Chapter 7: Status of Nonindigenous Species

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SUMMARY

Invasive, non-indigenous species present serious threats to ecosystem community structure and function throughout South Florida. As such, controlling invasive species is cited as a critical resource management activity in the South Florida Water Management District (District or SFWMD) *Strategic Plan, 2012–2017* (SFWMD 2012). Successfully managing invasive species is also important to other strategic goals as their far-reaching effects must be considered during many District activities—from evaluating Environmental Resource Permits to managing the Everglades Stormwater Treatment Areas (STAs) to restoring natural fire regimes. In support of collective activities of the many agencies involved in Everglades restoration, this chapter reviews the broad issues involving invasive, nonindigenous species in South Florida and their relationship to restoration, management, planning, organization, and funding. The report provides updates for many priority invasive species, programmatic overviews of regional invasive species initiatives, and key issues linked to managing and preventing biological invasions in South Florida ecosystems.

While detailed information on many invasive species is not available, this document attempts to provide an update and annotations for priority plant and animal species, including summaries of new research findings. As part of continued efforts to streamline reporting, this year's update emphasizes new information obtained during Fiscal Year 2016-2017 (October 1, 2016–September 30, 2017).

In addition to providing the status of nonindigenous species programs and outlining programmatic needs, this document summarizes what, if any, control or management is under way for priority nonindigenous species considered capable of impacting the resources that the District is mandated to manage or restore. The District continues to collaborate with the regional cooperative invasive species management areas (CISMAs), Lake Okeechobee Interagency Aquatic Plant Management Team, South Florida Ecosystem Restoration Task Force (SFERTF), and other cross-jurisdictional teams. These critical collaborations have facilitated the implementation of regionwide invasive species monitoring programs, rapid response efforts, standardized data management, and outreach initiatives. As such, this report includes a great deal of information and summaries of accomplishments attributed to the efforts of these collaborative teams. Active partners in invasive species management within the South Florida Ecosystem include but are not limited to the following entities: Broward County, Collier County, Florida Fish and Wildlife Conservation Commission (FWC), Miami-Dade County, Miccosukee Tribe of Indians of Florida, Palm Beach County, The Nature Conservancy, Seminole Tribe of Florida, United States Army Corps of Engineers, United States Department of Agriculture, United States Department of the Interior, United States

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NONINDIGENOUS PLANTS

- Seventy-five species of nonindigenous plants are District priorities for control. Old World climbing fern (*Lygodium microphyllum*), melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), and Australian pine (*Casuarina* sp.) continue to be systemwide priorities, while aquatic plants such as hydrilla (*Hydrilla verticillata*), waterhyacinth (*Eichhornia crassipe*s), and tropical American watergrass (*Luziola subintegra*) are priorities in the Kissimmee Basin and Lake Okeechobee.
- Efforts to control invasive plants continue throughout District-managed natural areas, STAs, project lands, lakes, and flood control canals and levees. The District has one of the country's largest aquatic plant management programs, controlling floating and submerged aquatic vegetation (SAV) systemwide. The interagency melaleuca management program is a national model for regional, interagency invasive plant control programs. Melaleuca has been systematically controlled from Water Conservation Area (WCA) 2 and WCA-3 and Lake Okeechobee and is now under maintenance control in these regions.
- Interagency efforts to achieve maintenance control of priority invasive plant species in areas with more severe infestations continue. USFWS, FWC, and the District are actively engaged in aggressive control efforts in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR) where melaleuca and Old World climbing fern remain problematic. NPS resource managers are collaborating with FWC and District invasive species biologists to leverage resources towards achieving maintenance level control of melaleuca, Brazilian pepper, and other aggressive invaders in Everglades National Park (ENP) and Big Cypress National Preserve.
- Biological control of several invasive plants is showing promising results, with substantial reductions of melaleuca documented. The Comprehensive Everglades Restoration Plan's (CERP's) Biological Control Implementation Project continues to move forward. The mass rearing facility at the existing United States Department of Agriculture's Agricultural Research Service biological control laboratory in Davie, Florida, now supports biological control agent rearing and field release for melaleuca, Old World climbing fern, water hyacinth, air potato (*Dioscorea bulbifera*), and other invasive nonindigenous plant species.
- Range expansions of invasive non-indigenous plant species into new areas remain a concern for resource managers. The District and partner agencies are assessing feasible means of monitoring and controlling these expanding populations based on threat prioritization and financial resource availability.

NONINDIGENOUS ANIMALS

- Considerable numbers of nonindigenous animals are known to occur in South Florida, ranging from approximately 62 species in the Kissimmee Basin to over 130 species in the Greater Everglades. Ranking animals for control is a serious challenge and prioritizing related threats across regulatory agencies is needed.
- Burmese pythons (*Python bivittatus*) continue to be observed and removed in the Everglades and surrounding rural areas. The District remains an active partner in regional efforts to halt the spread of this invasive reptile by conducting regional search and removal operations. In addition to an established systemwide monitoring program for

Burmese pythons and other priority invasive reptiles, the District and FWC began independent python hunter incentive programs in Fiscal Year 2016-2017. To date, the two programs have resulted in the removal of 626 Burmese pythons.

- FWC continues to build its nonindigenous animal management program and coordinates closely with the District, NPS, USFWS, and other partners to manage nonnative animal species in South Florida. During 2016–2017, federal, state, local, and tribal partners continued efforts to control expanding populations of several invasive animal species including northern African pythons (*Python sebae*), Argentine black and white tegus (*Tupinambis merianae*), and the spectacled caiman (*Caiman crocodilus*).
- University of Florida continues to operate the Everglades Invasive Reptile and Amphibian Monitoring Program (EIRAMP) in cooperation with and with support from SFWMD, FWC, United States Geological Survey (USGS), NPS, and FWS. The purpose of EIRAMP is to develop an early detection, rapid response, removal and monitoring program for invasive reptiles and amphibians within Greater Everglades ecosystems.

INVASIVES IN THE RESTORATION CONTEXT

- Invasive species detract from the integrity of Greater Everglades. Billions of dollars are being spent on Everglades restoration yet an ecosystem filled with invasive species is not truly restored. Everglades restoration efforts, such as removal of canals and levees, may limit the spread of some of the worst invasive species in the area (Burmese pythons, Argentine black and white tegus, etc.), however, care must be taken to make sure that unintended consequences do not result in opposite effects such as spreading invasive fish into the surrounding marsh.
- Invasive species should be incorporated more often in planning and implementing restoration efforts. Adding invasive species to conceptual ecological models will help draw attention to the issue and provide managers a framework with which to make decisions.
- Future restoration species policies will be improved by incorporating invasive species and considering how they affect components of the ecosystem that are also targeted for restoration. Or, conversely, how those other components may affect invasive species, either positively or negatively.

PROGRESS TOWARD MANAGEMENT AND CONTROL

The following section provides updates for Fiscal Year 2016-2017 on control, research, monitoring, and coordination activities on invasive nonindigenous species that threaten the success of the mission of the District.

SUMMARY OF INVASIVE SPECIES CONTROL TOOLS

Many different techniques are used to control invasive plants and animals in South Florida (Langeland and Stocker 1997, Wittenberg and Cock 2001). The District and other agencies typically use tools in an integrated fashion with the goal of minimizing impacts of invasive species by the most cost-effective and environmentally sound means. The following is a summary of available management tools for controlling invasive species.

Invasive Plant Control Tools

Tools for controlling invasive plants are well developed and widely utilized although their application in natural areas has limitations. Researchers are refining these control methods to be more effective in natural areas. The following list provides a generalized description of available plant control techniques:

- **Biological controls** include the use of living organisms, such as predators, parasitoids, and pathogens. "Classical" biological control seeks to locate host-specific pests from the plant's native range and import these species to attack and control the plant in regions where it has become invasive. For example, the alligatorweed flea beetle (*Agasicles hygrophila*) was introduced to North America in 1964 from Argentina to combat alligatorweed (*Alternanthera philoxeroides*). This insect continues to provide excellent alligatorweed control and has not caused damage to any other plants.
- **Herbicides** are pesticides designed to control plants. Herbicides approved for aquatic use or in terrestrial natural areas are a vital component of most control programs and are used extensively for invasive plant management in South Florida. There are over 20 herbicides employed to control invasive plants in South Florida. Commonly used herbicides for control of broadleaf species in wetlands include 2,4-D, triclopyr, imazamox, and metsulfuron-methyl. Glyphosate and imazapyr are non-selective herbicides and are used for a variety of plant types. Fluazifop-p-butyl is used to control perennial grass species specifically. Floating and submerged aquatic plants are controlled with several herbicides with 2,4-D, diquat, fluoridone, endothall, and triclopyr being the most commonly used.
- **Manual and mechanical controls** include the use of bulldozers, specialized logging equipment, aquatic plant harvesters, or hand pulling to control invasive plants. While costly, these methods are often used when other control techniques may cause unacceptable damage to native species or when removal of invasive plant biomass is necessary to achieve restoration objectives.
- **Cultural practices** include the use of prescribed burning, water level manipulation, or native species plantings to control invasive plants. Fire can be used to suppress plant growth and kill both native and nonnative plants that are not fire tolerant. Regulating water levels may reduce invasive plant species in aquatic and wetland habitats. Planting native species may reduce the susceptibility of aquatic and wetland sites in some cases.

Invasive Animal Control Tools

Operational management tools to control invasive animals in Florida's natural areas have only been developed within the past decade and, in many cases, are developed but not fully implemented. By creating the Exotic Species Section in 2010, FWC became the first agency in the state with a dedicated program to deal with the operational-type control and management of nonindigenous wildlife or marine species. That section has since grown in size considerably and is now the Wildlife Impact Management Section. Invasive fish and wildlife are managed within the Nonnative Fish and Wildlife Program of the section. The following list provides a generalized description of techniques for control of nonindigenous animal species:

- **Exclusion** is the use of barriers (e.g., electrical, hydraulic, and sound) in terrestrial or aquatic environments to prevent target species from moving into unaffected areas. For example, electrical barriers are currently being utilized to limit movement of Asian carp (*Ctenopharyngodon* sp.) from the Illinois River into the Great Lakes. This technique has yet to be tested for controlling invasive species in the Greater Everglades.
- **Habitat manipulation** is the removal of cover, food and/or water sources, or breeding sites, or preventing the use of habitats by target species to reduce species population growth or tendency to occupy an area. An example is the District removal of large melaleuca slash piles in and around the area known to harbor the northern African python. These large debris stockpiles were thought to provide nesting habitat for this species.
- **Trapping** is the use of snares, nets, or cage traps to catch and remove individuals of the target species.
- **Expert catchers** are trained and managed members of the public who have the proclivity and ability to catch target species.
- **Hunting or fishing** is the use of recreational hunting or fishing as a means to reduce populations of the target species. Hunting programs are frequently used to manage nutria (*Myocastor coypus*) populations in Louisiana and other states and have been utilized as part of Burmese python management in Florida
- **Biological control** is the development of biological agents that can be introduced to reduce target species populations. Intentional releases of the Myxoma virus have successfully reduced invasive rabbit populations in Australia.
- **Chemical contro**l is the use of direct chemical application or bait stations to dispatch target species or interrupt breeding.
- **Sterilization** reduces reproduction to phase out populations of the target species in specific areas. For example, new chemical fertility control technologies are being utilized in Australia and Asia to control invasive rodent species.

INVASIVE PLANT MANAGEMENT

The District and other agencies continue to make significant progress toward achieving maintenance control of some invasive, nonindigenous plant species on public conservation lands in South Florida. Large sections of the Greater Everglades and the marshes of Lake Okeechobee have reached or are nearing maintenance-control levels where melaleuca once dominated. However, remote sections of the southeastern area of ENP and LNWR remain moderately to heavily impacted by difficult-to-control invasive plants. In these areas, the challenges of invasive plant control are immense due to inadequate financial resources and heavy infestations in difficult-to-access areas. It will likely be decades until these areas are successfully under control. Since 2014, the District, FWC, and USFWS have collaborated to implement an aggressive control program for melaleuca and Old World climbing fern in LNWR. Utilizing FWC funding, District

invasive species biologists are working collaboratively with USFWS resource managers to augment existing LNWR control efforts. The strategy involves utilizing District-managed ground applicators in the southern reaches of the LNWR moving systematically northward while USFWS managed contractors continue control efforts in the northern half of the LNWR where infestations are most severe.

Old World climbing fern also continues to present significant challenges for natural resource managers in the Everglades and the Kissimmee River Basin. This highly invasive plant is proving difficult to control, in part due to its ability to establish and thrive in remote, undisturbed areas. Continued research to develop herbicides, biological controls, and control strategies are needed for successful long-term management of this species. The District, in partnership with FWC, recently executed a multi-year agreement with the University of Florida to further expand Old World climbing fern management research. The primary focus of this work will be evaluating new herbicides and refining integrated pest management strategies in areas where this plant is most difficult to control.

In **Table 7-1**, the District's Fiscal Year 2016-2017 expenditures for nonindigenous plant control are summarized by land management regions. The purpose of this table is to report expenditures for the most abundant invasive plant species on District managed lands in support of the District's environmental restoration and flood control missions. In addition to these species, the District directs its staff and contractors to control all invasive plant species identified by the Florida Exotic Pest Plant Council (FLEPPC) as Category I species (FLEPPC 2015). These species are documented to alter native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with native species. In Fiscal Year 2016-2017, the District spent more than $19 million for overall invasive species prevention, control, and management in South Florida. In anticipation of continued budget shortfalls, the District reevaluated invasive plant management priorities to assure that gained ground is not lost. Experience has shown that vigilant reconnaissance and retreatment is necessary to maintain low levels of established invasive species. Biological controls are proving to be beneficial in this regard by reducing the rate of reestablishment for some species (Rayamajhi et al. 2008, Overholt et al. 2009). However, successful biological control programs are in place for only a handful of priority species so land managers must persist with frequent monitoring and control efforts. Note: The SFERTF is compiling expenditure information for participating member agencies. This information will be used to create a cross cut budget for invasive exotic species to increase strategic coordination efforts (SFERTF 2016).

Table 7-1. Invasive plant species control expenditures by the District in Fiscal Year 2016-2017 organized by land management region.

Priority Invasive Species	Upper Lakes	Kissimmee/ Okeechobee	Lake Okeechobee	Everglades	East Coast	West Coast	Biocontrol	Total
Melaleuca (*Melaleuca quinquenervia*)				2,038,655		557,371	150,000	2,746,025
Old World climbing fern (*Lygodium microphyllum*)	96,098	336,183		1,314,376	292,502	68,746	486,000	2,593,905
Brazilian pepper (*Schinus terebinthifolius*)	2,213	71,638		437,803	321,402	357,574		1,190,630
Floating plants Waterhyacinth (*Eichhornia crassipes*) and Waterlettuce (*Pistia stratiotes*)		101,578	112,643	411,612	63,051	31,145	333,000	1,053,029
Torpedograss (*Panicum repens*)	518		199,095	150,727	15,453	75,258		441,053
Shoebutton ardisia (*Ardisia elliptica*)				152,539	130,611			283,150
Hydrilla (*Hydrilla verticillata*)	45,255	28,527		20,813	12,945	23,165		130,706
Australian pine (*Casuarina equisetifolia*)				31,482				31,482

Biological Control of Invasive Plant Species

Most non-native plant species in Florida arrived without their specialized natural enemies and, thus, grow larger, produce more offspring, spread more quickly, and often end up dominating and degrading important habitats in Florida. The objective of classical biological control is to reunite host-specific natural enemies from the native range of the non-natives by introducing and establishing them into Florida to reestablish a natural regulation of the pest populations.

Although several biological control projects have been very successful in Florida, this method rarely controls the target completely; rather it complements existing tactics by weakening the target plant and making it less competitive with native plants, while increasing their susceptibility to herbicides and fire. Developing biological control agents is necessarily a long-term process due to the importance of ensuring the environmental safety of prospective agents. Overseas and United States quarantine studies are used to confirm the specificity of an agent, which is then subjected to a rigorous and lengthy review by state and federal regulatory agencies before they can be introduced. Despite these hurdles, biological control research and implementation has led to the permanent transformation of formerly intractable weeds into less invasive forms.

Melaleuca

The melaleuca weevil (*Oxyops vitiosa*) was introduced in 1997 and established on melaleuca throughout the region. Feeding by the weevil can reduce the tree's reproductive potential as much as 99 percent, reduce its rate of growth by more than 80 percent, and shorten its height by half (Tipping et al. 2008). Those trees that do reproduce have smaller flowers containing fewer seeds (Pratt et al. 2005, Rayamajhi et al. 2008). The melaleuca psyllid (*Boreioglycaspis melaleucae)* was released in 2002 and, in conjunction with the weevil, has led to decreases in melaleuca canopy cover over a 10-year period (1997–2007), resulting in a fourfold increase in native plant species diversity at some sites (Rayamajhi et al. 2009). A five-year field study found that melaleuca reinvasion was reduced by 97.8 percent compared to pre-biocontrol population densities despite a large fire that, in the past, would have promoted dense recruitment of seedlings (Tipping et al. 2012). The melaleuca midge (*Lophodiplosis trifida*) is the most recent biological control agent for melaleuca. The larvae feed within the stems, stimulating the formation of galls, which diverts the tree's resources away from growth and reproduction to the point where sapling height was reduced by 10.1 percent, leaf biomass by 42 percent, woody biomass by 42.7 percent, and root biomass by 30.3 percent (Tipping et al. 2016) (**Figure 7-1**). This agent also works in concert with the other melaleuca biological control agents in suppressing this tree, rendering it less invasive and easier to control using herbicides and fire. There is a new agent under development in United States Department of Agriculture (USDA) quarantine that galls the leaves; this species will probably get a release permit within 2 to 3 years.

Figure 7-1. Galls of the melaleuca midge (*L. trifida*) stunt and deform melaleuca stem growth (photo by SFWMD).

Old World Climbing Fern

The white lygodium moth (*Austromusotima camptozonale*) was the first agent to be released against Old World climbing fern in Florida. Releases of this insect began in 2004 and continued through 2012 and, despite the release of more than 110,000 individuals, this species did not establish. In contrast, a second biocontrol agent, the brown lygodium moth (*Neomusotima conspurcatalis*), was first released in Florida in 2008 and rapidly established large field populations at release sites (Boughton and Pemberton 2009; **Figure 7-2**). The population density of the moth varies across the landscape in South Florida. Outbreaks of the moth caused heavy damage to Old World climbing fern in multiple areas in winter 2016-2017. To date, 620,312 brown lygodium moths or larvae have been released in South Florida.

Figure 7-2. Damage to Old World climbing fern from the brown lygodium moth in LNWR during winter 2015-2016 (photo by SFWMD).

The lygodium gall mite (*Floracarus perrepae*) induces leaf roll galls on the leaves of Old World climbing fern. It also damages the apical meristems or new growing tips. First released in 2008, mite establishment has been patchy, and successful gall induction on field plants is much lower than anticipated. However, the mite has shown the ability to undergo long distance dispersal and continues to colonize

lygodium populations far from release sites, including areas within ENP. The mite recolonized a site after a prescribed burn in ENP and caused heavy damage to the Old World climbing fern regrowth. During Fiscal Year 2016-2017, more than 292,548 mites have been released in Florida. Current research is investigating the effects of biotic and abiotic factors on *F. perrepae* population dynamics to improve rearing methods and field establishment of this agent. In addition to the two established agents, host range testing is also under way in the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) quarantine facility in Fort Lauderdale for three candidate biocontrol agents: *Lygomusotima stria* (moth), *Neostrombocerus albicomus* (sawfly), and the newly colonized *Callopistria* sp. (moth).

Waterhyacinth

Waterhyacinth is an exotic floating plant that aggressively colonizes freshwater ecosystems in the southeastern and southwestern United States including the Everglades. Several biological control agents of water hyacinth introduced during the 1970s have reduced biomass by more than 50 percent and seed production by 90 percent, but additional agents are needed to reduce surface coverage. The latest biocontrol agent, the waterhyacinth planthopper (*Megamelus scutellaris*), was released into the field in February 2010 (Tipping et al. 2014), making it the first new agent on waterhyacinth in more than 30 years. During Fiscal Year 2016-2017, a total of 608,733 insects to date were released in Florida, most of them in the Everglades STAs. The species is cold tolerant and can overwinter at least as far north as Gainesville, Florida. Experimental field evaluations of waterhyacinth herbivory from the plant hopper and the previously established waterhyacinth weevils (*Neochetina* spp.) demonstrates that these agents can exert considerable herbivory pressure on the aquatic weed **(Figure 7-3)**. Other biological control agents for waterhyacinth and waterlettuce (*Pistia stratiotes*) are being evaluated in USDA-ARS quarantine in Davie, Florida.

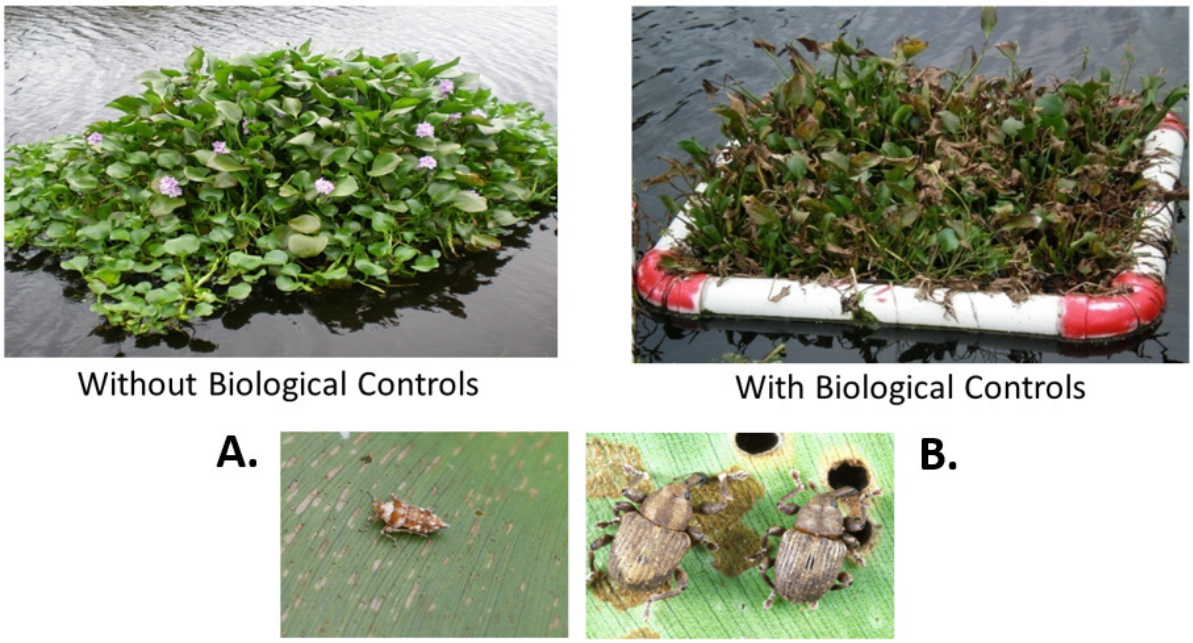


Figure 7-3. Experimental field comparison of biological control impacts on waterhyacinth. Plants on the left received insecticide treatments to prevent herbivory by agents; plants on the right received no insecticide. Agents responsible for herbivory include the (A) waterhyacinth planthopper (*M. scutellaris*) and (B) waterhyacinth weevils (*Neochetin a* spp.) (photos by USDA-ARS).

CERP Biocontrol Implementation Project

The CERP Melaleuca Eradication and Other Exotic Plants – Implement Biological Controls Project is dedicated to the implementation of biological control agents to address the spread of non-native weeds throughout the CERP area. The project included the construction of a mass rearing annex to the existing USDA-ARS biological control facility in Davie, Florida, to mass rear, release, establish, and monitor approved biological control agents for melaleuca and other non-native weeds in the CERP area. The final project implementation report/environmental assessment (USACE and SFWMD 2010), the project partnership agreement and cooperative agreement on lands, and the design-build contract were all executed in 2010 with the construction of the mass rearing facility completed in 2013. USDA-ARS, in close coordination with the District and United States Army Corps of Engineers (USACE), has begun the operational phase of the project and has released more than 1.5 million insects and mites on three weed species in Fiscal Year 2016-2017; releases are continuing. Intensive and extensive field monitoring and evaluation of the biological control agents are under way.

Invasive Plant Management Strategies and Challenges

Successful invasive plant management in South Florida requires flexibility in control strategies and the ability to quickly alter priorities in response to shifting inputs. Land managers and invasive species biologists understand that there is a suite of diverse factors that influences control strategies, and plan modifications necessarily occur. Occasionally these factors are predictable. For example, recently completed restoration projects often produce foreseeable changes in plant community composition along with shifts in non-indigenous plant invasiveness—either positive or negative. More often post-restoration outcomes relating to invasive plants are unanticipated and necessitate rapid assessments and plan modifications by land managers. For this reason, integration of adaptive management principals with invasive plant management strategies should be exercised.

Adaptive management can be intuitive to seasoned land managers, particularly if they have had similar past experiences. However, introductions of new species on the landscape or a range expansion of an existing plant into a novel community can present new uncertainties. A newly introduced plant that exhibits potential to spread rapidly could be a priority for control but techniques for novel species are often unknown. The most cost-effective strategy is early suppression of new invasions, but land managers rarely have the luxury of time and resources to implement control plans rapidly.

Chemical or mechanical control for a plant species that has no history on the South Florida landscape is often initiated based on knowledge of control techniques for other plants that are closely related or have similar physiology. Longer-term refinements of best management practices for these newly established species are achieved through research conducted by collaborating agencies, careful documentation, and field trials. The Areawide Management and Evaluation of Melaleuca (TAME Melaleuca!) program is an example of a ten-year collaborative effort between state, federal, academic, and local entities that resulted in an integrated control formula that is still used across the state to successfully manage melaleuca.

Today there are a host of invasive, non-native species in Florida—some of which have been established for years—that do not have clearly defined treatment protocols. For example, two invasive canegrasses, napiergrass (*Pennisetum purpureum*) and Burmareed (*Neyraudia reynaudiana*), dominate over 4,000 acres of soil-disturbed project lands in the Frog Pond and Rocky Glades region of Miami-Dade County. Mowing and prescribed fire are not long-term control solutions because both these grasses grow extensive root systems, which enable them to resprout quickly. Foliar herbicide applications are also a short-term method of control. Resprouting is common, and the propagule pressure (seed rain) from widespread populations on the landscape ensure herbicide treatments will be required in perpetuity. Land managers struggle with the treatment of these grasses because once established they form dense monospecific stands that prevent the recruitment of desirable species. Repeated herbicide applications are not sustainable and prevent succession to a desired native community type. Due to the dense root mats, shredding or tilling rarely achieves

complete control, and additional soil disturbance only enhances conditions for these disturbance-adapted species. It is possible that a combination of mowing, fire, and herbicide applications can create enough of a reduction in above and belowground biomass that native species can begin to gain a foothold. The District plans to initiate field trials in the Frog Pond area, following adaptive management protocols, to test several types of treatment rotations.

Old World climbing fern has been treated across most of the District for more than 15 years. While some populations are greatly reduced, it has not been eradicated from any sites. The first lygodium management plan was published in 2001. It was updated in 2006 to reflect advances in biological control agents targeting the fern and updates on cultural and chemical management research. The plan noted that more research was needed to answer basic questions such as whether Old World climbing fern was adequately absorbing and translocating the herbicides to control the plants extensive rhizome system. Today, that specific question remains incompletely answered along with other knowledge gaps identified by Enloe (2015). Sustainable long-term control of Old World climbing fern will only be possible with a better understanding of how factors such as timing, habitat type, spore viability, and herbicide translocation influence treatment efficacy. Fortunately, Old Word climbing fern research funded by the District is being conducted by UF to answer some of these outstanding questions. Similar questions exist for other invasive plant species in Florida.

Some of the challenges associated with Old World climbing fern control could be alleviated with biological control agents. The biological control program seeks to identify natural insect pests in a plant's native range. These insects are subject to quarantine, host-specificity testing and a rigorous approval process prior to release. It can take more than seven years to go from exploration to quarantine and testing to approval for release. Biocontrol agents rarely kill plants. Rather, they act as one component of integrated pest management by reducing seed and spore production or slowing growth. One of the reasons the TAME Melaleuca! program has been successful is because land managers have had the help of three successful biological control agents. These insects, when present, have often dramatically reduced the ability of melaleuca to produce flowers and generally slowed its growth, giving land managers more time between herbicide treatment intervals. This increase in retreatment interval significantly reduces herbicide control costs. To further support the biological control component of the regional integrated management strategy, the District and the United States Army Corps of Engineers (USACE) entered into an agreement in 2010 to construct and support a USDA biological control mass-rearing facility in Davie, Florida (see project summary below).

It is becoming widely recognized by scientists and decision-makers that successful invasive species management is a critical component of Everglades restoration. Many of the worst invasive plant species in the Everglades can alter topography, hydrology, and biogeochemistry and create changes in ecosystem processes that result in a reduction in native plant species viability, changes in fire regimes, and diminished wildlife habitat. It is not enough to restore flow and water quality. These ecosystem engineers need to be controlled for restoration to be successful. As Everglades restoration progresses and water deliveries are modified, hydroperiods and patterns are fluctuating from the Kissimmee Chain of Lakes region south through the Florida Keys. Many management areas that today are characterized by mesic plant communities will soon be inundated as restoration of surface water sheet flow and natural hydropatterns is implemented.

The impacts on the abundance and distribution of invasive, non-native plant species will vary greatly by species, habitat, and restoration activities. In the Kissimmee Chain of Lakes, the abundance of Brazilian pepper could be greatly reduced as seedlings will be unable to germinate under sustained high water levels. Without the influx of newly germinated plants, the amount of time and money spent by land managers on Brazilian pepper will be greatly reduced. Conversely, lengthening the hydroperiod in the floodplains will likely open more suitable habitat for invasive creeping water primrose (*Ludwigia* spp.), a species for which land managers do not have an effective control technique in this habitat. Creeping water primrose willow on the Kissimmee River thrives in open marshes, intermixed with buttonbush (*Cephalanthus occidentalis*), hibiscus (*Hibiscus* spp,) and other desirable natives (Toth 2010). Cost-effective aerial treatments would

damage native species and selective control with ground crews is costly and difficult because of access challenges. Similar treatment and access challenges are anticipated with invasive, non-native grass species in and around the river and floodplain. It is likely that river restoration will lead to shifts in the distribution of exotic wetland grass species where invasibility may drive restoration outcomes (Toth 2015). Invasive grasses such as paragrass (*Urochloa mutica*) and limpograss (*Hemarthria altissima*) will get flooded out at low elevations but should persist in higher locations. Meanwhile, West Indian marsh grass (*Hymenachne amplexicaulis*) will likely expand its footprint into new areas of deeper sustained water.

Challenges faced by invasive species biologists are compounded by the routine introduction of novel plant species that arrive in South Florida natural areas through various methods. Some are unintentionally brought to Florida ports on shipping containers and dispersed by wind, water, and animals. It is impossible to screen every ship and container that enters each one of the ports in the state and accidental introductions occur. Other novel species are attractive to homeowners because of their vigor, quick growth, and ability to thrive in Florida's climate. With years of sustained seed pressure some can develop self-sustaining populations in Florida's natural areas. Fortunately, fewer than 4 percent of non-native plants in Florida have become naturalized and of those, only 10 percent of those are considered invasive (Gordon 1998). Screening and predictive tools developed by the UF Institute of Food and Agricultural Sciences (IFAS) and the Australian Weed Risk Assessment can help determine if a new plants species is likely to become problematic in natural areas but these tools are limited. With adequate data, they can predict invasive potential 90 percent of the time (Gordon et al. 2006). This can help land managers decide if they should focus any of their limited resources on a new introduction.

We know that the most cost-effective time to treat a plant is at the moment of its detection, before it is well established in any given location and has had the chance to produce quantities of seeds. However, when the decision to treat one species means neglecting another species land managers need to be able to correctly assess risk potential. If land managers are unable to implement a comprehensive program for invasive species management, it is often due to insufficient resources, either financial, personnel, or both. Securing funding is particularly challenging for both prevention and early detection and rapid response (EDRR). State and federal regulations prohibit listed aggressive plants from entering Florida and the United States, respectively. Preventing new establishments in Florida requires two tools. The first is instituting programs that will effectively screen plants that are imported to the state and prohibit those that are predicted to be harmful. The second facet is funding EDRR programs that will detect new occurrences of invasive, non-native plant species before they have an opportunity to become established and that have dedicated funding for treatment and monitoring of the site. It is difficult to institute EDRR programs because they require managers to accept uncertainty and to fund programs based on potential rather than known threats. Obtaining support for EDRR programs requires effective outreach and education—another component of a complete invasive species management program. Backing from the public, lawmakers, and agency managers is critical to the success of a comprehensive invasive species management program. **Figure 7-4** illustrates the components of a successful invasive species management program, several of which have been addressed in this section.

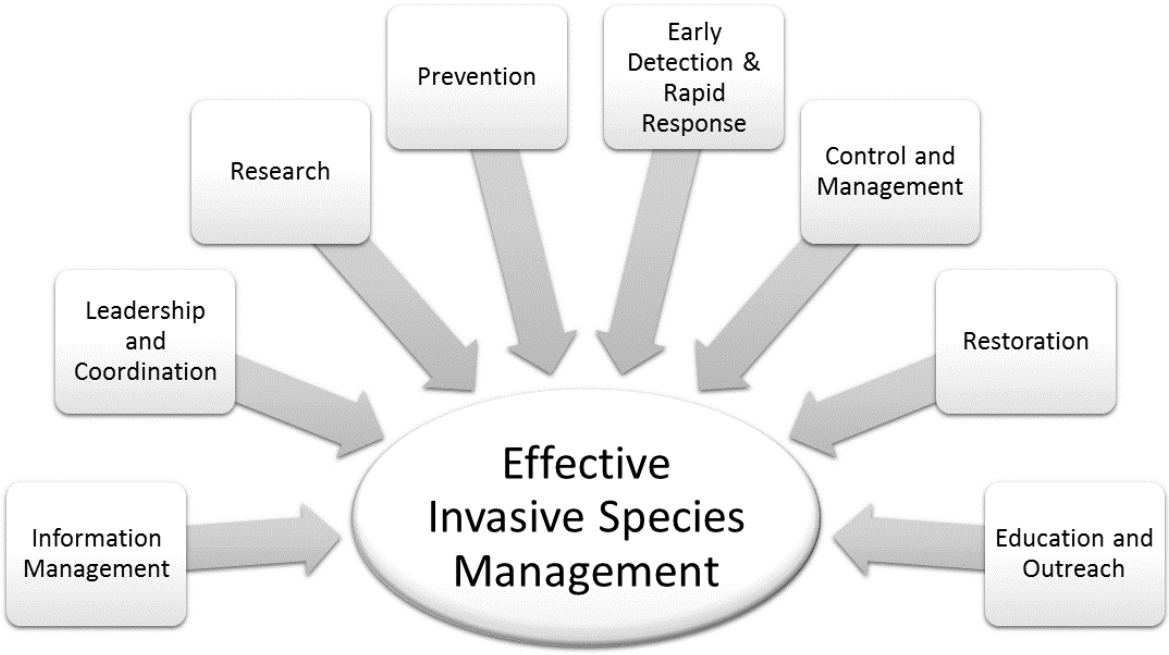


Figure 7-4. Common components of effective, integrative strategies for invasive species management.

INVASIVE ANIMAL MANAGEMENT

Efforts to develop control tools and management strategies for several priority animal species continued in Fiscal Year 2016-2017. These include the Burmese python and other giant constrictors, the Nile monitor (*Varanus niloticus*), and the Argentine black and white tegu. Control tools are very limited for free-ranging reptiles, and the application of developed methods is often impracticable in sensitive environments where impacts to non-target species are unacceptable. Potential tools for removing reptiles generally include catching, trapping, toxicants, barriers, dogs, and introduced predators (Witmer et al. 2007), as well as visual searching and pheromone attractants. Reed and Rodda (2009) provide a thorough review of primary and secondary control tools that may be considered for giant constrictors.

Regional invasive biologists associated with the Everglades Cooperative Invasive Species Management Area (ECISMA) have developed a conceptual response framework for establishing priority invasive animals in South Florida. Objectives within this framework are classified into three main categories— containment (slow the spread), eradicating incipient populations (remove outliers), and suppression (reduce impact in established areas). Resources to implement this framework remain insufficient, but close collaboration between agencies has allowed for some coordinated efforts. For example, multiple agencies are working together to contain the Argentine black and white tegu, determine its population status, develop monitoring and control tools, and better understand the natural history of this invader in South Florida habitats. A significant step toward a more structured and coordinated framework would be the formation of a regionwide EDRR strike team possibly modeled after the NPS Exotic Plant Management Teams. To date, this strike team has not been formalized; however, EIRAMP does provide a beginning framework and coordinated efforts through the ECISMA have the potential to continue development of an EDRR program.

There were several ongoing and new invasive animal initiatives in Fiscal Year 2016-2017, including ongoing monitoring and research efforts for Burmese python, northern African python, Argentine black and white tegu, Nile monitors, and Gambian pouched rat (*Cricetomys gambianus*), among others. Updates on these activities are discussed in the *Invasive Species Status Updates* section in this chapter.

Everglades Invasive Reptile and Amphibian Monitoring Project

In 2010, UF, FWC, and SFWMD began collaboration on the Everglades Invasive Reptile and Amphibian Monitoring Project. The purpose of the project is to develop a monitoring program for priority invasive reptiles and amphibians and their impacts to South Florida. Specifically, the program seeks to (1) determine the status and spread of existing populations and the occurrence of new populations of invasive reptiles and amphibians, (2) provide additional EDRR capability for removal of invasive reptiles and amphibians, and (3) evaluate the status and trends of populations in native reptiles, amphibians, and mammals.

The monitoring program involves visual searches for targeted invasive species on fixed routes along levees and roads within LNWR, WCA-2, WCA-3, Big Cypress National Preserve (BCNP), Southern Glades Wildlife Management Area, ENP, Corkscrew Swamp Sanctuary, and other areas such as the C-51 canal, US Highway 1, and Card Sound Road. Visual searches and call surveys are conducted to monitor invasive species and their potential prey species. Twenty-one routes have been established. and seven are active. The encounter rates for Burmese pythons ranged from 0.0014 to 0.0035 observations per kilometer. In 2016, green iguanas (*Iguana iguana*), anoles (*Norops sagrei*), house geckos (*Hemidactylus* spp.), brown basilisks (*Basiliscus vittatus*), Cuban treefrogs (*Osteopilus septentrionalis*),), greenhouse frogs (*Eleutherodactylus planirostris*), cane toads (*Rhinella marina*), coyotes (*Canis latrans*), wild pigs (*Sus scrofa*), and black rats (*Rattus rattus*) were the most commonly observed nonindigenous species of reptile, amphibian, and mammal, respectively (Frank Mazzotti, UF, unpublished data). Virginia white-tailed deer (*Odocoileus virginianus*), raccoons *(Procyon lotor*), and opossums (*Didelphis virginiana*) were the most common native mammals observed. Green treefrogs (*Hyla cinerea*), southern leopard frogs (*Lithobates sphenocephalus*), and pig frogs (*Lithobates grylio*) were the most common native amphibians observed. Cottonmouths (*Agkistrodon piscivorus*), peninsula cooters (*Pseudemys floridana*), and southern watersnakes (*Nerodia fasciata*) were the most abundantly observed native reptiles. To date, 105 Burmese pythons have been detected during these visual surveys.

Moving forward, the team plans to refine survey methods to correspond with peak Burmese python movement periods. In addition, the team has an occurrence experiment to evaluate whether the presence of invasive species is related to the absence of native species. In addition to fixed routes, the UF, FWC, and SFWMD team has joined with Venom One to provide EDRR capability for invasive reptiles in the ECISMA. The EDRR surveys and trapping have resulted in the removal of 85 Nile monitors, 2,210 Argentine black and white tegus, 6,001 Oustalet's chameleons (*Furcifer oustaleti*), 24 veiled chameleons (*Chamaeleo calyptratus*), 979 spectacled caiman, 13 Burmese pythons, one white-throated monitor (*Varanus albigularis*), one Nile crocodile (*Crocodylus niloticus*), one boa constrictor (*Boa constrictor*), one ball python (*Python regius*), one leopard gecko (*Eublepharus macularius*), and three black spinytail iguanas (*Ctenosaura similis*). A small group of volunteers is managed as part of this program and they have removed 92 Burmese pythons since April 17, 2015. In 2018, EIRAMP will increase focus on removal of priority species.

Python Hunter Incentive Program

In spring 2017, the District and FWC began collaboration to develop independent but parallel incentivized python hunter programs. This initiative is an evolution of a pilot program developed by the District and UF where EIRAMP managed a small number of experienced volunteer python hunters to survey for and remove pythons from District lands. The new programs added monetary incentives to these former volunteers and other vetted applicants. The goals of both programs include deploying experienced

python removal experts (**Figure 7-5**) to specific areas and compensating them to go out often, collect useful data on search effort, and remove as many pythons as possible.

Figure 7-5. District python hunter, Donna Kalil (right) with an assistant, after capturing a 3.1-meter python on the L-28 levee in Miami-Dade County. (photo by SFWMD).

Both agencies announced their programs in March 2017. The call for applicants received a great deal of interest from hunting enthusiasts. After an extensive vetting process, the District and FWC hired 25 and 21 contractors, respectively. The vetting process looked at previous python removal experience, background checks, and availability to participate on a regular basis. District contractors began searches on March 25 and the FWC contractors began on April 15. The District pilot program was approved to run through May 31, then was extended to September 31, 2017. Due to the initial success of the program, the District intends to maintain the program through Fiscal Year 2017-2018.

Both agencies agreed to a two-tiered compensation structure. Contractors receive $8.10 per hour spent in the field surveying for pythons, up to eight hours each day. For the effort of capturing a Burmese python, the contractor receives additional compensation based on the animal's length: $50 for the first four feet and an additional $25 per foot above four feet. The District also compensates their contractors $200 for each verified, viable python nest found in the field. At the time of this writing (August 24, 2017), District contractors have conducted over 5,000 survey hours and have captured 599 Burmese pythons (**Figure 7-6**). The average length of the pythons removed by District contractors is 2.6 meters (8.6 feet), with the largest python being 5.1 meters (16.8 feet). District contractors spent an average of 3.25 hours in the field per search event. These survey efforts have resulted in over $115,000.00 in payouts, which is an average of $250.00 per python removed. Additionally, over 400 eggs have been found from the removed gravid females.

The FWC contractors have completed 160.75 survey hours in four FWC wildlife management areas within South Florida (Everglades and Francis S. Taylor, Holeyland, Rotenberger, and Picayune Strand). The FWC contractors averaged 3.5 hours for each survey and have captured 5 adult pythons, averaging just under eight feet per snake. One python, a 12-foot female, was captured while on her nest of 39 eggs. The FWC has paid out $3,652, which includes both surveys and python payments through June 2017. The FWC's program has resulted in a cost of $98.70 per python.

FWC and SFWMD continue to work together on improving survey techniques, sharing contractor observations, and communicating about the respective programs. Inclusion of incentivized python hunting in the regional python control effort is another example of integrative pest management principals. Utilization and integration of multiple control tools, including telemetry, citizen scientist reporting (e.g., Ivegot1 Hotline), detection dogs, expert hunters, and other tools is likely to generate the most effective python management strategies. FWC, SFWMD, and other partners will continue working together to develop and implement new management techniques and refine existing technologies, with the goal of removing as many pythons from the Everglades ecosystem as possible.

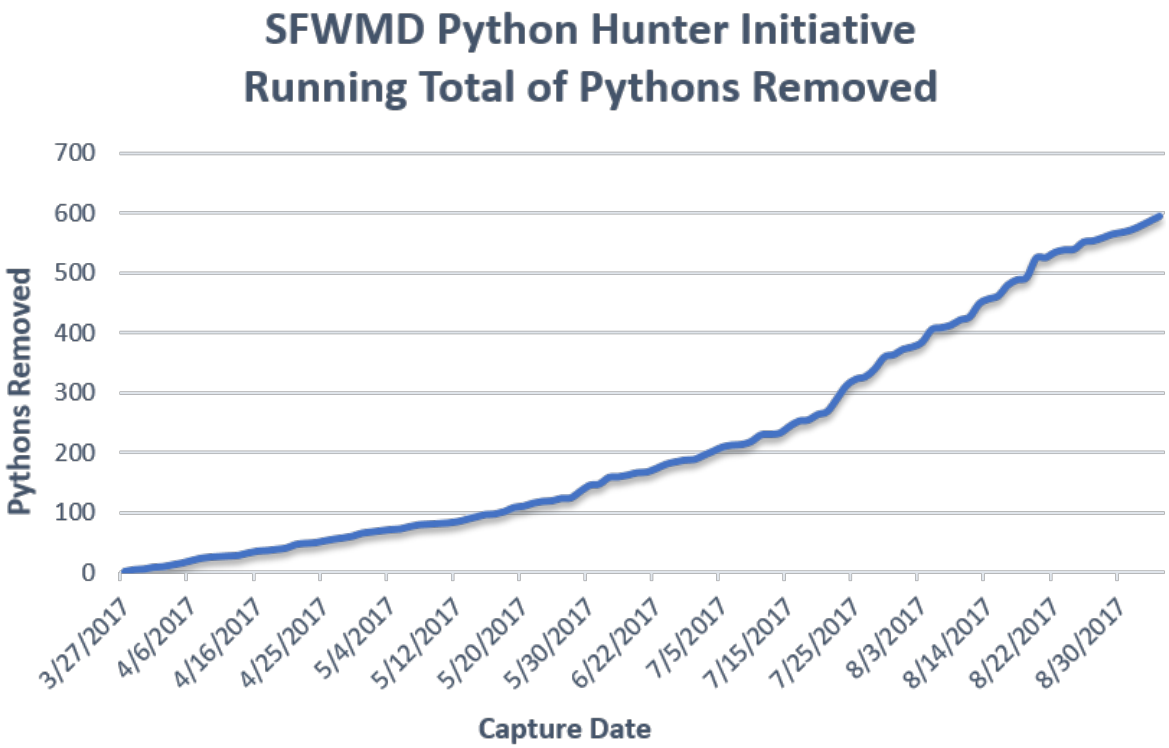


Figure 7-6. Running total of Burmese pythons removed from Broward and Miami-Dade Counties during the first five months of the District's Python Hunter.

Invasive Animal Research Update

An array of research projects related to invasive animals in the Everglades footprint has been undertaken by multiple collaborating agencies and universities. Adaptive management requires integration of monitoring and research as control efforts continue. This section summarizes key research efforts and conclusions to help guide future management of invasive animals.

Burmese python research continues to build upon work completed over the last decade. Early trials of traps resulted in low python capture rates (Reed et al. 2011) but the development of a pheromone (or other) attractant may improve the utility of traps. James Madison University, USDA, and FWC are collaborating to test effectiveness of pheromones in luring pythons. Pythons in Florida were radio tracked extensively (Pittman et al. 2014, Hart et al. 2015, Smith et al. 2016, Walters et al. 2016) but recent research by USGS and UF investigated the utility of global positioning system (GPS) telemetry. This technology allows more data collection with less effort but does not work well in closed canopy habitat preferred by pythons (B. Smith, USGS/UF, personal communication). Previous work on Burmese python diet reveals they are generalist predators (Dove et al. 2011, Snow et al. 2007a) and new stable isotope research by USGS and UF indicates pythons consume prey across a broad isotopic niche in saline and freshwater habitats and feeding across several trophic levels (B. Smith, USGS/UF, personal communication). Road surveys in the past were useful in providing evidence for dramatic declines in mammal populations as pythons increased their presence (Dorcas et al. 2012) and additional surveys show a predator-prey cycle relationship between pythons and opossums (F. Mazzotti, UF, unpublished data). Recent work also shows chronic, direct depredation of marsh rabbits by pythons (McCleery et al. 2015).

Improving detection of Burmese pythons is of critical importance since they are widely established in the region (**Figure 7-7**) and notoriously difficult to detect. Several studies have focused on refining our ability to detect pythons including detector dogs, Irula tribesmen from India, and environmental DNA

(eDNA). Detector dogs worked on Key Largo to find Burmese pythons by scent as well as in the Bird Drive Basin to search for northern African pythons. They succeeded in finding at least one python on Key Largo as well as many points of interest there and in the Bird Drive Basin. Irulas are expert snake hunters whose ancestors extirpated pythons from their region in India. They visited Florida for two months in 2017, detected 30 Burmese pythons, and removed 29 of them, including four pythons found in a Nike Missile silo on Key Largo. Irulas encounter rates measured 0.1253 pythons per hour and 0.0658 pythons per kilometer. They found more pythons per kilometer than local experts, largely due to their keen eye for snake sign such as shed skins, scat, and tracks (Metzger et al. 2017). A recent study using eDNA successfully detected Burmese pythons in five sites, including one where pythons were not yet documented (Piaggio et al. 2014).

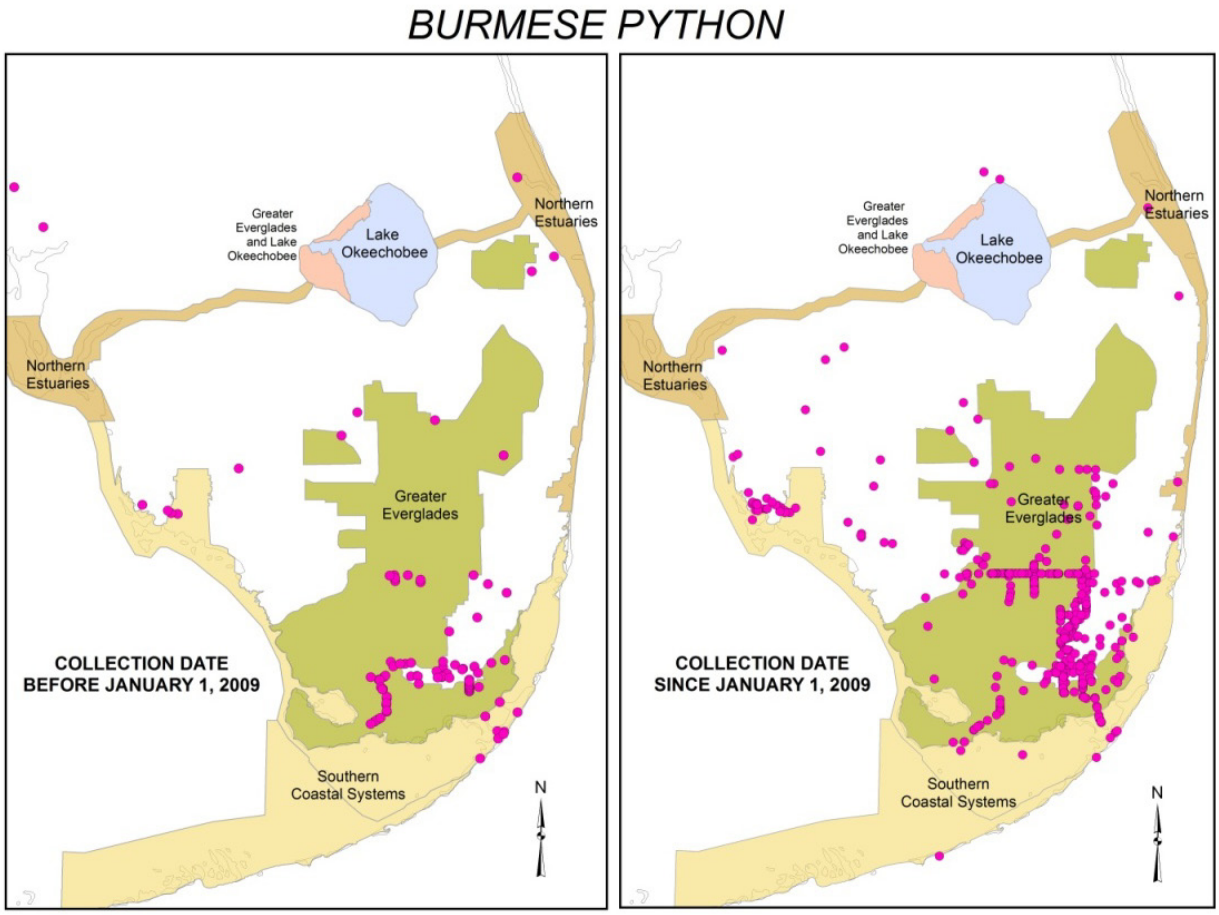


Figure 7-7. Locations of Burmese pythons (*P. molurus bivittatus*) removed from South Florida from 1999 through 2008 (left) and from 2009 to present (right)

Argentine black and white tegus received extensive attention from researchers during the last five years although they are not as well studied as pythons. Early radio telemetry work was conducted using very high frequency (VHF) transmitters and showed tegus spread readily in altered landscapes such as linear habitats and areas where water does not restrict movement (Klug et al. 2015). Recent research uses GPS transmitters that collect location data up to 12 times per day. Tegus are often in more open habitat than pythons and consequently GPS tags on tegus are generally more successful than those used with pythons (F. Mazzotti, UF, unpublished data). Several agencies trapped tegus extensively and used a wide variety of designs. Using chicken eggs as bait, Tomahawk and Havahart traps are the most effective tools for removing tegus (Nestler et al. 2017). Drift fences in conjunction with minnow traps successfully capture hatchling tegus (Nestler et al. 2017). The number of tegus removed during these efforts declined in 2016 and continues to decline in

early 2017, potentially demonstrating an impact on the tegu population in the current study area (Nestler et al. 2017, UF/USGS, unpublished data).

Northern African python research and control efforts continued into 2017. In addition to previously mentioned detector dog work, UF utilized surveys and refuges to continue searching for remaining African pythons. Because northern African pythons were not detected during surveys, Cole et al. (2017) estimated detection probability for northern African pythons using Burmese pythons as a surrogate. Detections probability was 0.0064 during EIRAMP surveys on Main Park Road in ENP, 0.00257 on C-110, and 0.0149 for surveys conducted by volunteer python hunters outside ENP. Using these detection probabilities, the minimum number of surveys needed to infer absence with a 95 percent confidence interval is 467 on Main Park Road and 1,164 on C-110. Increasing the detection probability to 0.0166 drops the number of surveys required to 179.

Removal of Nile monitors continued in 2017 by FWC and UF. Trap design was the central research focus and resulted in the successful capture of four monitors by UF. Scobel et al. (2017) reported trap success of 25.0 percent, similar to the success of trapping efforts in Cape Coral, Florida, where success averaged 29.2 percent (K. Hankins, City of Cape Coral, unpublished data). Sample size was too small to assess the best trap but the highest catch per unit effort (CPUE) in the study was 0.167 monitors per trap day for a Tomahawk S50 trap baited with chicken (Scobel et al. 2017).

Priorities Moving Forward

As management of invasive animals in the ECISMA footprint continues, we fill gaps in our knowledge. But important questions and the need for critical resources remain. Identifying and prioritizing future needs are important steps to move forward effectively and increase our likelihood of managing invasive fauna successfully. This section outlines future priorities.

The most consistent and important resource identified by most ECISMA partners is a steady and substantial source of dedicated funding. Resources for invasive animal research and management are much less substantial than inadequate funding for invasive plant work. Identifying a source capable of delivering sufficient and sustainable resources, developing a pathway to acquire them, and successfully executing that plan are vital to the success of managing invasive fauna.

Preventing introduction of new species or of existing species in new locations is the easiest and most cost-effective method of keeping the landscape free of nonnative species. Outreach, education, and risk assessment are important tools to achieve prevention. Outreach, education, and risk assessment are beginning to gain momentum in management efforts and the value of these programs should be reinforced. Creating regulations and patterns of responsible ownership to limit the introduction and spread of many nonnative species has occurred after introductions have occurred but would be more effective if set in place to prevent future introductions.

EDRR are the next best tools after prevention. Successful EDRR efforts already prevented the establishment and/or spread of several species such as sacred ibis (*Threskiornis aethiopicus*), Nile crocodiles, and panther chameleons (*Furcifer pardalis*). Maintaining a readily available response team with expertise across taxa is critical to success in extirpating a nonnative species already introduced.

Burmese pythons will likely remain a priority species due to their ability to impact native wildlife. Increasing detection of this cryptic predator is a high priority. Many avenues exist to pursue this goal. In the near future, work will continue with detector dogs and pheromone lures. Technology such as sophisticated cameras capable of scanning wavelengths invisible to the human eye will be investigated. Analyses of ideal conditions for python detection are nearly complete but should continue to be refined as data collection continues. Most control tools used for Burmese pythons also apply to northern African pythons and eradication efforts, while they are extremely limited geographically, should remain a key focus of managers in southern Florida. Judas snakes, snakes that are caught, radio-tagged, and released back into

the wild in an attempt to find nests, may be an effective tool for northern African pythons and should be deployed if possible. Continued monitoring of pythons will help in evaluation of control efforts.

Control of Argentine black and white tegus should continue and current declines are encouraging in suggesting that removal efforts may impact the population in local areas. Additional research on diet, body condition, and phenology of tegus is underway and will continue to shed light on the species, potentially leading us to weaknesses to exploit in removal efforts.

While Nile monitors are relatively confined geographically they are another species in need of forceful control efforts. A GPS telemetry study is needed to determine how monitors are using the landscape. Exploratory surveys and public outreach may provide important information on undiscovered metapopulations. We likely have an incomplete picture of where they occur and how they use the areas we already know they occur. Diet and body condition research on monitors is currently under way.

Several species have emerged as candidates for increased control measures. Spectacled caiman are sparsely distributed throughout the landscape of South Florida. Several agencies (FWC, SFWMD, and UF) plan to ramp up removal programs in an effort to extirpate local populations or even the entire species entirely from Florida. Green iguanas are observed to cause economic damage through crop damage, aircraft strikes, and structure damage (Falcon et al. 2013). For these reasons, FWC, UF, and SFWMD are beginning pilot programs to test iguana control methods from the Keys through Palm Beach County.

This section provides updates on key interagency coordination activities pertaining to invasive, nonindigenous species in South Florida during Fiscal Year 2016-2017. To be successful, regional management of nonindigenous species requires strategic integration of a broad spectrum of control measures across multiple jurisdictions. As such, numerous groups and agencies are necessarily involved with nonindigenous species management in Florida. More information on agency roles and responsibilities pertaining to nonindigenous species in Florida is available at http://www.eli.org/sites/default/files/eli-pubs/fillingthegaps.pdf.

INTERAGENCY COORDINATION

Cooperative Invasive Species Management Areas

Florida has a long history of invasive species organizational cooperation including the FLEPPC, Noxious Exotic Weed Task Team, Florida Invasive Animal Task Team, and Invasive Species Working Group. At more local levels, land managers and invasive species scientists have informally coordinated across the fence line for many years. These regional groups began formalizing their partnerships into cooperative invasive species management areas (CISMAs) to further enhance collaboration and coordination. CISMAs are local organizations, defined by a geographic boundary, that provide a mechanism for sharing invasive plant and animal management information and resources across jurisdictional boundaries to achieve regional invasive species prevention and control (MIPN 2006). Based on the success of CISMAs in Florida and in western states, the Florida Invasive Species Partnership, formerly the Private Lands Incentive Subcommittee of the Invasive Species Working Group, expanded its reach to act as a statewide umbrella organization for Florida CISMAs (www.floridainvasives.org). The Florida Invasive Species Partnership is an interagency collaboration of federal, state, and local agencies; nongovernmental organizations; and universities focused on addressing the threat of invasive, nonnative species to Florida's wildlife habitat and natural communities, and working agricultural and forest lands. The Florida Invasive Species Partnership serves Florida's CISMAs by facilitating communication between existing CISMAs, fostering the development of new CISMAs, providing training for invasive species reporting, and providing access to existing online resources and efforts. To date, there are 16 CISMAs in Florida covering roughly 98 percent of the state (**Figure 7-8**). Of these 16 CISMAs, seven occur either wholly or partially within the CERP footprint. Additional information on the Florida Invasive Species

Partnership and the ongoing cooperative efforts throughout Florida is available at www.floridainvasives.org/cismas.html.

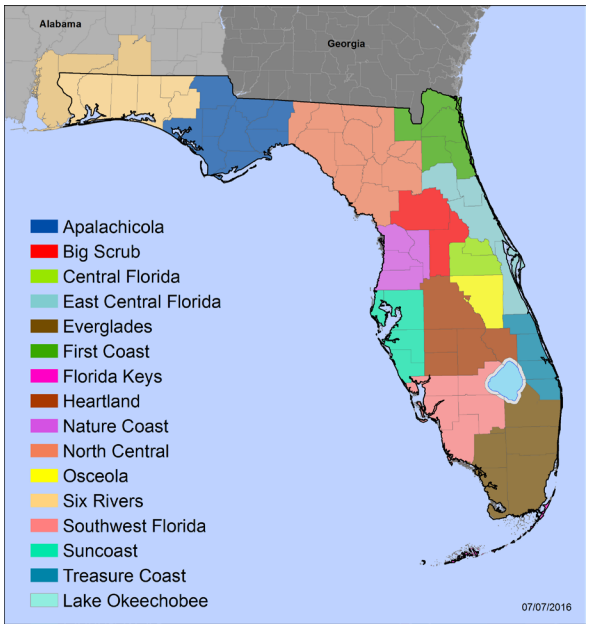


Figure 7-8. Locations of Florida's cooperative invasive species management areas (Map credit: University of Georgia – Center for Invasive Species and Ecosystem Health).

Everglades CISMA

Invasive species scientists and Everglades land managers formed the Everglades Cooperative Invasive Species Management Area (ECISMA) in 2006 in order to improve cooperation and information exchange related to invasive species management. The ECISMA partnership was formalized in 2008 with a memorandum of understanding (MOU) among the District, USACE, FWC, NPS, and USFWS. The MOU recognizes the need for cooperation in the fight against invasive species and affirms the commitment of signatories to a common goal. Currently, the ECISMA consists of 18 cooperators and partners, spanning the full spectrum of jurisdictions, including tribal, federal, state, local, and nongovernmental conservation organizations. The geographic extent of ECISMA includes all state and federal lands within the Everglades Protection Area (EPA) and Everglades Agricultural Area (EAA), Miccosukee and Seminole lands, and Broward, Palm Beach, and Miami-Dade counties. ECISMA has achieved much progress toward improved coordination and cooperation among those engaged in invasive species management in the Everglades. These accomplishments include development of regional monitoring programs, standardization of data management, completion of numerous rapid response initiatives, and enhanced coordination of management and research activities.

During the last year, ECISMA members represented the group by participating in several events, such as the 2nd Annual Invasive Species Awareness Event in Coconut Creek, the 3rd Annual Race Against Invasives in ENP, Pet Amnesty Days at Naples Zoo and Zoo Miami, The Spring Fish Slam in Big Cypress, and the Everglades Non-native Fish Round Up. Members also helped to raise public awareness by manning educational display booths at 11 events. In addition, a four-part lecture series was held at McMillan Middle School, where ECISMA members educated students about exotic species in South Florida and about ongoing research and ECISMA coordination to combat their invasions across the landscape. Several publications were developed by partners to educate the public about regional invasive species problems, responsible exotic pet practices, and to encourage the reporting of expanding invasive animal populations. Targeted outreach was implemented for Argentine black and white tegus in the Homestead area in the form of door hangers. This effort was successful in helping determine range and spread of the species, as well as testing a potential mechanism to contain it in its current range.

In July 2017, ECISMA partners convened for a two-day Everglades Invasive Species Summit in Broward County. Updates on invasive species management activities, new research, and outreach efforts were presented to attendees. During the second day, attendees divided into groups to tackle multiple issues including updating EDRR lists for both plants and animals, planning upcoming invasive plant workdays and the annual Spring Fish Slam, and discussing how to improve invasive animal data sharing between partners. FWC also held a Python Patrol Workshop to teach attendees non-native reptile identification and safe capture. More information about the ECISMA is available online at http://www.evergladescisma.org/.

Treasure Coast CISMA

The Treasure Coast CISMA (TC-CISMA) is a regional partnership established in 2007 to cooperatively address the threats of invasive plants and animals. The partnership extends from Indian River County south through St. Lucie, Martin, and northern Palm Beach Counties and includes representatives and land managers from local, state, and federal governments. Current active participants include SFWMD, USFWS, FWC, Florida Park Service, Martin County, The Nature Conservancy, Treasure Coast Resource Conservation and Development Council, Natural Resources Conservation Service, Palm Beach County Environmental Resources Management, UF IFAS, St. Lucie County, Aquatic Vegetation Control Inc., Habitat Specialists Inc., Florida Grazing Land Coalition, and The Florida Native Plant Society.

From October 2016 through September 2017, the TC-CISMA held an all members meeting and has planned serval workdays and workshops for fall 2017. TC-CISMA continued its private land efforts as a group, completing 5 workdays at The Boy Scouts of America's Tanah Keeta Scout Reservation in Martin County. Exotic species treated include downy rose-myrtle (*Rhodomyrtus tomentosa*), strawberry guava (*Psidium cattleianum*), earleaf acacia (*Acacia auriculiformis),* and Old World climbing fern. In addition, coastal private invasive work continued with maintenance at the 1.5-hectare Jensen Beach site that benefits the federally listed Lakela's mint (*Dicerandra immaculata*). The USFWS Partners for Fish and Wildlife Program application was submitted to fund O'Donnell Scrub Preserve work, which was completed. The TC-CISMA has submitted a preproposal to the Pulling Together Initiative Grant to try to aid private landowners with exotic removal projects.

The TC-CISMA is also involved with partnering with the public land manager members of the group. FWC Uplands Program projects were submitted by managers within the CISMA boundary and ranked by the Treasure Coast Working Group and are expected to be funded. The TC-CISMA participated in statewide Florida Invasive Species Partnership conference calls, and participated in the FLEPPC's Annual Symposium CISMA workshop. The TC-CISMA celebrated National Invasive Species Awareness Week with a multi-agency invasive removal workday and outreach event. The group banded together for a workday to target and remove an EDRR species, arrow bamboo (*Pseudosasa japonic*a), at Hobe Sound National Wildlife Refuge. More information about the Treasure Coast CISMA is available online at http://www.floridainvasives.org/treasure/.

Southwest Florida CISMA

The Southwest Florida CISMA, founded in 2008, is a partnership between the Florida Forest Service, FWC, Florida Park Service, USFWS, Lee County, Conservation Collier, Audubon of Florida, Conservancy of Southwest Florida, Naples Zoo, and others. This CISMA boundary encompasses 5 counties; Collier, Lee, Charlotte, Hendry, and Glades. This past year, members participated in several festivals and events to educate the public about invasive plants and animals including the 8th Annual Everglades Non-native Fish Round-up, Festival in the Woods at Picayune Strand State Forest, the Burrowing Owl Festival in Cape Coral, and the Florida Panther Refuge Open House. The CISMA's 20th Annual Southwest Florida Exotics Workshop was held at Florida Gulf Coast University, featuring 15 speakers, at which 180 people attended. Presentations covered topics such as biocontrol efforts, herbicide application research, python updates, citrus greening, Cuban tree frogs, and exotic fish. The Southwest Florida CISMA also held an Invasive Grass Identification workshop with IFAS in Charlotte County, educating 40 people about some of the worst exotic species in southwest Florida. Python research continues through the Conservancy of Southwest Florida and Dr. Paul Andreatis in tracking radio-telemetry tagged pythons. More information about the Southwest Florida CISMA is available online at http://www.floridainvasives.org/Southwest/.

Other CISMAs

In addition to the ECISMA, TC-CISMA, and Southwest Florida CISMA, there are four other CISMAs either wholly or partially within the footprint of the Greater Everglades ecosystem: Florida Keys Invasive Species Task Force, Heartland CISMA, Osceola County CISMA, and Central Florida CISMA. These CISMAs have also recognized many successes that have benefitted the Everglades ecosystem by furthering the concept of a landscape-level approach to invasive species management.

Lake Okeechobee Aquatic Plant Management Interagency Task Force

Invasive plant management on Lake Okeechobee is coordinated according to policy contained in the *Corps of Engineers Letter of Operating Procedures for Aquatic Plant Management on Lake Okeechobee* (USACE 1989), which was adopted by the involved agencies: USACE, SFWMD, Florida Department of Natural Resources, now the Florida Department of Environmental Protection (FDEP), and FWC. At semi-monthly meetings, interagency representatives plan treatment species and areas. Also, the group has flown semi-monthly since 1987 to estimate the lake's coverage of waterlettuce and waterhyacinth. The group's considerations include accounting for the presence of endangered species, conservation of quality fish and wildlife habitat, and navigation. Public stakeholders and nongovernmental organizations are always encouraged to attend and provide input to this process. More information about this task force is available online at http://www.floridainvasives.org/Okeechobee/index.html.

Kissimmee River and Kissimmee Chain of Lakes Coordination

Similar invasive plant treatment events are planned at interagency meetings for the Kissimmee River and Kissimmee Chain of Lakes, though these groups do not have a formal agreement such as the *Corps of Engineers Letter of Operating Procedures for Aquatic Plant Management on Lake Okeechobee*. Funding from the Florida Aquatic Plant Management Trust Fund and the Land Acquisition Trust Fund, administered by FWC, is available for much of the work in these waters. The primary lakes within the Kissimmee Chain of Lakes are given high state priority for large-scale aquatic plant management treatments, particularly for hydrilla, waterlettuce, waterhyacinth, Cuban bulrush (*Oxycaryum cubense*), and creeping water primrose. The primary lakes are large (1,620–13,800 hectares) and interconnected with flood protection canals, which are navigable with boat locks along the system.

South Florida Ecosystem Restoration Task Force

The South Florida Ecosystem Restoration Task Force (SFERTF) was established by Section 528(f) of the Water Resources Development Act of 1996. The task force consists of 14 members from four sovereign entities. There are seven federal, two tribal, and five state and local government representatives. The task force coordinates the development of consistent policies, strategies, plans, programs, projects, activities, and priorities addressing the restoration, preservation, and protection of the South Florida ecosystem. It recognizes the significant threat invasive exotic species pose to the goals and objectives of ecosystem restoration programs in South Florida. For more than a decade, task force member agencies have fought the rising tide of invasive exotics and the task force itself has supported those efforts through the coordination work of the Task Force Working Group and Science Coordination Group. Most recently, these two groups along with the Office of Everglades Restoration Initiatives recommended to the SFERTF that a comprehensive strategic action framework for invasive species be developed to improve coordination and boost the effectiveness of existing programs. The framework, completed in fall 2014, is a living, web-based document. The strategic action framework lists objectives and actions and highlights case studies as examples of the phases. More information on this effort is available at http://www.EvergladesRestoration.gov.

INVASIVE SPECIES STATUS UPDATES

The following section provides a summary of nonindigenous species that threaten the success of the District's mission. Regional invasive species scientists and land managers have adopted the invasion curve (**Figure 7-9**) as an organizing graphic to communicate the status, impacts, and management strategies for biological invaders. The curve depicts, at a glance, the ability to combat invasive exotic species in terms of time, resources, and likelihood of eradication or containment. The left-hand side of the invasion curve represents the best chance for long-term success. Since eradication of widely established invasive species is rarely achieved, a long-term commitment to controlling established species is required to protect vulnerable natural resources. Long-term suppression of established species is challenging and costly. Thus, early detection and control of new invasive species results in lower overall environmental impact and economic cost along with a higher likelihood for eradication.

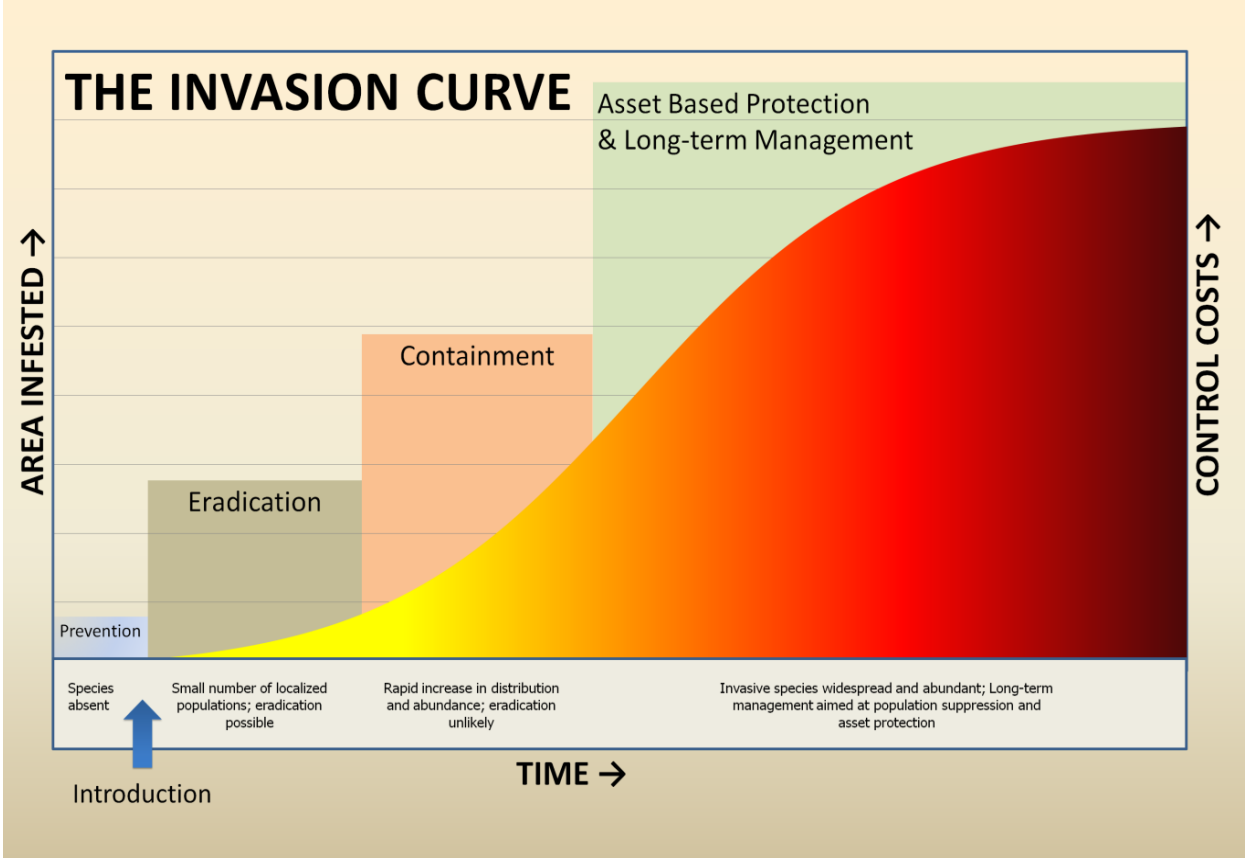


Figure 7-9. The invasion curve depicts the four major categories of management actions that may be taken to combat invasive exotic species as the invasion progresses from initial establishment to widespread dominance on the landscape. Graphic adapted from *Invasive Plants and Animals Policy Framework* (DEPI 2010).

In this section, each of the priority species is summarized in a one-page synopsis that highlights key management issues and provides general distribution information. Species are presented in three sections following principles of the invasion curve. The three sections group species according to the management strategies for long-term suppression or containment/eradication. Species managed by regional land managers for long-term suppression typically have wide distribution ranges and are assumed to be beyond regional containment or eradication. Species targeted for containment or eradication generally have

regionally limited or highly localized distributions and are thought to have the potential for containment or eradication due to limited distributions and/or sufficient control tools and resources. A third group includes non-indigenous species that are considered highly invasive in the South Florida Ecosystem but are not actively managed due insufficient control tools or management resources. These species may be the focus of monitoring and research on impacts to ecosystem- and species-level impacts.

Omitting specific mention of other nonindigenous species in the following priority summaries does not imply that the species are not problematic or that control is not important. On the contrary, the need is urgent for distribution and biological data for many of these organisms. In addition, numerous non-indigenous freshwater fishes with known or suspected impacts to native fauna are not included in this year's report. Ongoing monitoring and research regarding many of these fish species is beginning to elucidate the scope of the problem. The authors expect to provide details on the status of numerous non-indigenous freshwater fish in the *2019 South Florida Environmental Report* (SFER).

For each one-page synopsis, county (or coastline) distribution maps are provided. Distribution data were compiled from a variety of resources, but in only a few cases are data from systematic, statewide monitoring efforts. As such, these maps should be viewed as provisional and only intended to give general instruction on species' distribution. Primary data sources for the distribution maps and the module occurrence table found in Appendix 7-1 of the 2014 SFER – Volume I (Rodgers and Black 2014), include Early Detection and Distribution Mapping System (www.eddmaps.org/distribution/), ECISMA (www.evergladescisma.org/distribution/), FWC Florida's www.evergladescisma.org/distribution/ Florida's Nonnative Species (http://myfwc.com/wildlifehabitats/nonnatives/invasive-species/), USGS Nonindigenous Aquatic Species (nas.er.usgs.gov/), and University of South Florida Atlas of Florida Vascular Plants (www.plantatlas.usf.edu/).

Additionally, each species synopsis includes an indicator-based stoplight table that gauges the status of the species in each of the District's land management regions, as well as Lake Okeechobee, Florida Bay and the Florida Keys. These regions closely align with the CERP Restoration Coordination and Verification Program (RECOVER) modules, but are more inclusive of all conservation and project lands within the District boundary. The stoplight table technique was established through coordination among the Science Coordination Group, Noxious Exotic Weed Task Team, and Florida Invasive Animal Task Team of the SFERTF (Doren et al. 2009). Like its application in previous reports, the indicator table assesses each species by region per the following questions: (1) How many hectares within the module does this species occur in? (2) Is the distribution of the species in the module documented to be increasing, decreasing, or static? and (3) If the species is decreasing in coverage, is it a direct result of an active biocontrol or chemical/mechanical control program? A brief explanation of stoplight indicators provided for each priority species in the following species summaries is as follows:

- Red – Severe negative condition, or expected in near future, with out-of-control situation meriting serious attention

- Yellow – Situation is improving due to control program and is stable or moving toward stabilizing, or species is localized but expected to spread if sufficient resources or actions are not provided.

- Green – Situation is under control and has remained under control for several years.

SPECIES MANAGED FOR LONG-TERM SUPPRESSION

Twelve established plant species were selected by invasive species biologists from the District and partner agencies based on potential and current implications to the District's infrastructure and ecological concerns. The two established nonindigenous animal species presented in this section are in close alignment with the species identified by regional invasive species experts as priorities for long-term suppression and have active management programs in place. These species are generally presented with a "District-centric" justification for listing, and priority plant species may differ for other agencies, depending on regional factors and agency priorities and goals.

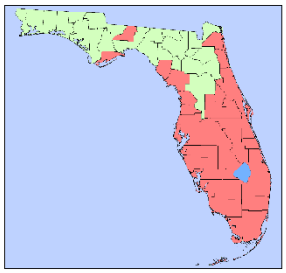
Table 7-2. Priority species currently managed within the South Florida Ecosystem for long-term suppression and/or asset protection (e.g., endangered species), ranked by taxonomic group and then alphabetically by common name.

Plants	
Australian pine (*Casuarina* spp.)	Melaleuca (*Melaleuca quinquenervia*)
Brazilian pepper (*Schinus terebinthifolius*)	Old World climbing fern (*Lygodium microphyllum*)
Cogongrass (*Imperata cylindrica*)	Shoebutton ardisia (*Ardisia elliptica*)
Creeping Water-rimroses (Ludwigia spp.)	Torpedograss (*Panicum repens*)
Downy rose myrtle (*Rhodomyrtus tomentosa)*	Waterhyacinth (*Eichhornia crassipes*)
Hydrilla (*Hydrilla verticillata*)	Waterlettuce (*Pistia stratiotes*)
Mammals	**Reptiles**
Feral hog (*Sus scrofa*)	Burmese python (*Python molurus bivittatus*)

Australian Pine (*Casuarina* spp.)

SUMMARY: Three nonindigenous species in Florida are collectively referred to as Australian pine: *Casuarina equisetifolia*, *C. glauca*, and *C. cunninghamiana*. Australian pine is a large, fast-growing tree that readily colonizes coastal and inland habitats (Morton 1980). Mature plants produce thick litter mats containing plant growth inhibiting compounds (Batish et al. 2001; **Figure 7-10**), making the plant particularly destructive to native plant communities. Australian pine can interfere with sea turtle and American crocodile (*Crocodylus acutus*) nesting (Klukas 1969b), and small mammal populations are lower in habitats dominated by this invader (Mazzotti et al. 1981).

Figure 7-10. The dense litter mat of Australian pine inhibits growth of other plants (photo by SFWMD).



KEY MANAGEMENT ISSUES

Distribution: Australian pine is still common routinely encountered in northeastern ENP, in the District's East Coast Buffer Lands, C-111 Basin, and Biscayne Bay National Park. While maintenance control is achieved throughout most of the EPA and most District-managed conservation lands, recent monitoring in the Southern Glades and Model Lands suggests a slight increase in abundance of Australian pine. However, Australian pine is still abundant on small tracts of lands throughout South Florida, especially in Dade and Broward counties.

Control Tools: Herbicide controls are well established for this species although access to remote infestations makes control challenging. Research confirms hybridization of *Casuarina* in Florida (Gaskin et al. 2009), which may present challenges for future biological control efforts.

Monitoring: Agencies monitor for this species in high priority public lands regionwide. Aerial mapping is conducted biennially within the Greater Everglades and on most District-owned lands.

Interagency Coordination: Agency-sponsored control efforts are ongoing but are complicated by local and state initiatives to allow plantings of this genus in certain situations or prevent control of the species for aesthetic reasons.

Regulatory Tools: *Casuarina* species are designated as Florida Prohibited Aquatic Plants. *C. equisetifolia* and *C. glauca* are designated as Florida Noxious Weeds. Florida law allows plantings of *C. cunninghamiana* for windbreaks in commercial citrus groves.

Critical Needs: State and local restrictions on planting and maintaining Australian pine. Research into potential biological control agents is also needed.

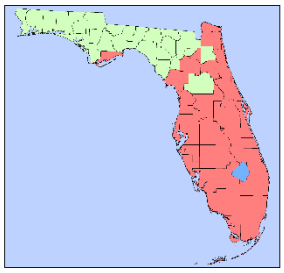
2017 Status of Australian Pine by Management Region

Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Brazilian Pepper (*Schinus terebinthifolius*)

SUMMARY: Brazilian pepper is an aggressive weed found throughout most of South and Central Florida. This shrub rapidly establishes in disturbed areas then expands into adjacent natural areas (Cuda et al. 2006). Once established, Brazilian pepper severely reduces native plant and animal diversity (Workman 1979, Curnutt 1989) and alters fire regimes (Stevens and Beckage 2009). The invasiveness this plant is partly explained by hybrid vigor. Florida's Brazilian pepper originated from multiple genetic strains (Mukherjee et al. 2012). The Florida hybrids were recently found to have greater fitness (germination rate and seedling survival) relative to their progenitors (Geiger et al. 2011).

Figure 7-11. Brazilian pepper typically forms dense single-species thickets (Phot by UF)



KEY MANAGEMENT ISSUES

Distribution: Brazilian pepper is the most widespread and abundant nonindigenous species in the District. This prolific seed producer is a dominant component of southwestern ENP and invades tree islands throughout the Greater Everglades region (Rodgers et al. 2014). Brazilian pepper also remains abundant on rights-of-way and private lands, facilitating constant reestablishment on conservation lands.

Control Tools: Managers typically use herbicidal, mechanical, and cultural controls. Two biological control agents to target Brazilian pepper have been identified and tested by USDA-ARS. Field releases are awaiting final approval.

Monitoring: Agencies monitor for this species in high priority public lands regionwide wide. Digital aerial sketchmapping (DASM) is conducted biennially within the Greater Everglades and on all District-owned lands

Interagency Coordination: An interagency management plan was developed that called for the need for coordination. ECISMA partners have begun to coordinate control efforts on adjacent lands in the Everglades. More coordination between major land holders is needed.

Regulatory Tools: Brazilian pepper is designated a Florida Noxious Weed and Florida Prohibited Aquatic Plant. There are no federal regulations regarding this species.

Critical Needs: Development and implementation of statewide private lands initiatives is needed to reduce propagule pressure on conservation lands.

2017 Status of Brazilian Pepper by Management Region

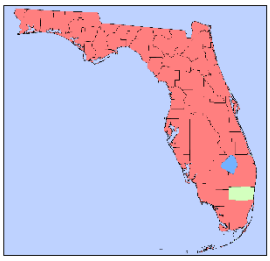
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Cogongrass (*Imperata cylindrica*)

SUMMARY: Cogongrass is among the top worst weeds internationally (Holm et al. 1977). Widely planted for forage in the early 1900s, this fast-growing perennial Asian grass is now estimated to infest 400,000 hectares in Florida (Miller 2007). Cogongrass invades pine flatwoods (**Figure 7-12**), disturbed sites, and marshes where it often displaces understory plant communities and alters ecosystem processes such as fire regimes (Lippincott 2000) and biogeochemical cycling (Daneshgar and Jose 2009, Holly et al. 2009).

Figure 7-12. Once established, cogongrass quickly dominates pineland understories (photo by University of Georgia).

KEY MANAGEMENT ISSUES



Distribution: Cogongrass is documented in natural areas throughout Florida. Within the District boundaries, cogongrass is most prevalent in the Kissimmee and Caloosahatchee watersheds, but in recent years it has spread in the Lake Okeechobee marsh, BCNP, Dupuis Management Area, and East Coast Buffer Lands. The plant appears to be spreading throughout the District along levees where it is easily spread by mowers.

Control Tools: This species is difficult to control and may require judicious implementation of integrated controls including repeated herbicide applications, prescribed fire, mechanical controls, and native revegetation efforts (IFAS 2013). No biocontrol agents have been approved for release.

Monitoring: Agencies monitor for this species in high priority public lands regionwide.

Interagency Coordination: The Regional Cogongrass Conference in 2007 produced a comprehensive cogongrass management guide for the Southeastern United States. FDACS with USDA has provided a cost-share program to reduce the spread of cogongrass by helping private landowners control existing infestations. FWC prioritizes treatments of this species on public lands and gives land managers the option to have it treated twice per year.

Regulatory Tools: Cogongrass is designated as both a federal and Florida noxious weed.

Critical Needs: Development of biological control agents would greatly improve regional control of this species. Increased control efforts on utility corridors are needed.

2017 Status of Cogongrass by Management Region

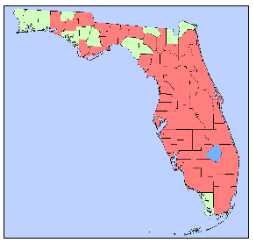
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Creeping Water Primroses (*Ludwigia* spp.)

SUMMARY: A complex of invasive aquatic *Ludwigia* species native to South and Central American have become widely established in Florida. Involved species include *L. grandiflora*, *L. hexapetala*, *L. uruguayensis*, and *L. peploides*. Here, *L. grandiflora* will be used as a "catchall" species name. Young plants of the "creeping water primroses" grow horizontally across the surface spreading into other plant communities. When mature, some grow upright to form dense stands up to six feet tall, and the dense rhizome mats fill the water column. In the Kissimmee Chain of Lakes, creeping water primrose overwhelms populations of valued emergent native plants. Allelopathic effects further contribute to the plants invasiveness (Dandelot et al. 2008). Genetic analysis has shown hybridization between *L. grandiflora* and *L. hexapetala* on Lake Tohopekaliga, yielding unknown changes in plant growth and invasive characteristics (M.D. Netherland, perssonal communication, July 26, 2016).

Figure 7-13. *Ludwiga hexapetala* establishing in broad leaf marsh of the Kissimmee River restoration area (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Creeping water primroses are now found from Kissimmee to Lake Okeechobee. They are reported from many other Florida waters including the St. Johns River system.

Control Tools: Young surface growth of creeping water primroses can be controlled with herbicides. However, they have little effect upon mature dense stands. The USDA-ARS is evaluating numerous insects in in South America for possible biocontrol use in the United States.

Monitoring: There is no comprehensive monitoring program for this species, but involved agencies share information regarding populations.

Interagency Coordination: The Florida Aquatic Plant Management and Land Acquisition Trust Funds, as administered by FWC, fund control of these species.

Regulatory Tools: None of the creeping water primrose species are listed as Federal Noxious Weeds or Florida Prohibited Plants.

Critical Needs: Continued funding and effort are essential to maintain pressure on new and previously treated creeping water primrose populations. Communication continues to be important as trials are made with promising new methods and materials. Containment is unlikely as propagules and seeds move with flows and as contaminants from boating and other activities.

2017 Status of Creeping Water Primroses by Management Region

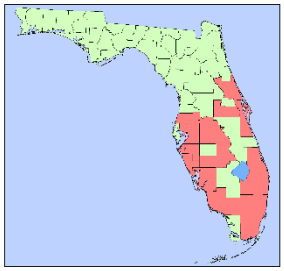
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Downy Rose Myrtle (*Rhodomyrtus tomentosa*)

SUMMARY: Downy rose myrtle (**Figure 7-14**) is an ornamental shrub of Asian origin. Introduced to Florida in the late 1800s, the plant now occurs in natural areas throughout South and Central Florida. This fast growing shrub spreads into pine flatwoods and drained cypress strands, even in the absence of disturbance, and can form dense thickets that crowd out native vegetation. It is very fire tolerant. Successful control of downy rose myrtle with herbicides is being accomplished where adequate resources are available. The high cost per hectare to clear advanced invasions shows the value of detecting and eliminating downy rose myrtle before it dominates a natural area.

Figure 7-14. Downy rose myrtle displaces understory plant communities in pine flatwoods (photo by USDA-ARS).

KEY MANAGEMENT ISSUES



Distribution: Downy rose myrtle occurs throughout Central and South Florida.

Control Tools: This species is difficult to control, but improvements in herbicide control show promise. Glyphosate and imazapyr are effective but kill native plants and inhibit revegetation. Dicamba provides good control of downy rose myrtle and spares many native plants. This selectivity is an advantage for use in natural areas. Shredding with heavy equipment and treating regrowth is effective but expensive. Not only are herbicides more effective on regrowth after shredding, but fresh growth appears in the field to be very susceptible to rust (*Puccinia psidii*) (Rayamajhi et al. 2013), which slows growth. Several candidate biological control agents are currently undergoing testing in quarantine and third is expected to enter quarantine in October 2017 and foreign exploration to discover additional agents is under way.

Monitoring: Because downy rose myrtle is difficult to detect from the air, monitoring is currently limited to observations by land managers.

Interagency Coordination: TC-CISMA makes this species a priority for regional coordination.

Regulatory Tools: Downy rose myrtle is designated a Florida Noxious Weed.

Critical Needs: Statewide private lands initiatives to reduce propagule pressure on conservation lands; plans to guide regional, integrated management; and monitoring to support early detection.

2017 Status of Downy Rose Myrtle by Management Region

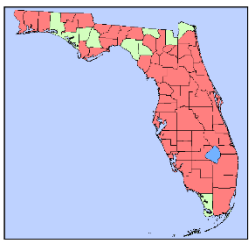
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Hydrilla (*Hydrilla verticillata*)

SUMMARY: Hydrilla is a rooted submerged plant that often forms dense mats through the water column (**Figure 7-15**), displacing native plant communities. It is native to the Old World and Indo-Pacific and was likely first introduced to Florida in the 1950s as an aquarium plant. By the 1990s, hydrilla was widely distributed in the state, occupying more than 56,000 hectares of public lakes and rivers. Hydrilla also supports the growth of a cyanobacterial epiphyte (*Aetokthonos hydrillicola*), which produces an avian toxin affecting herbivorous waterbirds and their avian predators (e.g., coots [*Fulica americana*] and bald eagles [*Haliaeetus leucocephalus*]; Wilde 2005, 2014, Martin 2015).

Figure 7-15. Dense hydrilla mats aggressively overtake native aquatic vegetation (photo by USDA).

KEY MANAGEMENT ISSUES



Distribution: Hydrilla is found in all types of Florida waterbodies. It has often dominated much of the Kissimmee Chain of Lakes. Hydrilla has been in Lake Okeechobee for over 20 years, but has not been a consistent problem.

Control Tools: Hydrilla management has primarily depended on herbicide applications. This weed developed resistance to a commonly used systemic herbicide, so agencies now use a contact herbicide. Of several newly-labeled aquatic herbicides, CLIPPER (flumioxazin) and GALLEON (penoxsulam) are controlling hydrilla. Additional herbicides may receive aquatic labels soon.

Monitoring: FWC monitors hydrilla throughout Florida's public waters and ranks these waters according to environmental and societal factors to prioritize funding distribution for treatment.

Interagency Coordination: FWC coordinates management of hydrilla by allocating funds from the Florida Invasive Plant Management Control Trust Fund to local agencies for control.

Regulatory Tools: Hydrilla is designated a Federal Noxious Weed and a Florida Prohibited Aquatic Plant.

Critical Needs: Continued research on effective systemic herbicides. Foreign exploration to locate potential biological control agents is continuing. This element of integrated management is needed for long-term control.

2017 Status of Hydrilla by Management Region

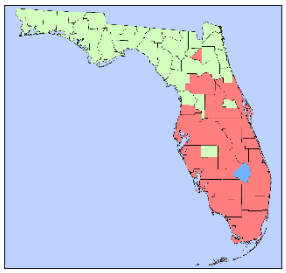
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Melaleuca (*Melaleuca quinquenervia*)

SUMMARY: Before organized state and federal nonindigenous plant control operations were initiated in 1990, melaleuca (**Figure 7-16**) was widely distributed throughout the WCAs, ENP, BCNP, Lake Okeechobee, and LNWR. Overall, agency efforts to control melaleuca are succeeding in containing and reducing its spread. Still, melaleuca remains widely distributed on private lands throughout South and Central Florida, but the successful biological control program has reduced its rate of spread (Pratt et al. 2005). Melaleuca infests an estimated 110,000 hectares of public and private lands within the District (Ferriter et al. 2008).

Figure 7-16. A former sawgrass marsh now dominated by melaleuca (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Melaleuca has been systematically cleared from Lake Okeechobee, WCA-2, WCA-3, and BCNP. These areas are now under maintenance control, but melaleuca continues to reestablish in cleared areas. Land managers report slower reinfestation rates as a result of biological control. Significant infestations remain in LNWR, eastern sections of ENP, East Coast Buffer Lands, and many west coast properties. However, significant progress has been made toward control in Broward County East Coast Buffer lands, and several west coast properties over the past few years.

Control Tools: The region's melaleuca management program is integrated. Herbicidal, mechanical, physical, and biological controls are all used. There are now three established biological control agents exerting substantial control on melaleuca.

Monitoring: Agencies monitor for this species in high priority public lands regionwide. DASM is conducted biennially within the Greater Everglades and on all District-owned lands (see the *Invasive Plant Management* section for more information).

Interagency Coordination: Interagency coordination has proven successful for this species.

Regulatory Tools: Melaleuca is listed as a Federal Noxious Weed, a Florida Noxious Weed, and Florida Prohibited Aquatic Plant.

Critical Needs: Private land initiatives to reduce remaining infestations near conservation lands.

2017 Status of Melaleuca by Management Region

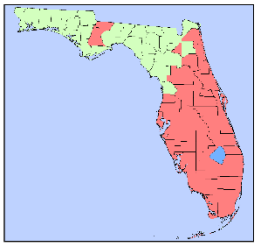
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Old World Climbing Fern (*Lygodium microphyllum*)

SUMMARY: Perhaps no other plant species poses a greater threat to South Florida's mesic upland and wetland ecosystems than Old World climbing fern (**Figure 7-17**). This highly invasive fern smothers native vegetation severely compromising plant species composition, destroying tree island canopy cover, and dominating understory communities. This species could potentially overtake most of South Florida's mesic and hydric forested plant communities (Gann et al. 1999, Lott et al. 2003, Volin et al. 2004).

Figure 7-17. Old World climbing fern overtaking a cypress swamp (photo by USDA-ARS).

KEY MANAGEMENT ISSUES



Distribution: Old World climbing fern dominates many tree islands, strand swamps, pine flatwoods, and other forested wetlands throughout South and Central Florida. First collected in Martin County, this species continues to expand its range northward. Dense infestations are particularly widespread in southwestern ENP, LNWR, and the Kissimmee River region.

Control Tools: Herbicides are used to control Old World climbing fern, but rapid reestablishment makes herbicide control costly and unlikely to succeed alone. Biological control is a critical component to effective long-term management of this plant. Three agents have been released in Florida; two have established. The brown lygodium moth and lygodium mite are being mass-reared and released, and are dispersing from release sites (Boughton and Pemberton 2009, Lake et al. 2014, Smith et al. 2014).

Monitoring: Agencies monitor for this species in high priority public lands regionwide. DASM is conducted biennially within the Greater Everglades and on all District-owned lands.

Interagency Coordination: An interagency management plan was developed for this species and agencies are coordinating control and monitoring efforts.

Regulatory Tools: Old World climbing fern is designated a Florida Noxious Weed.

Critical Needs: Successes in biological control efforts, ground-based monitoring programs, and private lands initiatives to reduce propagule pressure on conservation lands.

2017 Status of Old World Climbing Fern by Management Region

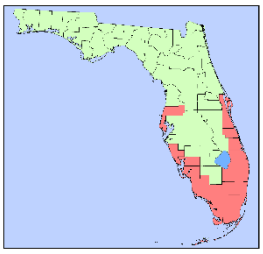
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Shoebutton Ardisia (*Ardisia elliptica*)

SUMMARY: Shoebutton ardisia (**Figure 7-18**) was imported as an ornamental shrub as early as 1900 (Gordon and Thomas 1997). It aggressively invades understories of hammocks, tree islands, and disturbed wetlands. This species often forms single-species stands, resulting in local displacement of native plants. There is a tendency for reinvasion by shoebutton ardisia or other exotic plants following removal of dense thickets of this species. Early infestations may go unnoticed due to this species' physical similarity to the common native marlberry (*A. escallonioides*).

Figure 7-18. Shoebutton ardisia dominates under and mid-stories of many Biscayne Bay Coastal Wetlands mangroves (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Shoebutton is established in natural areas in southeastern Florida, particularly in the Southern Glades and eastern portions of ENP.

Control Tools: Light infestations can be treated by cut stump herbicide application. This approach is costly in dense thickets and is only employed in sensitive wetland habitats where other removal methods are not feasible. The most efficient approach for dense infestations is mechanical shredding followed by herbicide application. Several herbicides have been used with moderate success, and evaluations are ongoing. Retreatments to control seedlings are required to control the residual seedbank. There are currently no biological controls or feasibility studies for potential agents for this species.

Monitoring: Shoebutton ardisia is difficult to detect from the air. Monitoring is currently limited to ground-based observations by land managers.

Interagency Coordination: While there is no regionwide strategic coordination for this species, biologists from the District, Miami-Dade County, and ENP are working closely to address major infestations in the Southern Glades region.

Regulatory Tools: Shoebutton ardisia is listed as a Florida Noxious Weed.

Critical Needs: A comprehensive feasibility study on the potential for biological control is needed. Increased funding to remove dense infestations in eastern Everglades; improved revegetation methods after removal of shoebutton ardisia; and monitoring to identify new populations are also needed.

2017 Status of Shoebutton Ardisia by Management Region

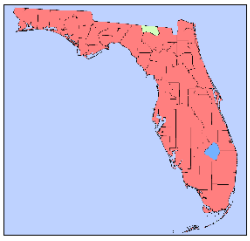
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Torpedograss (*Panicum repens*)

SUMMARY: Torpedograss (**Figure 7-19**), an Old World grass originally introduced to Florida for forage, forms dense stands that out compete native plants. Rhizomes make up most the plant's mass storing nutrients that enable the plant to recover from fire, drought, herbicide application, and frost (Langeland et al. 1998). Although seed originating from Florida has shown to have very low viability, torpedograss readily spreads vegetatively to new sites.

Figure 7-19. Torpedograss forms dense, impenetrable mats in open marsh (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Torpedograss is ubiquitous in most regions of South Florida, dominating disturbed wetlands, ditches, road swales, and lake margins. In areas such as Lake Okeechobee, where active torpedograss management is taking place, populations have been significantly reduced. However, many areas where this species exists are either not being managed for torpedograss, or control efforts have been unsuccessful in reducing infestations.

Control Tools: Mowing and grazing can marginally impact torpedograss, but herbicidal control is the only feasible method of long-term control. Non-selective herbicides such as imazapyr and glyphosate have been the main tools for control, however recent research has shown some efficacy with selective graminoid herbicides. While these graminoid-specific herbicides will not replace non-selective herbicides, they give land managers more flexibility in avoiding damage to native plant populations, and could help prevent possible development of herbicide resistance.

Monitoring: The District and FWC have tracked torpedograss infestations on Lake Okeechobee since the 1980s. Control efforts here have been generally successful. For instance, in 2007 and 2008, the District treated 26,080 acres of torpedograss on Lake Okeechobee. More recently, in 2016 and 2017 infestations were significantly reduced, and only 3,766 acres were treated. Outside of the lake, there is no systematic monitoring program for this species, and monitoring is limited to observations by land managers.

Regulatory Tools: There are no federal or state prohibitions for this species, however, torpedograss is listed as a FLEPPC Category 1 invasive species.

Critical Needs: Investigation of treatment timing with graminoid herbicides is needed to maximize treatment efficacy. Also, strategies to control torpedograss in situations where inundation prevents significant control of rhizome mass need to be developed.

2017 Status of Torpedo Grass by Management Region

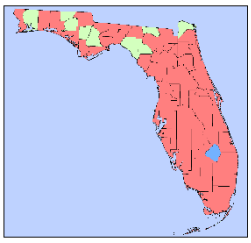
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Waterlettuce (*Pistia stratiotes*)

SUMMARY: Waterlettuce (**Figure 7-20**) is a floating aquatic plant native to South America, although now found throughout the tropics and subtropics. Rapid production of vegetative daughter plants occurs during all but the coolest months. New plants are also readily produced from seed and found to be up to 80 percent viable (Dray and Center 1989). Waterlettuce was reported by William Bartram in 1765 as forming dense mats on the St. Johns River. These mats continue to occur, clogging waterways and water management structures.

Figure 7-20. Dense floating mat of waterlettuce (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Waterlettuce inhabits all water body types in South Florida. Herbicide control efforts have nearly eliminated waterlettuce from many canal systems. However, most large lakes continue to harbor significant populations requiring frequent control. Waterlettuce populations have expanded when treatments have ceased to accommodate Everglade snail kite (*Rostrhamus sociabilis plumbeus*) foraging and nesting on lakes in the Kissimmee Chain of Lakes and Lake Okeechobee. When treatments can resume, treatment costs increased significantly since greater amounts of the plants are present.

Control Tools: Waterlettuce is readily controlled by herbicides, but rapid reestablishment of this species in some water bodies necessitates frequent retreatments. Newly-labeled products are showing promise as additional control tools for this plant. A single biocontrol agent, *Neohydronymus affinis,* is established in Florida, but its suppressive effects on the plant do not meet management standards.

Monitoring: FWC monitors waterlettuce in all public waters, and the District routinely monitors its canals for large populations.

Interagency Coordination: FWC coordinates interagency management of waterlettuce and other aquatic plants via solicitation of annual work plans from local public agencies and then allocates funds from the FWC Invasive Plant Management Control Trust Fund.

Regulatory Tools: Waterlettuce is listed as a Florida Prohibited Aquatic Plant.

Critical Needs: Development of additional biological controls is needed.

2017 Status of Waterlettuce by Management Region

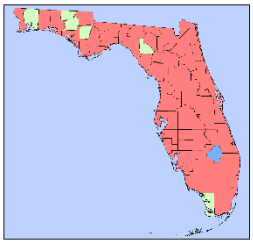
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Waterhyacinth (*Eichhornia crassipes*)

SUMMARY: Waterhyacinth (**Figure 7-21**), a floating plant native to tropical South America, was brought to Florida in 1884. It quickly blocked navigation on the St. Johns River. Vegetative reproduction occurs rapidly during all but the coolest months. New plants are also produced from seed, which germinate copiously on exposed moist soils (Perez 2011). Low nutrient needs and wide tolerance for water conditions enable its persistence and spread.

Figure 7-21. Dense floating mat of waterhyacinth (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Waterhyacinth inhabits all water body types in South Florida. Herbicide treatments have virtually eliminated it from many canal systems, including urban Miami-Dade and Broward counties. However, most large lakes continue to harbor significant populations requiring frequent control. In the Kissimmee Chain of Lakes and Lake Okeechobee, populations have expanded when treatments are suspended to accommodate Everglade snail kite foraging and nesting. When treatments resume, expanded populations are much costlier to control.

Control Tools: Waterhyacinth is readily controlled by herbicides, but rapid reestablishment of this species in some water bodies necessitates frequent retreatments. Newly labeled products, including GALLEON (penoxsulam) and CLIPPER (flumioxazin), are showing promise as additional control agents for waterhyacinth. The USDA has released and established four waterhyacinth biocontrol insects in Florida, including two weevils of the genus *Neochetina*. These agents reduce biomass by up to two-thirds and seed production by up to 90 percent, but do not reduce surface coverage enough to meet management standards. Herbivory by these agents makes the plant more susceptible to herbicides. In 2010, a new waterhyacinth-feeding insect was released in Florida, *Megamelus scutellaris*. This planthopper is now established in Florida and can be more readily integrated with herbicides than the previously released agents.

Monitoring: FWC monitors waterhyacinth in all Florida public waters. The District routinely monitors its canals for large populations of this and other floating aquatic weeds.

Interagency Coordination: FWC coordinates interagency management of waterhyacinth and other aquatic plants via solicitation of annual work plans from local public agencies and then allocates funds from the FWC Invasive Plant Management Control Trust Fund.

Regulatory Tools: Waterhyacinth is listed as a Florida Prohibited Aquatic Plant.

Critical Needs: Continued development of biological controls is needed.

2017 Status of Waterhyacinth by Management Region

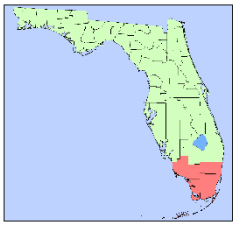
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Burmese Python (*Python bivittatus*)

SUMMARY: The Burmese python is widely established in the southern Everglades (Snow et al. 2007b) and increased sightings in the central Everglades indicate it is spreading. A metapopulation has also emerged in southwestern Florida. This large constrictor is a top predator known to prey upon more than 20 native Florida species and is implicated in substantial declines of mammal populations in ENP (Dorcas et al. 2012). Control of this species is a top priority among agencies. Despite widespread mortality of Burmese pythons following the 2010 cold event (Mazzotti et al. 2010), Burmese pythons of all age classes continue to be removed from the Everglades (**Figure 7-22**). See the *Invasive Animal Management* section above for more detailed updates on monitoring and removal efforts to date.

Figure 7-22. Detection of Burmese pythons is primarily along levees, roads, and other edge features (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: The Burmese python is found throughout the southern Everglades, particularly in ENP and adjacent lands (**Figure 7-7**).

Control Tools: Control options for this species are limited, primarily due to very low detectability (reference). Reed and Rodda (2009) review control tools and their applicability to large constrictors in Florida. Potential controls include visual searching, traps, detection dogs, Judas snakes, pheromone attractants, and toxicants. Research and development for many of these tools is ongoing.

Monitoring: A regional python monitoring network continues to develop and expand in South Florida. Pythons are regularly reported by members of the public to the 888-IVE-GOT1 hotline and EDDMapS reporting website (https://www.eddmaps.org/) and app.

Interagency Coordination: There is interagency coordination for this species, but efforts to implement programs are constrained by limited resources and few control tools. FWC and partner agencies are working together to create an interagency python management plan. USGS hosted an interagency meeting in 2017 to summarize past research conclusions and identify research gaps.

Regulatory Tools: The Burmese python is listed as a Conditional Reptile by the State of Florida. A federal ban on importation and interstate trade was instated in January 2012 but the United States Court of Appeals for the District of Columbia Circuit ruled the federal government cannot prevent interstate trade in 2017.

Critical Needs: Develop technologies to improve detection in the field; more funding for telemetry, Judas snake programs, and detection dogs; protect vulnerable resources such as bird rookeries.

2017 Status of the Burmese Python by Management Region

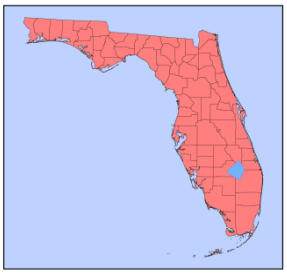
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Feral Hog (*Sus scrofa*)

SUMMARY: Feral hogs (**Figure 7-23**) have existed on the Florida landscape since their introduction by Spanish explorers four centuries ago. Feral hogs consume a variety of vegetation, invertebrates, insects, reptiles, frogs, bird eggs, rodents, small mammals, and carrion (Laycock 1966, Baber and Coblentz 1987). This invasive mammal is also known to prey on sea turtles, gopher tortoises (*Gopherus polyphemus*), and other at-risk wildlife (Singer 2005). Rooting by feral hogs can damage plant communities and may facilitate establishment of invasive plant species (Belden and Pelton 1975, Duever et al. 1986). Feral hogs are estimated to cause $2 million in losses to Florida cattle production. Plans are to document these impacts more fully in future work (Wisely 2016). $1.5 billion is conservatively estimated as the annual United States costs of feral swine damage (Mississippi State University Extension Service 2014).

Figure 7-23. A pair of feral hogs at Lake Okeechobee (photo by FWC).

KEY MANAGEMENT ISSUES



Distribution: Wild hogs are reported in all 67 Florida counties. Within the District, feral hog populations are particularly high in the counties immediately north and west of Lake Okeechobee, and in the Big Cypress and East Coast regions.

Control Tools: Hunting, trapping, and toxicants may be used to control feral hogs. The District has improved contract procedures for hog control. In the first 10 months of this program (beginning September 2012), 19 agents removed 1,800 hogs from District lands. Hog removal contracts are no cost; the incentive is that the permittee keeps the hogs.

Monitoring: There is no regional, coordinated monitoring program for hogs. Monitoring is limited to efforts associated with trapping programs and game management.

Interagency Coordination: Agencies coordinate control efforts to varying degrees at the local level. However, higher-level coordination is necessary to direct regional strategies for maintaining feral hog populations at the lowest feasible level.

Regulatory Tools: Hunting regulations could be modified to better control hog populations

Critical Needs: Development of target specific toxicants or contraceptives and initiatives for control on private lands.

2017 Status of Feral Hogs by Management Region

Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

SPECIES MANAGED FOR CONTAINMENT OR ERADICATION

Five invasive plant species were identified as priorities for regional containment or eradication by invasive species biologists from the District and partner agencies. Three graminoid species—tropical American watergrass (*Luziola subintegra*), West Indian marsh grass, and Wright's nutrush (*Scleria lacustris*)—are well established in the northern reaches of the District and Lake Okeechobee western marsh. Land managers are working to contain the spread of these species and prevent further expansion in the southern reaches of the Everglades and elsewhere. The eight established nonindigenous animal species presented in this section are also targeted for containment or eradication. Species with numerous population cores, such as the Nile monitor, are actively managed for regional containment while others with still limited geographic distributions (e.g., northern African python) remain candidates for eradication from Florida.

Table 7-2. Priority species currently managed within the South Florida Ecosystem for geographic containment or eradication, ranked by taxonomic group and then alphabetically by common name.

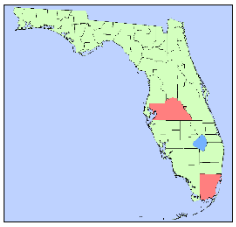
Plants	Reptiles
Exotic black mangrove (*Lumnitzera racemosa*)	Argentine black and white tegu (*Salvator merianae*)
Mile-a-minute (*Mikania micrantha*)	Nile monitor (*Varanus niloticus*)
Wright's nutrush (*Scleria lacustris*)	Northern African python (*Python sebae*)
Tropical American watergrass (*Luziola subintegra*)	Oustalet's chameleon (*Furcifer oustaleti*)
West Indian marsh grass (*Hymenachne amplexicaulis*)	Spectacled caiman (*Caiman crocodilus fuscus*)
	Veiled chameleon (*Chamaeleo calyptratus*)
Mollusks	**Mammals**
Giant African land snail (*Lissachatina fulica*)	Gambian pouched rat (*Cricetomys gambianus*)

Argentine Black and White Tegu (*Salvator merianae*)

SUMMARY: The Argentine black and white tegu (**Figure 7-24**) is a large, omnivorous lizard filling a niche similar to that of the Nile monitor. In its native range, it prefers open grassy areas and nests in burrows (Winck and Cechin 2008). Two populations are known in Florida—Hillsborough County (Enge et al. 2006) and southern Miami-Dade County (Pernas et al. 2012)—both of which likely resulted from deliberate releases by pet breeders (Hardin 2007). There are confirmed reports near Naples and Fort Pierce but the status of tegus there is unknown. Eight of nine tegus observed in Fort Pierce were removed (Eric Suarez, FWC, unpublished data). This species may impact Everglades restoration efforts by increasing predation on threatened and endangered species, including the American crocodile and the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) (Kevin Enge, FWC, unpublished data) and ecologically important species such as the American alligator (*Alligator mississippiensis*; Mazzotti et al. 2015). Given the large population size and the species' ability to expand through both natural and disturbed areas, eradication from Florida is unlikely, but containment may still be possible.

Figure 7-24. An Argentine black and white tegu fitted with a transmitter package (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Recent monitoring results suggest that the South Florida population is expanding, particularly in the Model Lands region and western Homestead. Interagency removal efforts resulted in the removal of over 552 tegus between January 1 and June 30, 2017 (FWC, UF, USGS, and Florida Power & Light, unpublished data). Private trappers have removed approximately 200 tegus from January 1, 2017, to July 23, 2017.

Control Tools: Trapping with baited traps and/or drift fences and removal by firearms may be effective control tool.

Monitoring: Interagency collaborators initiated rapid response measures in 2011. These efforts are ongoing and have expanded to include deployment of 119 camera traps, 341 live traps, and telemetry of 23 tegus in 2017 (FWC, UF, USGS, and Florida Power & Light unpublished data).

Interagency Coordination: There is interagency monitoring and trapping coordination for tegus. However, funding is needed for expanded removal efforts if containment is to be achieved.

Regulatory Tools: This species should be considered for Conditional Reptile designation by the State of Florida as private trappers continue to collect feral tegus and sell to the public.

Critical Needs: Dedicated funding for rapid response initiatives; research on severity of impacts; and federal and state regulations to restrict possession of this species.

2017 Status of the Argentine Black and White Tegu by Management Region

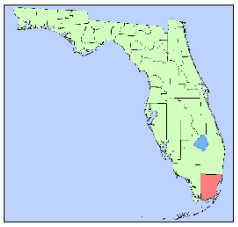
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Exotic Black Mangrove (*Lumnitzera racemosa*)

SUMMARY: The exotic black mangrove (also known as kripa; **Figure 7-25**) is native to Asia and Australia but escaped cultivation from Fairchild Tropical Botanic Garden. The plant was discovered to be rapidly proliferating in neighboring Matheson Hammock Preserve in 2008. Exotic black mangrove aggressively out-competes native mangrove species. The full effects of a major invasion of this species on Florida mangrove swamp diversity and function are difficult to predict. Given the important contributions of mangroves to marine productivity and the economy of South Florida, regional invasive species biologists launched a rapid response effort almost immediately after the invasion was detected.

Figure 7-25. Exotic black mangrove (photo by Fairchild Tropical Botanic Garden).

KEY MANAGEMENT ISSUES



Distribution: Exotic black mangrove is known to occur in Florida only in and around Fairchild Tropical Botanic Garden in Miami-Dade County.

Control Tools: This plant is readily controlled by herbicides, but rapid reestablishment of this species from the seedbank has required repeated treatments. Several cooperative interagency workdays eliminated many of the invading plants, but this approach seemed inadequate for eradication. FWC support for eradication allowed for more aggressive treatments using vegetation management contractors. The number of plants removed annually from the 8-hectare area continues to decline and are almost entirely seedlings and saplings, indicating that the seed bank is diminishing.

Monitoring: Biologists at Fairchild Tropical Botanic Gardens with the support of Everglades CISMA collaborators conduct annual monitoring for this species.

Interagency Coordination: In the absence of a formalized, regional rapid response program, the nine-year eradication effort led by Everglades CISMA is a model for grassroots coordination between agency resource managers.

Regulatory Tools: There are no federal or state prohibitions for this species, however, exotic black mangrove is listed as a FLEPPC Category 1 invasive species.

Critical Needs: Continued annual efforts to monitor and remove remaining established plants. State and federal agencies should review this species for future importation restrictions.

2017 Status of Exotic Black Mangrove by Management Region

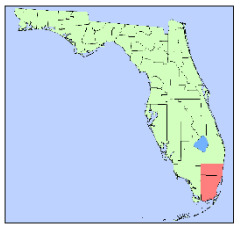
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Mile-a-minute (*Mikania micrantha*)

SUMMARY: Mile-a-minute is a federally-listed noxious weed that recently appeared in South Florida. This South American vine has turned into a serious weed where it was introduced in Asia, Australia, and Africa (Holm et al. 1977, Zhang et al. 2004). Mile-a-minute was discovered near Homestead in 2008. An aggressive reconnaissance and eradication effort began immediately after its discovery. Controlling the plant is challenging, in part due to infestations on private lands (Dozier 2012), although the threat of FDACS quarantine is an incentive for nursery owners to eliminate the weed. Eradication from Florida seems unlikely but containment and suppression remains a priority to prevent it from colonizing large natural areas like the South Dade Wetlands and ENP.

Figure 7-26. Mile-a-minute is a prolific seed producer and quickly overtakes native vegetation (photo by FDACS).

KEY MANAGEMENT ISSUES



Distribution: Apart from a single site discovered in 2014 in Broward County that appears to have been eradicated, mile-a-minute's distribution appears to be limited to the Homestead area in Miami-Dade County. Occurrences and densities vary, from single plants along the roadside, to much larger infestations that create problems in disturbed areas of hardwood hammocks.

Control Tools: This plant is readily controlled by herbicides. Mile-a-minute was treated by Miami-Dade County crews on 32 properties in 2017, including three nature preserves. After several years of treatment, it appears the plant may be eradicated for many population cores, but limited monitoring access on private lands is hindering control efforts.

Monitoring: Biologists at Miami-Dade County with the support of Everglades CISMA collaborators conduct annual monitoring for this species.

Interagency Coordination: In the absence of a formalized, regional rapid response program, the eight-year eradication effort led by Everglades CISMA is a model for grassroots coordination between agency resource managers.

Regulatory Tools: Mile-a-minute is designated a Federal Noxious Weed.

Critical Needs: Continued annual efforts to monitor and remove remaining established plants, particularly on private lands and outreach and education to the Florida nurseries that may spread this species.

2017 Status of Mile-a-minute by Management Region

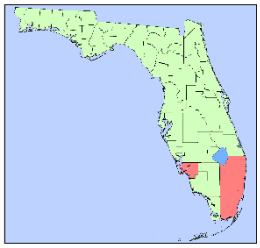
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Nile Monitor (*Varanus niloticus*)

SUMMARY: The Nile monitor (**Figure 7-27**) is a large predatory lizard known for its intelligence and adaptability (Bennett 1998). It is a generalist feeder (Losos and Greene 1988) that commonly preys on crocodile eggs and hatchlings in Africa (Lenz 2004). The impact of Nile monitors on Florida fauna is unclear, but their potential to impact native species through competition and predation is high (Enge et al. 2004). This species a threat to American crocodiles, American alligators, sea turtles, gopher tortoises, burrowing owls (*Athene* spp.), and other ground-nesting species (Meshaka 2006, Hardin 2007). Diet studies found that 94 percent of Nile monitors had food in their gastrointestinal tracts with insects, snails, and reptiles being most commonly consumed.

Figure 7-27. Nile monitors grow to 1.5 meters in length (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Established populations are documented in Lee County (Enge et al. 2004), Miami-Dade County, and central Palm Beach County (Eckles et al. 2017). Numerous sightings have also been reported in Broward County near WCA-3B.

Control Tools: Snares, traps, and hunting are the only available control tools for this species. City of Cape Coral biologists respond to citizen reports in Lee County and FWC conducts regular removal surveys in Palm Beach County. In 2017, 30 Nile monitors were removed from Palm Beach County using firearms, traps and hand catching (Eric Suarez, FWC, unpublished data).

Monitoring: An interagency team is currently monitoring, and when possible, removing Nile monitors in Palm Beach County. FWC will institute monthly monitoring in Broward County. UF works with LNWR to increase surveys in the area.

Interagency Coordination: Higher-level coordination was moved forward by a Nile monitor workshop organized by FWS in May 2016. A formal interagency control program is needed.

Regulatory Tools: The Nile monitor is listed as a Conditional Reptile by the State of Florida. Federal regulations are needed to further curtail releases of this invasive species.

Critical Needs: Dedicated funding for aggressive control measures and federal regulations to restrict possession of this species to avoid additional releases are needed.

2017 Status of the Nile Monitor by Management Region

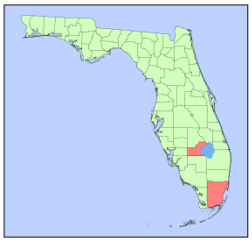
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Tropical American Watergrass (*Luziola subintegra*)

SUMMARY: Tropical American watergrass was first discovered in North America in 2007 in Lake Okeechobee (Kunzer and Bodle 2008). This perennial South American grass grows floating or emergent with prostrate creeping culms that form dense mats (**Figure 7-28**). UF researchers found that plants annually produce hundreds of fertile seeds that remain viable for long periods. Plants decline in winter; new spring and summer growth occurs from seed and surviving rhizomes. Managers aim to treat the plants before the onset of fall flowering.

Figure 7-28. Dense floating mats of tropical American watergrass (photo by FWC).

KEY MANAGEMENT ISSUES



Distribution: To date, the plant has been found in only two locations—Lake Okeechobee and one site in Miami-Dade County. The latter was eradicated. In Lake Okeechobee, the plant has spread well beyond its initial establishment area, although still within the lake's levee system. Continued treatments may not contain the plant much longer. It is likely that the plant will be transported outside the lake via wildlife or water releases.

Control Tools: Herbicides are the only control tool currently available. Trials with several of the newly labeled aquatic herbicides, separately and in combinations, may provide more control methods and prevent possible development of herbicide resistance to currently used herbicides. Little likelihood exists for biological control of tropical American watergrass. It is a grass in the rice tribe (Oryzeae) and the importance of rice agriculture will probably limit biological control as an option.

Monitoring: Interagency inspectors continue to monitor the plant and recommend control areas. Treatment funding is available from the Florida Invasive Species Management Trust Fund.

Interagency Coordination: Within the Lake Okeechobee Watershed, large property owners have been contacted to look out for the plant. Also, the Sanibel-Captiva Conservation Foundation was asked to look for the plant in their role as Caloosahatchee River Riverkeeper.

Regulatory Tools: Tropical American watergrass is not a federal or Florida noxious weed.

Critical Needs: Additional herbicide research and funding for monitoring and rapid response efforts.

2017 Status of Tropical American Watergrass by Management Region

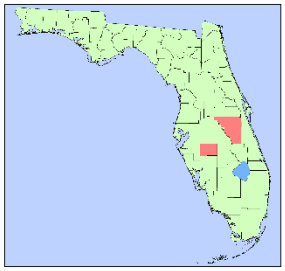
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Tropical Nutrush (*Scleria microcarpa*)

SUMMARY: Tropical nutrush (**Figure 7-29**) is a perennial sedge found throughout the American tropics. It has been found in a variety of countries including Mexico, Puerto Rico, Cuba, Panama, Peru, Venezuela, and Brazil. Although first detected in Florida in approximately 2007 it was not identified until 2016. As of 2017, it has been documented on the shorelines of five lakes in the Kissimmee Chain of Lakes including Lake Hatchineha, where it was first detected. It thrives along shorelines under a canopy. In areas dominated by cypress, this species grows in areas that lack significant vegetative cover so it is not directly competing with many plants. It also occurs in hardwood swamps where it is mixed with other graminoids.

Figure 7-29. Tropical nutrush under cypress canopy (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Documented in Polk and Osceola counties but may extend into adjacent counties.

Control Tools: Although some treatment occurred in 2017 and is planned for 2018, this species has had very little control efforts to date. Preliminary work shows that glyphosate is an effective herbicide treatment. Additional herbicide trials are needed to determine if season and hydrology impact efficacy of treatments. In hardwood marshes, it may be difficult to have selective treatments since it is found growing mixed with other sedges and grasses. Biological control efforts are not being considered for this species, which is part of a large genus that includes nine native species.

Monitoring: This species must be detected from the ground since it thrives under canopy. Heartland-CISMA has provided outreach to engage land managers in the region in detection and reporting.

Interagency Coordination: Heartland-CISMA makes this species a priority for regional reporting coordination.

Regulatory Tools: Tropical nutrush is not a regulated or prohibited species.

Critical Needs: Expanded survey for tropical nutrush including private lands and additional herbicide trials.

2017 Status of Tropical Nutrush by Management Region

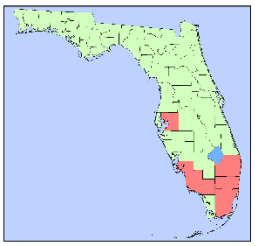
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Chameleons (*Furcifer oustaleti and Chamaeleo calyptratus*)

SUMMARY: The Oustalet's chameleon (*Furcifer oustaleti*) is a large chameleon native to Madagascar where it utilizes a wide variety of habitats, including human altered environments (D'Cruze et al. 2007). Diet analysis indicates that this chameleon population consumes a variety of insect and anole species, particularly moth larvae (Krysko et al. 2012). The veiled chameleon (*Chamaeleo calyptratus*) naturally occurs in mountain and coastal regions of the Arabian Peninsula. The veiled chameleon (**Figure 7-30**) is also known to utilize a wide range of habitats. Florida populations of both species are suspected to have been established through intentional releases by reptile enthusiasts. If chameleons demonstrate the ability to spread from suburban and agricultural land and build populations in native Florida habitats, then the argument for an aggressive eradication program will be strong.

Figure 7-30. The veiled chameleon (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: A population of the Oustalet's chameleon was discovered in rural Miami-Dade County in early 2010. This species does not appear to be spreading without human assistance and the number of chameleons per survey has decreased, indicating eradication may be possible if regular surveys resume. Breeding populations of the veiled chameleon are now documented in the Lee County (northwest estuaries), Miami-Dade County (one population near ENP a second adjacent to BCNP), Broward County, and Palm Beach County near the southern tip of LNWR (FWC 2013). In addition, reports of veiled chameleons are now common from Buckingham, Alva, Cape Coral, Marco Island, and Lutz, Florida.

Control Tools: Nighttime searches using flashlights are generally the best way to detect chameleons.

Monitoring: An interagency team, led by FWC, began a rapid assessment monitoring project in July 2011. Between July 2011 and July 2017, biologists removed 601 Oustalet's chameleons from a 49-hectare site (Mike Rochford, UF, personal communications).

Interagency Coordination: FWC and partnering agencies coordinate response efforts for this species, but efforts to implement controls are constrained by limited resources and few control tools.

Regulatory Tools: There are no federal or state prohibitions for these species.

Critical Needs: Efforts to remove remaining populations of both species should continue.

2017 Status of Chameleons by Management Region

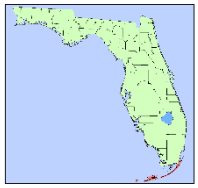
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Gambian Pouched Rat (*Cricetomys gambianus*)

SUMMARY: The Gambian pouched rat is a large, omnivorous rodent of African origin. Once popular in the exotic pet trade, the United States Center for Disease Control banned their importation in 2003 because they are a carrier of monkey pox. Prior to this ban, numerous Gambian rats escaped captivity in the Florida Keys (Grassy Key) and established a reproducing population. This species is considered likely to invade the Florida mainland and is viewed as a significant threat to endangered rodents and other fauna, agriculture, and human health (Engeman et al. 2006). These concerns prompted rapid response measures in 2005, which appeared to have been successful. In 2009, FWC biologists cautiously declared that the population was eradicated while continuing periodic monitoring for the rodent. Then in 2011, the Gambian pouched rat was again reported on Grassy Key. USDA and FWC biologists reinitiated trapping efforts in early 2011 and removed 31 rats to date. The last removal and sighting occurred in 2012. Unfortunately, in August 2017 a picture surfaced of an American crocodile with what appears to be a pouched rat in its mouth. Officials are currently assessing the situation.

Figure 7-31. Gambian pouched rats continue to occur in the Florida Keys despite years of trapping (photo by USDA).

KEY MANAGEMENT ISSUES



Distribution: The Gambian pouched rat is known to occur in the Florida Keys, with breeding confirmed on Grassy Key.

Control Tools: Toxicant baits were effectively used to control most the population (Engeman et al. 2007). Control efforts for remaining animals involve baited traps (**Figure 7-31**).

Monitoring: FWC maintains an active monitoring program to for this species.

Interagency Coordination: USDA, FWC, and the Florida Keys Invasive Exotic Task Force coordinate closely on early detection and rapid response efforts for this species.

Regulatory Tools: The United States Center for Disease Control banned the importation of the Gambian pouched rat in 2003.

Critical Needs: Continued efforts to monitor and remove remaining populations should continue.

2017 Status of Gambian Pouched Rat by Management Region

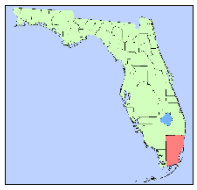
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Giant African Land Snail (*Lissachatina fulica*)

Figure 7-32. The giant African land snail is a host of the rat lungworm (photo by FDACS).

SUMMARY: A population of the giant African land snail was discovered in 2011 in an area of Miami (FDACS-DPI 2011, USDA 2013). The giant African land snail is known to eat a great variety of vegetation, including crop plants, horticultural plants, and environmentally valuable plants. This species has invaded other places outside its native range in Africa, often causing substantial damage. It is an intermediate host of the rat lungworm (*Angiostrongylus cantonensis*; **Figure 7-35**), which can infect humans and cause meningitis (Cowie 2013). This parasite, which has been almost unknown in the mainland United States, was recently detected in Miami-Dade County (Iwanowicz et al. 2015). A previous infestation of this snail occurred in Miami in 1966. The Florida state eradication effort took 10 years at a cost of $1 million (USDA 2013).

KEY MANAGEMENT ISSUES



Distribution: The Giant African land snail is known to occur in developed areas of Broward and Miami-Dade counties, from Davie south to Homestead. As of July 2017, researchers have identified 31 population cores in Miami-Dade County and a single core in southern Broward County (Eduardo Varona, USDA Animal and Plant Health Inspection Service [APHIS], personal communication).

Control Tools: Eradication is challenging and requires public support and education. Hand collection (wearing gloves) and snail toxicants are being used. Toxicants containing metaldehyde are used (FDACS 2013). There are indications that control efforts are having an effect, as fewer large snails are being seen. Local extinctions of the snail are being observed in many of the population cores (Roda et al. 2016).

Monitoring: An aggressive federal and state cooperative program is now under way to eliminate the existing population. Over 4,500 parcels are under survey in the cooperative program.

Interagency Coordination: The USDA-FDACS eradication program is a model for collaborative rapid response efforts.

Regulatory Tools: USDA APHIS established regulated areas within Miami-Dade County for quarantine in 2012.

Critical Needs: Continued annual efforts to monitor and remove remaining populations, particularly on private lands.

2017 Status of Giant African Land Snail by Management Region

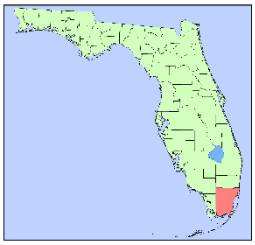
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Northern African Python (*Python sebae*)

SUMMARY: Since 2001, over 40 northern African pythons have been found in western Miami-Dade County (Jacob Kline, FWC, personal communication). This giant constrictor (**Figure 7-33**) shares many natural history traits with the Burmese python and is considered a high risk for establishment and expansion throughout South Florida (Reed and Rodda 2009). Rapid response efforts to delineate and eradicate this population are now of highest priority. The District, Miccosukee Tribe of Indians, and Miami-Dade County, the primary landowners within the Bird Drive Basin, are working closely with FWC and other agencies to address this threat.

Figure 7-33.
The northern African python (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: The northern African python is thought to occur within a 100 square kilometer area centered around the Bird Drive Basin in western Miami-Dade County, immediately east of ENP and WCA-3B.

Control Tools: Control options for this species are limited, primarily due to very low detectability. Potential controls include visual searching, traps, detection dogs, Judas snakes, Judas prey, pheromone attractants, and toxicants.

Monitoring: FWC, with numerous partnering agencies, continues surveys in the Bird Drive Basin. A northern African python was photographed by a private citizen in 2017 but was not removed despite rapid response efforts. Soon after, another individual was found and removed by District staff. Irula tribesmen searched the area in 2017 but did not find additional animals. Detector dogs did not locate snakes but did find points of interest (see the *Invasive Animal Research Update* section above for additional information on the Irula tribesmen and detector dogs).

Interagency Coordination: There is excellent interagency coordination for this species, but efforts to implement controls are constrained by limited resources and few control tools.

Regulatory Tools: A permit is required to possess, import, sell, or breed the northern African python in Florida (Chapter 68-5.002, Florida Administrative Code). In 2017, a federal court ruled that FWS could not ban interstate trade for this species.

Critical Needs: Critical needs include development of effective technology to improve detection; more funding for implementation of a Judas snake (or prey) program; implementation of a detection dog program; and increased understanding of movement patterns to improve search protocols.

2017 Status of Northern African Python by Management Region

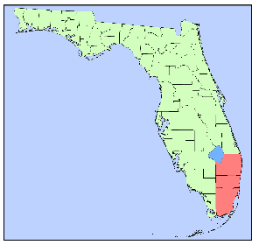
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Spectacled Caiman (*Caiman crocodilus fuscus*)

SUMMARY: Spectacled caiman (**Figure 7-34**) from the exotic pet trade were first reported from canals at the Homestead Air Force Base as early as 1960 (Ellis 1980). Native to Central and South America, this secretive crocodilian can reach up to 2.4 meters. In Florida, spectacled caiman are commonly encountered in ditches, canals, and disturbed wetlands but are occasionally found in relatively undisturbed marshes. This crocodilian feeds primarily on fish, mammals, waterbirds, and snails in its native range (Thorbjarnarson 1993). Breeding populations are documented in localized areas of Miami-Dade and Broward counties. Given its intolerance of cold temperatures, breeding populations will remain limited to southern Florida.

Figure 7-34. The spectacled caiman (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Currently, the spectacled caiman's range includes parts of Miami-Dade and Monroe counties with most records located in Homestead, Florida City, along US-41 (including the northern part of ENP), and along Loop Road in BCNP. Spectacled caiman has been observed and captured in western Broward county, as well as one in Palm Beach County suggesting the original population may have spread northward or other introductions have occurred. A small population of caiman was recently discovered within the footprint of the Biscayne Bay Wetlands Complex. Increased freshwater flow may encourage that population to expand into Biscayne National Park.

Control Tools: Spectacled caimans are controlled primarily by shooting. This is done by trained experts to ensure native crocodilians are not harmed. Efforts by FWC, SFWMD, and UF have resulted in the removal of 100 caiman since 2011.

Monitoring: FWC and UF plan to collaborate on caiman removal surveys beginning in late 2017.

Interagency Coordination: There is excellent interagency coordination for this species, but efforts to implement controls are constrained by limited resources and few control tools.

Regulatory Tools: There are no federal or state prohibitions for these species.

Critical Needs: Continued efforts to monitor and remove remaining populations of this species should continue.

2017 Status of Spectacled Caiman by Management Region

Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

ESTABLISHED INVASIVE SPECIES WITHOUT CONTROL PROGRAMS

The final group of invasive species consists of species that are well established in the Everglades ecosystem and are known or presumed to exert significant negative impacts on Florida ecosystems or native species populations, but are not currently the focus of active management. Common reasons for the limited management of these species are inadequate control tools, limited resources for project implementation, and/or limited risk assessment information. Most of these species are the focus of ongoing monitoring and research to better understand their impacts to the South Florida environment or to develop control tools. While there are many other species that may warrant inclusion in this section, particularly freshwater fishes, the included species represent some of the most concerning organisms for South Florida.

Table 7-2. Priority species currently managed within the South Florida Ecosystem for geographic containment, ranked by taxonomic group and then alphabetically by common name.

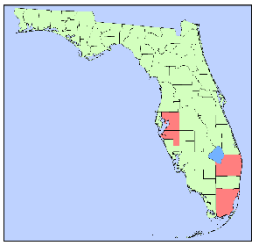
Mollusks	**Birds**
Island applesnail (*Pomacea maculata*)	Purple swamphen (*Porphyrio porphyrio*)
Insects	**Amphibians**
Laurel wilt (*Raffaelea lauricola*)	Cuban treefrog (*Osteopilus septentrionalis*)
Mexican bromeliad weevil (*Metamasius callizona*)	
Fishes	
Asian swamp eel (*Monopterus albus*)	

Asian Swamp Eel (*Monopterus albus*)

SUMMARY: Asian swamp eels (**Figure 7-35**) 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 are generalist predators with a voracious appetite for invertebrates, frogs, and fishes. Wild populations in Florida originated as escapes or releases associated with aquaculture, the pet trade, or live food markets. Regional biologists are concerned that this species may become widely established, since the diverse wetland habitats of the Greater Everglades may be suitable for the species. Additionally, Asian swamp eels have a broad salinity tolerance giving concern that this species could also establish populations in estuaries (Schofield and Nico 2009).

Figure 7-35. Asian swamp eel (photo by NPS).

KEY MANAGEMENT ISSUES



Distribution: During the late 1990s, three reproducing populations of Asian swamp eel 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). Unfortunately, recent monitoring efforts confirm the spread of this species into ENP from adjacent canal systems (Jeff Kline, ENP, personal communication).

Control Tools: Given the abundance and wide distribution of swamp eels in Florida's canals, eradication is probably impossible; however, various control methods, such as electrofishing, are currently under investigation.

Monitoring: There is no regional, coordinated monitoring program for Asian swamp eels, but USFWS and NPS biologist conduct periodic surveys in the eastern Everglades region.

Interagency Coordination: No significant interagency coordination presently aims to manage this species.

Regulatory Tools: There are currently no regulations that prohibit the importation or possession of this species in Florida.

Critical Needs: Research to better determine potential species' impacts and spread; research and development of control techniques; and increased collaboration with CERP planners to integrate prevention measures for this and other aquatic invasive species in CERP-related projects.

2017 Status of Asian Swamp Eel by Management Region

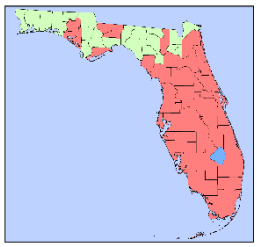
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Cuban Treefrog (*Osteopilus septentrionalis*)

SUMMARY: The Cuban treefrog (**Figure 7-36**) is native to Cuba, the Cayman Islands, and the Bahamas. It was first reported in Florida in the 1920s, and was likely transported in cargo or ornamental plant shipments. Cuban treefrogs consume a variety of invertebrates and native treefrog species (Maskell et al. 2003). Native green (*Hyla cinerea*) and squirrel (*Hyla squirella*) tree frogs are less likely to be found when Cuban treefrogs are present (Waddle et al. 2010), and when Cuban treefrogs are removed from an area, the abundance of native treefrogs increases (Rice et al. 2011). Given the Cuban treefrog's wide distribution and habitat tolerances, mounting evidence of direct impacts to native species, and the lack of management programs, the status of this species is red in all management regions.

Figure 7-36. The Cuban treefrog is now widely dispersed throughout Florida (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Cuban treefrogs inhabit natural and human-modified habitats throughout most of South and Central Florida. Natural habitats invaded by this species include pine forests, hardwood hammocks, mangrove forests, and swamps. In urban and suburban settings, they are most commonly found on and around homes and buildings, and in gardens and landscape plants. They also occur in agricultural settings, orange groves, and plant nurseries (Johnson 2007).

Control Tools: There are currently no agency-sponsored, coordinated control efforts for the Cuban treefrog in South Florida. Polyvinyl chloride (PVC) pipes are frequently used by many treefrog species and Cubans may be detected and removed by using them.

Monitoring: The District and UF continue to monitor Cuban treefrogs and other priority invasive animals in the Everglades (Everglades Invasive Reptile and Amphibian Monitoring Program). This species is found on all survey routes and are the second most frequently encountered invasive amphibian. In addition, UF maintains a small monitoring and outreach program, but state and federal agencies need to assist with coordinating a statewide program.

Interagency Coordination: No significant interagency coordination presently aims to manage this species.

Regulatory Tools: There are currently no regulations that prohibit the importation or possession of this species in Florida.

Critical Needs: Research on the severity of impacts and development of control techniques.

2017 Status of the Cuban Treefrog by Management Region

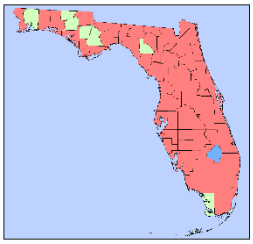
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Island Applesnail (*Pomacea maculata*)

SUMMARY: The island applesnail (**Figure 7-37**) is a large (up to 10 centimeters) South American freshwater mollusk now established in Florida. It was introduced through intentional releases from aquaria and as a food crop. Likely impacts include destruction of native vegetation, competition with native fauna, and disease transmission. The island applesnail may out-compete the native applesnail, *P. paludosa*, the primary food of the endangered Everglade snail kite. Juvenile kites have difficulty handling larger island applesnails and experience lower net daily energy balances when feeding on them (Cattau et al. 2010). Also, a newly described cyanobacterium (*Aetokthonos hydrillicola*) found in the Kissimmee Chain of Lakes is associated with a lethal neurologic disease, avian vacuolar myelinopathy (AVM), which affects avifauna in the southeastern United States (Wilde et al. 2005). Research confirms island applesnail bioaccumulation of a neurotoxin produced by *A. hydrillicola* and 100 percent development of AVM in laboratory birds fed affected snails (Dodd et al. 2016), suggesting a significant risk to the snail kite and other avifauna.

Figure 7-37. The island applesnail (photo by FWC).

KEY MANAGEMENT ISSUES



Distribution: The island applesnail has been reported widely throughout Florida (Rawlings 2007). It is found in most freshwater systems. Monitoring by ENP and the Miccosukee Tribe indicate that this species' abundance is increasing in many canals near or within the Everglades. In 2013, a sudden increase in the snail decimated submerged vegetation in STA-1 East, followed by significant decrease in phosphorus uptake in the treatment cell (Lou Toth, SFWMD, personal communication, 2013).

Control Tools: No control tools exist with applicability in large natural areas. State and federal agencies should dedicate resources to develop control strategies.

Monitoring: State and federal monitoring programs are either limited to small geographic areas or participatory monitoring through outreach.

Interagency Coordination: Limited interagency coordination has yielded little information and few attempts to understand this species' distribution, potential impacts, and possible control.

Regulatory Tools: This species is widely sold in the aquarium trade. Additional regulations are needed to curb the release of this and other nonnative *Pomacea* species.

Critical Needs: Development of control tools; research to better understand impacts of this species; and continued and expanded regional monitoring efforts.

2017 Status of Island Applesnail by Management Region

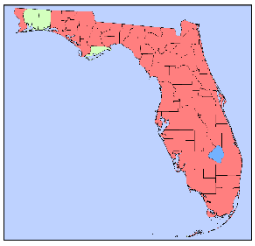
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Laurel Wilt (*Raffaelea lauricola*)

SUMMARY: Laurel wilt is a lethal disease of red bay (*Persea borbonia*; **Figure 7-26**) and other members of the Laurel family (Lauraceae). The disease is caused by a fungus (*Raffaelea lauricola*) that is introduced into trees by the wood-boring redbay ambrosia beetle (*Xyleborus glabratus*) (FDACS 2011). This Asian beetle was introduced into the United States via infested wood used for shipping crates (Harrington et al. 2011). Once infected, susceptible trees rapidly succumb to the pathogen and die. The disease also impacts other members of the Lauraceae family (Hanula et al. 2009) including swamp bay (*P. palustris*), an important species of many Everglades plant communities.

Figure 7-38. Dying red bay trees in a mixed hardwood forest (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Laurel wilt disease is now found throughout Florida. Since the 2010 detection of the redbay ambrosia beetle in Miami-Dade County, laurel wilt has spread across 372,052 hectares of the central Everglades (Rodgers and Pernas 2015) and is also present in LNWR. Laurel wilt is also widespread throughout the District's East Coast land management region and the Kissimmee River Basin.

Control Tools: There is currently no feasible method for controlling this pest or associated disease in natural areas. A systemic fungicide (propiconazole) can protect individual trees for up to one year, but widespread utilization in natural areas is impractical (Mayfield et al. 2008). Biological control and development of laurel wilt resistant strains of swamp bay are proposed areas for research.

Monitoring: State and federal agencies are monitoring the spread of laurel wilt disease through the Cooperative Agricultural Pest Survey Program. There is little research under way to assess ecological impacts of laurel wilt disease.

Interagency Coordination: Interagency and tribal coordination has begun. Workshops were conducted during 2013 to identify research and management strategies.

Regulatory Tools: The redbay ambrosia beetle is considered a plant pest, so screening for additional introductions is carried out.

Critical Needs: Critical research areas include (1) continued evaluation of *Persea* resistance, (2) *Persea* seed/germplasm conservation efforts, (3) potential chemical or biological control tools, (4) discovery of chemical attractants for *X. glabratus*, and (5) impacts on native flora, ecological processes, and native fauna such as the Palamedes swallowtail butterfly (*Papilio palamedes*).

2017 Status of Laurel Wilt by Management Region

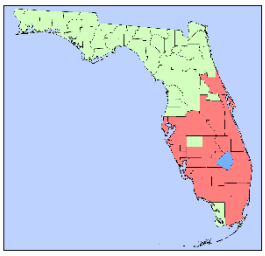
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
		not applicable				not applicable	

Mexican Bromeliad Weevil (*Metamasius callizona*)

SUMMARY: The Mexican bromeliad weevil was originally introduced to Florida via a shipment of bromeliads imported from Mexico. It was first detected in 1989, and is now found in many parts of South and Central Florida (Frank and Cave 2005). Larvae of the weevil destroy bromeliads by mining into their stems (**Figure 7-39**). This damaging insect is documented to attack 12 native bromeliad species, 10 of which are state-listed as threatened or endangered, and one of which occurs naturally only in Florida. Two of these bromeliad species were listed due to damage done to their populations by the weevil. Among the contributions of bromeliads to wildlife is that they catch rainwater, making is available to a variety of animals during dry periods.

Figure 7-39. A tillandsia plant heavily damaged by larva of the Mexican bromeliad weevil (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: The Mexican bromeliad weevil now infests bromeliads in the Sebastian, St. Lucie, Loxahatchee, Caloosahatchee, Peace, Myakka, and Manatee river systems as well as non-riverine sites. It is in BCNP, Rookery Bay National Estuarine Preserve, LNWR, Fakahatchee Strand Preserve State Park, Myakka River State Park, and several other state parks (Howard Frank, UF, personal communication).

Control Tools: The only practicable control tools for this species are biological control and prevention of new introductions. One agent, a parasitic fly (*Lixadmontia franki*), has been approved for release in the United States, but the insect has yet to become established. Facilities for rearing have been improved and additional fly releases are anticipated.

Monitoring: Regional monitoring of this species is limited to underfunded but determined efforts of university scientists engaged in biological control research.

Interagency Coordination: Interagency coordination is limited to exchange of reporting information and some coordinated research.

Regulatory Tools: Federal screening needs improvement to prevent new introductions. Additionally, improved export screening is needed to prevent transport from Florida to other vulnerable regions (e.g., Puerto Rico).

Critical Needs: Development of biological controls; continued monitoring of weevil spread and its effect on bromeliad populations; and conservation measures for impacted native bromeliads.

2017 Status of Mexican Bromeliad Weevil by Management Region

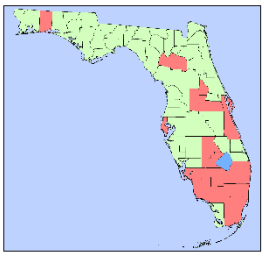
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Purple Swamphen (*Porphyrio porphyrio*)

SUMMARY: The purple swamphen (**Figure 7-40**) is a rail native to Australia, Europe, Africa, and Asia. Its introduction was likely due to escapes from the Miami Zoo and private aviculturists in Broward County. This invasive rail feeds on shoots and reeds, invertebrates, small mollusks, fish, snakes, and the waterfowl eggs and young (Pranty et al. 2000). Highly aggressive and territorial, the purple swamphen could impact native water birds through competition, destruction of habitat, and direct predation. Rapid response efforts between 2006 and 2009 did not successfully reduce the abundance or distribution of this species. The management goal for this species has shifted from eradication to monitoring (Hardin et al. 2011).

Figure 7-40. The purple swamphen (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: The original Florida purple swamphen population is believed to have established in Pembroke Pines in 1996 (Hardin et al. 2011). Purple swamphens are established in the WCAs, Lake Okeechobee, and in all Everglades STAs and continue to expand into wetlands to the north and west.

Control Tools: Previous efforts to remove birds by hunting did not significantly deplete the population (Hardin et al. 2011). No other control tools are currently developed for this species. There are currently no control efforts in place.

Monitoring: Agencies rely on reports from the public and agency personnel to track the spread of this species.

Interagency Coordination: Local and state agencies have attempted to analyze this species' population and implement control. However, efforts to date have not halted the further spread of this species, and eradication is no longer considered feasible. FWC have removed over 3,000 purple swamphens to date, mostly from Lake Okeechobee, STAs, and WCA-2B (Johnson and McGarrity 2009, Hardin et al. 2011). Florida Atlantic University studied habitat use and diets of purple swamphens to assess impacts this species may have on the Greater Everglades ecosystem (Callaghan and Gawlik 2016)

Regulatory Tools: There are currently no regulations that prohibit import or possession of this species in Florida. Regulations to restrict possession of this species would help avoid new releases.

Critical Needs: Additional monitoring to assess population expansion; additional information on impacts of this species on native species; and regulations to restrict possession of this species.

2017 Status of Purple Swamphen by Management Region

Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

FUTURE NEEDS IN MANAGEMENT AND CONTROL

The elements of a comprehensive management program for some nonindigenous plant species—legislation, coordination, planning, research, education, training, and funding—have been in place in Florida for many years. Most plants identified in this chapter as priority species are being managed on public lands by local, state, or federal agencies. This is not true for most nonindigenous animal species. The threat of nonindigenous animals is becoming an important ecological and restoration issue for many agencies in Florida. Meaningful legislation to significantly limit new invasions, funding for control programs, and coordination at all levels are needed for a comprehensive nonindigenous animal management program for Florida. The 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 management operations or accept their occurrence and consequences in natural areas.

Given the documented impacts of nonindigenous organisms in South Florida, scientists are obliged to factor these species and their impacts into restoration planning and models. Research is needed to understand the distribution, biology, and impacts of these nonindigenous organisms. Controlling and managing nonindigenous organisms in an all taxa approach is a new idea, even among ecologists, but it is sure to emerge as an important field of science given global trade and insufficient regulatory controls. Organisms will continue arriving and establishing breeding populations in new environments, especially in South Florida.

Regardless of taxa, the process of biological invasion—from introduction to establishment to ecosystem engineer—is complex, involves many environmental factors, and may take many decades to complete. Relatively few nonindigenous species become invasive in their new environments, but a very few species can wreak major economic and ecologic havoc. Species that appear benign for many years or even decades may suddenly spread rapidly following floods, fires, droughts, hurricanes, long-term commercial availability, or other factors. Resource managers must recognize these species during the early, incipient phase to maximize the potential for containing or eradicating them. As part of this effort, an applied monitoring program and a tracking system for nonindigenous plant and animal species are needed before their introduction.

Species like the Argentine black and white tegu in the Everglades and Gambian pouched rat in the Florida Keys illustrate the need for agencies to act quickly to contain and attempt to eradicate animals that have the potential to become widespread and difficult to control. While definitive research is lacking to support the immediate management of these 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 nonindigenous species 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 most feasible.

The use of an 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. Implementing an EDRR program is also typically much less expensive than a long-term 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. Prompt cooperative action to eliminate emerging populations of sacred ibis and the invasive mangrove species *Lumnitzera racemosa* have been successful. These EDRR efforts may have prevented widespread ecological harm by these new invaders and saved significant public resources required to manage more widespread invasions. Biological risk assessments are being developed to enable agencies to determine which species are most likely to become problems (Gordon et al. 2006, Simons and De Poorter 2009; Christina Romagosa, University of Florida, personal communication). 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 the cooperative invasive species management areas and the SFERTF are attempting to initiate additional EDRR efforts.

An overarching theme in this chapter is describing the alarming extent and impacts of some nonindigenous species and stating the need for increased coordination and control. While these observations are valid, control efforts against certain nonindigenous species have proven successful and demonstrate that effective management is possible with effective interagency support and adequate funding. For instance, melaleuca once was thought to be unmanageable in the state because it was so widespread and difficult to control. The District-led melaleuca management program is entering its twentieth year. Resource management agencies estimate this program has cost nearly $41 million to date. However, melaleuca is now under maintenance control on Lake Okeechobee and in most of the Greater Everglades, and Florida's melaleuca management program is a model for invasive species management nationally. The success of this program is largely attributed to integrated management approaches, sustained funding, and close interagency coordination, all of which foster information and technology transfer, regional strategic planning, increased financial efficiency, and improved public awareness.

For the nonindigenous species that are already widely established, long-term commitments to integrated control programs are the only feasible means of containing and reversing impacts. Effective management of other entrenched and difficult-to-control species, such as Old World climbing fern and the Burmese python, will require sustained resource allocation for development and implementation of control programs, like that used for the management of melaleuca, if Everglades restoration is to be successful. Further, many biological invasions are likely to be permanent and may easily reestablish dominance if maintenance and control management is not sustained. For this reason, preventing importation of potentially invasive species through improved regulatory programs and regional monitoring programs should be a priority focus of policy makers, regulators, scientists, and land managers moving forward.

LITERATURE CITED

Baber, D.W. and B.E. Coblentz. 1987. Diet, nutrition, and conception in feral pigs on Santa Catalina Island. *Journal of Wildlife Management* 51:306-317.

Batish, D.R., H.P. Singh and R.K. Kohli. 2001. Vegetation exclusion under *Casuarina equisetifolia* L.: Does allelopathy play a role? *Community Ecology* 2:93-100.

Belden, R.C. and M.R. Pelton. 1975. European wild hog rooting in the mountains of eastern Tennessee. *Proceeding of the Annual Conference of the Southeastern Association of Game and Fish Commissioners* 29:665-671.

Bennett, D. 1998. *Monitor Lizards, Natural History, Biology and Husbandry*, *Edition Chimaira (Andreas S. Brahm)*. Frankfurt am Main, Germany.

Boughton, A.J. and R.W. Pemberton. 2009. Establishment of an imported natural enemy, *Neomusotima conspurcatalis* (Lepidoptera; Crambidae) against an invasive weed, Old World climbing fern, *Lygodium microphyllum*, in Florida. *Biocontrol Science and Technology* 19:769-772.

Callaghan, C.T. and D.E. Gawlik. 2016. Diet and selectivity of *Porphyrio porphyrio* (purple swamphen) in Florida. *Southeastern Naturalist* 15:8.

Cattau, C., J. Martin and W.M. Kitchens. 2010. Effects of an exotic prey species on a native specialist: Example of the snail kite. *Biological Conservation* 143:513-520.

Cole, J.M., J.H. Nestler, J. Ketterlin Eckles and F.J. Mazzotti. 2017. *How to Infer Absence of Northern African Pythons from the Bird Drive Basin, Miami-Dade County, Florida*. Prepared by University of

Florida, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL, and submitted to Florida Fish and Wildlife Conservation Commission, Davie, FL.

Cooper, T.M., J.H. Frank and R.D. Cave. 2013. Loss of phytotelmata due to an invasive bromeliad-eating weevil and its potential effects on faunal diversity and biogeochemical cycles. *Acta Oecologica* 54:51-56.

Cowie, R.H. 2013. Biology, systematics, life cycle, and distribution of *Angiostrongylus cantonensis*, the cause of rat lungworm disease. *Hawaii Journal of Medicine and Public Health* 72(2).

Cuda, J.P., A.P. Ferriter, V. Manrique and J.C. Medal. 2006. *Interagency Brazilian Peppertree (*Schinus terebinthifolius*) Management Plan for Florida*, *Second Edition*. Florida Exotic Pest Plant Council, http://www.fleppc.org/.

Curnutt, J.L. 1989. Breeding bird use of a mature stand of Brazilian pepper. *Florida Field Naturalist* 17(3):53-76.

D'Cruze, N.J. Sabel, K. Green, J. Dawson, C. Gardner, J. Robinson, G. Starkie, M. Vences and F. Glaw. 2007. The first comprehensive survey of amphibians and reptiles at Montagne des Français, Madagascar. *Herpetological Conservation and Biology* 2:87-99.

Dandelot S., C. Robles, N. Pech, R. Verlaque and A. Caxaubon. 2008. Allelopathic potential of two invasive *Ludwigia* spp. *Aquatic Botany* 88:311-316.

Daneshgar, P. and S. Jose. 2009. *Imperata cylindrica*, an alien invasive grass, maintains control over nitrogen availability in an establishing pine forest. *Plant and Soil* 320(1-2):209-218.

DEPI 2010. *Invasive Plants and Animals Policy Framework*. Department of Environment adad Primary Industries, Victoria, Australia. Available online at http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds/invasive-plants-and-animals/invasive-plants-and-animals-policy-framework.

Dodd, S.R., R.S. Haynie, S.M. Williams and S.B. Wilde. 2016. Alternate food-chain transfer of the toxin linked to avian vacuolar myelinopathy and implications for the endangered Florida snail kite (*Rostrhamus sociabilis*). *Journal of Wildlife Diseases* 52(2):335-344

Dorcas, M.E., J.D. Willson, R.N. Reed, R.W. Snow, M.R. Rochford, M.A. Miller and K.M. Hart. 2012. Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park. *Proceedings of the National Academy of Sciences* 109:2418-2422.

Doren, R.F., J.C. Volin and J.H. Richards. 2009. Invasive exotic plant indicators for ecosystem restoration: An example from the Everglades restoration program. *Ecological Indicators* 9S:S29-S36.

Dove, C.J., R.W. Snow, M.R. Rochford and F.J. Mazzotti. 2011. Birds consumed by the invasive Burmese python (*Python molurus bivittatus*) in Everglades National Park, Florida, USA. *The Wilson Journal of Ornithology* 123:126-131.

Dozier, J. 2012 The *Mikania micrantha* wrap up. *Everglades Cooperative Invasive Species Management Area Newsletter* 3(1): March.

Dray, Jr., F.A. and T.D. Center. 1989. Seed production by *Pistia stratiotes* L. (water lettuce) in the United States. *Aquatic Botany* 33(1-2):155-160.

Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.R. Alexander, R.L. Myers and D.P. Spangler. 1986. *The Big Cypress National Preserve*. Research Report 8, National Audubon Society, New York, NY.

Eckles, J.K., F. Mazzotti, D. Giardina, D. Hazelton and L. Rodgers. 2017. First evidence for reproduction of Nile monitors (*Varanus niloticus*) in Palm Beach County. *Southeastern Naturalist* 15(8):114-119.

Ellis, T.M. 1980. Caiman crocodilus: An established exotic in South Florida. *Copeia* 1:152-154.

Elnoe, S.F. 2015. *Old World Climbing Fern Assessment and Research Recommendations*. Prepared by University of Florida, Center for Aquatic and Invasive Plants, Gaineseville, FL and submitted to South Florida Water Management District, West Palm Beach, FL.

Enge, K.M., K.L. Krysko, K.R. Hankins, T.S. Campbell and F.W. King. 2004. Status of the Nile monitor (*Varanus niloticus*) in southwestern Florida. *Southeastern Naturalist* 3(4):571-582.

Enge, K.M., B.W. Kaiser and R.B. Dickerson. 2006. Another Large Exotic Lizard in Florida, the Argentine Black and White Tegu. *Proceedings of the 28th Annual Gopher Tortoise Council Meeting, October 26–29, 2006, Valdosta, GA*. Gopher Tortoise Council, http://www.gophertortoisecouncil.org/.

Engeman, R.G., J.W. Woolard, N.D. Perry, G. Witmer, S. Hardin, L. Brashears, H. Smith, B. Muiznieks and B. Constantin. 2006. Rapid assessment for a new invasive species threat: The case of the Gambian giant pouched rat in Florida. *Wildlife Research* 33: 439-448.

Engeman, R.M., G.W. Witmer, J.B. Bourassa, J.W. Woolard, B. Constantin, P.T. Hall, S. Hardin and N.D Perry. 2007. The Path to Eradication of the Gambian Giant Pouched Rat in Florida. Pages 305–311 in: G.W. Witmer, W.C. Pitt and K.A. Fagerstone (eds.). *Managing Vertebrate Invasive Species: Proceedings of an International Symposium*, United States Department of Agriculture/Animal and Plant Health Inspection Services, Wildlife Services, National Wildlife Research Center, Fort Collins, CO.

Falcón, W., J.D. Ackerman, W. Recart and C.C. Daehler. 2013. Biology and Impacts of Pacific Island Invasive Species. 10. *Iguana iguana*, the Green Iguana (Squamata: Iguanidae). *Pacific Science* 67(2): 157-186.

FDACS. 2011. *Laurel Wilt/Redbay Ambrosia Beetle Detection Update*. Florida Department of Agriculture and Consumer Services. Available online at http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Pests-Diseases/Laurel-Wilt-Disease as of February 3, 2016.

FDACS. 2013. *Frequently Asked Questions about Metaldehyde for Controling Snails and Slugs. Florida Department of Agriculture and Consumer Services*. Available online at http://www.freshfromflorida.com/content/download/32845/794011/Metaldehyde-QA.pdf as of February 3, 2016.

FDACS-DPI. 2011. *Giant African land snail*. Florida Department of Agriculture and Consumer Services-Division of Plant Industry. Available on-line at http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Pests-Diseases/Giant-African-Land-Snail as of February 3, 2016.

Ferriter, A., B. Doren, R. Winston, D. Thayer, B. Miller, B. Thomas, M. Barrett, T. Pernas, S. Hardin, J. Lane, M. Kobza, D. Schmitz, M. Bodle, L. Toth, L. Rodgers, P. Pratt, S. Snow and C. Goodyear. 2008. Chapter 9: The Status of Nonindigenous Species in the South Florida Environment. In: *2008 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

FLEPPC. 2015. Florida Exotic Pest Plant Council's 2013 list of invasive plant species. Florida Exotic Pest Plant Council, http://www.fleppc.org/. Available online at http://www.fleppc.org/list/list.htm.

Frank, J.H. and R.D. Cave. 2005. *Metamasius callizona* is Destroying Florida's Native Bromeliads. Pages 91–101 in: M.S. Hoddle (ed.), *Second International Symposium on Biological Control of Arthropods, September 12–16, 2005, Davos, Switzerland, Volume I*. Forest Service Publication FHTET-2005-08, United States Department of Agriculture, Washington, DC.

Fuller, P., L.G. Nico and J.D. Williams. 1999. *Nonindigenous Fishes Introduced to Inland Waters of the United States*. Special Publication 27, American Fisheries Society, Bethesda, MD.

FWC. 2013. *Species Profiles: Nonnatives – Veiled Chameleon*. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. Available online at http://myfwc.com/wildlifehabitats/nonnatives/reptiles/veiled-chameleon/.

Gann, G.D., K.A. Bradley and S.W. Woodmansee. 1999. *Initial Report: Long-term Monitoring of L. microphyllum* (Lygodium microphyllum *(Cav.) R. Br.) in Southeastern Florida*. Prepared by Institute for Regional Conservation, Miami, FL, and submitted to South Florida Water Management District, West Palm Beach, FL.

Gaskin, J.F., G.S. Wheeler, M.F. Purcell and G.S. Taylor. 2009. Molecular evidence of hybridization in Florida's sheoak (*Casuarina* spp.) invasion. *Molecular Ecology* 18:3216-3226.

Geiger, J.H., P.D. Pratt and G.S. Wheeler. 2011. Hybrid vigor for the invasive exotic Brazilian peppertree (*Schinus terebinthifolius* Raddi., Anacardiaceae) in Florida. *International Journal of Plant Science* 172(5):655-663.

Gordon, D.R. 1998. Effects of Invasive, Non-Indigenous Plant Species on Ecosystem Processes: Lessons from Florida. *Ecological Applications* 8(4):975-989.

Gordon, D.R. and K.P. Thomas. 1997. Florida's invasion by nonindigenous plants: History, screening, and regulation. Pages 21–37 in: D. Simberloff, D.C. Schmitz and T.C. Brown (eds.), *Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida,* Island Press, Washington, DC.

Gordon, R., A.M. Fox and R.K. Stocker. 2006. *Testing a Predictive Screening Tool for Reducing the Introduction of Invasive Plants to Florida*. Prepared by The Nature Conservancy, Arlington, VA, and University of Florida, Gainesville, FL, and submitted to United States Department of Agriculture, Animal Plant Health Inspection Service, Washington, DC.

Hanula, J., A. Mayfield, S. Fraedrich and R. Rabaglia. 2009. Biology and Host Associations of Redbay Ambrosia Beetle, Exotic Vector of Laurel Wilt Killing Redbay Trees in the Southeastern United States. Page 33 in: K.A. McManus and K.W. Gottschalk (eds.), *Proceedings, 19th U.S. Department of Agriculture Interagency Research Forum on Invasive Species 2008*, General Technical Publication NRS-P-36, United States Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA.

Hardin S. 2007. Managing Non-native Wildlife in Florida: State Perspective, Policy and Practice. Pages 43–52 in: G. Witmer, W. Pitt and K. Fagerstone (eds.), *Managing Vertebrate Invasive Species: Proceedings of an International Symposium, August 7-9, 2007*, United States Department of Agriculture, Animal Plant Health Inspection Service Wildlife Services, National Wildlife Research Center, Fort Collins, CO.

Hardin, S., E. Donlan, M. Ward and D. Eggeman. 2011. Attempted Eradication of *Porphyrio porphyrio* Linnaeus in the Florida Everglades. *Managing Biological Invasions* 2:47-55.

Harrington, T.C., H.Y. Yun, S. Lu, H. Goto, D. Aghayeva and S. Fraedrich. 2011. Isolations from the redbay ambrosia beetle, *Xyleborus glabratus*, confirm that the laurel wilt pathogen, *Raffaelea lauricola*, originated in Asia. *Mycologia* 103:1028-1036.

Hart, K.M., M.S. Cherkiss, B.J. Smith, F.J. Mazzotti, I. Fujisaki, R.W. Snow and M.E. Dorcas. 2015. Home range, habitat use, and movement patterns of non-native Burmese pythons in Everglades National Park, Florida, USA. *Animal Biotelemetry* 3:8.

Holly, D.C., G.N. Ervin, C.R. Jackson, S.V. Diehl and G.T. Kirker. 2009. Effect of an invasive grass on ambient rates of decomposition and microbial community structure: A search for causality. *Biological Invasions* 11:1855-1868.

Holm, L.G., D.L. Plucknett, J.V. Pancho and J.P. Herberger. 1977. *The World's Worst Weeds: Distribution and Biology*. University Press of Hawaii, Honolulu, HI.

IFAS 2013. *Cogongrass*. Center for Aquatic and Invasive Plants, Institute for Food and Agricultural Sciences, University of Florida, Gainesville, FL. Available online at http://plants.ifas.ufl.edu/node/199.

Iwanowicz, D.D., L.R. Sanders, W.B. Schill, M.V. Xayavong, A.J. da Silva, Y. Qvarnstrom and T. Smith. 2015. Spread of the rat lungworm (*Angiostrongylus cantonensis*) in giant African land snails (*Lissachatina fulica*) in Florida, USA. Journal of Wildlife Diseases 51(3):749-753.

Johnson, S. 2007. *The Cuban Treefrog (*Osteopilus septentrionalis*) in Florida.* Publication WEC 218, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Available online at edis.ifas.ufl.edu/UW259.

Johnson, S.A. and M. McGarrity. 2009. *Florida's Introduced Birds: Purple Swamp Hen (*Porphyrio porphyrio*)*. Publication WEC 270, Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL.

Klug, P.E., R.N. Reed, F.J. Mazzotti, M.A. McEachern, J.J. Vinci, K.K. Craven and A.A. Yackel Adams. 2015. The influence of disturbed habitat on the spatial ecology of Argentine black and white tegu (*Tupinambis merianae*), a recent invader in the Everglades ecosystem (Florida, USA). *Biological Invasions* 17:1785-1797.

Klukas, R.W. 1969a. Exotic terrestrial plants in South Florida with emphasis on Australian pine (*Casuarina equisetifolia*). Report 33030, Homestead, Florida: Everglades National Park.

Klukas, R.W. 1969b. *The Australian Pine Problem in Everglades National Park: Part 1. The Problem and Some Solutions*. Internal report, South Florida Research Center, Everglades National Park, Homestead, FL.

Krysko, K.L., C.R. Gillette, R.M. Reichart, L.P. Nunez, N.T. Coutu, J.A. Wasilewski, K.M. Enge and A.P. Borgia. 2012. Preliminary dietary analysis for the non-indigenous Oustalet's Chameleon, *Furcifer oustaleti* (Mocquard 1894) (Squamata: Chamaeleonidae), in southern Florida. *IRCF Reptiles & Amphibians* 19(4):280-287.

Kunzer, J.M. and M.J. Bodle. 2008. *Luziola subintegra* (Poaceae: Oryzeae), new to Florida and the United States. *Journal of the Botanical Research Institute of Texas* 2(1):633-638.

Lake, E.C., M.C. Smith, P.D. Pratt, A.J. Boughton and R.W. Pemberton. 2014. Dispersal and establishment of new populations of the biological control agent *Floracarus perrepae* (Acariformes: Eriophyidae) on Old World climbing fern, *Lygodium microphyllum* (Polypodiales: Lygodiaceae). *Florida Entomologist* 97:827-829.

Langeland, K.A. and R.K. Stocker. 1997. *Control of Non-native Plants in Natural Areas of Florida*. SP 242, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Available online at edis.ifas.ufl.edu/WG209.

Langeland, K., B. Smith and C. Hanlon. 1998. Torpedograss–forage gone wild. *Wildland Weeds* summer 1998. Available at http://www.se-eppc.org/wildlandweeds/pdf/su98-langeland-p4-6.pdf.

Laycock, G. 1966. *The Alien Animals*. Natural History Press, Garden City, NY.

Lenz, S. 2004. *Varanus niloticus*. Pages 133–138 in: E.R. Pianka, D.R. King and R.A. King (eds.), *Varanoid Lizards of the World,* Indiana University Press, Indianapolis, IN.

Lippincott, C.L. 2000. Effects of *Imperata cylindrica* (L.) Beauv. (cogongrass) invasion on fire regime in Florida sandhill. *Natural Areas Journal* 20:140-149.

Losos, J.B. and H.W. Greene. 1988. Ecological and evolutionary implications of diet in monitor lizards. *Biological Journal of the Linnean Society* 35(4):379-407.

Lott, M.S., J.C. Volin, R.W. Pemberton and D.F. Austin. 2003. The reproductive biology of the invasive ferns *Lygodium microphyllum* and *L. japonicum* (Schizaeaceae): Implications for invasive potential. *American Journal of Botany* 90:1144-1152.

Martin, S. 2015.Researchers identify, name toxic cyanobacteria killing American bald eagles. *University of Georgia News*. Available online at http://m.phys.org/news/2015-02-toxic-cyanobacteria-american-bald-eagles.html.

Maskell, A.J., J.H. Waddle and K.G. Rice. 2003. *Osteopilus septentrionalis*: Diet. *Herpetological Review* 34:137.

Mayfield, A.E., E.L. Barnard, J.A. Smith, S.C. Bernick, J.M. Eickwort and T.J. Dreaden. 2008. Effect of propiconazole on laurel wilt disease development in redbay trees and on the pathogen in vitro. *Arboriculture and Urban Forestry* 34(5):317-324.

Mazzotti, F.J., W. Ostrenko and A.T. Smith. 1981. Effects of the exotic plants *Melaleuca quinquenervia* and *Casuarina equisetifolia* on small mammal populations in the eastern Florida Everglades. *Florida Science* 44:65-71.

Mazzotti, F.J., M.S. Cherkiss, K.M. Hart, R.W. Snow, M.R. Rochford, M.E. Dorcas and R.N. Reed. 2010. Cold-induced mortality of invasive Burmese pythons in South Florida. *Biological Invasions* 13(1):143-151, DOI 10.1007/s10530-101-9797-5.

Mazzotti, F.J., M. McEachern, M. Rochford, R.N. Reed, J.K. Eckles, J. Vinci, J. Edwards and J.Wasilewski. 2015. *Tupinambis merianae* as nest predators of crocodilians and turtles in Florida, USA. *Biological Invasions* 17:47-50.

McCleery, R.A., A. Sovie, R.N. Reed, M.W. Cunningham, M.E. Hunter and K.M. Hart. 2015. Marsh rabbit mortalities tie pythons to the precipitous decline of mammals in the Everglades. *Proceedings of the Royal Society B* DOI: 10.1098/rspb.2015.0120.

Meshaka, W.E., Jr. 2006. An update on the list of Florida's exotic amphibian and reptile species. *Journal of Kansas Herpetology* 19:16-17.

Metzger, E.F., J.H. Nestler, J. Ketterlin Eckles, R.E. Whitaker, J. Lenin, J.A. Wasilewski, M.R. Rochford, and F.J. Mazzotti. 2017. *Can Irula Snake-catchers from India Improve Our Ability to Detect and Capture Pythons in Greater Everglades Ecosystems?* Prepared by University of Florida, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL, and submitted to Florida Fish and Wildlife Conservation Commission, Davie, FL.

Miller, J.H. 2007. *The Context of the South's Cogongrass Crisis. A Cogongrass Management Guide*. Available online at https://www.invasive.org/weedcd/pdfs/cogonmanagement.pdf#page=7.

MIPN. 2006. *CWMA Cookbook: A Recipe for Success.* Midwest Invasive Plant Network. Available online at http://weedcenter.org/cwma/index.html.

Mississippi State University Extension Service. 2014. *Wild Pig Info*. Available online at http://www.wildpiginfo.msstate.edu/.

Morton, J.F. 1980. The Australian pine or beefwood (*Casuarina equisetifolia* L.), an invasive "weed" tree in Florida. *Proceedings of the Florida State Horticulture Society* 93:87-95.

Mukherjee, A., D.A. Williams, G.S. Wheeler, J.P. Cuda, S. Pal and W.A. Overholt. 2012. Brazilian peppertree (*Schinus terebinthifolius*) in Florida and South America: Evidence of a possible niche shift driven by hybridization. *Biological Invasions* 14(7):1415-1430.

National Invasive Species Council. 2003. *General Guidelines for the Establishment and Evaluation of Invasive Species Early Detection and Rapid Response Systems*. Department of the Interior, Office of the Secretary, Washington, DC. Version 1, June 2003. Available online at http://digitalcommons.unl.edu/natlinvasive/18/.

Nestler, J.H, R. Harvey, S.K. Cooke, B.M. Mason, M.R. Bradbury, J. Ketterlin Eckles, M.R. Rochford and F.J. Mazzotti. 2017. *Tegu Removal and Research in C-111 Basin and Redland Agricultural Area in Miami-Dade County (1 May 2016–15 June 2017)*. Prepared by University of Florida, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL, and submitted to Florida Fish and Wildlife Conservation Commission, Davie, FL.

Overholt, W., L. Markle, E.N. Rosskopf, V. Manrique, J.P. Albano, E. Cave and S.T. Adkins. 2009. The interactions of tropical soda apple mosaic tobamovirus and *Gratiana boliviana* (Coleoptera: Chrysomelidae), an introduced biological control agent of tropical soda apple (*Solanum viarum*). *Biological Control* 48:294-300.

Perez, E.A., J.A. Coetzee, T. Ruiz Tellez and M.P. Hill. 2011. A first report of water hyacinth (*Eichhornia crassipes*) soil seed banks in South Africa. *South African Journal of Botany* 77(3) 795-800.

Pernas, T., D.G. Giardina, A. McKinley, A. Parns and F.J. Mazzotti. 2012. First observations of nesting by the Argentine black and white tegu, *Tupinambis merianae*, in South Florida. *Southeastern Naturalist* 11:765-770.

Piaggio, A.J., R.M. Engemen, M.W. Hopken, J.S. Humphrey, K.L. Keacher, W.E. Bruce and M.L. Avery. 2014. Detecting an elusive invasive species: a diagnostic PCR to detect Burmese python in Florida waters and an assessment of persistence of environmental DNA. *Molecular Ecology Resources* 14:374-380.

Pittman, S.E., K.M. Hart, M.S. Cherkiss, R.W. Snow, I. Fujisaki, B.J. Smith, F.J. Mazzotti and M.E. Dorcas. 2014. Homing of invasive Burmese pythons in South Florida: Evidence for map and compass senses in snakes. *Biology Letters* 10:20140040.

Pranty, B., K. Schnitzius, K. Schnitzius and H.W. Lovell. 2000. Discovery, origin, and current distribution of the purple swamphen (*Porphyrio porphyrio*) in Florida. *Florida Field Naturalist* 28:1-40.

Pratt P.D., M.B. Rayamajhi, T.K. Van, T.D. Center and P.W. Tipping. 2005. Herbivory alters resource allocation and compensation in the invasive tree *Melaleuca quinquenervia*. *Ecological Entomology* 30:316-326.

Rawlings, T.A., K.A. Hayes, R.H. Cowie and T.M. Collins. 2007. The identity, distribution and impacts of non-native snails in the continental United States. *Biomedical Central Evolutionary Biology* 7:97.

Rayamajhi M.B., P.D. Pratt, T.D. Center, P.W. Tipping and T.K. Van. 2008. Aboveground biomass of the invasive tree melaleuca (*Melaleuca quinquenervia*) before and after herbivory by adventive and introduced natural enemies: A temporal case study in Florida. *Weed Science* 56:451-456.

Rayamajhi, M.B., P.D. Pratt, T.D. Center, P.W. Tipping and T.K. Van. 2009. Decline in exotic tree density facilitates increased plant diversity: The experience from *Melaleuca quinquenervia* invaded wetlands. *Wetlands Ecology and Management* 17:455-467.

Rayamajhi, M.B., P.D. Pratt, N. Klopfenstein, A. Ross-Davis and L. Rodgers. 2013. First report of *Puccinia psidii* caused rust-disease epiphytotic on the invasive shrub *Rhodomyrtus tomentosa* in Florida. *Plant Disease* 97:1397.

Reed, R.N. and G.H. Rodda. 2009. *Giant Constrictors: Biological and Management Profiles and an Establishment Risk Assessment for Nine Large Species of Pythons, Anacondas, and the Boa Constrictor*. Open-File Report 2009-1202, United States Geological Survey, Washington, DC.

Reed, R.N., K.M. Hart, G.H. Rodda, F.J. Mazzotti, R.W. Snow, M. Cherkiss, R. Rozar, and S. Goetz. 2011. A field test of attractant traps for invasive Burmese pythons (*Python molurus bivittatus*) in southern Florida. Wildlife Research 38:114-121.

Rice, K.G., J.H. Waddle, M.W. Miller, M.E. Crockett, F.J. Mazzotti and H.F. Percival. 2011. Recovery of native treefrogs after removal of nonindigenous Cuban treefrogs, *Osteopilus septentrionalis*. *Herpetologica* 67:105-117.

Roda, A., G. Nachman, S. Weihman, M.Y. Cong and F. Zimmerman. 2016. Reproductive ecology of the giant African snail in south Florida: Implications for eradication programs. *PLoS ONE* 11(11), e0165408. http://doi.org/10.1371/journal.pone.0165408

Rodgers, L. and D. Black. 2014. Appendix 7-1: Summary of South Florida's Nonindigenous Species by RECOVER Module. In: *2014 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.

Rodgers, L. and T. Pernas. 2015. Laurel wilt impacts, expansion and future in the Everglades. Conference on Laurel Wilt Disease and Natural Exosystems: Impacts, Mitigation, and the Future, Coral Springs, FL, June 16 2015. Available online at http://conference.ifas.ufl.edu/LaurelWilt/index.html as of February 3, 2016.

Rodgers, L. T. Pernas and S.D. Hill. 2014. Mapping invasive plant distributions in the Florida Everglades using the digital aerial sketch mapping technique. *Invasive Plant Science and Management* 7:360-374.

Schofield, P.J. and L.G. Nico. 2009. Salinity tolerance of non-native Asian swamp eels (Teleostei: Synbranchidae) in Florida, USA: Comparison of three populations and implications for dispersal. *Environmental Biology of Fishes* 85:51-59.

Scobel, N.J., J.H. Nestler, J. Ketterlin Eckles and F.J. Mazzotti. 2017. *Testing effectiveness of trapping for Nile monitors within the C-51 Basin and Southwest Ranches, Palm Beach and Broward Counties, Florida*. Prepared by University of Florida, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL, and submitted to Florida Fish and Wildlife Conservation Commission, Davie, FL.

SFERTF. 2016. *Invasive Exotic Species Strategic Action Framework*. South Florida Ecosystem Restoration Task Force. Available online at http://www.evergladesrestoration.gov/content/ies/.

SFWMD. 2012. *Strategic Plan, 2012–2017*. South Florida Water Management District, West Palm Beach, FL.

Simons, S.A. and M. De Poorter (eds.). 2009. *Proceedings of an Expert Workshop on Preventing Biological Invasions: Best Practices in Pre-Import Risk Screening for Species of Live Animals in International Trade,, University of Notre Dame, Indiana, USA, April 9–11, 2008*. Global Invasive Species Programme, Nairobi, Kenya.

Singer, F.J. 2005. Wild pig populations in the national parks. *Environmental Management* 5:263-270.

Smith, B.J., M.S. Cherkiss, K.M. Hart, M.R. Rochford, T.H. Selby, R.W. Snow and F.J. Mazzotti. 2016. Betrayal: radio-tagged Burmese pythons reveal locations of conspecifics in Everglades National Park. *Biological Invasions* 18:3239-3250.

Smith, M.C., E.C. Lake, P.D. Pratt, A.J. Boughton and R.W. Pemberton. 2014. Current status of the biological control agent *Neomusotima conspurcatalis* (Lepidoptera: Crambidae), on *Lygodium microphyllum* (Polypodiales: Lygodiaceae) in Florida. *Florida Entomologist* 97:817-820.

Snow, R.W., K.L. Krysko, K.M. Enge, L. Oberhofer, A. Warren-Bradley and L. Wilkins. 2007. Introduced populations of *Boa constrictor* (Boidae) and *Python molurus bivittatus* (Pythonidae) in southern

Florida. Pages 416–438 in: R.W. Henderson and R. Powell (eds.), *The Biology of Boas and Pythons*, Eagle Mountain Publishing, Eagle Mountain, UT.

Snow, R.W., M.L. Brien, M.S. Cherkiss, L.A. Wilkins and F.J. Mazzotti. 2007. Dietary habits of the Burmese python, *Python molurus bivittatus*, in Everglades National Park, Florida. *Herpetological Bulltein* 101:5.

Stevens, J. and B. Beckage. 2009. Fire feedbacks facilitate invasion of pine savannas by Brazilian pepper (*Schinus terebinthifolius*). *New Phytologist* 184:365-375.

Thorbjarnarson, J.B. 1993. Diet of the spectacled caiman (*Caiman crocodilus*) in the Central Venezuelan Llanos. *Herpetologica* 49(1):108-117.

Tipping, P.W., A. Sosa, E.N. Pokorny, J. Foley, D.C. Schmitz, J.S. Lane, L. Rodgers, L. McCloud, P. Livingston-Way, M.S. Cole and G. Nichols. 2014. Release and establishment of *Megmelus scutellarius* (Hemiptera: Delphacidae) on waterhyacinth in Florida. *Florida Entomologist* 97:804-806.

Tipping, P.W., M.R. Martin, P.D. Pratt, T.D. Center and M.B. Rayamajhi. 2008. Suppression of growth and reproduction of an exotic invasive tree by two introduced insects. *Biological Control* 44:235-241.

Tipping, P.W., M.R. Martin, R. Pierce, T. Center, P.R. Pratt and M.B. Rayamajhi. 2012. Post-biological control invasion trajectory for *Melaleuca quinquenervia* in a seasonally inundated wetland. *Biological Control* 60:163-168.

Tipping, P.W., M.R. Martin and L.A. Gettys. 2016. A gall-forming biological control agent supresses vegetative growth of an invasive tree. *Biocontrol Science and Technology* 26:1586-1589.

Toth, L.A. 2010. Unrealized Expectations for Restoration of a Floodplain Plant Community. *Restoration Ecology* 18: 810–819.

Toth, L.A. 2015. Invasibility drives restoration of a floodplain plant community. *River Research and Applications* 31:1319–1327.

USACE and SFWMD. 2010. *Central and Southern Florida Project Compehensive Everglades Restoration Plan Melaleuca Eradication and Other Exotic Plants Implement Biological Controls Final Integrated Project Implementation Report and Environmental Assessment*. United States Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL.

USACE. 1989. *Corps of Engineers Letter of Operating Procedures for Aquatic Plant Management on Lake Okeechobee*. United States Army Corps of Engineers, Jacksonville, FL.

USDA 2013. *Plant Pest Information. Giant African Snail*. United States Department of Agriculture, Washington, DC. Available online at http://www.aphis.usda.gov/plant_health/plant_pest_info/gas/index.shtml.

Volin, J.C., M.S. Lott, J.D. Muss and D. Owen. 2004. Predicting rapid invasion of the Florida Everglades by Old World climbing fern (*Lygodium microphyllum*). *Diversity and Distributions* 10:439-446.

Waddle, J. H., R.M. Dorazio, S.C. Walls, K.G. Rice, J. Beauchamp, M.J. Schuman and F.J. Mazzotti. 2010. A new parameterization for estimating co-occurrence of interacting species. *Ecological Applications* 20(5):1467-1475.

Walters, T.M., F.J. Mazzotti and H.C. Fitz. 2016. Habitat selection by the invasive species Burmese python in southern Florida. *Journal of Herpetology* 50:50-56.

Wilde, S.B. 2005. Avian vacuolar myelinopathy linked to exotic aquatic plants and a novel cyanobacterial species. *Environmental Toxicology* 20(3):348-353.

Wilde, S.B. 2014. *Aetokthonos hydrillicola gen. et sp. nov.*: Epiphytic cyanobacteria on invasive aquatic plants implicated in Avian Vacuolar Myelinopathy. *Phytotaxa*: 181(5): 243-260.

Wilde, S.B., T.M. Murphy, C.P. Hope, S.K. Habrun, J. Kempton, A. Birrenkott, F. Wiley, W.W. Bowerman and A.J. Lewitus. 2005. Avian vacuolar myelinopathy of the central nervous system of bald eagles and American coots. *Veterinary Pathology* 35:479-487.

Winck G. and S. Cechin. 2008. Hibernation and emergence pattern of *Tupinambis merianae* (Squamata: Teiidae) in the Taim Ecological Station, Southern Brazil. *Journal of Natural History* 42(3-4):239-247.

Wisely, S. 2016. Pig pen: Rooting swing a costly problem for cattle ranches. *Explore: Research at the University of Florida* 21(1):8.

Witmer, G.W., W.C. Pitt and K.A. Fagerstone (eds.). 2007. Managing Vertebrate Invasive Species: *Proceedings of an International Symposium, Fort Collins, CO, August 7–9, 2007*, United States Department of Agriculture, Animal Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Fort Collins, CO.

Wittenberg, R. and M.J. Cock. 2001. *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices*. CABI Publishing, Wallingford, Oxon, UK.

Workman, R. 1979. *Schinus*. *Technical Proceedings of Techniques for Control of Schinus in South Florida: A Workshop for Natural Area Managers*. Sanibel-Captiva Conservation Foundation, Sanibel, FL.

Zhang, L.Y., W.H. Ye, H.L. Cao and H.L. Feng. 2004. *Mikania micrantha* H.B.K. in China—An overview. *Weed Research* 44:42-49.