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’s (District’s or SFWMD) Strategic Plan, 2019–2024 (SFWMD in prep). 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 2019 (FY2019; October 1, 2018–September 30, 2019).

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 (USACE), United States Department of Agriculture – Agricultural Research Service (USDA-ARS), United States Department of the Interior, United States Geological Survey, National Park Service (NPS), United States Fish and Wildlife Service (USFWS), and University of Florida (UF).

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NONINDIGENOUS PLANTS

- Eighty 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 hydrialla (*Hydrilla verticillata*), and waterhyacinth (*Eichhornia crassipes*) 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 in 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 invasive plants continue. The District closely coordinates aquatic plant management efforts on Lake Okeechobee with FWC and USACE. USFWS, FWC, and the District are actively engaged in aggressive control efforts in WCA-1 (part of 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 (BCNP). Biologists with Palm Beach County, FWC, and the District are coordinating treatments of missiongrass (*Cenchrus polystachios*), a newly discovered noxious weed in Palm Beach County.

- Biological control of several invasive plants is showing promising results. Permits to release two insects for biological control of Brazilian pepper were issued this year. 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 Brazilian pepper, melaleuca, Old World climbing fern, water hyacinth, and other invasive nonindigenous plant species. To date, more than 6 million biocontrol agents have been released in more than 2,500 sites.

- Range expansions of non-indigenous plant species into new areas remain a concern for resource managers. Two Caribbean sedges, tropical nutrush (*Scleria microcarpa*) and Eggers nutrush (*Scleria eggersiana*) have recently been discovered in South Florida. Tropical paspalum (*Paspalum arundinaceum*), also native to tropical America, is becoming more abundant in areas that it had previously been somewhat uncommon. The District and partner agencies are assessing the threats posed by novel introductions such as these and are monitoring and controlling these populations, when deemed appropriate, based on threat prioritization and financial resource availability. Species that are spreading rapidly include *Rotala rotundifolia* and *Azolla pinnata*. 
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 March 2017. To date, the two programs have resulted in the removal of 2,930 Burmese pythons. The District and FWC are currently expanding removal and research efforts in support of python management in response to recent direction from Governor DeSantis. Expanding incentivized hunting and research into new detection technologies are the top priorities for this increased effort.

- 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 FY2019, 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*).

- UF continues to operate the Everglades Invasive Reptile and Amphibian Monitoring Program (EIRAMP) in cooperation with and with support from SFWMD and FWC. The purpose of EIRAMP is to develop a systemwide monitoring program to assess status and trends of priority invasive reptiles and amphibians within Greater Everglades ecosystems.

INVASIVES IN THE RESTORATION CONTEXT

- Invasive species detract from the integrity of the 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 FY2019 on control, research, monitoring, and coordination activities on invasive nonindigenous species that threaten the success of the District’s mission.

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 and land managers 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 natural enemies from a 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 dichlorophenoxyacetic acid (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, reduce aboveground biomass 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. In some cases, planting native plant species may reduce a site’s susceptibility to invasion by nonnative species.
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 spp.) 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 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 control** 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. Four terrestrial non-native plant species—Australian pine, Brazilian pepper, Old World climbing fern, and melaleuca—are priorities for control across the landscape. 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, many regions in the Greater Everglades, including 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 (Figure 7-1). It will likely be decades until these areas are successfully under control. See the Update on Invasive Plant Management in Water Conservation Area 1 (Arthur R. Marshall Loxahatchee National Wildlife Refuge) section later in this chapter for more information.

Old World climbing fern 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 UF to further expand Old World climbing fern management research. The primary focus of this work is to evaluate new herbicides and refine integrated pest management strategies in areas where this plant is most difficult to control.

In addition to the four priority nonindigenous plant species listed above, 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 2019). 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 FY2019, the District spent more than $20.4 million for overall invasive species prevention, control, and management in South Florida. As part of Everglades restoration and to reduce seed and propagule pressure on neighboring lands, the District continues to expand invasive plant treatment into new areas when feasible. Because initial treatments require follow up control, new work areas must be planned and included in budgets for subsequent fiscal years. 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).

In hydrologically altered, high nutrient regions of the Everglades system, some native plants can be nuisance species and are actively controlled by land managers. Carolina willow (Salix caroliniensis) is expanding rapidly in the Kissimmee River floodplain and in CERP project areas on the eastern boundary.
of ENP. Prescribed fire is a critical tool for long-term habitat management in both these areas. Carolina willow is not fire susceptible and readily colonizes graminoid marshes, shading out the grasses and sedges that are necessary to carry fire across the landscape. The District is conducting trials to determine the most effective treatment methods and herbicides for controlling Carolina willow while limiting impacts on desirable vegetation. Another native broadleaf plant, Mexican primrosewillow (*Ludwigia octovalvis*), is similarly impacting portions of the southeastern Everglades, particularly in newly disturbed sites. Mexican primrosewillow was one of the first plants to establish in recently constructed CERP components in the Rocky Glades where it has become the dominant species in sections where it was not controlled. It persists in portions of the Frog Pond, Southern Glades, and the Biscayne Bay Coastal Wetlands due to its prolific seed production and ability to tolerate fluctuations in water levels. Preliminary observations suggest that the plant can be successfully controlled if it’s treated immediately when it appears, but once multiple generations of plants have seeded it becomes increasingly difficult to manage the constant succession of new plants. With this knowledge, land managers can anticipate resource needs in new project areas and, if funding allows, initiate treatment immediately.

**Integrated Pest Management in Florida Natural Areas**

Integrated pest management (IPM) is used by land and water managers, farmers, and scientists throughout the world. The guiding principle of IPM is that using a series of control tools designed to work synergistically will yield an optimal strategy for pest control (Prokopy 2003). When used mindfully and deliberately, IPM improves invasive plant management outcomes while reducing herbicide usage and overall costs (Ehler 2006). The tools available for invasive plant management vary depending on the species to be controlled, site conditions, and control objectives.

In South Florida, implementation of IPM in natural areas (including both upland and aquatic systems) may involve a combination of mechanical, cultural, biological, and chemical management tools. Mechanical control methods may include root grubbing and soil scraping for terrestrial pest plants or tow boat harvesting of floating aquatic plants. Cultural management tools may include water level manipulation and prescribed fire. Biological control agents are available for several priority invasive plants in Florida (see the *Biological Control of Invasive Plant Species* section later in this chapter). Chemical treatment is accomplished using herbicides approved by the United States Environmental Protection Agency (USEPA) for use in natural areas and aquatic systems.

While it is widely recognized that IPM strategies are important for responsible and sustainable invasive species control, most of the tools available, if used on their own, are only moderately effective. Mechanical, cultural, and biological control tools all require the addition of chemical control to considerably reduce pest plant populations. The use of herbicide allows land managers to consistently keep pest plant populations in maintenance (at the lowest feasible) levels and prevents population explosions. Achieving maintenance levels of pest plants is important, particularly in aquatic settings. Uncontrolled floating and rooted non-indigenous plants inhibit water conveyance and facilitate environmental degradation (Netherland 2005). Control of nuisance aquatic plants is required for SFWMD to fulfill its water quality improvement and flood control missions. Additionally, high densities of aquatic plants contribute to low levels of dissolved oxygen and create impenetrable masses of vegetation that impede wildlife movement and foraging. Moreover, if aquatic weeds expand to large dense populations, subsequent control efforts can lead to extreme fluxes in decaying plant biomass further depleting dissolved oxygen and, in eutrophic waters, trigger new disturbance regimes favoring blue-green algae blooms (Bicudo et al. 2007).

Numerous herbicides have been approved by USEPA for use in aquatic and natural area settings. These herbicides receive USEPA approval because they require high concentrations (well above approved label maximum usage rates) to be detrimental to fish and invertebrates and they readily breakdown in soil and water through microbial activity and photolysis. The District only uses herbicides approved by USEPA for use in aquatic and natural areas and in strict accordance with the product labels. Twelve of the eighteen herbicides registered for use in Florida waters have a half-life of two weeks or less; some have a half-life
of just hours (UF-IFAS 2019). Products with the active ingredient glyphosate are some of the most widely used herbicides because of their ability to control multiple weed species, minimal cost, and relatively low environmental toxicity (Solomon and Thompson 2003, Rolando et al. 2017). The SFWMD relies on glyphosate as a safe, cost-effective way to treat natural areas terrestrial weeds and nuisance plants on levees and rights-of-way. Glyphosate is used for targeted plant control in and along some SFWMD waterways but it is a minor component of the aquatics program.

**Biological Control of Invasive Plant Species**

Most nonnative 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 nonnatives by introducing them in Florida to reestablish a natural regulation of the pest plant 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 its 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%, reduce its rate of growth by more than 80%, 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% 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). 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 3 years.
Old World Climbing Fern

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 2018-2019. To date, 182,684 brown lygodium moths or larvae have been released in South Florida.

The lygodium gall mite (*Floracarus perrepae*) induces leaf roll galls on Old World climbing fern. It also damages the apical meristems or new growing tips and can reduce vine growth. First released in 2008, mite establishment has been patchy. 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. Monitoring has revealed that mites are especially abundant in Martin County where > 75% of leaflets in a site can exhibit galls. To date in FY2019, more than 920,048 mites have been released in South 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. New research is under way to determine how to integrate biological control with other management techniques including herbicide applications and prescribed burns. In addition to the two established agents, host range testing is also under way in the USDA-ARS quarantine facility in Fort Lauderdale for three candidate biocontrol agents: *Lygomusotima stria* (moth), *Neostrombocerus albicomus* (sawfly), and *Callopistria exotica* (moth).

Waterhyacinth

Waterhyacinth is an exotic floating plant that aggressively colonizes freshwater ecosystems in the southeastern and southwestern United States including the Everglades. Three biological control agents of waterhyacinth introduced during the 1970s have reduced biomass by more than 50% and seed production by 90%, 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 FY2019, a total of 348,791 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 planthopper 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 are being considered for waterhyacinth at the USDA-ARS Invasive Plant Research Laboratory 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 (*Neochetina* 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 nonnative 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 nonnative 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 USACE, has begun the operational phase of the project and, to date, has released more than six million insects and mites on three weed species. Releases are continuing along with extensive field monitoring and evaluation of the biological control agents.

**Adaptive Management Strategies for Controlling Canegrass**

South Florida contains a suite of large, nonindigenous grasses that are collectively known as canegrass. Two species of canegrass, napiergrass (*Cenchrus purpureum*) and Burmareed (*Neyraudia reynaudiana*) collectively dominate over 1,600 hectares (ha) of soil-disturbed project lands in the Frog Pond and Rocky Glades region of Miami-Dade County. These lands have a history of intensive farming that transformed the historically nutrient and soil poor marl prairies and pine rocklands into high nutrient, high soil profile regions that facilitate the invasion of large canegrass and other invasive plant species. Treatment protocols for canegrass infestations do not exist and traditional control methods are not effective. Mowing and prescribed fire are not long-term control solutions because both these grasses create significant seed banks and grow extensive root systems, which enable them to regrow 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.
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.

District land managers suspected that a combination of chemical, mechanical, and cultural treatment methods, implemented in the proper sequence, could provide long-term control of canegrass infestations (Figure 7-4). In FY2019, the District began trials in the Frog Pond using an adaptive management strategy designed to identify and refine promising results. Thirty-six different treatment sequences using combinations of mechanical work (mowing, diskimg, and roller chopping), chemical treatments (aerial and ground, glyphosate, and glyphosate plus imazapyr), and prescribed fire (backing fires and headfires) proved that acceptable levels of control could be achieved with the following sequence: aerial herbicide followed by mechanical control, then prescribed fire, then diskimg, and finally ground herbicide spot treatments. It was not initially clear if one type of pre-burn mechanical treatment was more effective or if pre-burn mechanical treatment was even necessary. These questions will guide the next series of trials in FY2020. An 83-ha site was aerially treated and half of it was then treated mechanically. The other half was left alone until the entire unit was burned. Following the burn, portions of the unit were mechanically treated. Short-term results suggest that mechanical treatment before prescribed fire is not necessary but diskimg post-burn is critical to help expose sections of living rhizomes. At the end of FY2019, a third round of trials was initiated to refine the post-fire mechanical treatments.

An important component of effective invasive species control is establishing a new, stable, desirable plant community after the previous infestation is eliminated. The disturbed, former agricultural sites in Miami-Dade County do not favor native plant establishment and easily revert to canegrass and woody exotic species infestations. Part of the adaptive management process in the Frog Pond involves trial and error to determine which native plants will thrive in the atypical site conditions and help begin the process of changing soil chemistry and establishing canopy and ground cover. The District recently planted 4,000 South Florida slash pine saplings (Pinus elliottii var. densa) across 3.5 ha in the initial trial area. It is expected that in the future the needle casting will initiate a change in soil pH and the mature trees will create shade, both of which will inhibit canegrass establishment.


Despite decades of invasive plant management in the Everglades, significant infestations of priority invasive species persist within WCA-1, a major component of LNWR. To meet the growing challenge, beginning in 2014, the District, FWC, and USFWS have collaborated to increase control efforts in WCA-1 and, in 2018, the District and USFWS entered into a new license agreement for the USFWS to manage WCA-1 as part of LNWR. In the new agreement, the District will take the lead role in invasive plant
management and has completed a five-year strategic plan to complete all initial treatments in WCA-1. The USFWS is to provide the District with at least $1.25 million annually for invasive plant management. The FWC continues to support this initiative with additional funding each fiscal year.

WCA-1 is a 58,275-ha wetland landscape characterized by a matrix of peat-based bayheads (tree islands) and freshwater marsh (sawgrass marsh, slough, and wet prairie). This area represents the northern most extent of the historic Everglades. The most prolific and damaging invasive plant species within WCA-1 are melaleuca and Old World climbing fern. Initial treatments of these two species have been conducted in many portions of WCA-1 and some areas have received multiple treatments. A 1,600-ha section in the north central portion of WCA-1 contains moderate to high density stands of melaleuca that have yet to be initially treated. Large-scale aerial treatments of dense Old World climbing fern were carried out in 2007, 2008, 2013, 2015, and 2017. However, an abundance of suitable habitat and limited resources for control have resulted in a significant expansion of Old World climbing fern throughout WCA-1 over the last two decades (Figure 7-5).

Figure 7-5. Distribution and abundance of Old World climbing fern within WCA-1 between 1995 and 2015.

Invasive plant monitoring is an important component of the District’s focused efforts within WCA-1. The District utilizes digital aerial sketch mapping (DASM) to determine distribution and abundance of priority plant species across geographically large areas in a timely and cost-effective manner. The DASM approach, which utilizes global positioning system (GPS)-linked tablet computers and specialized software, allows trained biologists to rapidly collect spatial data for invasive plant infestations during aerial reconnaissance flights. (see Rodgers et al. 2014 for detailed descriptions of DASM methodology).
District and NPS have utilized this monitoring technique to meet multiple monitoring objectives within the Everglades restoration footprint since 2008, including landscape-level distribution and abundance assessments, detailed mapping to assist land managers with control strategies, and early detection of new infestations (Rodgers et al. 2018).

Using DASM sampling techniques, the District has established a monitoring protocol—systematic reconnaissance flights (SRF)—to assess landscape-level changes in distribution and abundance of priority invasive species within WCA-1. SRF utilizes fixed east-west 1-kilometer (km) flight transects overlaying a 1-km grid. Six 0.5-ha plots are randomly established within each 1-square kilometer (km²) grid cell. Observers in a low-flying helicopter record the estimated aerial cover of each invasive species observed within a plot. Aerial cover estimates are averaged for each 1-km cell (sample size [n] = 6) to calculate a mean cover estimate for each cell. This method allows for visual representation of the distribution and relative abundance of invasive plant species at the landscape scale. These data are then used to develop and refine control strategies and to document spatial trends in abundance over time. Abundance estimates using the SRF protocol suggest that low abundance Old World climbing fern infestations (< 2% cover) occupy 46% of WCA-1 (10,689 ha) while moderate (2 to 25% cover) and high (> 25% cover) occupy 21% and 2%, respectively. A similar abundance pattern was observed for melaleuca (Table 7-1). Figure 7-6 shows the spatial spread of abundance within WCA-1 for Old World climbing fern and melaleuca.

While the SRF sampling protocol described above provides useful landscape-scale information, detailed infestation data for tree island plant communities is not captured. Tree islands provide critical wildlife habitat within WCA-1 (Brandt et al. 2002) and have an important mechanistic role in Everglades biogeochemical cycling (Wetzel et al. 2017). Unfortunately, ecologically important plant communities are extremely vulnerable to invasive plant species, particularly Old World climbing fern. As such, the District’s invasive plant management strategy requires more detailed, fine-scale distribution and abundance information for tree islands specifically.

Small tree islands are easily surveyed from the ground, but large strand islands are more efficiently monitored from the air. To provide higher resolution spatial data for these larger tree islands, a 100-meter (m) grid was overlaid on all LNWR tree islands greater than 3.2 ha. The abundance of invasive, nonnative plants was recorded for each 100-m grid cell using the DASM technique during February 2019. Mean aerial cover of each invasive species was calculated for each island (Figure 7-7).

Table 7-1. Estimated infestation area of Old World climbing fern and melaleuca within WCA-1.

<table>
<thead>
<tr>
<th>Cover Class</th>
<th>Old World Climbing Fern</th>
<th>Melaleuca</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2%</td>
<td>10,689</td>
<td>28,346</td>
</tr>
<tr>
<td>2-25%</td>
<td>5,037</td>
<td>10,691</td>
</tr>
<tr>
<td>&gt; 25%</td>
<td>522</td>
<td>739</td>
</tr>
<tr>
<td>Total</td>
<td>16,249</td>
<td>39,777</td>
</tr>
</tbody>
</table>
Figure 7-6. Distribution and abundance of melaleuca (left) and Old World climbing fern (right) within WCA-1 on August 2018.
Figure 7-7. Mean percent cover (in five cover classes) of Old World climbing fern and canopy condition on large tree islands (> 3.2 ha) within WCA-1. Data was collected February 2019.
In addition, each island was assigned one of three canopy conditions: intact, moderately impaired, impaired. The criteria for canopy condition included density of native canopy species and apparent health of canopy species (e.g., fire damage, laurel wilt disease, and non-target herbicide damage from past aerial treatments). Canopy condition and mean invasive plant cover were then tabulated to generate a decision matrix for short- and long-term treatment priorities (Table 7-2). For example, tree islands with intact native canopies and moderate to high coverage of Old World climbing fern were classified as short-term treatment priorities to prevent imminent canopy collapse. These “triage” islands are the focus of immediate (within the next 3 years) control efforts by the District. Similarly, tree islands with intact canopies and low invasive species cover are considered a priority for maintenance control. Typically, these islands were recently treated by ground-based herbicide applicators and should be revisited in the near term to ensure long-term control is maintained. There are many tree islands with heavy infestations of Old World climbing fern and little to no remaining native canopy. In the near term, these remnant islands are considered low priority for herbicide treatment. Instead, these islands will be integrated into a long-term recovery plan (e.g., aerial herbicide treatments and restoration plantings) once landscape-level maintenance control of other tree islands is achieved.

Table 7-2. WCA-1 tree island area in ha and number of islands by Old World climbing fern infestation level and canopy condition.

<table>
<thead>
<tr>
<th>Old World Climbing Fern Cover</th>
<th>Tree Island Area (Number of Islands)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intact Canopy</td>
</tr>
<tr>
<td>&lt; 5%</td>
<td>104 (6)</td>
</tr>
<tr>
<td>5–25%</td>
<td>63 (7)</td>
</tr>
<tr>
<td>&gt; 25%</td>
<td>135 (5)</td>
</tr>
</tbody>
</table>

The 2019 tree island canopy condition assessments indicate that 15% of large tree islands (by area) have intact canopies. Moderately impaired and impaired canopies represent 59% and 26% of tree island area, respectively. Among the 111 tree islands assessed, 18 (16%) were determined to have intact canopies, and of these intact islands, 66% were found to have moderate- to high-level infestations of Old World climbing fern (5 to 100% cover) (Table 7-2).

**INVASIVE ANIMAL MANAGEMENT**

Efforts to develop control tools and management strategies for several priority animal species continued in FY2019. 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 nontarget 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 species 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 invasive animal initiatives in FY2019 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 later 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 (EIRAMP). 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 early detection rapid response (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, BCNP, ENP, Corkscrew Swamp Sanctuary, US Highway 1, Card Sound Road, US Highway 27, Frog Pond Wildlife Management Area (WMA), and other areas such as the C-51 canal and Southern Glades WMA. 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 on these routes ranged from 0.0012 to 0.0042 observations per kilometer. In 2019, the most commonly observed nonnative reptiles were tropical house geckos (Hemidactylus mabouia), brown anoles (Norops sagrei), and northern curly-tailed lizards (Leiocephalus carinatus); nonnative amphibians were greenhouse frogs (Eleutherodactylus planirostrus) and Cuban treefrogs (Osteopilus septentrionalis); and nonnative mammals were wild hogs (Sus scrofa), black rats (Rattus rattus), and domestic cats (Felis catus). The most observed native amphibians were southern leopard frogs (Lithobates sphen cancellatus), green treefrogs (Hyla cinerea), and pig frogs (Lithobates grylio); native reptiles were peninsular cooters (Pseudemys floridana), Florida green watersnakes (Nerodia floridana), and southern watersnakes (Nerodia fasciata); and native mammals were white-tailed deer (Odocoileus virginiana), raccoons (Procyon lotor), and Virginia opossums (Didelphis virginiana). To date, 132 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, EIRAMP provides EDRR capability for invasive reptiles in the ECISMA. The EDRR surveys and trapping have resulted in the removal of 101 Nile monitors (Figure 7-8), 2,178 Argentine black and white tegus, 601 Oustalet’s chameleons (Furcifer oustaleti), 24 veiled chameleons (Chamaeleo calyptratus), 140 spectacled caiman, 13 Burmese pythons, one white-throated monitor (Varanus albigularis), one Nile crocodile (Crocodylus niloticus), one Morelet’s crocodile (Crocodylus moreletii), one boa constrictor (Boa constrictor), one ball python (Python regius), one leopard gecko (Eublepharus macularius), and four black spinytail iguanas (Ctenosaura similis). A small group of volunteers managed, as part of this program from 2015 to 2017, to remove 92 Burmese pythons. In 2020, EIRAMP will increase focus on removal of priority species.
Figure 7-8. Traps are strategically deployed to capture Nile monitors along District canals (photo by FWC).

Python Hunter Incentive Program

In spring 2017, the District and FWC began collaboration to develop independent but parallel incentivized python removal programs. The FWC and the District drafted this program to encourage public participation in the removal of invasive pythons. 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 to specific areas and compensating them to go out often, collect useful data on search effort, and remove as many pythons as possible from public lands.

Both agencies announced their programs in March 2017. The call for applicants received a great deal of interest from 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, 2017, and FWC contractors began on April 15, 2017. The District pilot program was approved to run through May 31, then was extended to September 31, 2017. Due to its success, the District

Figure 7-9. Mike Kirkland, SFWMD Python Program Coordinator, with a 5.3-meter Burmese python near WCA-3B (photo by SFWMD).
maintained the program through FY2019 and has secured a recurring budget for subsequent fiscal years. The FWC’s program has continued without interruption. Each agency’s respective programs have since expanded to include new areas and additional contractors.

Both agencies agreed to a multi-tiered compensation structure. Contractors receive minimum wage (currently $8.46 per hour) for time spent in the field surveying for pythons, up to 10 hours each day. The FWC also compensates contractors at the rate of $15.00 per hour in all locations outside of Everglades Francis S. Taylor WMA and ENP to increase survey effort in areas searched less frequently. For the effort of capturing a target species, 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 and FWC compensate their contractors $200 for each verified, viable python nest found in the field. At the time of this writing (July 31, 2019), District and FWC contractors have removed 2,930 Burmese pythons from the program areas (Figure 7-10). The District program’s contractors conducted 22,827 survey hours, resulting in the removal of 2,300 pythons, with an average of 10.00 hours of surveying per python caught. The mean body length of pythons removed by District contractors was 1.97 meters (6.47 feet), with the largest python being 5.31 meters (17.42 feet).

![SFWMD and FWC Python Contractor Initiatives: Running Total of Pythons Removed](image)

**Figure 7-10.** Running total of Burmese pythons removed from the Everglades region during the first 29 months of the SFWMD and FWC python removal programs (both programs combined).

Since the FWC Python Removal Contractor Program began in April 2017, FWC contractors have completed 9561 survey hours in four FWC WMAs (Everglades and Francis S. Taylor WMA, Holeyland, Rotenberger, and Picayune Strand) and two federally managed lands (BCNP and ENP). The FWC and the District work collectively along with partner agencies to expand their contractor programs. A recent success includes the FWC and NPS working together to grant FWC contractors access to ENP. FWC contractors were granted permission to survey ENP on July 1, 201,8 and since that time, 25.90% of the pythons captured by contractors have been caught within the park and 29.50% of the pythons were captured in BCNP. As of July 2019, contractors have captured a total of 630 pythons, with an average of 18.57 hours of surveying per python caught. The mean body length of pythons removed by FWC contractors was 1.88 meters.
(6.17 feet), with the largest python being 5.49 meters (18.00 feet). One python, a 12-foot female, was captured while on her nest of 39 eggs. Currently, the FWC Python Removal Contractor Program contains 41 contractors.

FWC and SFWMD continue to work together on improving survey techniques, sharing contractor observations, and communicating about their respective programs. Inclusion of incentivized python removal in the regional python control effort is another example of integrative pest management principles. Integration of multiple control tools, including telemetry, citizen scientist reporting (e.g., Ivegot1 Hotline), detection dogs, expert surveyors and removers, 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.

**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 United States Geological Survey (USGS) and UF scientists investigated the utility of 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 (Snow et al. 2007a, Dove et al. 2011) and new stable isotope research by USGS and UF indicates pythons consume prey across a broad isotopic niche in saline and freshwater habitats and feed 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 predation 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 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; DNA that is collected from a variety of environmental samples such as soil, seawater, or even air rather than directly sampled from an individual organism). 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).

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 2018 compared to this time in 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 2019. 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 the C-110 canal, 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% 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 2018 by FWC. Habitat assessment was the central research focus and will result in maps to visualize monitor habitat quality. Scobel et al. (2017) reported trap success of 25.0%, similar to the success of trapping efforts in Cape Coral, Florida, where success averaged 29.2% (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 or 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. These tools 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 initiatives 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. Soon, 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. Sentinel snakes, snakes that are caught, radio-tagged, and released back into the wild 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 under way 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 in which we already know they occur. Nile monitor diet and body condition research is currently under way.

Several species have emerged as candidates for increased control measures. Spectacled caimans are sparsely distributed throughout the landscape of South Florida. FWC, SFWMD, and UF plan to ramp up removal programs to extirpate local populations or even the entire species entirely from Florida. Green iguanas (Iguana iguana) 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 Florida Keys through Palm Beach County. FWC staff have removed 93 black spinytail iguanas from No Name Key in Monroe County and a FWC supported contractor, Natural Selections of South Florida, has removed 2,417 green iguanas from 5 state parks in Monroe County.

INTERAGENCY COORDINATION

This section provides updates on key interagency coordination activities pertaining to invasive, nonindigenous species in South Florida during FY2019. 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.

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 (CISMA) 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% of the state (Figure 7-11). 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.

**Everglades CISMA**

Invasive species scientists and Everglades land managers formed the Everglades Cooperative Invasive Species Management Area (ECISMA) in 2006 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 4th Annual Race Against Invasives in ENP, Pet Amnesty Days, The Spring Fish Slam, and the Everglades Non-native Fish Round Up. Members also helped to raise public awareness by manning educational display booths at 12 events. ECISMA partners also held three invasive species training events targeting technicians and other field workers who spend time in the Everglades. These are the strategic “eyes on the ground” personnel who are most likely to observe these animals in the field. 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. During the reporting period, 730 Nile monitor door hangers were distributed to residents in areas with known populations.
In July 2019, 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 spectacled caiman management strategies and new technologies for python detection and control. FWC also held a Python Patrol Workshop to teach attendees nonnative reptile identification and safe capture. More information about 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’s Institute of Food and Agricultural Sciences (IFAS), St. Lucie County, Aquatic Vegetation Control Inc., Habitat Specialists Inc., Florida Grazing Land Coalition, and The Florida Native Plant Society.

From October 2017 through September 2018, the TC-CISMA held two all members meetings discussing various topics and planned upcoming events. The TC CISMA successfully conducted 6 workdays on private properties and public conservation lands in Indian River, St. Lucie, Martin, and Palm Beach counties including a project during the National Invasive Species Awareness Week where the CISMA partnered with a local homeowners association to remove invasive plants from coastal dunes and replant the area with native species. Two educational workshops were held by CISMA members, one with Palm Beach State College professors teaching skills in native and invasive grass identification and the other hosted by Palm Beach County Environmental Resource Management staff that covered their management of invasive species and a tour of a created wetland. Two CISMA members partnered with USDA and released air potato leaf biocontrol beetles on at least 850 sites within the CISMA boundary. CISMA members also volunteered at 4 different outreach events where they provided information to the public about the importance of controlling invasive species. The CISMA often partners with private landowners and met onsite to discuss and plan invasive species control projects at approximately 8 different sites. The CISMA has successfully completed an EDRR project at the Hobe Sound National Wildlife Refuge and presented their success story during the CISMA breakout session at the annual FEPPC annual conference.

At the most recent TC CISMA meeting, workdays were planned for the upcoming year and several open positions within the steering committee were filled. 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 two Everglades Non-native Fish Roundups. The CISMA’s 22nd Annual Southwest Florida Exotics Workshop was held at Florida Gulf Coast University, featuring 9 speakers. Presentations covered topics such as biocontrol efforts, herbicide application research, wildfire effects on invasive species, and cane toads (Rhinella marina). 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 (*Pistia stratiotes*) 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](http://www.floridainvasives.org/Okeechobee).

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 (*Ludwigia* spp.). The primary lakes are large (1,620–13,800 ha) 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 online at [http://www.EvergladesRestoration.gov](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 7-12) 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 7-12.** 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 nonindigenous freshwater fishes with known or suspected impacts to native fauna are not included in this year’s report.

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 Nonnative Species (https://myfwc.com/wildlifehabitats/nonnatives/), 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 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 (Table 7-3). 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 (Table 7-3). 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 7-3. 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.

<table>
<thead>
<tr>
<th>Plants</th>
<th>Mammals</th>
<th>Reptiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian pine (Casuarina spp.)</td>
<td>Feral hog (Sus scrofa)</td>
<td>Burmese python (Python molurus bivittatus)</td>
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<tr>
<td>Brazilian pepper (Schinus terebinthifolius)</td>
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<tr>
<td>Cogongrass (Imperata cylindrica)</td>
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<tr>
<td>Creeping water primroses (Ludwigia spp.)</td>
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<tr>
<td>Downy rose myrtle (Rhodomyrtus tomentosa)</td>
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<td>Hydrilla (Hydrilla verticillata)</td>
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<td>Melaleuca (Melaleuca quinquenervia)</td>
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<td>Old World climbing fern (Lygodium microphyllum)</td>
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<td>Shoebutton ardisia (Ardisia elliptica)</td>
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<td>Torpedogras (Panicum repens)</td>
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<tr>
<td>Waterhyacinth (Eichhornia crassipes)</td>
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<td>Waterlettuce (Pistia stratiotes)</td>
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</table>
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), making the plant particularly destructive to native plant communities. Australian pine can interfere with sea turtle and American crocodile (Crocodylus acutus) nesting (Klukas 1969), and small mammal populations are lower in habitats dominated by this invader (Mazzotti et al. 1981).

KEY MANAGEMENT ISSUES

Distribution: Australian pine is present throughout South Florida, especially in coastal counties. It often occurs in monocultures on small tracts of private land, along rights-of-way, and in windbreaks on agricultural land. Control efforts in natural areas have largely been successful, but recruitment is inevitable in areas adjacent to mature stands, necessitating perpetual maintenance control. Australian pine occupies an estimated 2,639 ha within the Everglades restoration area, primarily in the South Dade wetlands and eastern ENP (Rodgers et al. 2014).

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 provides better guidance for future biological control efforts.

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

Interagency Coordination: Agency-sponsored control efforts are ongoing and gaining public support through education. However, local opposition to control efforts, especially on beaches, can sometimes complicate efforts. One group in Key West has negotiated an MOU preventing the treatment of Australian Pines in Fort Zachary Taylor Historic State Park.

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 male C. cunninghamiana for windbreaks in commercial citrus groves in Martin, St. Lucie, and Indian River counties.

Critical Needs: State and local restrictions are needed on planting and maintaining Australian pine. Numerous potential biological control agents have been identified but support for research into their development and implementation is needed.

2019 Status of Australian Pine by Management Region

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<tr>
<th>Upper Lakes</th>
<th>Kissimmee</th>
<th>Lake Okeechobee</th>
<th>East Coast Region</th>
<th>West Coast Region</th>
<th>Everglades</th>
<th>Florida Bay &amp; Southern Estuaries</th>
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Brazilian Pepper (*Schinus terebinthifolius*)

**SUMMARY:** Brazilian pepper is an aggressive weed that rapidly establishes in disturbed areas then expands into adjacent natural areas (Cuda et al. 2006). 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).

**KEY MANAGEMENT ISSUES**

**Distribution:** Brazilian pepper is the most widespread and abundant nonindigenous species within District boundaries. This prolific seed producer invades most natural communities from mangrove forests to freshwater swamps, even scrub habitat, and can become dominant in all these areas if left unmanaged. Brazilian pepper also remains abundant on rights-of-way and private lands, facilitating constant reestablishment on conservation lands. Brazilian pepper occupies an estimated 30,379 ha within the Everglades restoration area, primarily in southwestern ENP (Rodgers et al. 2014).

**Control Tools:** Managers typically use herbicidal, mechanical, and cultural controls. Two biological control agents to target Brazilian pepper have been tested by USDA-ARS. Field releases were authorized by USDA’s Animal and Plant Health Inspection Service (APHIS) in June 2019. Releases of the thrips *Pseudophilothrips ichini* biological control agent began in 2019. A second biological control agent, the leaf gall former *Calophya latiforceps*, will be released later this year. These two species are being mass produced for distribution through the invaded range and especially within the SFWMD area of responsibility. With Brazilian pepper dominating so many hectares of private lands, biological control agents are the most important tool we can use to reduce the reintroduction of seed to maintained natural areas.

**Monitoring:** Agencies monitor for this species in high priority public lands regionwide. Monitoring is conducted 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 landholders 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.

**2019 Status of Brazilian Pepper by Management Region**

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<th>Upper Lakes</th>
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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 ha in Florida (Miller 2007). Cogongrass invades pine flatwoods, 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). Recent experimental evidence supports concerns that ornamental cultivars may hybridize with invasive biotypes of cogongrass resulting in increased cold tolerance and range expansion (MacDonald 2009).

**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 is spreading throughout the District along levees where it is easily spread by mowers.

**Control Tools:** As is the case with most rhizomatous grasses, labeled rates of imazapyr alone are most effective in reducing cogongrass and require multiple treatments a year. In circumstances where non-target damage is an issue, successful control may require an integration of approaches 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.

**Regulatory Tools:** Cogongrass is designated as both Federal and Florida noxious weeds.

**Critical Needs:** Development of biological control agents would greatly improve regional control of this species. Regulatory pressure is needed to encourage increased control efforts on rights-of-way. Assistance for private landowners could greatly increase the amount of cogongrass treated in the state as much of these infestations occur on ranches in Central Florida.

### 2019 Status of Cogongrass by Management Region

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Creeping Water Primroses (*Ludwigia* spp.)

**SUMMARY:** A complex of invasive aquatic *Ludwigia* species native to South and Central America have become widely established in Florida. Involved species include *L. grandiflora*, *L. hexapetala*, 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 plant’s 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, personal communication, July 26, 2016).

**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. USDA-ARS is evaluating numerous insects 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.

**2019 Status of Creeping Water Primroses by Management Region**

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<th>Upper Lakes</th>
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<th>Everglades</th>
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*Figure 7-16.* Monotypic stands of *Ludwigia hexapetala* dominate large areas of the Kissimmee River floodplain (photo by SFWMD).
**Downy Rose Myrtle (Rhodomyrtus tomentosa)**

**SUMMARY:** Downy rose myrtle 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.

**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. Multiple candidate biological control agents have been evaluated and rejected as not specific to the weed. USDA researchers are planning to survey the Philippine islands soon for prospective agents.

**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 are needed.

### 2019 Status of Downy Rose Myrtle by Management Region

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<tr>
<th>Upper Lakes</th>
<th>Kissimmee</th>
<th>Lake Okeechobee</th>
<th>East Coast Region</th>
<th>West Coast Region</th>
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<td><img src="image7" alt="Florida Bay &amp; Southern Estuaries" /></td>
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Hydrilla (*Hydrilla verticillata*)

**SUMMARY:** Hydrilla is a rooted submerged plant that often forms dense mats through the water column, 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 ha 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 7-18. Dense hydrilla mats aggressively overtake native aquatic vegetation (photo by USDA).](image)

**KEY MANAGEMENT ISSUES**

**Distribution:** Hydrilla is found in all types of Florida water bodies. 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 is needed. Foreign exploration to locate potential biological control agents is continuing in China and Korea. This element of integrated management is needed for long-term control.

**2019 Status of Hydrilla by Management Region**

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<th>Upper Lakes</th>
<th>Kissimmee</th>
<th>Lake Okeechobee</th>
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<th>West Coast Region</th>
<th>Everglades</th>
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Melaleuca (*Melaleuca quinquenervia*)

**SUMMARY:** Before organized state and federal nonindigenous plant control operations were initiated in 1990, melaleuca 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 17,802 ha in the Everglades restoration area (Rodgers et al. 2014).

**KEY MANAGEMENT ISSUES**

**Distribution:** Melaleuca has been systematically cleared from Lake Okeechobee, WCA-2, and WCA-3 and these areas are now under maintenance control. Land managers report slower reinfestation rates as a result of biological control. Significant infestations remain in LNWR, and many west coast properties. Recent shifts in climate have brought weather extremes including extreme drought which has amplified fire behavior in South Florida. Areas in BICY and Picayune Strand State Forest have experienced an explosion of melaleuca seedlings blanketing areas previously under control. In many instances, single seeding trees have turned into hectares of seedlings following severe fire events.

**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. One additional agent is being evaluated.

**Monitoring:** Agencies monitor for this species in high priority public lands regionwide. Monitoring is conducted 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 are needed to reduce remaining infestations near conservation lands. Consistent funding is needed to ensure the success of these efforts does not reverse due to irregular treatment resulting in exponential expansion following fire events.

**2019 Status of Melaleuca by Management Region**

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<th>Upper Lakes</th>
<th>Kissimmee</th>
<th>Lake Okeechobee</th>
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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. 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, Volín et al. 2004).

**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. Old World climbing fern occupies an estimated 7,033 ha within the Everglades, primarily in WCA-1 (part of LNWR) (Rodgers et al. 2014).

**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 Federal and 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 are critical needs.

**2019 Status of Old World Climbing Fern by Management Region**

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<th>Upper Lakes</th>
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Shoebutton Ardisia (*Ardisia elliptica*)

**SUMMARY:** Shoebutton ardisia was imported as an ornamental shrub as early as 1900 (Gordon and Thomas 1997). This species often forms monocultures, 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*).

**KEY MANAGEMENT ISSUES**

**Distribution:** Ardisia is established in natural areas throughout coastal counties in South and Central Florida, particularly in forested wetlands and riparian corridors.

**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. Follow-up treatments are required to control plants germinating from the seedbank. There are currently no biological controls or feasibility studies for potential agents for this species.

**Monitoring:** Shoebutton ardisia is difficult to detect from aerial reconnaissance. 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. Also needed are 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.

### 2019 Status of Shoebutton Ardisia by Management Region

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**Torpedograss (Panicum repens)**

**SUMMARY:** Torpedograss, an Old World grass originally introduced to Florida for forage, forms dense stands that outcompete native plants. Robust, partitioned rhizomes, sometimes with starchy nodules, allow this plant to recover from fire, drought, herbicide application, frost, and mechanical disturbance. Although seed originating from Florida has shown to have very low viability, torpedograss readily spreads vegetatively to new sites.

**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:** Torpedograss is one of the most difficult weeds for land managers in South Florida to eradicate. 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 are the only tools that have proven effective in eliminating significant rhizome mass in natural areas. Eradication requires bare soil treatments of imazapyr or multiple treatments per year of high concentration (5%) glyphosate.

**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 10,554 ha of torpedograss on Lake Okeechobee. More recently, in 2016 and 2017 infestations were significantly reduced, and only 1,528 ha were treated. There were no herbicide treatments on Lake Okeechobee in 2018. 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 an FLEPPC Category 1 invasive species.

**Critical Needs:** Strategies that have proven successful in reducing torpedograss rhizome differ significantly from other weed management strategies. Therefore, proper education, including a comprehensive understanding of torpedograss biology, is needed for land managers who wish to attempt controlling this species. Also, strategies to control torpedograss in situations where inundation prevents significant control of rhizome mass need to be developed.

### 2019 Status of Torpedo Grass by Management Region

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Waterlettuce (*Pistia stratiotes*)

**SUMMARY:** Waterlettuce 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% 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.

**KEY MANAGEMENT ISSUES**

*Distribution:* Waterlettuce inhabits all water body types in South Florida. Herbicide control efforts have suppressed the waterlettuce population from many canal systems. However, most large lakes continue to harbor significant populations requiring frequent control. Aquatic vegetation barriers installed in many canal systems have prevented the release of waterlettuce into other water bodies. Routine maintenance for control of this plant is required, as it reproduces rapidly by vegetative offshoots formed on short, brittle stolons.

*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. Two biocontrol agents, *Neohydronomus affinis* and *Spodoptera pectinicornis*, have been released in Florida with efforts to suppress the waterlettuce population but did not meet management standards. Mechanical harvestings for waterlettuce is practical when piled up and not intermixed with native vegetation.

*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 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.

**2019 Status of Waterlettuce by Management Region**

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Figure 7-24. Dense floating mat of waterlettuce (photo by SFWMD).
**Waterhyacinth (Eichhornia crassipes)**

**SUMMARY:** Waterhyacinth, 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.

**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 (*Rostrhamus sociabilis plumbeus*) 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 ProcellaCOR (Florpyrauxifen-benzyl) has shown promising results at low rates in conjunction with Clipper (flumioxazin) to provide long term control of 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%, 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, *Megamelus scutellaris*, was released in Florida. 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 and treats 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.

**2019 Status of Waterhyacinth by Management Region**

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<th>Upper Lakes</th>
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**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 in southwestern Florida is now contiguous with the main population. This large constrictor is a top predator known to prey upon more than 60 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. See the Invasive Animal Management section above for more detailed updates on monitoring and removal efforts to date.

**KEY MANAGEMENT ISSUES**

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

**Control Tools:** Control options for this species are limited, primarily due to very low detectability. Reed and Rodda (2009) review control tools and their applicability to large constrictors in Florida. Potential controls include visual searching, traps, detection dogs, sentinel snakes, pheromone attractants, and toxicants. Research and development for many of these tools and innovative tools is ongoing or in the beginning stages of development. Python removal programs using volunteers and/or paid contractors are in place with SFWMD, NPS, and FWC.

**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 the Early Detection Distribution Mapping System (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 control and management plan to align management goals and leverage resources among partners. 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:** Technologies need to be developed to improve detection in the field. More funding is needed for telemetered snake programs and detection dogs. Vulnerable resources such as bird rookeries should be protected.

### 2019 Status of the Burmese Python by Management Region

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<th>Upper Lakes</th>
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Feral Hog (*Sus scrofa*)

SUMMARY: Feral hogs 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 hog damage to rangeland pasture is estimated to result in at least $2 million in losses to Florida cattle production (Bankovich et al. 2016). 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).

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 exclusion 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. No toxicants are approved for use on wild hogs in Florida at this time.

**Monitoring:** There is no regional, coordinated monitoring program for wild hogs. Monitoring is limited to efforts associated with removal programs.

**Interagency Coordination:** The Florida Feral Hog Working Group was established in 2018 to better coordinate feral hog policy, research, outreach, control, hunting, and other stakeholder services between agency and non-governmental organization (NGO) partners to best serve Florida stakeholders and natural resource management.

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

**Critical Needs:** Target specific toxicants or contraceptives and initiatives need to be developed for control on private lands.

### 2019 Status of Feral Hogs by Management Region

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**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 (Table 7-4). Three graminoid species—tropical American watergrass (*Luziola subintegra*), West Indian marsh grass (*Hymenachne amplexicaulis*), 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 (Table 7-4). 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 7-4.** Priority species currently managed within the South Florida ecosystem for geographic containment or eradication, ranked by taxonomic group and then alphabetically by common name.

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

**SUMMARY:** The Argentine black and white tegu is a large, omnivorous lizard that is known to eat eggs. In its native range, it prefers open grassy areas and nests in burrows (Winck and Cechin 2008). Three breeding populations are known in Florida—Hillsborough County (Enge et al. 2006), southern Miami-Dade County (Pernas et al. 2012), and an emerging population in Charlotte County (Sarah Funck, FWC, personal communication)—which likely resulted from releases by pet breeders (Hardin 2007). There are confirmed reports in additional locations across the state but the status of tegus in these areas is unknown. FWC has received 16 confirmed reports of tegus observed in Fort Pierce (St. Lucie County); ten were removed. This species may impact Everglades restoration 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.

**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 498 tegus between January 1 and July 31, 2019 (FWC, UF, USGS, and Florida Power & Light, unpublished data). Additionally, the FWC has removed 85 tegus from the Charlotte County population since its discovery in 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 82 camera traps and 385 live traps.

**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 could 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 and continued removal efforts within breeding range; research on severity of impacts; utilization of a model to predict optimal trapping regimes; and federal and state regulations to restrict possession of this species are needed.

**2019 Status of the Argentine Black and White Tegu by Management Region**

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**Exotic Black Mangrove**  
* (*Lumnitzera racemosa*)

**SUMMARY:** The exotic black mangrove (also known as kripa) is native to Asia and Australia and escaped from Fairchild Tropical Botanic Garden cultivation. 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.

**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 and small plants can be hand pulled, 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-ha 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 ten-year eradication effort led by Everglades CISMA is a model for grassroots coordination between agency resource managers. Cooperative annual workdays continue to pull seedlings and survey outlying areas for new plants.

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

**Critical Needs:** Annual efforts to monitor and remove remaining established plants should be continued. State and federal agencies should review this species for future importation restrictions.

**2019 Status of Exotic Black Mangrove by Management Region**

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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 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 Florida Department of Agricultural and Consumer Services (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.

**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 periodic 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 and Florida 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 are needed.

**2019 Status of Mile-a-minute by Management Region**

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Nile Monitor (Varanus niloticus)

SUMMARY: The Nile monitor 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 threatens American crocodiles, American alligators, sea turtles, gopher tortoises, burrowing owls (Athene spp.), and other ground-nesting species (Meshaka 2006, Hardin 2007). Diet studies found 94% of Nile monitors had food in their gastrointestinal tracts with insects, snails, and reptiles most commonly consumed.

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 firearm hunting are the only available control tools for this species. City of Cape Coral and FWC biologists respond to citizen reports in Lee County and FWC conducts regular removal surveys in Palm Beach County. In 2019, 1 Nile monitor was removed from Palm Beach County (Kristin Laurie, FWC, unpublished data) and 31 were removed in Lee County by FWC and the City of Cape Coral (Dan Quinn, FWC, unpublished data) using a combination of techniques including traps, firearms, and opportunistic capture.

Monitoring: FWC and UF are 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 USFWS 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.

2019 Status of the Nile Monitor by Management Region

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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. 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.

**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 federal or Florida noxious weeds.

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

### 2019 Status of Tropical American Watergrass by Management Region

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*Figure 7-32. Dense floating mats of tropical American watergrass (photo by FWC).*
Tropical Nutrush (*Scleria microcarpa*)

**SUMMARY:** Tropical nutrush 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 2018, 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.

**KEY MANAGEMENT ISSUES**

**Distribution:** Documented in Polk, Orange, and Osceola counties and, in 2018 in Palm Beach County but may extend into adjacent counties.

**Control Tools:** Although some treatments occurred in 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 under way 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 as it 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 but it is listed as an FLEPPC Category I species.

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

**2019 Status of Tropical Nutrush by Management Region**

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*Figure 7-33. Tropical nutrush under cypress canopy (photo by SFWMD).*
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 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.

**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, but surveys stopped in 2017. Breeding populations of the veiled chameleon are now documented in Lee County (northwest estuaries), Miami-Dade County (one population near ENP and 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 and remove 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-ha site (Mike Rochford, UF, personal communication).

**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.

**2019 Status of Chameleons by Management Region**

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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.

**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.

**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. The Gambian pouched rat is considered a Prohibited Species by the State of Florida.

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

### 2019 Status of Gambian Pouched Rat by Management Region

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Giant African Land Snail (*Lissachatina fulica*)

**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, horticultural, 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*), 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 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, should continue.

**2019 Status of Giant African Land Snail by Management Region**

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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 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.

**KEY MANAGEMENT ISSUES**

**Distribution:** The northern African python is thought to occur within a 100-km² 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, sentinel snakes, sentinel 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). FWC will be supporting additional research projects using sentinel prey and detector dogs in the upcoming year to address this species.

**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:** The northern African python is considered a Conditional Species by the State of Florida. 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 sentinel snake (or prey) program; implementation of a detection dog program; habitat modification in areas where northern African pythons may find natural refugia; and increased understanding of movement patterns to improve search protocols.

### 2019 Status of Northern African Python by Management Region

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**Spectacled Caiman (Caiman crocodilus)**

**SUMMARY:** Spectacled caiman 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 South Florida.

**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 northern ENP), and along Loop Road in BCNP. This species 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 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, and changes to flow in the C-111 canal may do the same in ENP.

**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 140 caiman since 2011.

**Monitoring:** FWC, the District, and UF are conducting caiman removal surveys.

**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.

### 2019 Status of Spectacled Caiman by Management Region

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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 7-5. Priority species currently managed within the South Florida ecosystem for geographic containment, ranked by taxonomic group and then alphabetically by common name.

<table>
<thead>
<tr>
<th>Mollusks</th>
<th>Birds</th>
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<tbody>
<tr>
<td>Island apple snail <em>(Pomacea maculata)</em></td>
<td>Purple swamphen <em>(Porphyrio porphyrio)</em></td>
</tr>
<tr>
<td>Insects</td>
<td>Amphibians</td>
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<tr>
<td>Laurel wilt <em>(Raffaelea lauricola)</em></td>
<td>Cuban treefrog <em>(Osteopilus septentrionalis)</em></td>
</tr>
<tr>
<td>Mexican bromeliad weevil <em>(Metamasius callizona)</em></td>
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<tr>
<td>Fishes</td>
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<tr>
<td>Asian swamp eel <em>(Monopterus albus)</em></td>
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Asian Swamp Eel (*Monopterus albus*)

**SUMMARY:** Asian swamp eels are versatile animals, capable of living in extremely shallow water, traveling over land when necessary, and burrowing into mud to survive periods of drought. The eels 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).

**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 biologists 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 is needed.

**2019 Status of Asian Swamp Eel by Management Region**

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<tr>
<th>Upper Lakes</th>
<th>Kissimmee</th>
<th>Lake Okeechobee</th>
<th>East Coast Region</th>
<th>West Coast Region</th>
<th>Everglades</th>
<th>Florida Bay &amp; Southern Estuaries</th>
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Cuban Treefrog (Osteopilus septentrionalis)

**SUMMARY:** The Cuban treefrog 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) treefrogs 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.

**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 Cuban treefrogs 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 through EIRAMP. 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 is needed.

### 2019 Status of the Cuban Treefrog by Management Region

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<th>Upper Lakes</th>
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Figure 7-40. The Cuban treefrog is now widely dispersed throughout Florida (photo by UF).
**Island Applesnail (Pomacea maculata)**

**SUMMARY:** The island applesnail 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% development of AVM in laboratory birds fed affected snails (Dodd et al. 2016), suggesting a significant risk to the Everglade snail kite and other avifauna.

**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 of Indians of Florida 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 aquatic 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 are critical needs.

**2019 Status of Island Applesnail by Management Region**

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<th>Upper Lakes</th>
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Laurel Wilt \textit{(Raffaelea lauricola)}

**SUMMARY:** Laurel wilt is a lethal disease of red bay \textit{(Persea borbonia)} and other members of the Laurel family \textit{(Lauraceae)}. The disease is caused by a fungus, \textit{Raffaelea lauricola}, that is introduced into trees by the wood-boring redbay ambrosia beetle \textit{(Xyleborus glabratu)} (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 \textit{(P. palustris)}, an important species of many Everglades plant communities.

**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 ha 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 \textit{Persea} resistance, (2) \textit{Persea} seed/germplasm conservation efforts, (3) potential chemical or biological control tools, (4) discovery of chemical attractants for \textit{X. glabratu}, and (5) impacts on native flora, ecological processes, and native fauna such as the Palamedes swallowtail butterfly \textit{(Papilio palamedes)}.

### 2019 Status of Laurel Wilt by Management Region

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**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. 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 it available to a variety of animals during dry periods.

**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 are critical needs.

**2019 Status of Mexican Bromeliad Weevil by Management Region**

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<th>Upper Lakes</th>
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<th>West Coast Region</th>
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*Figure 7-43. A tillandsia plant heavily damaged by larva of the Mexican bromeliad weevil (photo by UF).*
Purple Swamphen (*Porphyrio porphyrio*)

**SUMMARY:** The purple swamphen 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 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) and preventing spread or establishment in new areas through early detection and rapid response.

**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 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 within known established areas, but FWC coordinates rapid response to sightings in new areas to prevent spread and establishment of new populations.

**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 are critical needs.

**2019 Status of Purple Swamphen by Management Region**

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<th>Upper Lakes</th>
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<th>Lake Okeechobee</th>
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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 “toolbox” 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 CISMA 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.

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