptozonale* moths were released in South Florida, but these failed to establish. 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 (see **Figure 9-5**). Early monitoring indicated that this release method held promise, as the caterpillars had survived and reproduced at half of the release sites (R. Pemberton, USDA-ARS, personal communication). Approval of the federal release permit for *F. perrepae* was issued in 2007, with initial releases planned for early 2008.

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). In addition to the agents mentioned above, numerous other insects are being studied both in the field abroad and in the laboratory for their biology and host specificity. These include the sawfly, *Neostrombocerus albicomus*, the noctuid moth, *Callopistria* spp., the pyralid moth, *Lygomusotima stria,* the flea beetle, *Manobia* spp., and the stem-boring moths, *Siamusotima aranea*, *Ambia* spp. "S", and *Ambia* spp. "H".

Brazilian pepper

Brazilian pepper (*Schinus terebinthifolius)* is common on levees and tree islands throughout the Greater Everglades. Unlike melaleuca, operational control for this species is not systematic in approach, with the exception of the ENP's "Hole in the Donut" (HID) Project, where impenetrable monocultures of Brazilian pepper are 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.

ENP staff observed large areas of dead or dying Brazilian pepper along the western edge of the Park after Hurricanes Katrina/Wilma in late 2005 (**Figure 9-31**). 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 continues to monitor this area.

Figure 9-31. Dead Brazilian pepper along western edge of the ENP following 2005 hurricanes (Photo by Tony Pernas, NPS).

There are two haplotypes of Brazilian pepper found in Florida, with extensive hybridization having occurred between the two (Williams et al., 2005). This further complicates the task of identifying suitable biocontrol agents because those agents (with suitable host specificity) that attack one haplotype are unlikely to attack the other, nor the hybrids of the two (G. Wheeler, USDA-ARS, personal communication). Extensive field explorations conducted in Argentina and Brazil have resulted in the identification of multiple potential agents. Two species (*Pseudophilothrips ichini* and *Heteroperreyia hubrichi)* have undergone extensive testing. In May 2007, TAG recommended the release of the thrips *P. ichini*. The University of Florida will prepare the Environmental and Biological Assessments in June 2007. Additional promising insects (some naturally occurring in Florida) are currently being tested for host specificity and effectiveness. Expanded field explorations are also planned for Brazil in the near future, pending the acquisition of collecting permits.

Figure 9-32. Australian pine (Photo by Amy Ferriter, Boise State University).

Australian pine

Australian pine (*Casuarina* spp.) grows quickly; is salt tolerant; fixes nitrogen; readily colonizes rocky coasts, dunes, sandbars, islands; and invades far-inland, moist habitats (Morton, 1980) (**Figure 9-32**). 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 is still common along District levee berms, in the District's southern saline glades (C-111 basin), and Biscayne National Park. In the northeastern portion of the ENP there no longer exist large, dense stands of Australian pine. Treatment efforts are focused on removing the remaining scattered stands with most areas now at maintenance levels. The coastal mainland and coastal islands are routinely colonized by Australian pine — but are also under maintenance control. The largest remaining populations found in the ENP exist in the saline glades in the southern region. Systematic treatment efforts have not yet been conducted in this area. The seeds are windblown, carried by birds, and probably drift throughout the Everglades via canals.

Australian pine threatens key habitat for the endangered Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis),* which needs the short-hydroperiod marl prairies of the southeastern Everglades to nest. To restore sparrow nesting habitat invaded by Australian pine, the ENP and USACE began a ground-based, systematic program along the eastern edge of the Park that is still ongoing. Australian pine in this region is currently at maintenance levels.

Shoebutton ardisia

Figure 9-33. Shoebutton ardisia *(Ardisia elliptica)* (Photo by Amy Ferriter, Boise State Univ.).

Shoebutton ardisia (*Ardisia elliptica*) is a shade-loving shrub that was originally reported in the HID (**Figure 9-33**). 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	2007 STATUS		1-2 YEAR PROGNOSIS	
GREATER EVERGLADES MODULE (Results in this row reflect module-level questions, not species-level questions)	Y	Old World climbing fern and Brazilian pepper still widespread, serious threats; 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 efficacy	Y	Good control of melaleuca and Australian pine; biocontrol for melaleuca effective; first biocontrol releases for Old World climbing fern, new biocontrol for Brazilian pepper soon; other species still localized, no new serious invaders detected	Y
Shoebutton Ardisia (*Ardisia elliptica*)	Y R	Was localized problem in Park but now infests tree islands and bayheads throughout WCAs; difficult to detect and not part of systematic monitoring program	Y R	No significant control program, no biocontrol effort; now found in WCA tree islands and bay-heads, posing a serious threat; difficult to monitor remotely; resembles native species, detection and control difficult	R
Australian Pine (*Casuarina* spp.)	Y	Still common in northeast portions of Park, on District canal banks and throughout South Dade Wetlands	Y	Chemical control effective; most natural areas clear with exception of northeast part of Park and South Dade Wetlands where significant control still needed; biocontrol research under way	Y
Old World Climbing Fern (*Lygodium microphyllum*)	R	Serious invader, rapidly spreading; invades most habitats and very destructive; long-term management difficult given variety of habitats it infests	R	No effective control yet, but biocontrol release made with additional release expected in 2007; chemical control studies continuing	R Y
Melaleuca (*Melaleuca quinquenervia*)	Y	Large portions of module under maintenance control and biocontrols showing promising results; however, some areas in east Everglades, Refuge, and Corbett WMA still need significant work	Y	Chemical control effective on most public lands; biocontrol agents effective and additional spread of existing agents and new agents expected in 2007 and 2008	Y G
Brazilian Pepper (*Schinus terebinthifolius*)	R	Rapidly spreading; invades most habitats, very destructive; chemical control ineffective in reducing overall spread; the Park (particularly mangroves) seriously impacted; no coordinated control program	R	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	R

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 underway. 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 and 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 9-7**, 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 9-34**).

Figure 9-34. Lobate lac scale (*Paratachardina* spp.*)* (Photo by F.W. Howard, Univ. Florida).

This insect is already seriously affecting 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. Recent observations indicate this species is decreasing across South Florida (P. Pratt, USDA-ARS, personal communication). However, 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), all warrant research to understand the distribution of this invasive species and steps to contain its spread.

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. Consequently, biological control agents are seen as the only option for controlling this species.

The USDA-ARS and the University of Florida have carried out extensive overseas searches for natural enemies of lobate lac scale. After several years of searching its native range, the USDA-ARS found populations of the scale in southern India in August 2005 (R. Pemberton, USDA-ARS, personal communication). Multiple Indian specimens (*Paratachardina lobata*) were shipped to the quarantine facility in Davie in order to develop biological control agents. Though parasitoids reared from the Indian material readily attacked Florida lobate lac scales, they failed to reproduce. Taxonomic analyses were recently conducted to determine the cause of this problem. Results demonstrate that the invasive scale in South Florida is not *P. lobata* and is a new species — also invasive in the Bahamas and Christmas Island. The USDA-ARS is currently

determining the origin of this new species (which appears to be Indonesia), and will begin developing biocontrol agents soon. 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).

Figure 9-35. Tropical almond leaf fed upon by *M. undatus* (Photos by Jeffry Lotz and Susan Halbert).

Sri Lanka Mimic Weevil

Weevils collected from numerous east coast South Florida locations extending from Homestead to Boca Raton were recently identified as Sri Lanka mimic weevil (*Myllocerus undatus*), a native of Sri Lanka and new to the Western Hemisphere (**Figure 9-35**). This weevil has an extremely broad host range; thus far it has been shown to attack 68 different plant species occurring in Florida (M. Thomas, FLDACS-DPI). This fact makes *M. undatus* a particularly frightening invader in South Florida. Unfortunately, very little is known about this weevil in its native range, and so control efforts are likely to prove difficult. A list of species known to be impacted by this insect can be found at www.doacs.state.fl.us/pi/enpp/ento/weevil-pest-alert.html.

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 is 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.). The pythons have also been repeatedly observed on the eastern Park boundary, along canal levees, in the remote mangrove backcountry, and in Big Cypress National Preserve. In recent years (2003–2007), individuals of all size classes have been seen with increasing regularity in and around the ENP. The measured total length for snakes recovered ranges from 2 to 14 feet, including five hatchling-sized animals recovered in the summer 2004 and two hatchlings in 2005. Clutches of eggs (both fertilized and already hatched) have been discovered since 2006.

The non-native Burmese python populations are continuing to expand at an alarming rate in the Greater Everglades, as documented in previous SFERs (**Figure 9-36**). In 2006, approximately 170 pythons were removed from the ENP and surrounding areas, representing a twofold increase from 2005. As of October 2007, 201 pythons were removed.

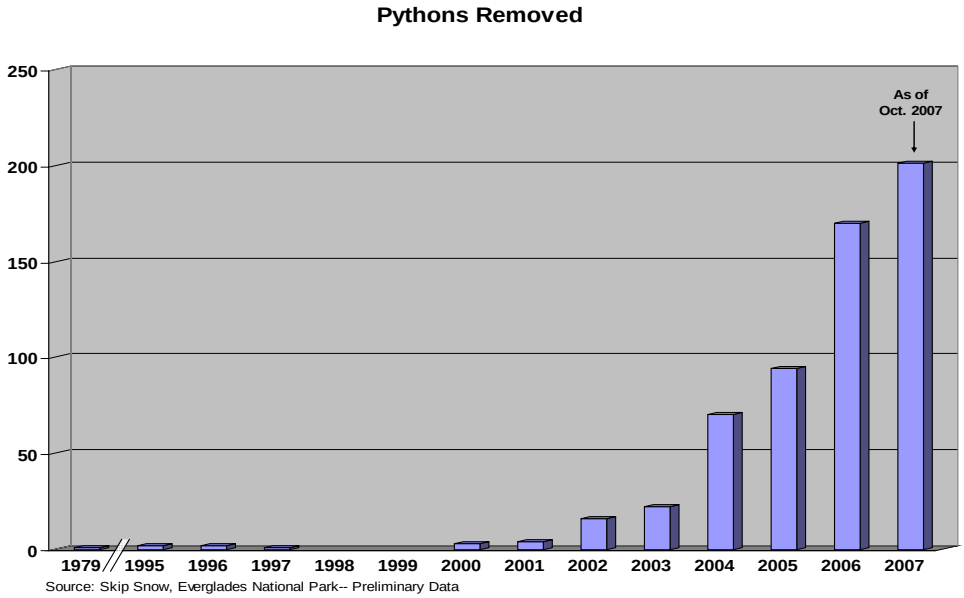


Figure 9-36. Number of Burmese pythons (*Python molurus bivittatus*) removed from the Greater Everglades region between 1979 to October 2007 (unpublished data courtesy of Skip Snow, NPS).

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. Observations of Burmese python/ American alligator conflicts are troubling, particularly because the alligator is widely considered a top predator in the Greater Everglades region (**Figure 9-37**).

The pathway of invasion for the Burmese python is through the pet industry; pythons are still commonly sold in pet stores. Roughly 6,000 Burmese pythons were imported through the Port of Miami between 2003 and 2005. In an attempt to "cork the bottle," the SFWMD Governing Board petitioned the USFWS to list 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 interstate commerce of animals that have been determined to be injurious to human beings or to wildlife resources of the U.S. To date, no decision on this request is made.

At the state level, however, the 2007 Florida Legislature passed Senate Bill 2766 which increases regulations for the capture, possession, transportation, or exhibition of "reptiles of concern." The revised regulations increase the penalties for releasing pythons, anacondas or other nonnative reptiles into the wild. The bill also authorizes the FWC to require annual registration fees for owners of listed reptiles, thereby limiting "impulse buys" that often lead to unlawful

Figure 9-37. Alligator consuming Burmese python in the ENP (Photo by Lori Oberhofer, ENP).

releases when large snakes become difficult to care for. In addition, the measure also increases the $1,000 bond required to 'exhibit' reptiles or certain wildlife to $10,000.

A multi-agency workshop convened in March 2007 to discuss the current Florida distribution, reproductive biology, and ecological impacts of the Burmese python. Scientists and regulators from a number of state and federal agencies (FWC, SFWMD, USFWS, USGS, USNPS) discussed the next steps necessary, on technical and policy fronts, to manage this invasive animal. The USFWS, USGS and NPS agreed to move forward with a risk assessment to determine the possible ecological impacts and potential expansion range of the Burmese python. This assessment and an economic impact analysis are necessary for USFWS to complete their review of the Burmese python under the Lacey Act. The workshop attendees also agreed to work collaboratively toward other priorities including development and implementation of capture technologies, improvements in communication (e.g. python listserve), improvements in funding through cross-cut budget initiatives, and identification of public education programs.

Island Applesnail (previously Channeled Applesnail)

Recent (2005) field observations by the Florida International University and ENP scientists indicate that other species such as the island applesnail (previously channeled applesnail, see the *Kissimmee Basin Module* section, page 9-86 for species-specific information) are present in the Greater Everglades Module. These snails and their 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, page 9-31, 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 recent years and many canals and levees in and around the Greater Everglades are now peppered with green iguana burrows. This extensive burrowing presents 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 9-38**). Burrows 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. Recent evaluations demonstrate that moderate densities of green iguanas have definite economic impacts on bank integrity and maintenance costs (Sementelli et al., in review).

Figure 9-38. Green iguana burrows (Photo by 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 their base 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 nonnative 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. It shares communal roosting and nesting areas with native wading and water birds, and has life cycle requirements similar to those of egrets, herons, and wood storks in Florida (Rodgers et al., 1996). The diet consists primarily of mollusks, frogs, and aquatic insects, but this species has been reported to prey upon the eggs and young of other wading birds.

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.

Figure 9-39. Adult sacred ibis and chick observed in Loxahatchee NWR (Photo by Garth Herring, FAU).

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.

During the 2007 wading bird breeding season, Florida Atlantic University researcher Garth Herring observed three sacred ibis nests (**Figure 9-39**) in an active wading bird rookery in the Refuge. At least three nesting adults were observed, though biologists were unable to dispatch them due to accessibility issues. Two nests hatched chicks (one and two chicks respectively), and the third had a clutch of three eggs. The three chicks were collected, and the nest with the eggs was destroyed (G. Herring, FAU, personal communication).

An adult sacred ibis was seen foraging near the Solid Waste Authority North County Landfill along the Florida Turnpike (Sarah Barrett, Palm Beach County ERM, personal communication), though it is unknown where the adults at the Refuge were foraging. Preliminary assessment of the three collected chicks suggests that their diet was most likely from waste management facilities, with unidentified meat comprising over 30 percent. To a lesser extent, crayfish and other invertebrates were also eaten. Over 25 percent of the chicks' diet consisted of non-food items: glass, metal pieces, and plastic. Most importantly, all sacred ibis chicks appeared to be in excellent condition.

Purple Swamphen

The purple swamphen (*Porphyrio porphyrio*) is a rail native to Australia, Europe, Africa, and Asia. 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 species has huge feet, pinkish legs and a characteristic bright red bill and red frontal shield that extend onto the crown. They may have escaped from Miami Metrozoo after Hurricane Andrew in 1992 or from avicultural hobbyists (Pranty et al., 2000). Little is known about purple swamphens in Florida; most information comes from overseas research. By nature, purple swamphens are communal. Multiple females share incubation and parental nurturing duties. Often more than one female lays eggs (3–6 each) in one nest. Purple swamphens feed on shoots and reeds, invertebrates, and small mollusks. However, they have also been reported to feed on the eggs and young of waterfowl.

The original South Florida purple swamphen population is believed to have established in Pembroke Pines in 1996 (S. Hardin, FWC, personal communication). This population has been reported on varied bird-watching web sites, including the Broward County Audubon Society. In recent years, purple swamphens have been sighted in WCAs and adjacent to the Greater Everglades Module in STA-1 West (STA-1W), STA-1E, STA-5, and STA 3/4 (**Figure 9-40**). 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. Efforts to locate swamphens in Loxahatchee Refuge and South Florida State Parks have not been successful (E. Donlan, SFWMD and H.T. Smith, personal communications).

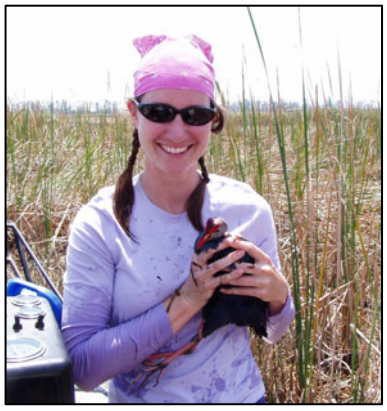


Figure 9-40. Ellen Donlan (SFWMD) and purple swamphen (Photo by SFWMD).

The purple swamphen seems to prefer the edges of manmade ponds, lakes, or impoundments, including storm treatment areas (STAs), and often uses levees and dikes for feeding and travel to, from, and within the STAs. 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. Consequently, a removal program is underway. Most state and federal agencies view this non-native bird species as a potential threat to native water bird populations. Control of purple swamphens in the Refuge is coordinated through the USFWS Region 4 Invasive Species Strike Team; no swamphens have been observed in recent inspections. The FWC has conducted a survey to document the absence/presence of this species on Florida's conservation lands, also producing a combination identification/fact sheet as a component of the initial survey package. Removal efforts have since begun, resulting in the removal of 600 individuals thus far.

Purple swamphens are under consideration 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 has yet to become effective. USFWS staff, aware that this species is not native to North America, 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 Asian swamp eel (*Monopterus albus*, **Figure 9-41**) were discovered in Florida: 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). It is believed that wild populations in Florida originated as escapes or releases associated with aquaculture, the pet trade, or live food markets.

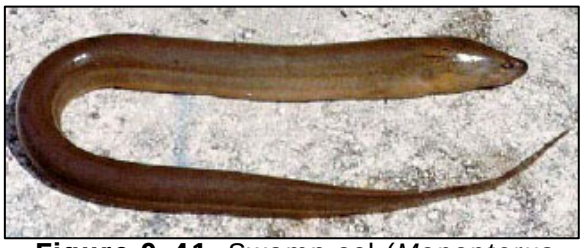


Figure 9-41. Swamp eel (*Monopterus albus)*(Photo Jim Williams USGS).

These fish are now 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 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.

Figure 9-42. Electrofishing for swamp eels (Photo John Galvez, USFWS).

Since the discovery of nonnative eels in Florida, USGS scientists have studied aspects of swamp eel biology, including changes in distribution and abundance, diet and reproduction, genetics, environmental tolerances, and ecological effects. Given the abundance and wide distribution of swamp eels in Florida's canals, elimination is probably impossible; however, various control methods are currently under investigation. The USFWS conducted a swamp eel removal project utilizing electrofishing techniques in 2006 (**Figure 9-42**). In addition to the Asian swamp eel, the project also focused on removing exotic spotfinned spiny eels *(Macrognathus siamensis*, aka peacock eels) which occur at bottom depths in slower moving water than Asian swamp eels. The project was conducted on C-111 and C-113 canals and resulted in an average 53 percent efficiency with the removal of 905 Asian swamp eels and 82 peacock eels (J. Galvez, USFWS, personal communication). This project continues during the summer of 2007.

Other Nonindigenous Fish

At least 32 nonindigenous fish species have become established in South Florida through anthropogenic introductions (**Table 9-2**), 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 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 believed 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 about nonindigenous fish species and their impacts in the marsh.

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 during a study in 2005. To determine establishment, their 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 greater than or equal to that within 1 km. The nonnative 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 3 to 4 km from the canal, suggesting it is established in the marsh. This species was caught only 3º C above its stated minimum lethal temperature (P. Shafland, personal communication). The Mayan cichlid (*C. urophthalmus*) was the eighth most abundant fish of the 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. It was captured up to 2º C above its stated minimum lethal temperature (P. Shafland, personal communication).

A juvenile brown hoplo (*Hoplosternum littorale*) was captured 2 to 3 km from the canal. While a single individual (**Figure 9-43**) 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. 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.

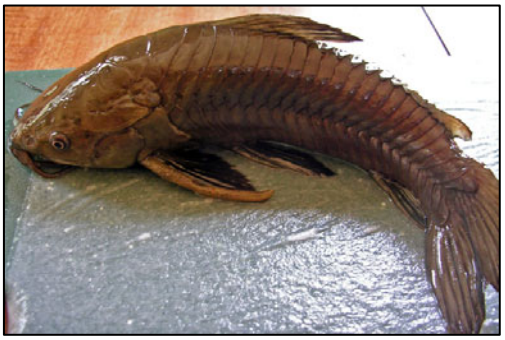


Figure 9-43. Brown hoplo (*Hoplosternum littorale*) (Photo by Joe Guthrie, courtesy Archbold Biological Station).

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 examining the community structure of fishes and invertebrates along transects originating at canals in the central and southern Everglades 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 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

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.

Nonindigenous Plants

The Seminole Tribe of Florida has completed an Invasive Species Management Plan, along with a Tribal Invasive Species database for internal tracking of invasive species populations. The Invasive Species Management Plan has aided in prioritizing target species such as melaleuca, Brazilian Pepper, *Lygodium*, and Tropical Soda Apple for treatment. The Seminole Tribe of Florida has also funded invasive species research on *Lygodium*. Melaleuca is effectively controlled on most public 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 having marked impacts to the melaleuca in this area.

Figure 9-44. Melaleuca weevil (Photo by Stephen Ausmus, USDA-ARS).

The first melaleuca biocontrol agent, a melaleuca weevil (*Oxyops vitiosa*), was introduced in 1997 and subsequently established on melaleuca throughout the region **Figure 9-44**. Recent studies by USDA entomologists have determined that weevil attacks suppress reproduction by 80 percent. The few trees that do reproduce have smaller flowers that contain fewer seeds. The second agent, the melaleuca psyllid (*Boreioglycaspis melaleucae*), was released in 2002. 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 (**Figure 9-45)**, 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 (**Figure 9-4**). A coordinated strategy concentrated 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 re-invasion of managed sites and halt continued melaleuca spread 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. Statewide, *O. vitiosa* and *B. melaleucae* have dispersed from their original release sites by 35 and 60 percent, respectively; statewide foliage destruction ratings are estimated at ~30 percent for both species, though this number varies by site (P. Pratt, USDA-ARS, unpublished data).

Figure 9-45. Melaleuca biocontrol weevil damage (top branch) (Photo by Peggy Greb, USDA-ARS).

The bud-gall fly, *Fergusonina turneri,* (and its obligate mutualistic nematode *Fergusobia quinquenerviae*) was the third insect species to be distributed against melaleuca. The USDA Animal and Plant Health Inspection Service (USDA-APHIS) issued a permit for the release of

F. turneri (+ F. quinquenerviae), and releases were made at six sites in South Florida in 2005. The original releases were not successful, though releases made in winter 2007 have resulted in the preliminary establishment of these mutualistic species. It will be necessary for these biocontrol agents to make it through the 2007 hurricane season before this release can be considered completely successful. Additional releases are planned for the near future in order to expand their distribution in South Florida (P. Pratt, USDA-ARS, personal communication). In addition to the above-mentioned biocontrol agents that have already been released, the melaleuca biocontrol program will soon be strengthened by the addition of the gall midge, *Laphlodiplosis trifida,* and the weevil, *Haplomyx multicolor*. The petition for release was submitted to the Technical Advisory Group in May 2007. *H. multicolor* is in quarantine with rearing techniques currently being perfected for this species.

Old World climbing fern, as in the Greater Everglades Module, poses a serious threat to restoration initiatives in this module. The District launched the first 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 continuously found. BCNP employs a "find and treat" contractor 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 9-46**). This species was previously thought to occur mostly north of Lake Okeechobee, and its possible invasion into southern Florida is of concern.

Figure 9-46. Japanese climbing fern (Photo by Chris Evans, River to River CWMA).

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.

Figure 9-47. Crested floating heart (*Nymphoides cristata*) (Photo by NPS).

Crested floating heart, *Nympmhoides cristata* (**Figure 9-47**) is an aquatic exotic species of Asian origin that escaped ornamental usage in 1996 and invaded south and central Florida. The majority of this plant's biomass is beneath the water surface. Numerous control efforts have been initiated against this species. However, it has proven difficult to control because treated leaves die back but are able to regenerate from stems in the substrate. Priority plant species for the Big Cypress Module are in **Table 9-7**.

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

	2006 STATUS	2007 STATUS		1-2 YEAR PROGNOSIS	
BIG CYPRESS MODULE (Results in this row reflect module-level questions, not species-level questions)	R	Exotic populations decreasing significantly on publicly owned areas; occasional reductions on privately held areas	R Y	Good control of melaleuca and Australian pine ; 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 documented by NPS	Y
Australian Pine (*Casuarina* spp.)	Y G	Remnant populations exist along canals and a few natural sites, but decreasing overall	Y G	Chemical control effective; most natural areas clear or clearable with modest effort; biocontrol research under way	G
Air Potato (*Dioscorea bulbifera*)	Y	Not in Indicator systematic monitoring program; mostly occurs in developed areas	Y	No coordinated control programs in the module; biocontrol effort under way	Y
Cogon Grass (*Imperata cylindrica*)	Y	Mainly distributed along roadsides and levees; not part of a systematic monitoring program; currently not severe	Y	Treated as encountered in BCNP; no significant coordinated control efforts; no biocontrol effort under way; potential serious invader	Y R
Old World Climbing Fern (*Lygodium microphyllum*)	R Y	Serious invader, rapid spread; invades most habitats and very destructive; chemical control so far effective due to localized populations but spreads rapidly	Y	Module-wide controls not coordinated; biocontrol release made with additional release expected 2007; chemical control studies continuing	Y G
Japanese Climbing Fern (*Lygodium japonicum*)	Y R	Southernmost extent of species so far; little is known about its impacts in the module	Y	Populations have been controlled in the module so far; however, distribution and spread are unknown and no biological control is program under way	Y R
Melaleuca (*Melaleuca quinquenervia*)	Y G	Coordinated efforts to control species but is still abundant on private lands; biocontrol agents reducing cover, spread throughout module	Y G	Chemical control effective on most public lands; biocontrol agents effective and additional spread of existing agents and new agents expected in 2007-2008	G
Crested Floating Heart (*Nymphoides cristata*)		Not new to module but new to table; difficult to control; not part of systematic monitoring program	Y R	Potential to spread widely; past and current control efforts not successful	R
Downy Rose-myrtle (*Rhodomyrtus tomentosa*)	Y	Localized in coastal uplands; not included in Indicator systematic monitoring program	Y	No fully coordinated control efforts in module; no biological control programs under way	Y R
Giant Salvinia (*Salvinia molesta*)	Y	Seems to be under control in module; not included in Indicator systematic monitoring program	Y G	Serious aquatic weed in many parts of the world and southern US; module populations do not present a serious threat now due to active control efforts	Y G
Brazilian Pepper (*Schinus terebinthifolius*)	Y	Serious invader with rapid spread; invades most habitats and very destructive; chemical control ineffective in reducing module-wide spread; local control programs effective where resources available	Y	BCNP control program effective; many populations slated for control; new biocontrol agents under study for future release in 2007-2008	Y G
Tropical Soda Apple (*Solanum viarum*)	Y	Little known about spread or distribution; not present in stable, natural areas; not included in Indicator systematic monitoring program	Y	Controlled when encountered in BCNP; distribution poorly understood; introduced in contaminated sod; biological control program under way	Y

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 underway. 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 and 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 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*, **Figure 9-48**) 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 traits that make it successful, including being extremely aggressive, saltwater-tolerant and guarding young from predation. The walking catfish (*Clarias batrachus*) is probably the best-known exotic fish in South Florida since it established in the 1980s and sparked a heated debate about the impact of exotic species. Adaptations that make this fish successful include the ability to emerge from water and move short distances across land, resistance to deoxygenated water, a cosmopolitan diet and the ability to produce many young.

Figure 9-48. African jewelfish (*Hemichromis letourneauxi)* (Photo by Noel Burkhead, USGS).

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 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 (**Figure 9-49**) are omnivorous and their diet varies seasonally. These hogs 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 forbs.

Figure 9-49. Feral hog (*Sus scrofa*) (Photo by Jim Mitchell, Global Invasive Species Database).

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. However, it is widely known 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; Engeman et al., 2003, 2004a, 2004b).

Hogs use their snouts 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 (Engeman et al., 2003, 2004a, 2004b). 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.

A recent damage estimate was conducted for feral swine impacts on Savannas Preserve State Park (see *Northern Estuaries – East Module* page 9-72), based on the monetary amounts wetland regulators have allowed to be spent in mitigation attempts to replace lost wetland resources. Even though the damage estimate was believed conservative by not taking all feral hog impacts into account, the benefit-cost ratio demonstrated that the benefits of feral hog removal are very high compared to the costs of control (Engeman et al., 2004a, 2004b).

Although the ecological impacts caused by this species in Florida are apparent (Engeman 2003, 2004a, 2004b), 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 opportunity, 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.

Figure 9-50. Mexican bromeliad weevil (*Metamasius callizona*) (Photo by Sean McCann, Univ. Florida).

Mexican Bromeliad Weevil

The Mexican bromeliad weevil (*Metamasius callizona*, **Figure 9-50**) was originally introduced to Florida via a shipment of bromeliads imported from Mexico. It was first detected in 1989, and is now found in 22 counties in South Florida (Frank and Thomas, 1994, H. Frank, University of Florida, personal communication). The weevil is now attacking epiphytes in Big Cypress National Preserve, Florida Panther National Wildlife Refuge, and Fakahatchee Strand Preserve State Park.

The weevil attacks native bromeliad species, including 10 that are state-listed as threatened and endangered, and one endemic species. Two of these bromeliad species were listed due to damage done to their populations by the weevil (F.A.C., 2000). 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. 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 9-51. Drs. Howard Frank and Ron Cave release biocontrol flies against *M. callizona* (Photo by Robin Koestoyo, IFAS).

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 potential biocontrol agent (the Honduran fly *Lixadmontia franki*) has been reared and tested for host specificity at the university's quarantine facility in Fort Pierce, Florida. Applications for its release permit were filed with APHIS-PPQ in December, 2006 and approved in May 2007. The first releases were made May 29, 2007, at Lake Rogers Park in Hillsborough County (**Figure 9-51**). Additional releases were made on the Loxahatchee National Wildlife Refuge on July 20, 2007, and October 12, 2007, and on August 29, 2007, at Big Cypress National Preserve. Baited traps will be put out over the course of the following months to determine whether the second generation of flies can find and parasitize the weevil (J. Frank, University of Florida, personal communication). In the meantime, additional field explorations have been and will continue to be conducted in Central America in search of supplementary biocontrol agents. 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.

Yellow Anaconda

The yellow anaconda, *Eunectes notaeus*, is a large snake native to South America that is almost always found near water (**Figure 9-52**). This heavily built animal can exceed 15 feet in length. It is yellow with uniform black oval markings down its body. Females are larger than males and give birth to live young (usually 8 to 30) after five months of gestation. This species was first discovered in South Florida in January 2007, likely introduced via the pet trade. Yellow anacondas feed primarily on small animals including heron, egrets, rodents, fish, and ducks. This diet makes their presence in the Everglades region particularly worrisome.

Figure 9-52. Yellow anaconda (*Eunectes notaeus*) (Photo by NPS).

Northern Estuaries – West Module

Figure 9-53. Invasive Species Strike Team and trailer (Photo by Bill Thomas, USFWS).

The Northern Estauries – West Module is made up of the coastal estuaries of the west coast. It includes the Caloosahatchee estuary and the coastal communities and islands.

The Region 4 Invasive Species Strike Team is a two-person team formed by the USFWS to coordinate invasive exotic plant and animal management activities in South Florida. While its coverage includes all Florida National Wildlife Refuges, the team is based out of this module at the "Ding" Darling National Wildlife Refuge. The team conducts rapid response eradication efforts of invasive species and coordinates efforts with land managers across Florida and the southeast U.S. (**Figure 9-53**).

Nonindigenous Plants

Figure 9-54. Fallen Australian pine trees cause extensive structural damage (Photo by SFWMD).

A large portion of the invasive plant control operations in the coastal Caloosahatchee Estuary are 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. There is currently an Island Partnership focusing on Australian pine, Brazilian pepper, java plum, earleaf acacia, and *Sanseveria*. The USFWS provided $1.1 million for exotic species control on Partner lands, regionally, extending through 2007, possibly continuing into 2008 to be fully completed. Work to control Brazilian pepper is ongoing, with several mechanical removal projects under way. Efforts to control well-established Australian pine on the coastal islands of the estuary originally met with public resistance. 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 9-54**). The tall trees also snapped power lines 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 now embrace the effort to control Australian pine on these coastal islands and other City-owned conservation lands (**Figure 9-55**). Federal Emergency Management Agency (FEMA) funding made broad scale control of this species possible. While Australian pine is at maintenance levels on most public, city, and conservation lands, it can still be found on private lands. The City of Sanibel strongly encourages private property owners to remove Australian pine, but at this time, there is no mandatory removal ordinance.

Figure 9-55. Mechanical control of Australian pine (Photo by Bill Thomas, USFWS).

Climbing cassia (*Senna pendula*) and seaside mahoe (*Thespesia populnea*, **Figure 9-56**) are new additions to the priority plant list for this module. Climbing cassia is encroaching roadsides of I-75 and beginning to appear on Sanibel conservation lands; in the City of Sanibel, on the "Ding" Darling Refuge and Sanibel Captiva Conservation Foundation. Invasive plant contractors in this module are encountering seaside mahoe with regularity on Sanibel and satellite coastal island refuges.

Figure 9-56. Seaside mahoe (*Thespesia populnea*) (Photo by Amy Richard, Univ. Florida).

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 Caloosahatchee River. 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 (see also the *Lake Okeechobee Module* section).

Figure 9-57. Guinea grass (*Panicum maximum*) (Photo by Vic Ramey, Univ. Florida).

Guinea grass (**Figure 9-57**) has been successfully controlled on "Ding" Darling Refuge. However, on Sanibel, it is being spread through routine mowing operations that use heavy equipment contaminated with the plant. Contracting mowing operations to private companies is further accelerating the problem, as well as sharing equipment among Island Partner groups; thus moving seeds from one conservation parcel to another.

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	2007 STATUS		1-2 YEAR PROGNOSIS	
NORTHERN ESTUARIES – WEST MODULE (Results in row reflect module-level questions, not species-level questions)	R Y	Much progress made with melaleuca, Brazilian pepper, Australian pine; other species gaining foothold and most not included in any Indicator monitoring program; little known about large majority of invaders and not able to assess their status in an objective or repetitive way to study trends	R Y	Some control of melaleuca; first biocontrol releases for Old World climbing fern; new biocontrol for Brazilian pepper under study; other species still localized but numerous; potentially serious invaders exist for which little is known about biology or spread	Y R
Australian Pine (*Casuarina* spp.)	Y G	Populations exist along roadsides, canals, around agricultural fields ,and a few natural sites, removal programs in place, considered effective	Y G	Chemical control effective, many natural areas clear or clearable with modest effort; biocontrol research under way	G
Air Potato (*Dioscorea bulbifera*)	Y	Little known about spread/dist; not included in Indicator systematic monitoring program	Y	Control efforts not coordinated; biocontrol effort under way	Y R
West Indian Marsh Grass (*Hymenachne amplexicaulis*)	Y	Distributed in wet areas; not included in Indicator systematic monitoring program	Y	Species problematic because it is difficult to control with herbicides in wetlands; no biocontrol	Y R
Cogon Grass (*Imperata cylindrica*)	Y	Little known about spread/dist; not included in Indicator systematic monitoring program	Y	Species problematic because it is difficult to control with herbicides; no biocontrol effort under way	Y R
Old World Climbing Fern (*Lygodium microphyllum*)	R	Serious invader; rapid spread throughout module; invades most habitats; very destructive	R	No significant effective controls; biocontrol release made; more expected in 2007; chemical control studies continuing	R Y
Melaleuca (*Melaleuca quinquenervia*)	Y G	Still abundant on private lands but biocontrol reducing cover and spread, reduction of dense monocultures attributed to land clearing (i.e. development)	Y G	Chemical control effective on most public lands; biocontrol agents reducing rate of spread; new agents expected 2007/2008; continuous effort required	Y G
Burma Reed (*Neyraudia reynaudiana*)	Y	Little know about spread or distribution in the module; not included in Indicator systematic monitoring program	Y	Species problematic because difficult to control with herbicides; no biocontrol effort under way	Y R
Guinea Grass (*Panicum maximum*)	Y	Little known about distribution; spread accelerated by mowing; not included in indicator systematic monitoring program	Y	Species problematic because difficult to control with herbicides; no biocontrol effort under way	Y R
Itch Grass (*Rottboellia cochinchinensis*)	Y	Spreading in wetland areas; not included in Indicator systematic monitoring program	Y	Difficult to control with herbicides in wetlands; in tropical America, a serious invader often leading to land abandonment	Y R
Half-flower (*Scaevola taccada*)	Y	Coastal species; spreading but easy to detect; not included in Indicator systematic monitoring program	Y	Control efforts effective where implemented; seed source from surrounding ornamental plantings makes long-term control necessary; biocontrol prospects limited due to native *Scaevola*	Y R
Brazilian Pepper (*Schinus terebinthifolius*)	Y	Serious invader with rapid spread throughout module; invades most habitats and is very destructive; local control programs are proving effective where resources available	R Y	Control programs in module effective in natural areas where management programs under way; new biocontrol agents under study for future release; spreads easily so constant control needed	R Y

Table 9-8. Continued

Climbing cassia (*Senna pendula*)		New to priority plant list but not to module; covers roadsides and increasing on conservation areas; not included in Indicator systematic monitoring program	Y	Populations increasing throughout module; potential to spread rapidly; no coordinated control efforts	Y R
Seaside Mahoe (*Thespesia populnea*)		New to priority plant list but not module; increasing on Sanibel and coastal island refuges; not in Indicator monitoring program	Y	Populations increasing here; potential to spread rapidly; no coordinated control efforts	Y R
Para grass (*Urochloa mutica*)	Y	Distributed in wetland and disturbed areas, un-maintained canal and roadside ditches; not included in Indicator systematic monitoring program	Y	No coordinated control efforts in place for the module; no biocontrol effort under way although local populations can be eliminated	Y R

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 underway. 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 and 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

Figure 9-58. Guayas cichlid (Photo by Ernst Sosnas, AquaNet).

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. In January 2007, a new species of nonindigenous fish, Guayas cichlid (*Cichlasoma festae,* **Figure 9-58**), was discovered in a freshwater lake in a subdivision in Lee County (USGS-NAS Alert, January 2007). The freshwater lake is connected directly to the Caloosahatchee River, raising fear among agencies that this species has the potential to become established in the Caloosahatchee drainage system and associated estuaries. Cichlids, in general, have the ability to tolerate a wide range of water salinities.

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*) was first noted in Cape Coral in 1990 and has rapidly colonized the region. The source of the Cape Coral population is undocumented, but researchers believe that several monitor lizards were either intentionally or accidentally introduced. This agile climber and swimmer has since dispersed to nearby islands such as Pine Island (G.S. Player, FWS, personnel communication), Sanibel Island (Brad Smith, SCCF, personnel communication) and the mainland, and has recently been observed in the sawgrass prairies in extreme southern Miami-Dade County (K. Krysko, Florida Museum of Natural History, personal communication; **Figure 9-59**). A number of individuals have been observed in a lake north of Orlando, and also along a canal in Palm Beach County, indicating that additional populations may be established around the state (T. Campbell, Univ. Tampa, personal communication).

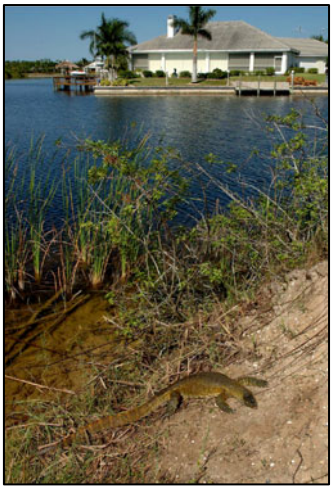


Figure 9-59. Nile monitor lizard (Photo by Todd Campbell, Univ. Tampa).

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 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 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, birds, eggs, and small mammals. Amphibians and reptiles, and the eggs of both, comprise a significant portion of their diets, and as a result, the impacts on native amphibians and reptiles may be significant.

Researchers fear that it is only a matter of time before the species begins to breed in other estuarine and freshwater swamps, marsh edges, riverbanks, 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 initiated an aggressive trapping program on Cape Coral (**Figure 9-60**). Unfortunately, funding for this program ran out in 2005, with only one part-time trapper currently employed. The Cape Coral population is now estimated at well over 1,000 individuals of various size classes, and is increasing. Cape Coral has the largest population of burrowing owls in Florida, and a Nile monitor lizard was once observed killing a young owl. Monitors could also impact populations of other listed species in this region (Enge et al., 2004).

Figure 9-60. Researcher Todd Campbell with Nile monitor (Photo by T. Campbell, Univ. Tampa).

One of the biggest concerns is an impact to birds on the "Ding" Darling Refuge on Sanibel Island, one of the most important bird sanctuaries in the state. Given the lack of funding to eradicate Nile monitors from Cape Coral and the surrounding area, land managers are trying to obtain funding to at least keep them off Sanibel Island (T. Campbell, Univ. Tampa, personal communication). A few sightings were regularly reported during 2005/2006 from the Sanibel Bayous, an exclusive community located due west of the "Ding" Darling Refuge and other Partner conservation lands. A flier was produced and distributed with contact information to report Sanibel sightings in an effort to rapidly respond and remove the animal(s). One individual animal was harvested 'under the radar' on Sanibel (Brad Smith, SCCF, personnel communication) since 2005, and a second individual was spotted on the island in June 2007, indicating there might be an established population.

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, information that is critical to 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 9-61**) and Mexican spiny-tailed iguana (*C. pectinata*) are large, primarily herbivorous reptiles that are established in South Florida. The spiny-tails have a more aggressive nature than green iguanas (*I. iguana*) and, although also introduced by the pet trade, are much less suitable as pets than the green iguana.

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 are more carnivorous than adults.

Figure 9-61. Black spiny-tailed iguana (*Ctenosaura similis*) (Photo by Ellen Donlan, SFWMD).

Black spiny-tailed iguanas were introduced to the 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). On the east coast, they occur in Key Biscayne and elsewhere in Miami-Dade and Broward counties (Townsend, 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, spiny-tailed iguana bites and claws can cause serious lacerations, and tail slaps can deliver powerful blows.

Native predators control young iguanas to some degree. Raccoons dig up nests while raptors, alligators, wading birds and snakes may possibly 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, Lee County commissioners recently voted unanimously to devote $180,000 toward the extermination of an estimated 20,000 iguanas purported to infest Boca Grande (at www.News-press.com, accessed April 2007). Lee County has also developed a brochure to educate tourists and residents about discouraging iguanas and effecting their breeding habits. The brochure, "Do Not Feed the Iguanas", shows photographs and facts about iguanas, including ways to stress them enough to reduce their population.

Green Mussel

The green mussel (*Perna viridis*) was first discovered in 1999 by maintenance divers inspecting a jammed intake valve at the Big Bend power plant 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 9-62**).

Figure 9-62. Green mussel (*Perna viridis*) (Photo by Patrick Baker, Univ. 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). In 2002, green mussels were confirmed in Pensacola Bay in the Florida Panhandle, in the Ten Thousand Island region, southwest Florida, and along the Northeast Florida coast stretching from Daytona Beach to the Georgia-Florida border. It is believed that these populations resulted from either adults being transported on vessel hulls or larvae present in contaminated ballast water (available at www.greenmussel.ifas.ufl.edu). The 1–2 year prognosis is bleak, as experts believe that this invasive species will continue to spread throughout Florida's waters.

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). Densities can be very high in these areas (**Figure 9-63**), and this nonindigenous species is replacing the biomass formerly produced by oysters. Baker (2003) found that the oyster reef matrix and structure remain, but over 90 percent of adult oysters are recently dead (shells still articulated by the ligament).

Figure 9-63. Green mussel infestation in Tampa Bay (Photo by Marc Blouin, USGS).

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 oyster beds 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 MODULE

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 mainly include coastal species. The majority of the work is done by the FDEP, local governments, and volunteer groups.

Nonindigenous Plants

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 Australian pine and Brazilian pepper. 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 Australian pine and Brazilian pepper. East coast populations of mangroves are near their northernmost range in this module and are impacted by periodic freezes. Because damaged mangrove communities reestablish slowly, they can be replaced by these faster-growing exotic species.

Figure 9-64. Air potato *(Dioscorea bulbifera)* (Photo by James Miller, USDA Forest Service).

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; 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 this 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 9-64**). A biological control program has been initiated against air potato, fortunately, with numerous promising species resulting from field explorations for potential candidates (R. Pemberton, USDA-ARS). Tropical soda apple (*Solanum viarum*) is found throughout improved and unimproved pastures within this module.

Downy rose myrtle (*Rhodomyrtus tomentosa,* **Figure 9-65**) is a landscape shrub of Asian origin that now occurs throughout South Florida, overtaking native pinelands' understory. This fast-growing shrub spreads more prolifically than shoebutton ardisia and other nonindigenous plant species currently of concern. Consequently, this species was added to the priority plant list in 2007. Little is known about its biology and it is challenging to control. Recent herbicide trials using Vanquish show promise since the chemical is effective and demonstrates reasonable selectivity in flatwoods.

Figure 9-65. Downy rose myrtle (Photo by Amy Richard, Univ. Florida).

In addition to the plants discussed above, the occurrence of a nonindigenous marine plant (an alga) in the region's coastal areas concerns many scientists and managers (**Figure 9-66**). 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 as 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 has already been documented as a problem for the reefs (Lapointe & Clark, 1992; Leichter et al., 2003).

Figure 9-66. Caulerpa (*Caulerpa brachypus*) (Photo by FDEP).

Since 1984, a related nonindigenous species, *C. taxifolia* (**Figure 9-67**) 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.

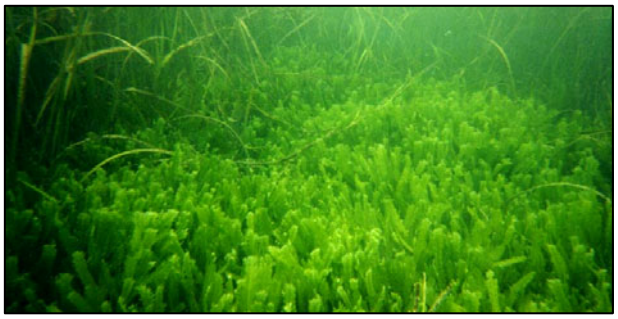


Figure 9-67. *Caulerpa taxifolia* (Photo by Rachel Woodfield, Merkel and Associates, Inc.).

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.

Figure 9-68. Feathered water fern (*Azolla pinnata*) plant and infestation (Photo by Mike Bodle, SFWMD).

In June 2007, feathered water fern, *Azolla pinnata*, was identified in the South Indian River Water Control District drainage canal system in unincorporated Jupiter, Florida. (**Figure 9-68**). Weir outfalls have undoubtedly released the plant into the drainage canal of the adjacent Florida Turnpike. This constitutes the plant's first Florida report, and the only previous North American report is from North Carolina (available at http://plants.usda.gov/java/profile?symbol=AZPI). This Old World native is listed as a Federal Noxious Weed, and the FDEP and the District are mounting containment treatments to try to restrict the population from wider establishment.

The priority plant species for the Northern Estuaries – East Module are in **Table 9-9**.

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

	2006 STATUS	2007 STATUS		1-2 YEAR PROGNOSIS	
NORTHERN ESTUARIES MODULE – EAST COAST (Results in row reflect module-level questions, not species-level questions)	Y	Much progress made with melaleuca, Brazilian pepper and Australian pine, other species increasing, most not included in Indicator monitoring programs; little known about majority of invaders; unable to assess status in repetitive way to determine trends	Y	Good control of melaleuca, Brazilian pepper, and Australian pine; first biocontrol releases for Old World climbing fern; Brazilian pepper biocontrol under study; other species still localized but numerous, potentially serious invaders exist for which little is known about biology or spread	Y R
Shoebutton Ardisia (*Ardisia elliptica*)	Y R	May be entering exponential spread phase; moving into floodplain communities and dominating understory; difficult to monitor, especially remotely	Y R	No coordinated, significant control efforts or biocontrol efforts underway	R
Feathered Water Fern (*Azolla pinnata*)		New to module; early eradication and containment programs in place	Y	Problematic species in other parts of world but rapid response efforts enacted	Y G
Australian Pine (*Casuarina* spp.)	Y G	Remnant populations exist along canals and a few natural sites, removal program in place and effective	Y G	Chemical control effective, most natural areas clear or clearable with modest effort; biocontrol research under way	G
Caulerpa (*Caulerpa brachypus*)	Y	Little known about spread or distribution; not included in Indicator systematic monitoring program	Y	Potential to eliminate most species on hard bottom coastal areas; no significant control efforts under way	Y R
Air Potato (*Dioscorea bulbifera*)	Y	Little known about spread or distribution; known populations increasing despite some control efforts; not included in Indicator systematic monitoring program	Y	Control programs in the module have limited success in natural areas; biocontrol effort under way	Y R
Old World Climbing Fern (*Lygodium microphyllum*)	R	Serious invader, rapidly spreading despite control efforts; invades most habitats; very destructive	R	No effective module-wide control programs; biocontrol release made, additional release expected in 2007; chemical control studies continuing	R
Melaleuca (*Melaleuca quinquenervia*)	Y G	Decreasing or static on public lands; increasing on private; biocontrol agents slowly establishing in this module	Y	Chemical control effective on public lands; biocontrol agents effective; and new agents expected in 2007/2008	Y
Torpedograss (*Panicum repens*)	Y	Little known about spread or distribution but increasing in many natural areas; not included in Indicator systematic monitoring programs	Y R	No coordinated control efforts in place; no biocontrol efforts underway	Y R
Downy Rose Myrtle (*Rhodomyrtus tomentosa*)		Not new to module, but new to table; moving into floodplain communities and dominating understory; difficult to monitor, especially remotely	Y R	No coordinated, significant control efforts or biocontrol efforts underway	R
Brazilian Pepper (*Schinus terebinthifolius*)	Y	Serious invader still spreading; chemical control ineffective in reducing systemwide spread; local control programs effective where resources available	Y	Control programs in the module effective on public lands; new biocontrol agents under study for future release in 2007-2008	Y G
Tropical Soda Apple (*Solanum viarum*)		Not new to module but new to table; increasing on private lands despite minor control efforts	Y	Control efforts limited, although local populations can be eliminated; additional biocontrol agents to be released in 2007	Y

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 underway. 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 and 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 9-9**, 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, page 9-66) 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, page 9-58) 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 island applesnail (= channeled applesnail) have all been found in or near the District's C-24 canal, as well as numerous exotic reptiles and amphibians (Meshaka and Smith 2005, Cress et al., 2007).

Feral Hog

Feral hogs (*Sus scrofa*, see *Big Cypress Module* page 9-57 for species specific information) were first introduced by the Spanish over 400 years ago and now occur throughout Florida. Economic impacts for feral swine damage were conducted in wetlands in Savannas Preserve State Park in this module in 2003 and again in 2004 following a one-year implementation of a swine control program (Engeman et al., 2004a, 2004b). Values used for the swine damage were based on the monetary amounts wetland regulators allowed to be spent on mitigation attempts to replace lost wetland resources. In 2003, the area of natural habitat damaged by feral hogs was given a monetary value (admitted to being a conservative estimate for not taking all feral hog impacts into account). The damage to the study area was re-estimated in January 2004, after swine removal. Damage was significantly reduced from 2003 to 2004, with 31 percent of sampling transects showing damage in January 2004, versus 92 percent in January 2003. Similarly, the total area and subsequent value of swine damage had also decreased dramatically in 2004. The benefit-cost ratio of the damage reduction against feral hog control costs was conservatively estimated at $480−$1,562, demonstrating that the benefits of swine removal are very high relative to the costs of control. Feral hog damages to pine flatwoods also have been evaluated in three Florida State Parks located in this module (Savannas Preserve, Jonathan Dickinson and Atlantic Ridge) (Engeman et al., 2003) Intensive hog removal at one park resulted in the lowest level of habitat damage (1.3 percent).

Northern Curlytail Lizard

The Northern Curlytail Lizard, *Leiocephalus carinatus armouri*, is endemic to the Little Bahama Bank. It was first introduced to Florida by the intentional release of 20 pairs on the island of Palm Beach in the 1940's, possibly to rid sugarcane fields of pests. This species is also popular in the pet trade, which has resulted in additional releases and escapes. Its range is contiguous for 90 km along the Atlantic Coast from Martin County to Broward County (Meshaka et al., 2005). Its rate of expansion on the Florida mainland was 2.4 km/year over a 34 year period (Smith and Engeman, 2004). Another subspecies (*L. carinuatus virescens*) occurred in Miami prior to 1940 but died out shortly afterwards. A third subspecies (*L. carinatus coryi*) was found on Virginia Key and Key Biscayne in Dade County, but its present status is unknown.

Figure 9-69. Northern curlytail lizard (*Leiocephalus carinatus armouri*) (Photo by Elizabeth Golden, DEP-Florida Park Service).

The northern curlytail lizard is found in mostly terrestrial habitats (Smith and Engelam, 2004) (**Figure 9-69**). It climbs well and prefers areas with ground rubble. Males may reach a length of 28 cm and be gray to tan, with light stripes on the nape and back. The dark-banded tail is held curved above the back. These lizards reach sexual maturity within one year and lay clutches of approximately four large eggs over a four or five month period (Meshaka et al., 2006). Their fast growth to maturity and their staggered generations contributed to the colonization success of this species (Meshaka et al., 2006).

Northern curlytails feed primarily on insects, but have been observed feeding on anoles (Smith and Engeman, 2004). Various falcons, hawks, a little blue heron, domestic and feral cats, black racers, and other animals have been witnessed feeding upon these lizards. Although competition between northern curlytails and native species has not yet been documented, populations of the exotic brown anole (*Anolis sagrei*) have been shown to decrease where they overlap with the current range of northern curlytails. It is reasonable to speculate that native lizards have been or will be impacted by northern curlytails within their expanding range (Smith and Engeman, 2004). Further study of this lizard and its interactions with native species is warranted.

Charru Mussel

The charru mussel *(Mytella charruana)* is native to Central and South America. It was first reported in Florida in 1986 when large numbers were found in power plant intake pipes on the St. Johns River. The mussel failed to become further established in the Jacksonville area, and most likely died off in the winter of 1987. (Boudreaux and Walters, 2006). The charru mussel was found in the Mosquito Lagoon Basin of the Indian River Lagoon in 2004 (Boudreaux and Walters, 2006). Since this report, many more charru mussels have been identified, and their numbers appear to be increasing, prompting the University of Central Florida to begin lagoon-wide surveys in 2006 to determine the distribution of the charru mussel in this module. As of Spring 2006, nearly 600 individuals had been collected from the Mosquito Lagoon portion of the Indian River Lagoon system. Like the green mussel (*Perna viridis*) described in the Northern Estuaries – West Module, this species threatens to compete with native mussels, oysters, and other organisms for food and colonizable substrate.

LAKE OKEECHOBEE MODULE

Lake Okeechobee is a 450,000-acre lake with an average depth of only 9 feet. It also contains approximately 100,000 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, 10 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 majority of invasive plant species of concern in the lake have dedicated funding and effective control programs in place. Still, however, 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 non-native 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.

Nonindigenous Plants

Floating aquatic plants, such as water hyacinth *(Eichhornia crassipes)* and water lettuce *(Pistia stratiotes)* (**Figure 9-70)** are currently managed by the USACE. The USACE program started in the 1920s with mechanical removal of hyacinth, and it 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. While hurricanes helped keep infestations low in 2005 through 2006, near-record low water levels kept populations down in 2007. In the past 16 years, the lake has averaged 240 acres (combined) of hyacinth and lettuce, with an average 5,000 acres treated each year. Without continued control of these plants, however, they would quickly expand and have severe environmental impacts on the lake. Even with the current control programs in place, damage to natives occasionally occurs with their displacement and accidental treatment during control. For this reason, and because herbicide treatments control hyacinth quickly but not permanently, well-dispersing biocontrol agents capable of building large populations rapidly are needed. Currently, one potential biocontrol agent is in quarantine, with additional agents from South America set to be studied shortly (P. Tipping, USDA-ARS).

Figure 9-70. Water lettuce (*Pistia stratiotes)* (Photo by Kenneth Langeland, Univ. Florida).

Hydrilla (*Hydrilla verticillata*) has been in Lake Okeechobee for 20 years, but 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 expanded rapidly to cover thousands of acres and required mechanical harvesting to open up boat trails. Wave and wind from hurricanes are partially responsible for keeping populations of hydrilla low. In 2007, water levels nearing record lows were responsible for keeping infestations small (M. Bodle, SFWMD, personal communication). However, hydrilla's exponential growth rate and new water regulation schedules could allow this plant to be a major concern in the future. Both the USDA-ARS and the

University of Florida are currently undergoing extensive field explorations in search of more effective biocontrol agents.

Alligator weed *(Alternanthera philoxeroides)* has not been problematic since the 1960s due to successful biocontrol. 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. Thousands of acres of alligator weed were treated annually by chemical and mechanical means prior to the introduction of the biocontrols. Barring any situation that would negatively impact the biocontrol agents, alligator weed is not expected to cause any measurable impacts in the near future, and serves as a good example of what successful biocontrol programs can accomplish.

Figure 9-71. Dense population of Brazilian pepper (*Schinus terebinthifolius*) (Photo by Amy Ferriter, Boise State University).

Extensive control programs from 1993 to 2007 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 biocontrol agents throughout the South Florida region are showing significant effects on large areas of melaleuca.

Two other exotic trees, Australian pine and Brazilian pepper (**Figure 9-71**), had originally established sizeable populations on artificially elevated sites in the lake's watershed including spoil deposits and the lake's levees. In the 1995–2007 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 retain maintenance control levels since no biological controls have yet been released in Florida for the control of either of these two species (although the release of the Brazilian pepper thrips is forthcoming).

West Indian marsh grass (*Hymenachne amplexicaulis*) is a perennial, stout semi-aquatic grass native to Central and South America (**Figure 9-72**). Invading tropical seasonally wet waterways, wetlands, and drainage systems, it impedes flood protection and water management and has overwhelmed riparian systems 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 occurs 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 (M. Bodle, SFWMD, personal

Figure 9-72. West Indian marsh grass (*Hymenachne amplexicaulis*) (Photo by Univ. Florida IFAS Extension IN491).

communication). The District initiated an herbicide control program for this species in 2005 within the FDEP aquatic plant control program.

Figure 9-73. Selective control efforts are being used to control torpedograss (Photo by Ann Murray, Univ. Florida).

Torpedograss (*Panicum repens*, **Figure 9-73**) 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 (M. 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. Torpedograss has been the target of extensive control in the lake's 100,000-acre western marsh since 1999. More than 29,000 acres of torpedograss were aerially treated in Lake Okeechobee from 2002 through 2007, though some of this acreage consists of infestations treated multiple times. (Treatment effectiveness varies from site to site due to uncontrollable variations in environmental conditions.) Large areas remain to be treated by both aerial and surface applications, however, because funding for the control of this invasive plant often falls short of management program needs. The District continues to treat torpedograss in the lake whenever possible, and wintertime trials show promise for selective treatments that will kill torpedograss and spare dormant native species.

Indian rosewood (*Dalbergia sissoo*) is an invasive tree originally introduced to the Lake Okeechobee Module as an ornamental shade tree at campgrounds and boat ramps (**Figure 9-74**). It has since become a nuisance plant. An intensive chemical and mechanical control program was initiated against this species by the District, and in 2007, the program reached maintenance levels where monitoring and treatment of seedlings are sufficient to keep this plant's population in check.

Figure 9-74. Indian rosewood (*Dalbergia sissoo*) (Photo by Jeff Hutchison, courtesy Archbold Biological Station).

In late July 2006, the first population of Old World climbing fern was reported along the north shore of the lake. This sighting was never successfully confirmed, however. State and federal agencies are actively searching for this species and will enact rapid response tactics if the plant should be discovered. If the species is confirmed present in this module, it will be added to the priority plant list for Lake Okeechobee.

Nonindigenous plant species considered a priority in the Lake Okeechobee Module are listed in **Table 9-10.**

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

	2006 STATUS	2007 STATUS		1-2 YEAR PROGNOSIS	
LAKE OKEECHOBEE MODULE (Results in row reflect module-level questions, not species-level questions)	Y	Restoration efforts under way for while, much progress made; however, several serious species occur in module and continued disturbance of littoral zone may increase chances of new invasions	Y	Module has had large control program under way for many years; progress on many species evident, but continued monitoring and control efforts needed to prevent serious reinvasions of the many species threatening region	Y
Alligator Weed (*Alternanthera philoxeroides*)	G	Effective biocontrol program underway for many years; control programs achieved complete control in most areas	G	Biocontrol and monitoring programs in place and achieving good results	G
Australian Pine (*Casuarina* spp.)	G	Effective removal program in place, not currently a serious problem in this module	G	Chemical control effective; natural areas clear with modest effort; biocontrol research under way	G
Indian rosewood (*Dalbergia sissoo*)		Not new to module but recent addition to priority plant table. Large efforts recently brought population under control	G	Recent control efforts brought population to maintenance levels; only modest effort needed in future to control new seedlings	G
Water Hyacinth (*Eichhornia crassipes*)	Y G	Control programs under way for years; maintenance control goals currently met due to record lows of Lake.	G	Ongoing control and monitoring programs in place; increases in water levels could trigger massive regrowth from seedbank	G Y
Hydrilla (*Hydrilla verticillata*)	Y G	Control programs in place, not necessary in recent years; hurricanes, hydrologic conditions, flocculent substrate prohibit widespread expansion	Y G	Effective control and monitoring programs in place and have been achieving good results; increases in water levels could trigger massive regrowth from seedbank	G Y
West Indian Marsh Grass (*Hymenachne amplexicaulis*)	Y	Little known about spread or distribution throughout system; not included in Indicator systematic monitoring program	Y	Increases in spread/distribution may be occurring; may become serious pest in areas where other exotics have been controlled	Y R
Melaleuca (*Melaleuca quinquenervia*)	G	Effective chemical control program under way for several years with excellent efficacy	G	Chemical and biocontrol effective; spread of agents, new agents expected in 2007/2008	G
Torpedograss (*Panicum repens*)	Y	Impacts at least 20,000 acres of wetlands; static; not included in Indicator systematic monitoring program	Y	Control efforts underway but frequently under-funded; lake management, drawdowns may increase spread despite program	Y R
Water Lettuce (*Pistia stratiotes*)	Y G	Control programs underway for years; maintenance control goals currently met due to record lows of Lake.	G	Ongoing control and monitoring programs in place; increases in water levels could trigger massive regrowth from seedbank	G
Brazilian Pepper (*Schinus terebinthifolius*)		Not new to module but recent addition to priority plant table; effective removal program in place, not currently a serious problem in this module	G	Chemical control effective; natural areas clear with modest effort; biocontrol research underway, new releases 2007/2008	G

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 underway. 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 and 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 Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*) has been observed in the lake (**Figure 9-75**). 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 their 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. 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, Orinoco sailfin catfish tunneling is believed to damage canals and levees and result in increased siltation (Hill, 2002; King, 2004).

Figure 9-75. Orinoco sailfin catfish *Pterygoplichthys multiradiata*) (Photo by Leo G. Nico, US Geological Survey).

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 ocellatu*, **Figure 9-76**), 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 extreme fluctuations of Lake Okeechobee water levels and resultant reduced and degraded habitat as having a negative impact on the bass and crappie populations. However, no links between invasive fishes and the declining habitat and falling native fish populations have been studied to date.

Figure 9-76. Oscar (*Astronotus ocellatu*) (Photo by Mac Kobza, SFWMD).

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 island applesnails (= channeled applesnails, see *Greater Everglades Modules* and *Kissimmee* sections). Any of these species could have negative impacts on the lake. Feral hogs are omnivores noted for foraging on roots of native trees and impacting native birds. Populations of brown anoles (*Anolis sagrei*, **Figure 9-77**) and Cuban treefrogs (*Osteopilus septentrionalis*) have increased around the lake, and the island applesnail has been documented in Lake Okeechobee. The purple swamphen (see the *Greater Everglades Module* section, page 9-51, for species-specific information) was observed in the marshes around Torry Island during 2005 and 2006. Though it has not been observed in this module recently, 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.

Figure 9-77. Brown anole (*Anolis sagrei*) (Photo A. Paterson, Williams Baptist College).

KISSIMMEE BASIN MODULE

The Kissimmee Basin Module includes a diverse group of wetland, aquatic and lake systems. Current initiatives in the Module include the Kissimmee River Restoration Project, Kissimmee River Headwaters Revitilization Project and the Kissimmee Chain of Lakes Long-Term Management Plan.

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 increased significantly during 2006 due to the flushing of plants from adjoining watersheds during fall hurricanes and heavy spring rains, but active control programs are currently keeping these populations static. Increased flow in restored portions of the river provides less suitable 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 re-flooded floodplain seem to provide suitable areas for growth of water hyacinth and water lettuce, at least temporarily.

Hydrilla continues to be a priority nonindigenous aquatic plant species in the lakes of the Kissimmee basin. Hydrilla infestations have covered 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 recent hurricanes, including uprooting by winds and persistent turbidity that limits regrowth, hydrilla in the KCOL covered only 6,500 acres during the 2006 and 2007 seasons (M. Bodle, SFWMD personal communication). These are the lowest levels in the last five 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, so hydrilla's impacts appear to be negligible at this time.

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 be needed for 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*, **Figure 9-78**), 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.

Figure 9-78. Cuban bulrush (*Scirpus cubensis*) (Photo by Kerry Dressler, Univ. Florida).

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. There are currently no active/coordinated control programs in place for these species in the Kissimmee Basin Module. Localized patches (totaling hundreds of acres) of West Indian marsh grass (*Hymenachne amplexicaulis*) have been found on the floodplain in the northern end of the restoration project area but were 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 9-79**). 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. Although no active control efforts have take place thus far, funding is available from the FDEP for future operation control work. The first coordinated chemical control effort occurred in June of 2007.

Figure 9-79. Limpograss *(Hemarthria altissima)* has invaded the Kissimmee floodplain from adjacent pastures (Photo by B. Cook, DPI & F Australia).

Figure 9-80. Chinese tallow *(Sapium sebiferum)* (Photo by Cheryl McCormick, Univ. Florida).

Chinese tallow (*Sapium sebiferum*) is a serious invader of wetlands in this region (**Figure 9-80**). 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 currently available, though field explorations for suitable biocontrol agents have recently commenced. This species has been of agricultural importance in China for a very long time. Consequently, pests (potential biocontrol agents) have been thoroughly documented, making the agent selection process more efficient.

There are already numerous species showing promise as excellent biocontrol agents. Chemical control is readily achieved against Chinese tallow, but no systematic control has begun.

Figure 9-81. Cogon grass (*Imperata cylindrica*) (Photo by Wilson Faircloth, USDA-ARS).

Archbold Biological Station staff indicated that natal grass (*Rhynchelytrum repens*) and cogon grass (*Imperata cylindrica*) are continuing to spread throughout the region, particularly in disturbed upland habitats (**Figure 9-81)**. 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 is also commonly found on the spoil mounds of channelized river.

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 increased the visibility of lygodium cover during aerial surveys and facilitated more thorough treatments of observed distributions of this species in the Kissimmee basin. Still, this plant currently occurs in multiple habitats with varying land ownership (public and private). Consequently, control efforts have been difficult to coordinate, leading to its present rate of spread.

Though not as 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 has also been found on Avon Park Air Force Range, where staff has expressed concern about the effectiveness of available herbicides for this species.

Tropical soda apple (*Solanum viarum*) is another pervasive exotic species of concern in the pastures of the Kissimmee valley (**Figure 9-82**). Cover of this species is reportedly increasing on private lands neighboring Avon Park Air Force Range. Chemical and mechanical control efforts put forth against this species have had limited effect. The biocontrol program has resulted in the release of one agent to date (*Gratiana boliviana*) with three additional species expected to be released by late summer 2007 by FLDACS-DPI. Other exotic plants that have been locally treated in the module include strawberry guava (*Psidium littorale*), caesarweed (*Urena lobata*), and star grass (*Cynodon nlemfuensis*).

Figure 9-82. Soda apple *(Solanum viarum)* (Photo by J. Jeffrey Mullahey, Univ. Florida).

Additional 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. An active biological control program against air potato is in the stages of field exploration, with numerous promising species resulting from these efforts (R. Pemberton, USDA-ARS, personal communication).

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.

Figure 9-83. Wright's nutrush (*Scleria lacustris*) (Photo by Vic Ramey, Univ. Florida).

Wright's nutrush (*Scleria lacustris*) is a sedge that was first reported in Florida in 1988 (**Figure 9-83**). Freshwater marshes and lake shorelines with seasonal water fluctuations are highly susceptible to invasion by this plant, which disperses its nutlets via birds, airboats, and water transport through drainage systems. Although this plant is not new to the Kissimmee Basin Module, recent increases in Wright's nutrush populations warrant its addition to the priority plant list. This plant currently occurs in multiple habitats with varying land ownership (public and private). Consequently, control efforts against Wright's nutrush have been disjointed and difficult to coordinate, leading to its present rate of spread.

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

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

	2006 STATUS	2007 STATUS		1-2 YEAR PROGNOSIS	
KISSIMMEE MODULE (Results in this row reflect only module-level questions, not species-level questions)		Many very serious nonindigenous species occur in this region for which little is known about how invasive they may become; restoration efforts underway in this module for many years, much progress made; new programs started		Many of the species occur only in this region and little is known about their biology, yet some are very serious weeds in other parts of world; rehydrated wetlands providing new habitat for aquatic species including hydrilla; many new control programs started	
Water Hyacinth (*Eichhornia crassipes*)		Significant control efforts underway for many years; control programs achieving good results		Systematic control and monitoring programs in place and achieving good results	
Limpograss (*Hemarthria altissima*)		Little known about spread or distribution; increasing in scope; included in FDEP aquatic plant surveys; new chemical program initiated		No biocontrol effort underway; new funding and chemical control program may be bring populations to maintenance level	
Hydrilla (*Hydrilla verticillata*)		Limited control efforts and biocontrol programs under way for many years; control programs have mixed results; storms and water levels currently having most impact		Systematic control and monitoring programs in place and achieving good results; recent herbicide resistance creating new control problems along with increased habitat on rehydrated floodplain	
West Indian Marsh Grass (*Hymenachne amplexicaulis*)		Little known about spread or distribution throughout the system; included in FDEP aquatic plant surveys; control efforts increasing		Control efforts in this module good and increasing; most populations in natural areas under reasonable control	
Cogon Grass (*Imperata cylindrica*)		Little known about spread or distribution; not in Indicator systematic monitoring program		Controlled to varying degrees on public lands in this 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; active biocontrol program but current agent effectiveness not yet seen		Chemical control has brought populations to maintenance levels on public land; biocontrol releases made, more expected in 2007; chemical studies continuing	
Japanese Climbing Fern (*Lygodium japonicum*)		Controlled thus far, but little known about potential impacts in module		Populations controlled so far; however, distribution and spread unknown; no biocontrol program underway	
Melaleuca (*Melaleuca quinquenervia*)		Still abundant on private lands but biocontrol reducing cover and spread		Chemical control effective on most public lands; biocontrol agents effective; additional spread & introductions expected in 2006	
Torpedograss (*Panicum repens*)		Little known about spread or distribution but believed to be increasing; 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 underway for several years; control programs achieving good results; included in FDEP aquatic plant surveys		Systematic control and monitoring programs in place and achieving good results	
Chinese Tallow (*Sapium sebiferum)*		Distributed along many lake edges in Kissimmee Chain of Lakes; not included in Indicator systematic monitoring program; populations increasing		No significant control efforts or effectiveness; no biocontrol effort underway although local populations can be eliminated	

Table 9-11. Continued.

Brazilian Pepper (*Schinus terebinthifolius*)	Y	Serious invader, invades most habitats, very destructive; chemical control ineffective in reducing systemwide spread so far; however, local control programs proving effective where resources available	Y	Control programs effective in natural areas where management programs under way; new biocontrol agents under study for future release	Y G
Wright's Nutrush (Scleria lacustris)		Not new to module but recent addition to priority plant table; not currently serious problem but uncoordinated control efforts leave this plant free for future expansion	Y R	Without coordinated control efforts in near future, population will continue to expand unabated	R
Tropical Soda Apple (*Solanum viarum*)	Y	Little known about spread or distribution; biological control agents released with more on way; not included in Indicator systematic monitoring program	Y	Control efforts limited, although local populations can be eliminated; additional biocontrol agents to be released in 2007	Y G

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 underway. 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 and 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

Several nonindigenous animal species are considered priorities 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, 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 despite the lack of a daily limit in most regions, so an increase in the length of the hunting season has been proposed to attempt to reduce the abundance of this species.

Similarly, although the population of Asian clam (*Corbicula fluminea*) has increased in the section of Kissimmee River channel with restored flow, its potential threat to reestablishment of native invertebrate fauna has not been determined. Avon Park staff has expressed concern about potential impacts of the broadly distributed populations of walking catfish (*Clarias batrachus*) in aquatic habitats, and Kissimmee Prairie staff is alarmed about increasing populations of European starlings (*Sturnus vulgaris*). White winged doves (*Zenaida asiatica*) appear to be locally common in at least Highlands County and have been observed roosting in large numbers in upland habitats adjacent to the Kissimmee River. Nile monitors, too, are appearing in this module. Ryan Higgins (SFWMD) has repeatedly seen a greenish-gold spotted 4-foot lizard on the banks of Shingle Creek, upstream of Lake Tohopekaliga in Osceola County. Numerous reports have also come from local residents in recent years.

Fishes

Extensive fish sampling was conducted throughout this module to provide current records about nonindigenous fish distribution in the Kissimmee River and floodplains. The brown hoplo (*Hoplosternum littorale*) is an armored catfish that occurs 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. It is both an aquarium and food fish, often released and harvested as a cultural food source. The vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) and Orinoco sailfin catfish (*Pterygoplichthys multiradiatus)* are also common in this module. These are very popular aquarium fish, commonly called "algae eaters." They are some of the most resilient exotic species in Florida. Although little is known about their habitat preferences, thick scales, venomous spines, and the abilities to breathe air and use teeth to scrape algae for nutrition make them adaptive and problematic. The Kissimmee River represents the northern range limit for many exotic tropical fishes.

Island Apple Snail

Recent taxonomic work (Tim Collins, Florida International University) indicates that the nonindigenous species previously known as the channeled apple snail (*Pomacea canaliculata*) was incorrectly named and is in all actuality the island apple snail (*Pomacea insularum*). The biology, distribution, and impact of this species remain the same; only the taxonomy has changed.

The island apple snail is a large (up to 10 cm) South American freshwater mollusk established in California, Texas, and Florida through the aquarium trade (**Figure 9-83**). 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 continued spread of the island applesnail may be a problem for the endangered everglades kite, in particular, if it outcompetes the native applesnail, *P. paludosa*, which is the primary food of the everglades kite. 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.

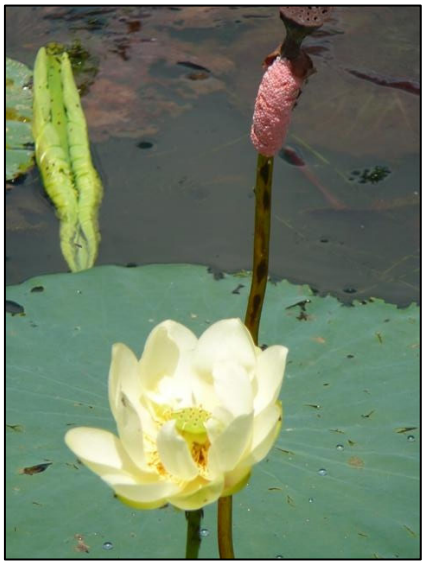
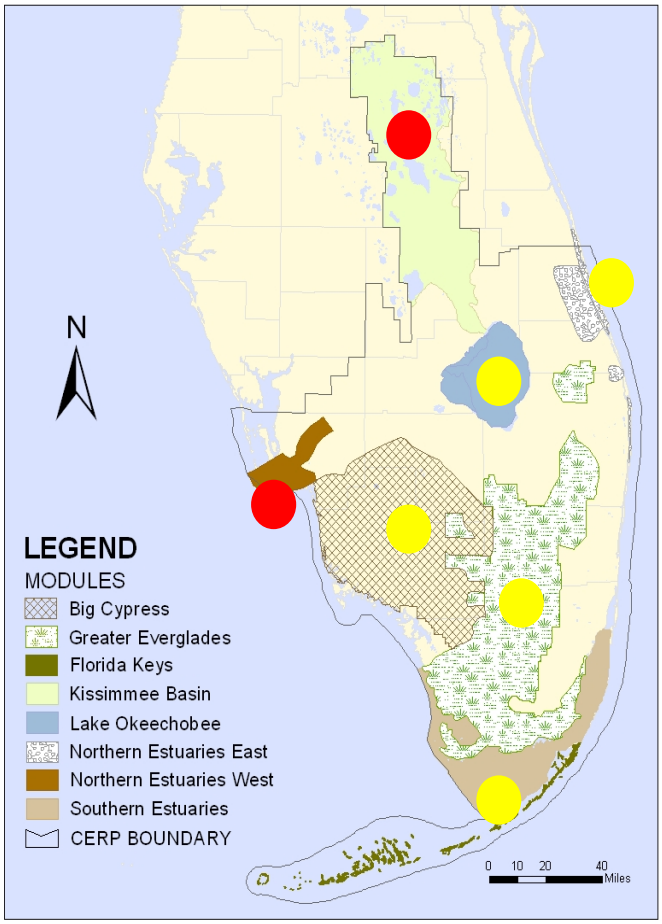


Figure 9-83. Island apple snail egg mass (*Pomacea canaliculata*) (Photo by SFWMD).

In the KCOL, the island apple snail is now common in northern Lake Tohopekaliga and particularly in the lake's northeastern Gobblett's Cove. 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. Studies conducted to date by the University of Florida suggest that any molluscicide that will be toxic to the island applesnail will also be toxic to the native applesnail. The only possibility for differential control between the two snails would be to apply toxicants directly to the easily recognized bright pink exotic apple snail eggs (W. Haller, Univ. Florida, personal communication), which a District employee is currently doing.

MODULE SUMMARY

For nonindiginouse plants, most modules have some level of control program for high priority species and are showing progress with commonly known and wide spread species such as melaleuca, particularly on public lands (Figure 9-84). Biocontrol efforts are proving successful against Melaleuca, and many other biocontrol agents are being released against other species. However, even Brazilian pepper and Old World climbing fern continue to be serious invaders in many modules, and several new and recently introduced species are being identified in many modules with little information in existence on distribution or control methods.



Red – Substantial deviations from restoration targets creating severe negative condition that merits action

Yellow – Current situation does not meet restoration targets and merits attention

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Green – Situation is good and restoration goals or trends have been reached. Continuation of management and monitoring effort is essential to maintain and be able to assess "green" status.

Figure 9-84. Overall module status in relation to exotic plants.

All of the modules have significant invasive exotic plant problems that are documented to be affecting natural areas and altering natural habitats and processes. Monitoring programs to assess the trends in invasive exotic plants only cover the entire restoration area for 6 high priority species, and monitoring that would identify new species or new distributions for existing species only covers portions of the Greater Everglades module; the other modules are not being monitored.

Key Recommendations

1. Existing monitoring programs need to be expanded to cover remaining modules in order to be able to determine where and when new species arrive (then establish) and assess success of control programs in these areas.
2. In order to get ahead of the exotic plant invasion rate, control programs (chemical and biological) need to expansion; the many agencies undertaking these programs need to develop formal strategic agreements regarding implementation and fiscal planning.
3. Effective preemptive monitoring is required at ports of entry to identify and assess new species and their invasion potential, and detect these species prior to their establishment in natural areas.
4. Risk assessments tools need to be formally accepted by the agencies and used to assess the invasion potential of the many exotic plant species in order to help prioritize resources and control programs.

Exotic animal trends by module differ from those of nonindigenous plants in that module-wide control efforts rarely exist. As stated throughout this document, the ubiquitous nature of animals makes large-scale monitoring and control efforts extremely difficult. The lack of baseline monitoring data for many nonindigenous animals makes tracking progress impossible. Still, select control efforts against some species have been aggressive and appear to be keeping them in check, e.g. the cactus moth (*Cactoblastis cactorum*) and purple swamphen (*Porphyrio porphyrio*). Key recommendations for exotic animal management are more basic than those listed for nonindigenous plants. It is crucial that consistent monitoring programs and risk assessment tools first be developed for nonindigenous animals.

SUMMARY OF NEEDS AND GAPS

The elements of a comprehensive nonindigenous plant management program — legislation, coordination, planning, research, education, training, and funding — have been in place in Florida for many years. The majority of plants identified in this document as priority species are all being controlled on public lands by local, state, or federal agencies. Unfortunately, the same cannot be said for animals, and there are hundreds of nonindigenous organisms in South Florida with unknown distributions and invasive potentials. The threat of nonindigenous animals is becoming an important ecological and restoration issue for many agencies in Florida, and certain species are beginning to be addressed. Funding and coordination for a comprehensive nonindigenous animal management plan for Florida are needed. There is also a need to set priorities for animal management in South Florida; this task is being undertaken on two fronts. First, the Everglades Cooperative Invasive Species Management Area (CISMA) is developing a proposal to evaluate the use of existing risk assessment tools for South Florida's nonindigenous animal species. Second, the South Florida Water Management District is developing a comprehensive literature review for those plant and animal species identified as most critical for restoration. 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 and consequences 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 species where interactions between and among nonindigenous species are a factor. It is also important for agencies to consider ways in which the public can be encouraged to identify, monitor and manage nonindigenous plant and animal species on privately held lands.

Given the documented impacts of nonindigenous organisms in South Florida, scientists are obliged to begin to factor these species into restoration models, and research is needed to understand the distribution, biology, and impacts of these nonindigenous organisms (**Table 9-12**). Controlling and managing nonindigenous organisms in an all-taxa approach is a nascent idea, even among ecologists, 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 new environments, including South Florida. The abundance of nonindigenous plants in the region 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 may be no coincidence that the Burmese python is common along canal levees covered with Burma reed.

Irrespective of taxa, the process an invasive species goes through from introduction to establishment to invasion to ecosystem engineer is complex, involves many environmental factors, and may take many decades to complete. Relatively few exotic species become invasive in *de novo* environments, but a very few species can wreak major economic and ecologic havoc. Species that appear benign for many years or even decades can suddenly spread rapidly following events such as flood, fire, drought, hurricane, long-term commercial availability, or other factors. Resource managers must 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 their introduction (to try to prevent introduction or to be better prepared for eradication efforts).

Species like the purple swamphen in the Greater Everglades and the Gambian pouch rat in the Keys illustrate the need for state and federal agencies to act quickly to contain and attempt to eradicate animals that have the potential to become widespread and difficult to control. Recent additions to non-native wildlife rules (now housed in the new Chapter 68-5 under Title 68) increase the scope of existing rules (limiting the trade of the red-eared slider for example). However, many more restrictions are called for to adequately curb the purposeful and accidental release of non-indigenous animals into the South Florida environment. 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, even where research may be inadequate or lacking. This is one of the most important reasons to develop a biological risk assessment "tool box" for exotic species in order to help discern which species are most likely to become invasive both prior to introduction and during the earliest phases of their establishment when eradication is feasible.

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 EDRR programs 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 or ecological research programs. Biological risk assessments are being developed (particularly for plants) to allow agencies to determine which species are most likely to become problems. Many states struggle with how to implement an EDRR approach because awareness and funding often lag, preventing a real "rapid" response. For South Florida, groups such as NEWTT and FIATT are attempting to initiate EDRR efforts. Species chosen by FIATT as EDRR candidates are noted in **Table 9-2** and include organisms such as the red palm mite (*Raoiella indica*) and redbay ambrosia beetle (*Xyleborus glabratus*), both of which do not currently occur in South Florida but present extreme risks if they establish.

The District's Strategic Plan provides the agency and the public it serves with a blueprint for meeting the challenges of balancing the needs of the natural environment with the demands of Florida's growing population and important agricultural industries. Control of nonindigenous species are cited as important strategies and success indicators in the District Strategic Plan. Exotic species treatment is specifically listed as a deliverable in five of the 11 overall Strategic Plan Goals. Successful management of these species is also tangentially key to many of the other Strategic Plan Goals as nonindigenous species impact everything from evaluating Environmental Resource permits to operating Stormwater Treatment Areas to restoring natural fire regimes.

Priority plant species are listed within each Module summary in this Chapter. Animal species have not been prioritized in a similar manner. Given differing agency priorities and responsibilities, a definitive "priority animal list" may be years from being developed and accepted by resource mananegment agencies in Florida. Given the District's mission, the following list is a summary of animal species which threaten the success the District's Strategic Plan Goals.. These animal species are presented with a "District-centric"justification for listing,

and it should be noted that priorities may differ for other agencies, depending on regional factors and agency priorities and goals.

District Priority Animal Species

1. Burmese python (*Python molarus bivittatus*)
    - As a top predator, threatens to disrupt entire food chain and ecosystem function within the Everglades
2. Feral hog (*Sus scrofa*)
    - Disrupts both plant and animal communities
    - Rooting behavior alters land management, increasing soil disruption and erosion
3. Bromeliad weevil (*Metamasius callizona*)
    - Directly threatens native bromeliad populations, many of which are threatened.
    - Removal of native epiphytes disrupts ecosystem function
4. Lac scale (*Paratachardina lobata* or different species, this is being studied by USDA-ARS)
    - Attacks numerous native tree and shrub species, threatening District Everglades tree island restoration
5. Green iguana (*Iguana iguana*)
    - Burrowing undermines and weakens infrastructure of canal banks, threatening District operation and maintenance infrastructure.
6. Purple Swamphen (*Porphyrio porphyrio*)
    - Disrupts wading bird communities, potentially impacting District Everglades restoration
7. Swamp eel (*Monopterus albus*)
    - Predators, may impact animal communities
    - Mainly in canal system, proximity to restoration efforts is a concern.
8. Island applesnail (*Pomacea insularum*)
    - Disrupts wetland communities
    - Threatens ecology of Everglades system
9. Sailfin catfish (*Pterygoplichthys spp.*)
    - May alter/decrease aquatic community function
    - Burrows into canals and levees, potentially impacting infrastructure
10. Monitor lizard (*Varanus niloticus*)
    - Predator, impacts bird, amphibian and reptile populations.
    - Potential for spread and to impact restotation activities

An overarching theme in this document is describing the alarming extent and impacts of some exotic species infestations and stating the need for increased control efforts. While these observations are entirely true and warrant more attention, it should be noted that past control

efforts against certain nonindigenous species have proven successful and demonstrate that control of some species is possible. For instance, melaleuca is now under maintenance control on Lake Okeechobee and in several WCAs. 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 may be reduced in some locations 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 or alterations will have on nonindigenous species throughout the system. Nutrient enrichment studies have evaluated changes to native flora but have virtually excluded the study of invasive species. The Mexican bromeliad weevil, lobate lac scale, 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 and ENP. A more comprehensive approach must be taken when looking at the long-term restoration process with regard to the nonindigenous species composition response. It is also necessary to stress to the public and policy makers that nonindigenous species will always require some level of maintenance and that new introductions and expected arrivals (such as the red palm mite) must be recognized and prevented early in order to avoid future costs.

Public awareness of invasive species and their impacts to Florida's natural resources is an important component of a successful prevention and management program. Promoting behavioral changes of individuals and industries can help curtail the introduction of potentially invasive species. The Florida Exotic Pest Plant Council was successful in working with the Florida Nursery Growers and Landscape Association to discourage the use and sale of known invasive plant species, and in 2006, the Lowe's chain of home-improvement stores agreed not to sell certain invasive plants in their Florida stores.

Table 9-12. Top five research gaps as identified by a consensus of the managers and scientists involved in South Florida invasive species management and control for South Florida restoration.

1. Develop control strategies and techniques, including control and monitoring methods and approaches, to control and manage invasive exotic, aquatic animals
2. Develop control strategies and techniques including control and monitoring methods and approaches to prevent the transfer and spread of invasive exotic organisms between wetland waterbodies in the Everglades via water management structures or operations. Also develop a detailed review and synthesize information on existing technologies and strategies used in other areas.
3. Identify research gaps for high priority species in order to develop better information about biology of different organisms and development of practical management practices.
4. Develop a biological risk assessment tool for helping prioritize new animal species for control, and management (Contact: J.T. Hillary. C.) • Includes fluctuating populations of animals over time • "Filters/Risk Assessments" for prioritizing species for control and management o Literature review of animal groups, lifeforms, species as to patterns of invasiveness ▪ Prediction models for determining invasiveness ▪ "Coarse" assessments • Evaluate "New Zealand" risk assessment tool for invasive animals • Begin with fish and reptiles
5. Development a integrated strategy and conceptual approach to guide the development of monitoring programs for individual animal groups, life forms or species to better coordinate and integrate monitoring data and sampling approaches.

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