Chapter 7: Status of Nonindigenous Species

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SUMMARY

Invasive, nonindigenous 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 (SFWMD or District) *Strategic Plan, 2021–2026* (SFWMD 2020). Successfully managing invasive species is also important to other strategic goals as their far-reaching effects must be considered during many SFWMD 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 2020 (FY2020; October 1, 2019–September 30, 2020).

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 SFWMD is mandated to manage or restore. SFWMD 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, United

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States Department of the Interior, United States Geological Survey (USGS), National Park Service (NPS), United States Fish and Wildlife Service (USFWS), and University of Florida (UF).

NONINDIGENOUS PLANTS

- Eighty species of invasive non-indigenous plant species are SFWMD 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 in terrestrial natural areas, while aquatic plants such as hydrilla (*Hydrilla verticillata*), waterhyacinth (*Eichhornia crassipe*s), and tropical American watergrass (*Luziola subintegra*) are priorities in the Kissimmee Basin, Lake Okeechobee, and SFWMD's canal systems.

- Efforts to control invasive plants continue throughout SFWMD-managed natural areas, STAs, project lands, lakes, and flood control canals and levees. SFWMD and partner agencies continue ongoing efforts to refine invasive plant management strategies with the goal of achieving cost-effective and environmentally-responsible maintenance control of the most harmful species. 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, WCA-3, and Lake Okeechobee and is now under maintenance control in these regions.

- USFWS, FWC, and SFWMD 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 SFWMD 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 SFWMD 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. The Comprehensive Everglades Restoration Plan's (CERP's) Biological Control Implementation Project continues rearing and release of approved agents at the United States Department of Agriculture's Agricultural Research Service biological control laboratory in Davie, Florida. During 2020, the program continued releases of biological control agents for Old World climbing fern and water hyacinth and initiated rearing and release of a recently-approved agent for Brazilian pepper. Since the project's inception in 2013, there have been 2,841 release events resulting in the release of over 8 million biocontrol agents.

- 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. SFWMD 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. Other species that are spreading rapidly include *Cenchrus polystachios*, *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. SFWMD 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, SFWMD and FWC began independent python removal incentive programs in March 2017. To date (December 28, 2020), the two programs have resulted in the removal of 6,466 Burmese pythons. During the reporting period, SFWMD and FWC expanded and aligned the two python incentive programs to increase the total number of removal agents to 100 and expand survey and removal efforts to ENP, BCNP, and other lands within the core python population area.
- FWC continues to build its nonindigenous animal management program and coordinates closely with SFWMD, NPS, USFWS, and other partners to manage nonnative animal species in South Florida. During FY2020, 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 system-wide monitoring program to assess status and trends of priority invasive reptiles and amphibians within Greater Everglades ecosystems.

INVASIVES IN THE RESTORATION CONTEXT

When Everglades restoration planning began, it was assumed that once historic water flow patterns were reestablished, ecological restoration goals would be largely achieved. However, our improved understanding of resilient, alternative stable states resulting from biological invasions has led ecologists to conclude that invasive species will be a direct threat to restoration success unless management of these species is directly addressed (Doren et al. 2009).

As restoration proceeds, existing and new invaders can act as both a cause of ecosystem degradation and a driver of ecosystem change (Norton 2009). Additionally, the unique responses of each invasive species to changing abiotic and biotic conditions further complicates our predictions of restoration outcomes. For example, removal of canals and levees may limit the spread of some of species that have exploited niches resulting from altered hydroperiods, while other species (e.g., invasive fish) may find new habitats to invade.

To address these unique challenges, SFWMD and USACE have worked to incorporate invasive species management into restoration programs. In 2012, CERP Guidance Memorandum (CGM) 62 was put into place, making invasive species management mandatory within CERP projects. Since this memorandum was put into place, invasive species management has been required within every phase of Everglades restoration: planning, construction, operations and maintenance. To facilitate this effort, invasive species management plans will now be developed for all CERP projects.

Although the incorporation of CGM-62 into Everglades restoration has made invasive species management more consistent, there are still challenges that land managers and biologists face when it comes

to managing invasive species. Successful restoration is incumbent upon the public being aware of their role in keeping the Everglades in its natural state. Enhancing education and outreach efforts to make the public more aware of their impact on the Everglades ecosystem, specifically regarding the introduction of new and invasive species, will be integral in maintaining the restored state of the Everglades. However, when prevention fails, and a new species is introduced into the system, a strategy to stop the spread immediately is vital. Controlling existing target species is a repeated management action that is funded year after year. However, when it comes to early detection and rapid response (EDRR) species, funding corridors become more clouded. The field of invasive species biology is always developing and changing. New plants and animals will be introduced to Florida each year, and it is impossible to predict which of those species will be the next to persist and spread throughout the landscape, and thereby impact restoration gains or goals. Having the capability to quickly respond to such species is integral in restoring the Greater Everglades ecosystem to its historic state. In the future, having flexible EDRR funds available to respond to new introductions in combination with additional prevention efforts (i.e., education and public outreach) will allow for the Everglades to not only return to its natural state, but remain as it was.

PROGRESS TOWARD MANAGEMENT AND CONTROL

The following section provides updates for FY2020 on control, research, monitoring, and coordination activities on invasive nonindigenous species that threaten the success of SFWMD's mission.

SUMMARY OF INVASIVE SPECIES CONTROL TOOLS

Many different techniques are used to control invasive plants and animals in South Florida (Enloe et al 2018, Wittenberg and Cock 2001). SFWMD 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 non-native 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 SFWMD 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 contro**l is the use of direct chemical application or bait stations to dispatch target species or interrupt breeding.

- **Sterilization** reduces reproduction to phase out populations of the target species in specific areas. For example, new chemical fertility control technologies are being utilized in Australia and Asia to control invasive rodent species.

INVASIVE PLANT MANAGEMENT

SFWMD and other agencies continue to make significant progress toward achieving maintenance control of some invasive, nonindigenous plant species on public conservation lands, project lands, and waterways in South Florida (**Figure 7-1**). Eighty invasive non-indigenous plant species have been identified for control across the landscape. Working with collaborating agencies, SFWMD continues to implement its invasive plant management strategy, which seeks to implement integrated pest management approaches toward maintenance level control of priority species. 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. It will likely be decades until invasives in these areas are successfully under control.

Old World climbing fern continues to present significant challenges for natural resource managers in the Everglades and 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. SFWMD, 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.

SFWMD 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 FY2020, SFWMD spent more than $20 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, SFWMD 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 2020).

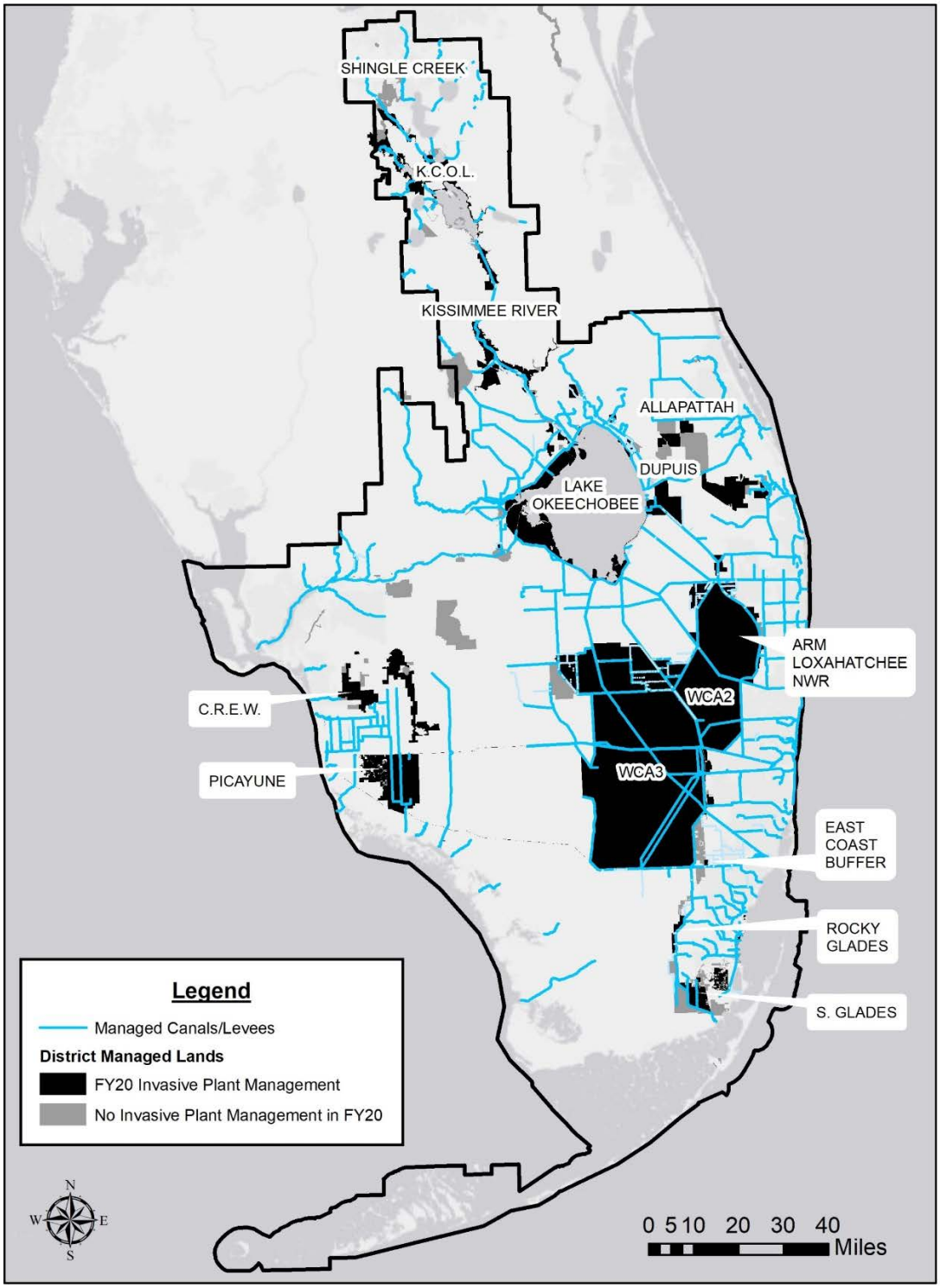


Figure 7-1. District-managed (or co-managed) lands and canals/levees where invasive plant control is routinely conducted. Black polygons indicate lands where invasive plant control occurred in FY2020. Nearly all canal/levee areas are subject to vegetation management each year, including control of priority invasive plant species. To maintain legibility, not all management areas are labelled. For more detailed information on District-managed lands and annual land stewardship activities, see Chapter 6B: Land Stewardship Annual Report in Volume II of this report.

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 caroliniana*) 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. SFWMD 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 southeast 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 is 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* subsection below). 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 fulfil 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 the 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. SFWMD only uses herbicides approved by the 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 2020). 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). 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 is a minor component of the aquatics program.

Biological Control of Invasive Plant Species

Most non-native plant species in Florida arrived without their specialized natural enemies, which allows them to grow larger, produce more offspring, spread more quickly, and often end up dominating and degrading important habitats in Florida. Classical biological control is a scientific process that provides a safe and effective management option that reunites these non-native weeds with their natural enemies after extensive testing for environmental safety. It is the only practical management tactic with the potential to not only fundamentally transform an invasive species into a less aggressive form, but also increase their susceptibility to conventional control methods like herbicides or burning for an overall better outcome.

Although several biological control projects have been very successful in Florida, this method rarely controls the target completely; rather it complements existing tactics by weakening the target plant and making it less competitive with native plants, while increasing their susceptibility to herbicides and fire. Developing biological control agents is necessarily a long-term process due to the importance of ensuring the environmental safety of prospective agents. Overseas and United States quarantine studies are used to confirm the identity and 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 reduces the tree's reproductive potential as much as 99%, reduces its growth rate by more than 80%, and shortens its height by half (Tipping et al. 2008). Those trees that 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. Eggs are oviposited on new growth and the neonate larvae bore into the growing tips of stems stimulating the formation of galls, diverting the tree's resources away from growth and reproduction. When exposed to *L. trifida*, sapling height was reduced by 10%, leaf biomass by 42%, woody biomass by 43%, and root biomass by 30% (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. Another agent, *Lophodiplosis indentata*, a related pea-galling midge has completed testing and found to be host specific to melaleuca. A petition for its release was submitted to the Technical Advisory Group for the Biological Control of Weeds at United States Department of Agriculture (USDA) Animal Plant Health Inspection Service (APHIS) in September 2019. In May 2020, the Technical Advisory Group for the Biological Control of Weeds responded by recommending *L. indentata* for release and forwarding the

petition to APHIS for regulatory approval. We anticipate this insect will be approved for release in FY2022. Although *L. indentata* was originally discovered alongside *L. trifida* in melaleuca stands in Queensland, Australia, they feed on different parts of the plant: *L. trifida* on growing tips and *L. indentata* on developing leaves and newer foliage. This feeding specialization will be particularly useful in areas were *O. vitiosa* has difficulty establishing because of hydrology.

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, *Lygodium microphyllum*) in multiple areas in winter 2018-2019. To date, 182,684 brown lygodium moths or larvae were released in South Florida during FY2020.

Figure 7-2. Damage to Old World climbing fern from the brown lygodium moth in 2019 (photo by USDA).

The lygodium gall mite (*Floracarus perrepae*) induces leaf roll galls on the leaves of Old World climbing fern. It also damages the apical meristems or new growing tips and can reduce vine growth (David and Lake 2020). First released in 2008, mite establishment has been patchy, yet the mite has shown the ability to undergo long distance dispersal and colonize Old World climbing fern populations far from release sites. Monitoring has revealed that mites are especially abundant in Martin County where > 75% of leaflets in a site can exhibit galls. Furthermore, the mite can quickly colonize Old World climbing fern regrowth following prescribed burns (David et al. 2020). To date in FY2020, more than 1.1 million mites have been released in South Florida. New research is underway to determine how to integrate biological control with other management techniques including herbicide applications. In addition to the two established agents, host range testing is also under way in the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) quarantine facility in Fort Lauderdale for three candidate biocontrol agents: *Lygomusotima stria* (moth), *Neostrombocerus albicomus* (sawfly), and *Callopistria exotica* (moth).

Waterhyacinth

Waterhyacinth (*Eichhornia crassipes*) 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 FY2020, a total of 176,410 insects were released with a grand total of almost 3 million insects, most of them in SFWMD STAs and Lake Okeechobee. The species is cold tolerant and can overwinter at least as far north as Gainesville, Florida. Experimental field evaluations of waterhyacinth herbivory from the plant hopper and the previously established waterhyacinth weevils (*Neochetina* spp.) demonstrate that these agents can exert considerable herbivory pressure on the aquatic weed as well as increase the efficacy of herbicidal control (**Figure 7-3**). Other biological control agents are being considered for waterhyacinth at the USDA-ARS Invasive Plant Research Laboratory in Davie, Florida.

CERP Biocontrol Implementation Project

The CERP Melaleuca Eradication and Other Exotic Plants – Implement Biological Controls Project is dedicated to the implementation of biological control agents to address the spread of non-native weeds throughout the CERP area. The project included the construction of a mass rearing annex to the existing USDA-ARS biological control facility in Davie, Florida, to mass rear, release, establish, and monitor approved biological control agents for melaleuca and other non-native weeds in the CERP area. The final project implementation report and 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 SFWMD and USACE, has begun the operational phase of the project and, to date, has released more than 8 million insects and mites (**Figure 7-3**) during 2,841 release events for control of three weed species: Old World climbing fern, air potato (*Liloceris cheni*), and waterhyacinth. Releases are continuing along with extensive field monitoring and evaluation of the biological control agents. A project was recently started on Brazilian pepper using a newly approved thrips species.

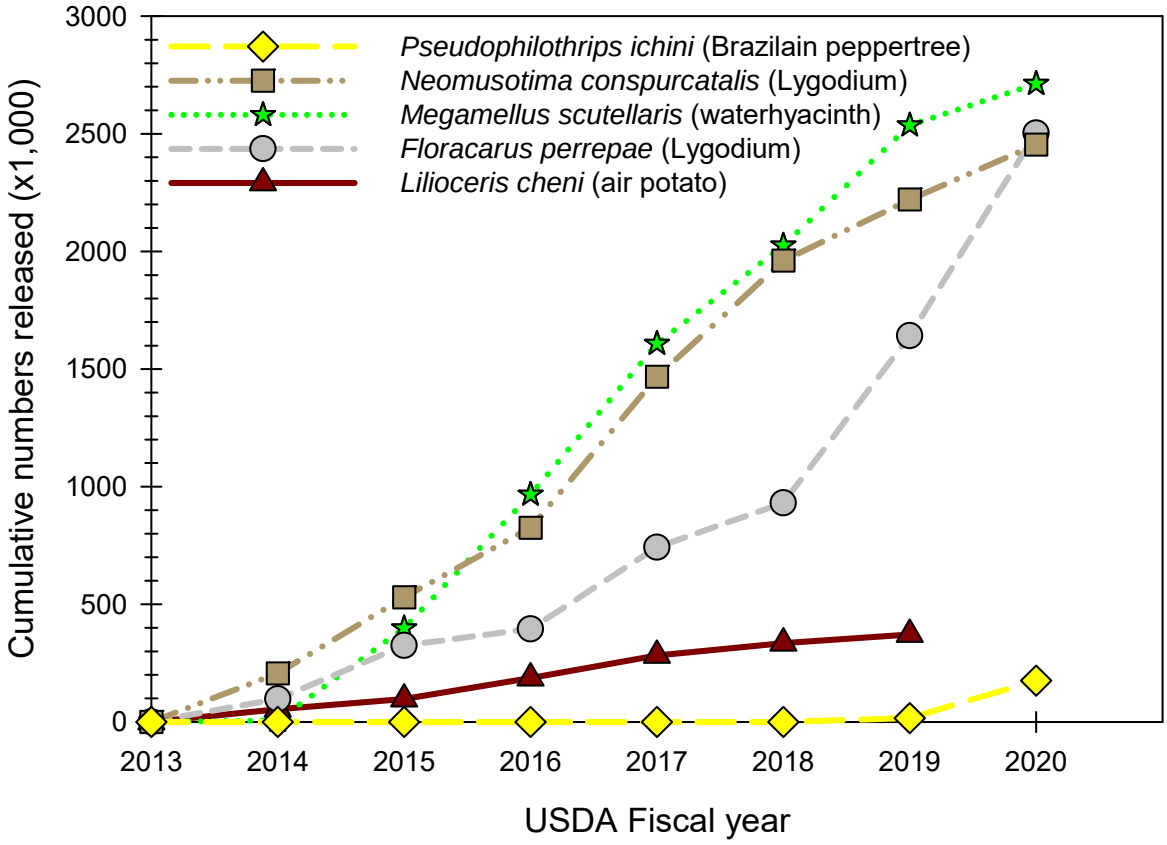


Figure 7-3. Cumulative numbers of biological control agents released between December 2013 and June 2020 within CERP project footprints.

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. Effective treatment protocols for canegrass infestations do not exist and traditional control methods are not efficient. 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.

SFWMD land managers suspected that a combination of chemical, mechanical, and cultural treatment methods (prescribed fire), implemented in the proper sequence could provide long-term control of canegrass infestations (**Figure 7-4**). In FY2018, SFWMD 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, disking, 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 disking, 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 guided the next series of trials in FY2019, which illustrated that mechanical work before prescribed fire is not necessary but disking post-burn is critical to help expose sections of living rhizomes. At the end of FY2019, a third round of trials were initiated to refine the post-fire mechanical component. Results were inconclusive and further trials are designed for FY2021.

Figure 7-4. Before (left photo) and after (right photo) monitoring sites in the phase two trial area demonstrate that dense stands of canegrass can be rapidly eliminated (photos by SFWMD).

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. SFWMD planted 4,000 South Florida slash pine saplings (*Pinus elliottii var. densa*) across 3.5 ha in the initial trial area in FY2019. 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. Approximately 80% of the trees survived the first year but will not grow above the dense forb layer for at least one more year. Planting trials for FY2021 include methods for grass collection, site preparation, and seeding. SFWMD will also plant larger pines and other fast-growing native woody species in the FY2019 treatment area.

INVASIVE ANIMAL MANAGEMENT

Efforts to develop control tools and management strategies for several priority animal species and to further expand management programs continued in FY2020. Priority species for control included the Burmese python and other giant constrictors, the Nile monitor (*Varanus niloticus*), and the Argentine black and white tegu. Despite years if investigation, control tools remain limited for free-ranging reptiles, and the application of developed methods is often impracticable in sensitive environments where impacts to non-target species are unacceptable. Potential tools for removing reptiles generally include catching, trapping (**Figure 7-5**), 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.

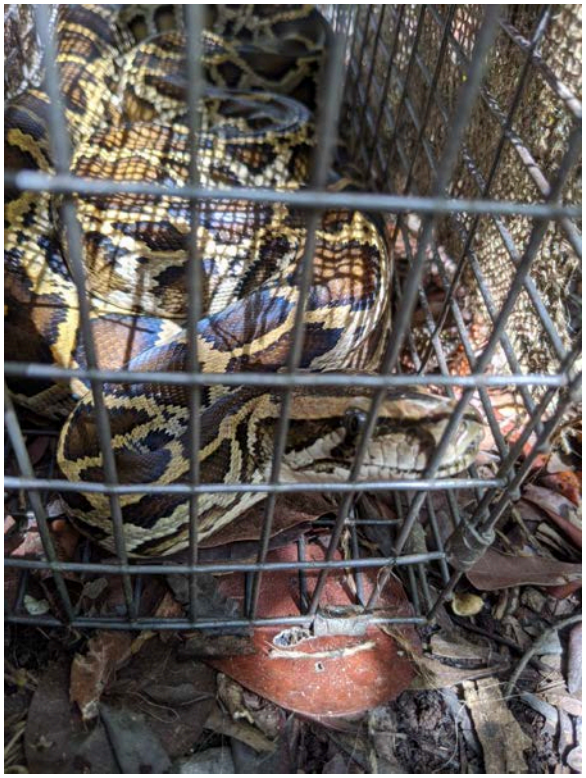


Figure 7-5. Traps are strategically deployed to capture various invasive reptiles. Here a Burmese python was captured in a trap targeting Argentine black and white tegus (photo by UF).

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

There were several ongoing invasive animal initiatives in FY2020 including ongoing monitoring and research efforts for Burmese python, northern African python, Argentine black and white tegu, Nile monitors, and spectacled caiman, among others. Updates on these activities are discussed in the *Invasive Species Status Updates* section in this chapter.

Everglades Invasive Reptile and Amphibian Monitoring Project

In 2010, UF, FWC, and SFWMD began collaboration on the Everglades Invasive Reptile and Amphibian Monitoring Project (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 EDRR capability for removal of invasive reptiles and amphibians, and (3) evaluate status and trends of populations in native reptiles, amphibians, and mammals.

The EIRAMP 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, Everglades and Francis S. Taylor Wildlife Management Area, and other areas such as the C-51 canal and Southern Glades Wildlife Management Area. Visual searches and call surveys are conducted to monitor invasive species and their potential prey species. Twenty-one routes have been established and eight are active. The encounter rates for Burmese pythons on these routes ranged from 0.00039 to 0.01125 observations per kilometer. In 2019, the most commonly observed nonnative reptiles were tropical house geckos (*Hemidactylus mabouia*), brown anoles (*Norops sagrei*), and green iguanas (*Iguana iguana*); nonnative amphibians were greenhouse frogs (*Eleutherodactylus planirostrus*), Cuban treefrogs (*Osteopilus septentrionalis*), and cane toads (*Rhinella marina*); 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 sphenocephalus*), green treefrogs (*Hyla cinerea*), and pig frogs (*Lithobates grylio*); native reptiles were southern watersnakes (*Nerodia fasciata*), Florida green watersnakes (*Nerodia floridana*), and cottonmouths (*Agkistrodon piscivorus*); and native mammals were white-tailed deer (*Odocoileus virginiana*), raccoons (*Procyon lotor*), and marsh rabbits (*Sylvilagus palustris*). To date, 149 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 109 Nile monitors, 2,701 Argentine black and white tegus, 601 Oustalet's chameleons (*Furcifer oustaleti*), 26 veiled chameleons (*Chamaeleo calyptratus*), 159 spectacled caiman, 312 Burmese pythons, one giant whiptail (*Aspidoscelis motaguae*), one common water monitor (*Varanus salvator*), one Nile crocodile (*Crocodylus niloticus*), one Morelet's Crocodile (*Crocodylus moreletii*), one boa constrictor (*Boa constrictor*), one rainbow boa (*Epicrates cenchria*), one ball python (*Python regius*), two African pythons (*Python sebae*), one red-headed agama (*Agama picticauda*), three brown basilisks (*Basiliscus vittatus*), one leopard gecko (*Eublepharus macularius*), one tokay gecko (*Gekko gecko*), one red-footed tortoise (*Chelonoidis carbonarius*), one rhinoceros iguana (*Cyclura cornuta*), four green iguanas (*Iguana iguana*), and five black spinytail iguanas (*Ctenosaura similis*). A small group of volunteers managed as part of this program from 2015 to 2017 to remove 108 Burmese pythons. In 2020, EIRAMP increased focus on removal of priority species.

Python Hunter Incentive Program

In spring 2017, SFWMD and FWC began collaboration to develop independent—but parallel—incentivized python removal programs. Both agencies developed this program to encourage public participation in the removal of invasive pythons. The new program was built from previous use of volunteers working with SFWMD and UF as a component of EIRAMP, which demonstrated that skilled, motivated volunteers can be an effective means of locating and removing giant constrictors. The objectives of both programs are to deploy experienced python removal experts to specific areas and compensate 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 vetting applicants, SFWMD and FWC hired 25 and 21 contractors, respectively (**Figure 7-6**). The vetting process looked at previous python removal experience, background checks, and availability to participate on a regular basis. SFWMD contractors began searches on March 25, 2017, and the FWC contractors began on April 15, 2017. The SFWMD pilot program was approved to run through May 31, then was extended to September 31, 2017. Due to its success, SFWMD maintained the program through FY2020 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.

Figure 7-6. SFWMD Python removal contractor Amy Siewe with a 5.3-meter Burmese python from BCNP (photo by Myron Looker).

Both agencies agreed to a multi-tiered compensation structure. Contractors receive minimum wage (currently $8.56 per hour) for time spent in the field surveying for pythons, up to 10 hours each day. Both agencies also compensate contractors at the rate of $15.00 per hour in all locations on the fringe of the known python range to increase survey effort in areas searched less frequently. For successfully 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. SFWMD and the FWC also compensate their contractors $200 for each verified, viable python nest found. At the time of this writing (December 28, 2020), SFWMD and FWC contractors have removed 6,466 Burmese pythons from the program areas (**Figure 7-7**). SFWMD program's contractors have conducted 31,359 survey hours, resulting in the removal of 3,429 pythons, with an average of 9.15 hours of surveying per python caught. The mean body length of pythons removed by SFWMD contractors was 1.9 meters (6.2 feet), with the largest python being 5.36 meters (17.6 feet). Currently SFWMD's program has 49 contractors.

Since the FWC Python Action Team – Removing Invasive Constrictors (PATRIC) began in April 2017, FWC contractors have completed 20,178 survey hours. As of December 28, 2020, FWC contractors have captured a total of 2,414 pythons. The mean body length of pythons removed by FWC contractors was 1.72 meters (5.64 feet), with the largest python being 5.59 meters (18.33 feet). Currently, the FWC PATRIC contains 49 contractors.

FWC and SFWMD work collectively along with partner agencies to expand their contractor programs. A 2020 Memorandum of Agreement between SFWMD, FWC, and NPS, authorizes python removal agents from both programs to conduct python removal surveys in designated areas within ENP and BCNP. As of June 2020, FWC contractors also have access to four Florida State Parks including Fakahatchee Strand Preserve State Park, Collier-Seminole State Park, Dagny Johnson Key Largo Hammock Botanical State Park, and John Pennekamp Coral Reef State Park.

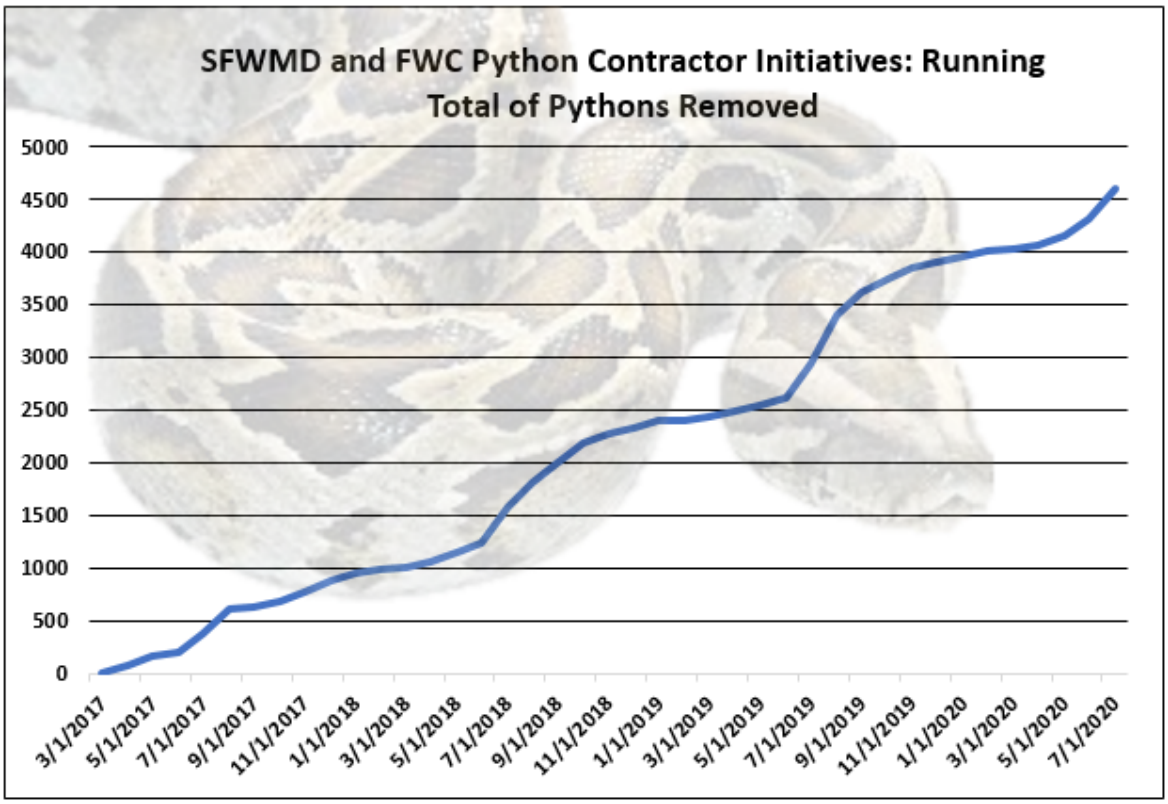


Figure 7-7. Running total of Burmese pythons removed from the Everglades region during the first 29 months of the SFWMD and FWC python removal programs (both programs combined).

Interagency Python Management Plan

The Interagency Python Management Plan (IPMP) is a collaborative effort that began in 2019 among land managers representing over a dozen federal, state, tribal, and local government organizations. The overarching goal of IPMP is to provide a cohesive resource to be used by land managers and stakeholders to address pythons on Florida lands and to facilitate development of a statewide action plan for python management.

IPMP development is scheduled to be completed in spring 2021. The plan will be a living document, focused on adaptive management, guided by science and revised as new information becomes available. Plan content is being driven by in-person workshops and online meetings. As with many environmental issues, the plan recognizes that multiple strategies working in concert will be the best path forward to protect natural resources from the threat of invasive pythons.

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 and UF, USDA, and FWS are collaborating on testing

a patented large reptile trap which is specifically designed to not capture non-target species. Pythons in Florida were radio tracked extensively (Pittman et al. 2014, Hart et al. 2015, Smith et al. 2016, Walters et al. 2016) but recent research by USGS and UF investigated the utility of global positioning system (GPS) telemetry. This technology allows more data collection with less effort but does not work well in closed canopy habitat preferred by pythons (Smith et al. 2018). Previous work on Burmese python diet reveals they are generalist predators (Dove et al. 2011, Snow et al. 2007a) and new stable isotope research by USGS and UF indicates pythons consume prey across a broad isotopic niche in saline and freshwater habitats and feeding across several trophic levels (B. Smith, USGS/UF, personal communication). Road surveys in the past were useful in providing evidence for dramatic declines in mammal populations as pythons increased their presence (Dorcas et al. 2012) and additional surveys show a predator-prey cycle relationship between pythons and opossums (F. Mazzotti, UF, unpublished data). Recent work also shows chronic, direct depredation of marsh rabbits by pythons (McCleery et al. 2015). The effect of python predation on native fauna can result in trophic cascades impacting Florida's ecosystems (Willson 2017). Pythons have been implicated in altering parasite and pathogen dynamics within their invasive range. Studies of Everglades virus have shown that with a reduced diversity of mammalian host species due to python predation, the virus has become more prevalent (Hoyer et al. 2017). Pythons have also introduced a nonnative pentastome parasite to Florida that has spilled over to infect native snakes (Miller et al. 2018). Native snakes are highly susceptible to infection which has facilitated the spread of this parasite to native snakes outside of the pythons range (Miller et al. 2020).

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). 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 signs 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). Orzechowski et al. (2019) utilized eDNA as a tool to identify the adverse impact pythons exert on wading bird breeding aggregations.

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). However, in 2019 an increase in the number of tegus removed was observed compared to 2018 warranting further examination of the impact of trapping efforts for tegu management (Cole et al. 2019).

Northern African python research and control efforts continued into 2020. In addition to previously mentioned detector dog work, UF utilized surveys and refuges to continue searching for remaining African

pythons. Because northern African pythons were not detected during surveys, Cole et al. (2017) estimated detection probability for northern African pythons using Burmese pythons as a surrogate. Detections probability was 0.0064 during EIRAMP surveys on Main Park Road in ENP, 0.00257 on C-110, and 0.0149 for surveys conducted by volunteer python hunters outside ENP. Using these detection probabilities, the minimum number of surveys needed to infer absence with a 95 percent confidence interval is 467 on Main Park Road and 1,164 on C-110. Increasing the detection probability to 0.0166 drops the number of surveys required to 179. Partners of ECISMA held several surveys for northern African pythons during 2019 – 2020 in response to recent sightings of these pythons within the Bird Drive Basin area. Verified reports have occurred in this area during 2018 – 2020, including removal of a large female, 37 hatchlings (confiscated by FWC law enforcement) originating from a clutch removed from the Bird Drive Basin, and two adult northern African pythons observed, but not captured. No northern African pythons were detected during interagency surveys; however, additional effort is needed to determine the status of the northern African python population in southern Florida.

Removal of Nile monitors continued in 2019 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 percent, similar to the success of trapping efforts in Cape Coral, Florida, where success averaged 29.2 percent (K. Hankins, City of Cape Coral, unpublished data). Sample size was too small to assess the best trap but the highest catch per unit effort (CPUE) in the study was 0.167 monitors per trap day for a Tomahawk S50 trap baited with chicken (Scobel et al. 2017).

Priorities Moving Forward

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

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

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

EDRR are the next best tools after prevention. Successful EDRR efforts already prevented the establishment and/or spread of several species such as sacred ibis (*Threskiornis aethiopicus*), Nile crocodiles (*Crocodylus niloticus*), 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 eradication

efforts. While this species' population is extremely limited geographically in South Florida, it should remain a key focus of invasive animal specialists. 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 underway and will continue to shed light on the species, potentially leading us to weaknesses to exploit in removal efforts.

While Nile monitors are relatively confined geographically, they are another species in need of forceful control efforts. A GPS telemetry study is needed to determine how monitors are using the landscape. Exploratory surveys and public outreach may provide important information on undiscovered metapopulations. We likely have an incomplete picture of where they occur and how they use the areas we already know they occur. 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. Several agencies (FWC, SFWMD, and UF) plan to ramp up removal programs to extirpate local populations or even the entire species entirely from Florida. Green iguanas are observed to cause economic damage through crop damage, aircraft strikes, and structure damage (Falcon et al. 2013). For these reasons, FWC, UF, and SFWMD are beginning pilot programs to test iguana control methods from the Florida Keys through Palm Beach County. FWC staff has removed 93 Black spinytail iguanas from No Name Key in Monroe County and 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 FY2020. 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 (CISMAs) to further enhance collaboration and coordination. CISMAs are local organizations, defined by a geographic boundary, that provide a mechanism for sharing invasive plant and animal management information and resources across jurisdictional boundaries to achieve regional invasive species prevention and control (MIPN 2011). 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

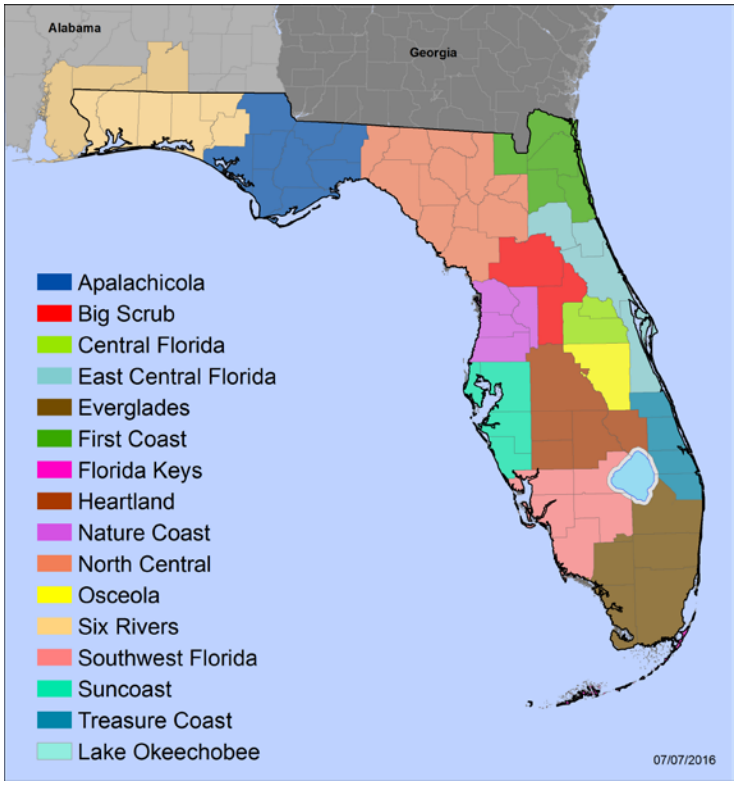


Figure 7-8. Locations of Florida's CISMAs (map credit: University of Georgia – Center for Invasive Species and Ecosystem Health).

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 7-8**). Of these 16 CISMAs, seven occur either wholly or partially within the CERP footprint. Additional information on the Florida Invasive Species Partnership and the ongoing cooperative efforts throughout Florida is available online at https://www.floridainvasives.org.

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 SFWMD, 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 Everglades Non-native Fish Round Up. Members also helped to raise public awareness by manning educational display booths at nine events. ECISMA partners also held 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. Due to COVID-19 restrictions, ECISMA postponed its Everglades Invasive Species Summit. This annual two-day meeting provides a forum for exchanging updates on invasive species management activities, new research, and outreach efforts as well as planning workshops to organize future collaborations and projects. As of this writing, a virtual summit is being planned for October 2020. More information about the ECISMA is available online at http://www.evergladescisma.org/.

Treasure Coast CISMA

The Treasure Coast CISMA (TC-CISMA) is a regional partnership established in 2007 to cooperatively address the threats of invasive plants and animals. The partnership extends from Indian River County south through St. Lucie, Martin, and northern Palm Beach counties and includes representatives and land managers from local, state, and federal governments as well as non-governmental organizations. 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, Indian River Country, Aquatic Vegetation Control Inc., Habitat Specialists Inc., Florida Grazing Land Coalition, and The Florida Native Plant Society.

From October 2019 through July 2020, the TC-CISMA held two all members meetings discussing various local topics and planned upcoming events. The TC CISMA successfully conducted six workdays on private properties and public conservation lands in Palm Beach, Indian River, and St. Lucie counties, including a project during the National Invasive Species Awareness Week where the TC-CISMA partnered with ECISMA to remove invasive plants from the Galaxy Elementary Costal Scrub parcel in Boynton Beach while educating elementary students about conservation and the role invasive species play in disrupting native communities. TC-CISMA members also volunteered at two different outreach events where they provided information to the public about the importance of controlling invasive species. TC-CISMA often partners with private landowners and provides guidance or meets onsite to discuss and plan invasive species control projects. During 2020, many TC-CISMA activities were canceled due to complications from COVID-19. More information about TC-CISMA is available online at http://www.floridainvasives.org/treasure/.

Southwest Florida CISMA

The Southwest Florida CISMA (SWCISMA), 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 five counties: Collier, Lee, Charlotte, Hendry, and Glades. The CISMA's Annual Southwest Florida Exotics Workshop was held at Florida Gulf Coast University, featuring 12 speakers. Presentations highlighted research and management of several invasive animals, biological control agents, and restoration efforts at regional sites. The 2nd annual Weed Wrangle was held at Koreshan State Park. Because of COVID-19, in-person events have been cancelled and SWCISMA has increased their on-line content to continue educating the public about invasive plants and animals. SWCISMA has begun highlighting all of the Category 1 species on their Facebook page. More information about the SFCISMA is available online at https://www.facebook.com/Southwest-Florida-CISMA-156866631138106/.

Other CISMAs

In addition to ECISMA, TC-CISMA, and SWCISMA, 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 Florida Department of Environmental Protection (FDEP), and FWC. At semi-monthly meetings, interagency representatives present planned invasive plant management projects.

Partners are encouraged to provide feedback and any concerns before approving projects as a group. Representatives from partner agencies in the group have 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. In recent years, greater emphasis has been put on implementing mechanical removal of floating aquatic plants incorporated with herbicide treatments. More information about this task force is available online at https://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* (USACE 1989). 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 the Water Resources Development Act of 1996 to help coordinate the intergovernmental Everglades restoration effort. The task force consists of 14 members from four sovereign entities. There are seven federal, two tribal, and five state and local government representatives at the Secretary/Assistant Secretary level. 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 is supported by a Florida-based Working Group, the Science Coordination Group, and the United States Department of the Interior's Office of Everglades Restoration Initiatives.

Recognizing the importance of managing the growing threats invasive exotic species pose to the health and restoration of the Everglades, SFERTF developed an Invasive Exotic Species Strategic Action Framework in 2015. This effort brought together invasive exotic species experts from federal, state, tribal, and local governments and established consensus goals, objectives, and priorities. The framework is organized along the four phases of the Invasion Curve: (1) Prevention, (2) Eradication through Early Detection and Rapid Response (EDRR), (3) Containment, and (4) Resource Protection and Long-term Management (**Figure 7-9**). This structure reflects the spectrum of activities required to combat invasive exotic plant and animal species in the Everglades. In 2019, the task force and its invasive exotic species partners, through the Office of Everglades Restoration Initiatives, began updating the framework and developing a set of complementary resources, including case studies, a 2015–2020 progress report, prioritization list, and an interagency snapshot budget for invasive exotic species. More information will be available fall 2020 at EvergladesRestoration.gov.

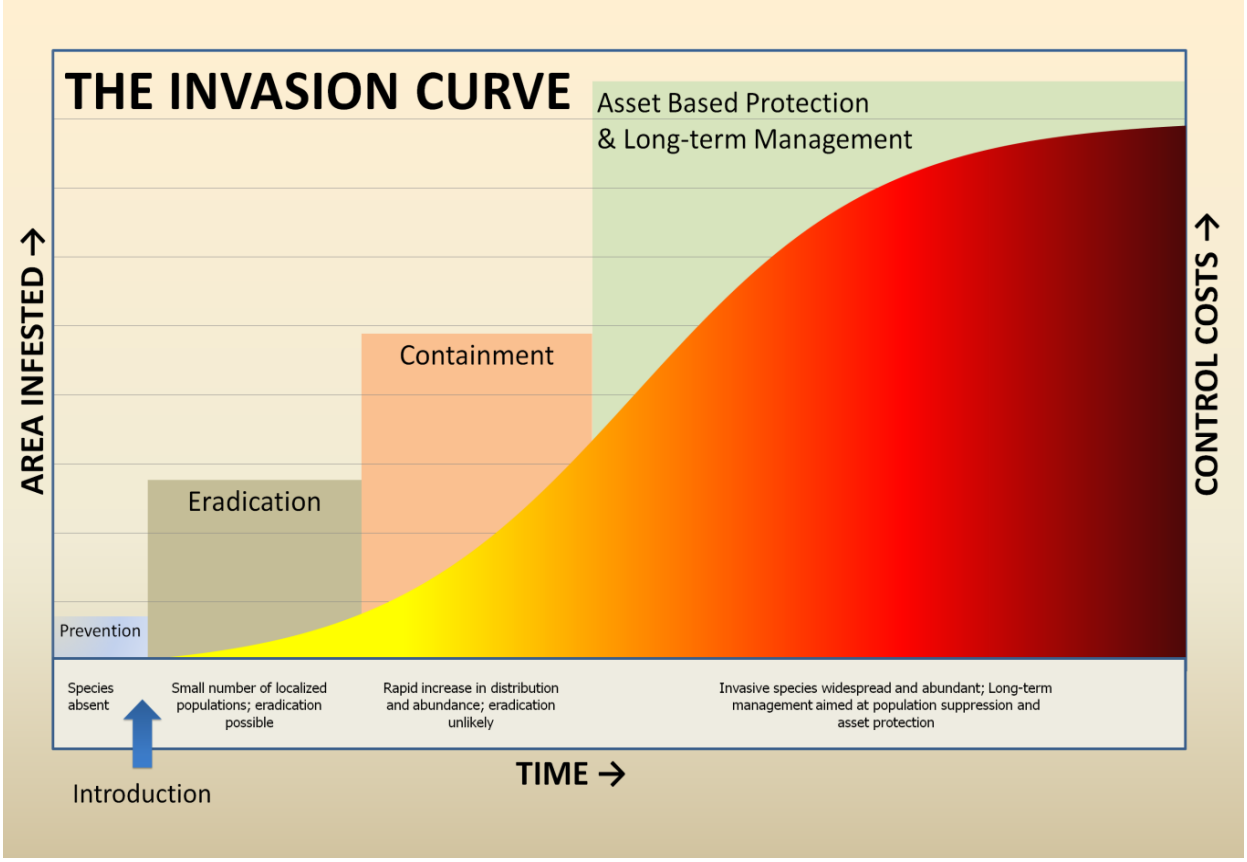


Figure 7-9. The invasion curve depicts the four major categories of management actions that may be taken to combat invasive exotic species as the invasion progresses from initial establishment to widespread dominance on the landscape. Graphic adapted from *Invasive Plants and Animals Policy Framework*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

INVASIVE SPECIES STATUS UPDATES

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

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

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

Omitting specific mention of other nonindigenous species in the following priority summaries does not imply that the species are not problematic or that control is not important. On the contrary, the need is urgent for distribution and biological data for many of these organisms. In addition, numerous non-indigenous freshwater fishes with known or suspected impacts to native fauna are not included in this year's report. Ongoing monitoring and research regarding many of these fish species is beginning to elucidate the scope of the problem. The authors expect to provide details on the status of numerous non-indigenous freshwater fish in the *2022 South Florida Environmental Report* (SFER).

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

- UF/IFAS Center for Aquatic and Invasive Plants – https://plants.ifas.ufl.edu/
- FWC Florida's Nonnative Fish and Wildlife – https://myfwc.com/wildlifehabitats/nonnatives/

Additionally, each species synopsis includes an indicator-based stoplight table that gauges the status of the species in each of SFWMD'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 SFWMD's boundary. The stoplight table technique was established through coordination among the Science Coordination Group, Noxious Exotic Weed Task Team, and Florida Invasive Animal Task Team of the SFERTF (Doren et al. 2009). Like its application in previous reports, the indicator table assesses each species by region per the following questions: (1) How many hectares within the module does this species occur in? (2) Is the distribution of the species in the module documented to be increasing, decreasing, or static? and (3) If the species is decreasing in coverage, is it a direct result of an active biocontrol or chemical/mechanical control program? A brief explanation of stoplight indicators provided for each priority species in the following species summaries is as follows:

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

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

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

SPECIES MANAGED FOR LONG-TERM SUPPRESSION

Twelve established plant species were selected by invasive species biologists from SFWMD and partner agencies based on potential and current implications to SFWMD's infrastructure and ecological concerns (**Table 7-1**). The two established nonindigenous animal species presented in this section are in close alignment with the species identified by regional invasive species experts as priorities for long-term suppression and have active management programs in place. These species are generally presented with a "District-centric" justification for listing, and priority plant species may differ for other agencies, depending on regional factors and agency priorities and goals.

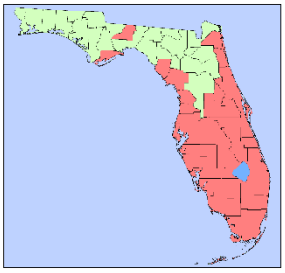
Table 7-1. Priority species currently managed within the South Florida ecosystem for long-term suppression and/or asset protection (e.g., endangered species), ranked by taxonomic group and then alphabetically by common name.

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

Australian Pine (*Casuarina* spp.)

SUMMARY: Three nonindigenous species in Florida are collectively referred to as Australian pine: *Casuarina equisetifolia*, *C. glauca*, and *C. cunninghamiana*. Australian pine is a large, fast growing tree that readily colonizes coastal and inland habitats (Morton 1980). Mature plants produce thick litter mats containing plant growth inhibiting compounds (**Figure 7-10**; 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).

Figure 7-10. Australian pines form dense litter mats that inhibit understory native species (photo by UF).



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 SFWMD-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 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.

2020 Status of Australian Pine by Management Region

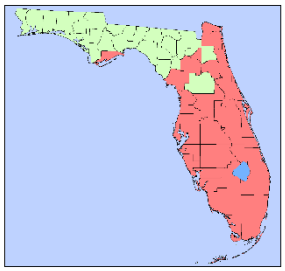
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Brazilian Pepper (*Schinus terebinthifolia*)

SUMMARY: Brazilian pepper is an aggressive invader that rapidly establishes in disturbed areas then expands into adjacent natural areas (Cuda et al. 2019). 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 have greater fitness (germination rate and seedling survival) relative to their progenitors (Geiger et al. 2011).

Figure 7-11. Just-released *Pseudophilothrips ichini* will feed on Brazilian pepper leaves and stems. (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Brazilian pepper is the most widespread and abundant nonindigenous species in SFWMD. 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. It also remains abundant on rights-of-way and private lands, facilitating constant reestablishment on conservation lands. It 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 recently been approved. Mass rearing and field releases of the Brazilian pepper thrips (*Pseudophilothrips ichini*; **Figure 7-11**) biological control agent began in 2019. Releases of the second approved biological control agent, the Brazilian pepper leaf gall former (*Calophya latiforceps*) are expected in 2020. Ultimately, the intention is to distribute these two species throughout 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 SFWMD-owned lands.

Interagency Coordination: An interagency management plan was developed that called for greater 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.

2020 Status of Brazilian Pepper by Management Region

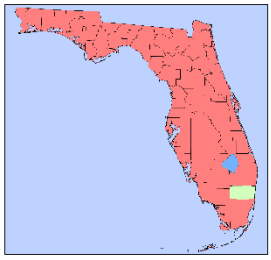
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Cogongrass (*Imperata cylindrica*)

SUMMARY: Cogongrass (**Figure 7-12**) 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).

Figure 7-12. Left untreated, cogongrass (white patches) transforms landscapes as seen is this pasture (photo by UF IFAS).

KEY MANAGEMENT ISSUES



Distribution: Cogongrass is documented in natural areas throughout Florida. Within SFWMD 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 spreading throughout SFWMD 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 the need for multiple treatments a year (Minogue et al. 2012). 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 (Sellers 2018). Research into biological control agents for the Southeastern United States has been ongoing since 2013, however no biocontrol agents have been approved for release (Overholt et al. 2016).

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

Interagency Coordination: The Regional Cogongrass Conference in 2007 produced *A Cogongrass Management Guide: Confronting the Congongrass Crisis across the South* (Loewenstein and Miller 2007).

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

Critical Needs: Development of biological control agents would greatly improve regional control of this species. 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.

2020 Status of Cogongrass by Management Region

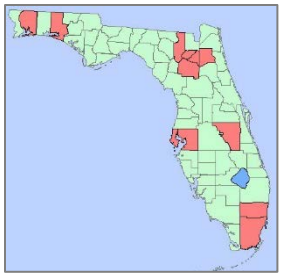
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Creeping Water Primroses (*Ludwigia* spp.)

SUMMARY: A complex of invasive aquatic *Ludwigia* species native to South and Central America have become widely established in Florida. Involved species include *L. grandiflora*, *L. hexapetala* (**Figure 7-13**), and *L. peploides*. Here, *L. grandiflora* will be used as a "catch all" 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).

Figure 7-13. Monotypic stands of *Ludwigia hexapetala* dominate large areas of the Kissimmee River floodplain (photo by SFWMD).

KEY MANAGEMENT ISSUES



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

Control Tools: Young surface growth of creeping water primroses can be controlled with herbicides. However, they have little effect upon mature dense stands. The USDA-ARS is evaluating numerous insects from 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.

2020 Status of Creeping Water Primroses by Management Region

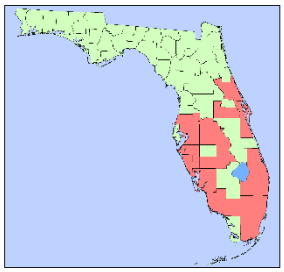
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Downy Rose Myrtle (*Rhodomyrtus tomentosa*)

SUMMARY: Downy rose myrtle 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 (**Figure 7-14**). It is very fire tolerant. Successful control of downy rose myrtle with herbicides is being accomplished where adequate resources are available. The high cost per hectare to clear advanced invasions shows the value of detecting and eliminating downy rose myrtle before it dominates a natural area.

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

KEY MANAGEMENT ISSUES



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

Control Tools: This species is difficult to control, but improvements in herbicide control show promise. Glyphosate and imazapyr are effective but kill native plants and inhibit revegetation. Cut and stump treatments of triclopyr are effective but time and labor intensive in dense infestation. 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.

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.

2020 Status of Downy Rose Myrtle by Management Region

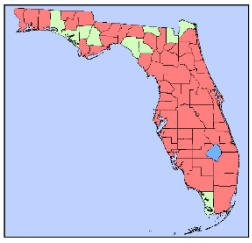
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Hydrilla (*Hydrilla verticillata*)

SUMMARY: Hydrilla is a rooted submerged plant that often forms dense mats through the water column, displacing native plant communities (**Figure 7-15**). 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 7-15. Dense hydrilla mats aggressively overtake native aquatic vegetation (photo by USDA).

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), GALLEON (penoxsulam), and PROCELLACOR (florpyrauxifen-benzyl) 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 and foreign exploration to locate potential biological control agents in China and Korea are needed. In addition, integrated management is needed for long-term control.

2020 Status of Hydrilla by Management Region

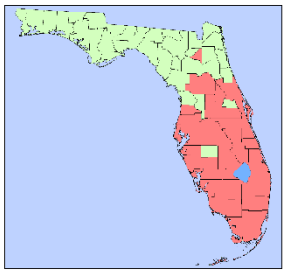
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Melaleuca (*Melaleuca quinquenervia*)

SUMMARY: Before organized state and federal nonindigenous plant control operations were initiated in 1990, melaleuca (**Figure 7-16**) was widely distributed throughout the WCAs, ENP, BCNP, Lake Okeechobee, and LNWR. Overall, agency efforts to control melaleuca are succeeding in containing and reducing its spread. Still, melaleuca remains widely distributed on private lands throughout South and Central Florida, but the successful biological control program has reduced its rate of spread (Pratt et al. 2005). Melaleuca infests an estimated 17,802 ha in the Everglades restoration area (Rodgers et al. 2014).

Figure 7-16. Melaleuca forms dense, single species stands in many South Florida ecosystems (photo by UF)

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 BCNP 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.

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

2020 Status of Melaleuca by Management Region

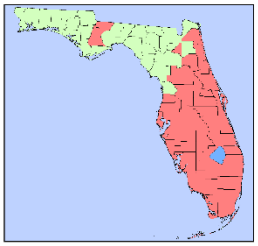
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Old World Climbing Fern (*Lygodium microphyllum*)

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

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

KEY MANAGEMENT ISSUES



Distribution: Old World climbing fern dominates many tree islands, strand swamps, pine flatwoods, and other forested wetlands throughout South and Central Florida. First collected in Martin County, this species continues to expand its range northward. Dense infestations are particularly widespread in southwestern ENP, LNWR, and the Kissimmee River region. Old World climbing fern occupies an estimated 7,033 ha within the Everglades restoration area, primarily in 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 gall 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. Aerial mapping is conducted biennially within the Greater Everglades and on all SFWMD-owned lands.

Interagency Coordination: An interagency management plan was developed for this species and agencies are coordinating control and monitoring efforts. FWC, USFWS, and SFWMD currently fund research investigating new herbicides, biological controls, and integrated pest management strategies for this species.

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

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

2020 Status of Old World Climbing Fern by Management Region

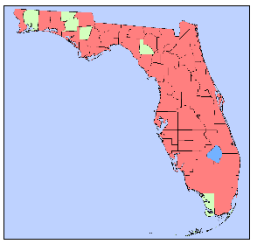
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Dwarf Rotala (*Rotala rotundifolia*)

SUMMARY: Dwarf rotala is a submersed aquatic plant native to India and Southeast Asia. It was introduced into Florida's natural waters as a disposed aquarium plant. Dwarf rotala was first collected in Florida in 1996 in Broward County and can now be found in Lee, Collier, Palm Beach, Broward, and Miami-Dade counties in Florida and Tuscaloosa County, Alabama (UF website/EDDMapS). It is unique in its ability to grow fully submersed, emerged, and terrestrially (**Figure 7-18**). Dwarf rotala roots at the nodes and grows year-round in Florida, which contributes to its invasive nature. Furthermore, this species can reproduce from seeds and fragmentation. The branching growth habit of rotala leads to the creation of thick clumps that can block waterways and inhibit water movement and navigation.

Figure 7-18. Rotala growing rooted in canal to canal surface (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Dwarf rotala primarily inhabits South Florida canal systems and is particularly troublesome in the Miami-Dade and Collier county canal systems. A small population exists in a sawgrass marsh near the Deering Pump Station in Miami-Dade county.

Control Tools: Control of dwarf rotala has been achieved using surface applications of a glyphosate and imazamox mixture or submersed applications of florpyrauxifen-benzyl or fluridone; however, fluridone is not a practical treatment method in many of the canal systems where water moves constantly. Bispyribac has also been shown to provide control when used as a foliar spray, but this method requires populations of rotala to be at the water's surface (Della Torre et al. 2017). Newly labeled ProcellaCOR (florpyrauxifen-benxyl) has shown promising results at low rates to provide long-term control of this species. Additionally, dwarf rotala is routinely mechanically removed from canal systems, but this method does not provide long-term control.

Monitoring: There is no comprehensive monitoring program for this species, but involved agencies share information regarding populations. SFWMD routinely monitors and treats its canals for large populations of this and other submersed and emerged aquatic weeds.

Interagency Coordination: More interagency coordination is needed to regulate the spread of this species.

Regulatory Tools: Dwarf rotala is listed as a Category II species by the FLEPPC. Given its increasing spread in Florida water bodies and continued sale as an aquarium plant, this species should be considered for additional risk assessments.

Critical Needs: Continued development of chemical control methods and biocontrol protocol is needed.

2020 Status of Rotala by Management Region

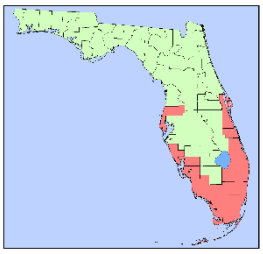
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Shoebutton Ardisia (*Ardisia elliptica*)

SUMMARY: Shoebutton ardisia (**Figure 7-19**) was imported as an ornamental shrub as early as 1900 (Gordon and Thomas 1997). This species often forms extremely dense monotypic stands, resulting in local displacement of native plants. There is a tendency for reinvasion by shoebutton ardisia or other exotic plants following removal of dense thickets of this species. Early infestations may go unnoticed due to this species' physical similarity to the common native marlberry (*A. escallonioides*).

Figure 7-19. Shoebutton ardisia is a prolific seed producer and creates dense stands comprised of multiple size classes. (Photo SFWMD)

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. Herbicide trials conducted by SFWMD that were designed to reduce the high cost of ardisia treatment in mangrove communities were ineffective. A second round of plots were established in FY2020 with results expected in FY2021. 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 SFWMD, Miami-Dade County, and ENP are working closely to address major infestations in the Southern Glades region.

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

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

2020 Status of Shoebutton Ardisia by Management Region

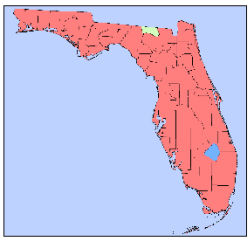
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Torpedograss (*Panicum repens*)

SUMMARY: Torpedograss, an Old World grass originally introduced to Florida for forage, forms dense stands that out compete native plants. Robust, partitioned rhizomes, sometimes with starchy nodules, enable 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 (**Figure 7-20**).

Monitoring: SFWMD 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, SFWMD 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 2020. 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 which 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.

2020 Status of Torpedograss by Management Region

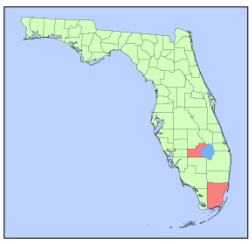
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Tropical American Watergrass (*Luziola subintegra*)

SUMMARY: Tropical American watergrass was first discovered in North America in 2007 in Lake Okeechobee (Kunzer and Bodle 2008). This perennial South American grass grows floating or emergent with prostrate creeping culms that form dense mats (**Figure 7-21**). UF researchers found that plants annually produce hundreds of fertile seeds that remain viable for long periods. Plants decline in winter; new spring and summer growth occurs from seed and surviving rhizomes. Managers aim to treat the plants before the onset of fall flowering.

Figure 7-21. Dense floating mats of tropical American watergrass (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: To date, the plant has been found in five locations—Lake Okeechobee, St. John's River, Lake Hicpochee in the upper Caloosahatchee River, Fisheating Creek Wildlife Management Area, and one site in Miami-Dade County. The latter was eradicated. In Lake Okeechobee, the plant has spread well beyond its initial establishment area and has expanded beyond the lake's levee system. Over 1,500 acres of this species is present on Lake Okeechobee due to lack of maintenance control treatments. It is likely that the plant will be transported outside the lake and continue to spread via wildlife, water releases, or by recreational boaters.

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. Mechanical control may complement herbicide treatment, but this species can spread by fragmentation and contamination of harvesting equipment is a major concern. Little likelihood exists for biological control of tropical American watergrass. It is a grass in the rice tribe (Oryzeae), and the importance of rice agriculture will probably limit biological control as an option.

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

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

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

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

2020 Status of Tropical American Watergrass by Management Region

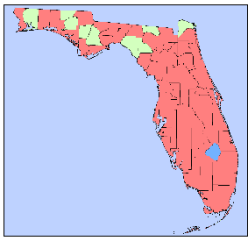
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

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 (**Figure 7-22**).

Figure 7-22. Dense floating mat of waterlettuce (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Waterlettuce inhabits all water body types in South Florida. Herbicide control efforts have 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 SFWMD routinely monitors its canals for large populations.

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

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

Critical Needs: Development of additional biological controls is needed.

2020 Status of Waterlettuce by Management Region

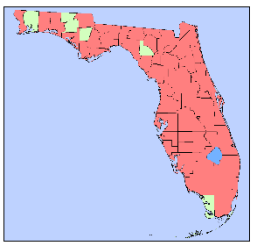
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Waterhyacinth (*Eichhornia crassipes*)

SUMMARY: Waterhyacinth (**Figure 7-23**), 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 et al. 2011). Low nutrient needs and wide tolerance for water conditions enable its persistence and spread.

Figure 7-23. Dense floating mat of waterhyacinth (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: Waterhyacinth inhabits all water body types in South Florida. Herbicide treatments have virtually eliminated it from many canal systems, including urban Miami-Dade and Broward counties. However, most large lakes continue to harbor significant populations requiring frequent control. In the Kissimmee Chain of Lakes and Lake Okeechobee, populations have expanded when treatments are suspended to accommodate Everglade snail kite (*Rostrhamus sociabilis*) 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-benxyl) 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 was released in Florida, *Megamelus scutellaris*. This planthopper is now established in Florida and can be more readily integrated with herbicides than the previously released agents.

Monitoring: FWC monitors waterhyacinth in all Florida public waters. SFWMD 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.

2020 Status of Waterhyacinth by Management Region

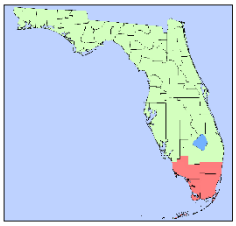
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Burmese Python (*Python bivittatus*)

Figure 7-24. Detection of Burmese pythons is primarily along levees, roads, and other edge features (photo by UF).

SUMMARY: The Burmese python (**Figure 7-24**) 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 south of Lake Okeechobee to the east and west coasts and into the northern Florida Keys, with the core of the python population occurring throughout the southern Everglades.

Control Tools: Control options for this species are limited, primarily due to very low detectability (Nafus et al. 2020). 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, and pheromone attractants. Research and development for these and other tools is ongoing or in the early stages of development. Python removal programs using volunteers and/or paid contractors are in place with SFWMD, NPS, and FWC. Collectively, these programs have removed approximately 5,000 pythons between 2017 and July 2020.

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

Interagency Coordination: There is interagency coordination for this species, but efforts to implement programs are constrained by limited resources and few control tools. FWC and partner agencies are working together to create an interagency python 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 SFWMD of Columbia Circuit ruled the federal government cannot prevent interstate trade in 2017.

Critical Needs: Critical needs include the development of technologies to improve detection in the field; more funding for telemetered snake programs and detection dogs; and protection of vulnerable resources such as bird rookeries.

2020 Status of the Burmese Python by Management Region

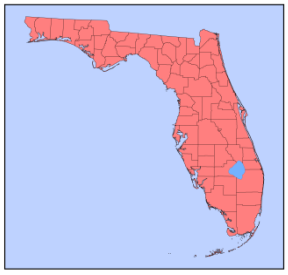
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Feral Hog (*Sus scrofa*)

SUMMARY: Feral hogs (**Figure 7-25**) 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).

Figure 7-25. A pair of feral hogs at Lake Okeechobee (photo by FWC).

KEY MANAGEMENT ISSUES



Distribution: Wild hogs are reported in all 67 Florida counties. Within SFWMD boundaries, 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. SFWMD has improved contract procedures for hog control. Since 2015, hog removal agents removed 6,041 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/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: Development of target specific toxicants or contraceptives and initiatives for control on private lands.

2020 Status of Feral Hogs by Management Region

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

SPECIES MANAGED FOR CONTAINMENT OR ERADICATION

Five invasive plant species were identified as priorities for regional containment or eradication by invasive species biologists from SFWMD and partner agencies (**Table 7-2**). 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 SFWMD and Lake Okeechobee's 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 7-2**). Species with numerous population cores, such as the Nile monitor, are actively managed for regional containment while others with still limited geographic distributions (e.g., northern African python) remain candidates for eradication from Florida.

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

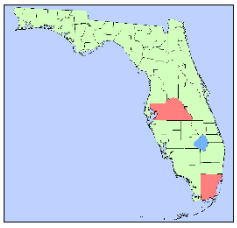
Plants	Reptiles
Exotic black mangrove (*Lumnitzera racemosa*)	Argentine black and white tegu (*Salvator merianae*)
Mile-a-minute (*Mikania micrantha*)	Nile monitor (*Varanus niloticus*)
Tropical American watergrass (*Luziola subintegra*)	Northern African python (*Python sebae*)
Tropical nutrush (*Scleria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

Argentine Black and White Tegu (*Salvator merianae*)

SUMMARY: The Argentine black and white tegu (**Figure 7-26**) 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)—of which likely resulted from releases by pet breeders (Hardin 2007). There are confirmed reports in various locations across the state but the status of tegus in these areas is unknown. The FWC has received 39 confirmed reports of tegus observed in Fort Pierce; 28 were removed and four were found dead. 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.

Figure 7-26. An Argentine black and white tegu captured in a standard trap (photo by FWC).

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 916 tegus between January 1 and June 30, 2020 (FWC, UF, and NPS unpublished data). Private trappers utilizing the FWC trap loan program have removed approximately 64 tegus from January 2019 to June 2020. Additionally, the FWC has removed 144 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 tools.

Monitoring: Interagency collaborators initiated rapid response measures in 2011. Since this time, these efforts are ongoing and have expanded to include deployment of approximately 600 camera traps and 1,600 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: As of July 1, 2020, tegus (genera *Salvator* and *Tupinambis*) have been granted Conditional Reptile designation by the State of Florida.

Critical Needs: Dedicated funding for rapid response initiatives and continued removal efforts within breeding range; research on severity of impacts; utilizing a model to predict optimal trapping regimes; and federal and state regulations to restrict possession of this species are all critical needs.

2020 Status of the Argentine Black and White Tegu by Management Region

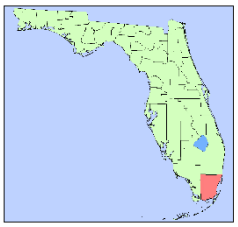
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Exotic Black Mangrove (*Lumnitzera racemosa*)

SUMMARY: Lumnitzera, the exotic black mangrove (also known as kripa; **Figure 7-27**) is native to Asia and Australia but escaped cultivation from Fairchild Tropical Botanic Garden. The plant was discovered to be rapidly proliferating in neighboring Matheson Hammock Preserve in 2009. Lumnitzera aggressively out-competes native mangrove species. The full effects of a major invasion of this species on Florida mangrove swamp diversity and function are difficult to predict. Given the important contributions of mangroves to marine productivity and the economy of South Florida, regional invasive species biologists launched a rapid response effort almost immediately after the invasion was detected.

Figure 7-27. Exotic black mangrove (photo by Fairchild Tropical Botanic Garden).

KEY MANAGEMENT ISSUES



Distribution: Lumnitzera 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. Unlike most other mangrove species, lumnitzera does establish a true seedbank. 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 the efforts to pull seedlings and survey outlying areas for new plants.

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

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

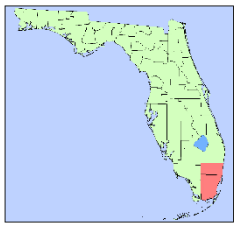
2020 Status of Lumnitzera by Management Region

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

Mile-a-minute (*Mikania micrantha*)

SUMMARY: Mile-a-minute (**Figure 7-28**) is a federally listed noxious weed that recently appeared in South Florida. This South American vine has turned into a serious weed where it was introduced in Asia, Australia, and Africa (Holm et al. 1977, Zhang et al. 2004). Mile-a-minute was discovered near Homestead in 2008. An aggressive reconnaissance and eradication effort began immediately after its discovery. Controlling the plant is challenging, in part due to infestations on private lands (Dozier 2012), although the threat of Florida Department of Agriculture and Consumer Services (FDACS) quarantine is an incentive for nursery owners to eliminate the weed. Eradication from Florida seems unlikely but, containment and suppression remain a priority to prevent it from colonizing large natural areas like the South Dade Wetlands and ENP.

Figure 7-28. Mile-a-minute is considered one of the top 100 global invasive pests (photo by FDACS Division of Plant Industry.)



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. Canopy openings in tropical hardwood hammocks from Hurricane Irma created favorable conditions for the weed and Miami-Dade County land managers continue to control it in six preserves. Treatment is challenging in canopy gaps because the state-endangered species *Passiflora pallens* and *P. sexflora* both grow in these areas.

Control Tools: This plant is readily controlled by herbicides. Mile-a-minute was treated by Miami-Dade County crews on six properties in 2020. After several years of treatment, it appears many population cores of the plant may be eradicated, but limited monitoring access on private lands is hindering control efforts.

Monitoring: Biologists at Miami-Dade County with the support of ECISMA 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 ECISMA is a model for grassroots coordination between agency resource managers.

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

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

2020 Status of Mile-a-minute by Management Region

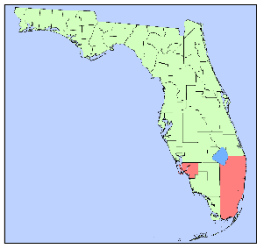
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Nile Monitor (*Varanus niloticus*)

SUMMARY: The Nile monitor (**Figure 7-29**) 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.

Figure 7-29. Nile monitors grow to 1.5 meters in length (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Established populations are documented in Lee (Enge et al. 2004), Miami-Dade, and central Palm Beach (Eckles et al. 2017) counties. 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. During FY2020, two Nile monitors were removed from Palm Beach County and 53 were removed in Lee County by FWC and the City of Cape Coral. Monitor lizards were removed 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 has instituted monthly monitoring in Broward County. UF works with LNWR to increase surveys in the area.

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

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

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

2020 Status of the Nile Monitor by Management Region

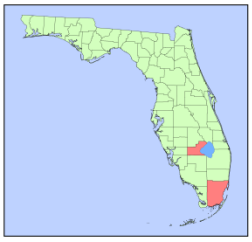
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Tropical American Watergrass (*Luziola subintegra*)

SUMMARY: Tropical American watergrass (**Figure 7-30**) 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.

Figure 7-30. Dense floating mats of tropical American watergrass (photo by FWC).

KEY MANAGEMENT ISSUES



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

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

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

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

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

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

2020 Status of Tropical American Watergrass by Management Region

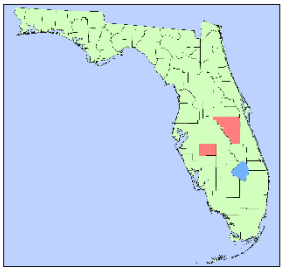
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Tropical Nutrush (*Scleria microcarpa*)

SUMMARY: Tropical nutrush is a perennial sedge found throughout the American tropics. It has been found in a several 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. This species prefers wetlands with diffused light and 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 and floodplains, forming dense, monotypic stands in the shaded understory of mixed hardwood swamps and cypress forests (**Figure 7-31**). This species is found in areas where there is otherwise a lack of significant vegetative cover, so it is not directly competing with many plants, but it also occurs in hardwood swamps where it is mixed with other graminoids.

Figure 7-31. Tropical nutrush under cypress canopy (photo by SFWMD).

KEY MANAGEMENT ISSUES



Distribution: To date this species has been documented in Polk, Orange, Osceola, Highlands, and Palm Beach counties. The latter was eradicated. This species is most abundant in Polk and Osceola counties but expansion of this species through the Greater Everglades Watershed is likely.

Control Tools: Recent, unpublished studies have shown that glyphosate is an effective herbicide treatment and imazamox may provide adequate and selective control of this species. Additional herbicide trials are underway to optimize control through treatment timing and frequency. In hardwood marshes, it may be difficult to have selective treatments since it is found growing mixed with other sedges and grasses. Biological control efforts are not being considered for this species, which is part of a large genus that includes nine native species.

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

Interagency Coordination: Heartland-CISMA makes this species a priority for regional reporting coordination. UF IFAS' Assessment of Non-Native Plants in Florida's Natural Areas (https://assessment.ifas.ufl.edu/) concluded this species to be invasive in Central Florida.

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 are needed.

2020 Status of Tropical Nutrush by Management Region

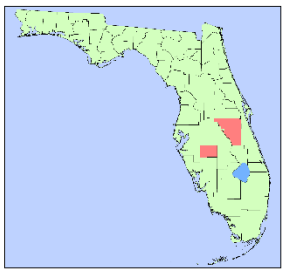
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Wright's Nutrush (*Scleria lacustris*)

SUMMARY: Wright's nutrush is a robust annual sedge that is considered to be native throughout the Caribbean, northern South America, and parts of Africa. The first Florida record is from 1988 but large, dense populations were not documented until 2001. Wright's nutrush prefers seasonally dry wetlands but once established, can tolerate occasional drought or prolonged flooding due to its persistent seedbank (Jacono et al. 2011). Sawgrass and maidencane marshes, cypress strands and floodplain basins are all vulnerable to invasion by Wright's nutrush, where it readily outcompetes the native graminoid species (**Figure 7-32**).

Figure 7-32. Wright's nutrush dominating native vegetation in Holeyland Wildlife Management Area (photo by Institute for Regional Conservation).

KEY MANAGEMENT ISSUES



Distribution: Established populations vary annually in size and density, depending on water levels and durations. To date, Wright's nutrush has been documented in 16 South and Central Florida counties but, while it exists in Broward and Miami-Dade counties, it is not yet widespread.

Control Tools: This plant is readily controlled by herbicide. Clipping seed heads and pulling plants can also be effective in areas with small populations but these methods are not feasible across multiple acres. Land managers often find treatment timing challenging. Too early in the season misses late germinations and, if seeds are clipped, plants will flower again. Late season treatments risk allowing viable seeds to enter the system. Follow-up annual treatments are necessary to control the persistent seed bank.

Monitoring: Land managers survey for this species each spring as water levels begin to rise.

Interagency Coordination: ECISMA has conducted two workdays to survey portions of WCA-3A and WCA-3B for outlier populations.

Regulatory Tools: Wright's nutrush is not a regulated or prohibited species but it is listed as an FLEPPC Category I species.

Critical Needs: Expanded surveys and control efforts for Wright's nutrush including private lands, particularly in the Kissimmee Chain of Lakes region.

2020 Status of Wright's Nutrush by Management Region

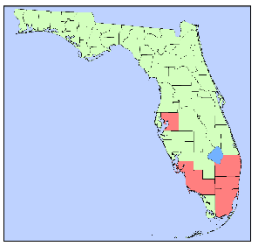
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys

Chameleons (*Furcifer oustaleti* and *Chamaeleo calyptratus*)

SUMMARY: The Oustalet's chameleon (*Furcifer oustaleti*) is a large chameleon native to Madagascar where it utilizes a wide variety of habitats, including human altered environments (D'Cruze et al. 2007). Diet analysis indicates that this chameleon population consumes a variety of insect and anole species, particularly moth larvae (Krysko et al. 2012). The veiled chameleon (*Chamaeleo calyptratus*; **Figure 7-33**) 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.

Figure 7-33. A veiled chameleon (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: A population of the Oustalet's chameleon was discovered in rural Miami-Dade County in early 2010. This species does not appear to be spreading without human assistance and the number of chameleons per survey has decreased, 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 a second adjacent to BCNP), Broward County, and Palm Beach County near the southern tip of LNWR (FWC 2020). In addition, reports of veiled chameleons are now common from Buckingham, Alva, Cape Coral, Marco Island, and Lutz, Florida.

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

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

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

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

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

2020 Status of Chameleons by Management Region

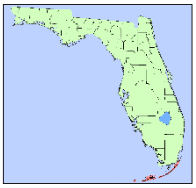
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Gambian Pouched Rat (*Cricetomys gambianus*)

SUMMARY: The Gambian pouched rat is a large, omnivorous rodent of African origin (**Figure 7-34**). Once popular in the exotic pet trade, the United States Center for Disease Control banned their importation in 2003 because they are a carrier of monkey pox. Prior to this ban, numerous Gambian rats escaped captivity in the Florida Keys (Grassy Key) and established a reproducing population. This species is considered likely to invade the Florida mainland and is viewed as a significant threat to endangered rodents and other fauna, agriculture, and human health (Engeman et al. 2006). These concerns prompted rapid response measures in 2005, which appeared to have been successful. In 2009, FWC biologists cautiously declared that the population was eradicated while continuing periodic monitoring for the rodent. Then in 2011, the Gambian pouched rat was again reported on Grassy Key. USDA and FWC biologists reinitiated trapping efforts in early 2011 and removed 31 rats to date. The last removal and sighting occurred in 2012. Unfortunately, in August 2017, a picture surfaced of an American crocodile with what appears to be a pouched rat in its mouth. Officials are currently assessing the situation.

Figure 7-34. Gambian pouched rats continue to occur in the Florida Keys despite years of trapping (photo by USDA).

KEY MANAGEMENT ISSUES



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

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

Monitoring: FWC maintains an active monitoring program 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.

2020 Status of Gambian Pouched Rat by Management Region

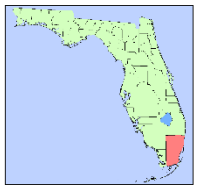
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Giant African Land Snail (*Lissachatina fulica*)

Figure 7-35. The giant African land snail is a host of the rat lungworm (photo by FDACS).

SUMMARY: A population of the giant African land snail (**Figure 7-35**) was discovered in 2011 in an area of Miami (FDACS-DPI 2020). The giant African land snail is known to eat a great variety of vegetation, including crop plants, horticultural plants, and environmentally valuable plants. This species has invaded other places outside its native range in Africa, often causing substantial damage. It is an intermediate host of the rat lungworm (*Angiostrongylus cantonensis*), 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 2020).

KEY MANAGEMENT ISSUES



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

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

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

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

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

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

2020 Status of Giant African Land Snail by Management Region

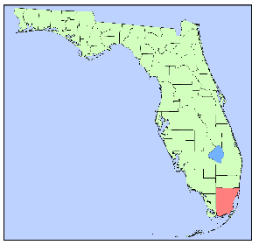
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Northern African Python (*Python sebae*)

SUMMARY: Since 2001, over 40 northern African pythons (**Figure 7-36**) 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. SFWMD, Miccosukee Tribe of Indians, and Miami-Dade County, the primary landowners within the Bird Drive Basin, are working closely with FWC and other agencies to address this threat.

Figure 7-36.
The northern African python (photo by UF).

KEY MANAGEMENT ISSUES



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

Control Tools: Control options for this species are limited, primarily due to very low detectability. Potential controls include visual searching, traps, detection dogs, 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 SFWMD 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* subsection above for additional information on the Irula tribesmen and detector dogs). The 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.

2020 Status of Northern African Python by Management Region

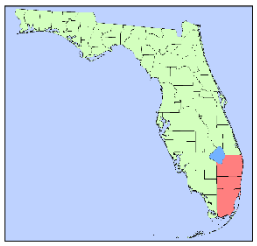
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Spectacled Caiman (*Caiman crocodilus*)

SUMMARY: Spectacled caiman (**Figure 7-37**) from the exotic pet trade were first reported in 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 current intolerance of cold temperatures, breeding populations may remain limited to southern Florida.

Figure 7-37. A spectacled caiman (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Currently, the spectacled caiman's range includes parts of Miami-Dade and Monroe counties with most records located in Homestead, Florida City, along US-41 (including the northern part of ENP), and along Loop Road in BCNP. Spectacled caiman has been observed and captured in western Broward county, as well as one in Palm Beach County suggesting the original population may have spread northward or other introductions have occurred. A small population of caiman was recently discovered within the footprint of the Biscayne Bay Coastal 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 hunting. 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 291 caiman since 2011.

Monitoring: UF is currently in collaboration with SFWMD and USFWS in efforts to remove caiman.

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

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.

2020 Status of Spectacled Caiman by Management Region

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

ESTABLISHED INVASIVE SPECIES WITHOUT CONTROL PROGRAMS

The final group of invasive species consists of species that are well established in the Everglades ecosystem and are known or presumed to exert significant negative impacts on Florida ecosystems or native species populations but are not currently the focus of active management (**Table 7-3**). 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 7-3. Priority species currently managed within the South Florida ecosystem for geographic containment, ranked by taxonomic group and then alphabetically by common name.

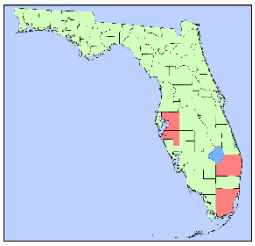
Mollusks	**Birds**
Island apple snail (*Pomacea maculata*)	Purple swamphen (*Porphyrio porphyrio*)
Insects	**Amphibians**
Laurel wilt (*Raffaelea lauricola*)	Cuban treefrog (*Osteopilus septentrionalis*)
Mexican bromeliad weevil (*Metamasius callizona*)	
Fishes	
Asian swamp eel (*Monopterus albus*)	

Asian Swamp Eel (*Monopterus albus*)

SUMMARY: Asian swamp eels (**Figure 7-38**) are versatile animals, capable of living in extremely shallow water, traveling over land when necessary, and burrowing into mud to survive periods of drought. The eels are generalist predators with a voracious appetite for invertebrates, frogs, and fishes. Wild populations in Florida originated as escapes or releases associated with aquaculture, the pet trade, or live food markets. Regional biologists are concerned that this species may become widely established, since the diverse wetland habitats of the Greater Everglades may be suitable for the species. Additionally, Asian swamp eels have a broad salinity tolerance giving concern that this species could also establish populations in estuaries (Schofield and Nico 2009).

Figure 7-38. Asian swamp eel (photo by NPS).

KEY MANAGEMENT ISSUES



Distribution: During the late 1990s, three reproducing populations of Asian swamp eel were discovered in Florida: North Miami canals, canal networks near Homestead adjacent to ENP, and in water bodies near Tampa (Fuller et al. 1999; L.G. Nico, USGS, personal communication). Unfortunately, recent monitoring efforts confirm the spread of this species into ENP from adjacent canal systems (Jeff Kline, ENP, personal communication).

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

Monitoring: There is no regional, coordinated monitoring program for Asian swamp eels, but USFWS and NPS 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 are needed.

2020 Status of Asian Swamp Eel by Management Region

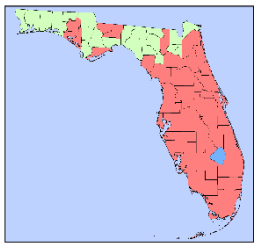
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Cuban Treefrog (*Osteopilus septentrionalis*)

SUMMARY: The Cuban treefrog (**Figure 7-39**) is native to Cuba, the Cayman Islands, and the Bahamas. It was first reported in Florida in the 1920s and was likely transported in cargo or ornamental plant shipments. Cuban treefrogs consume a variety of invertebrates and native treefrog species (Maskell et al. 2003). Native green (*Hyla cinerea*) and squirrel (*Hyla squirella*) tree frogs are less likely to be found when Cuban treefrogs are present (Waddle et al. 2010), and when Cuban treefrogs are removed from an area, the abundance of native treefrogs increases (Rice et al. 2011). Given the Cuban treefrog's wide distribution and habitat tolerances, mounting evidence of direct impacts to native species, and the lack of management programs, the status of this species is red in all management regions.

Figure 7-39. The Cuban treefrog is now widely dispersed throughout Florida (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Cuban treefrogs inhabit natural and human-modified habitats throughout most of South and Central Florida. Natural habitats invaded by this species include pine forests, hardwood hammocks, mangrove forests, and swamps. In urban and suburban settings, they are most commonly found on and around homes and buildings, and in gardens and landscape plants. They also occur in agricultural settings, orange groves, and plant nurseries (Johnson 2017).

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: SFWMD and UF continue to monitor Cuban treefrogs and other priority invasive animals in the Everglades (Everglades Invasive Reptile and Amphibian Monitoring Program [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 are needed.

2020 Status of the Cuban Treefrog by Management Region

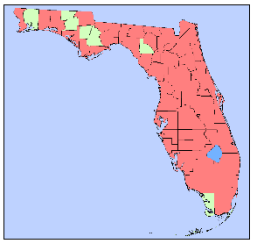
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Island Applesnail (*Pomacea maculata*)

SUMMARY: The island applesnail (**Figure 7-40**) 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, 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 avian vacuolar myelinopathy in laboratory birds fed affected snails (Dodd et al. 2016), suggesting a significant risk to the snail kite and other avifauna.

Figure 7-40. The island applesnail (photo by FWC).

KEY MANAGEMENT ISSUES



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

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

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

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

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

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

2020 Status of Island Applesnail by Management Region

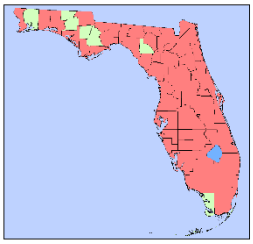
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Green Iguana (*Iguana iguana*)

SUMMARY: The green iguana (**Figure 7-41**) is a large, predominantly herbivorous lizard native to South and Central America and some Caribbean islands. The species was introduced to Florida through the exotic pet trade in the 1960s (King and Krakauer 1966) and is now firmly established in human-modified habitats throughout South Florida. Although they occupy some natural areas where they consume native vegetation and displace native animals such as burrowing owls (*Athene cunicularia*), green iguanas are primarily a threat to SFWMD infrastructure. Their high burrow densities along canals and near water control structures are likely to accelerate erosion and, in severe cases, could compromise levee integrity during high flow events. Green iguanas directly impact stakeholders as a pest species because they destroy ornamental vegetation and defaces property with feces which may contain *Salmonella* bacteria. The green iguana is increasingly becoming a priority taxon due to apparently exponential population growth from Key West to Pinellas County.

Figure 7-41. Green iguana (photo by Ed Metzger).

KEY MANAGEMENT ISSUES



Distribution: Escaped or released pet green iguanas have been reported throughout Florida, but distribution of the breeding population is limited to South Florida. The species is found along most human-modified waterways and on the periphery of natural areas. Anecdotal reports suggest that iguana abundance is increasing but may suddenly decrease after an extreme cold weather event.

Control Tools: Manual removal, firearms, and trapping are all effective control tools. Since eradication of green iguanas is not possible, SFWMD is prioritizing control efforts in areas with the greatest infrastructure damage.

Monitoring: The EIRAMP monitors green iguanas throughout the Greater Everglades. UF has conducted removal/monitoring in certain urban areas but most metropolitan monitoring is through reports from the public.

Interagency Coordination: SFWMD has funded EIRAMP monitoring and removal since 2011, as well as special projects focused on levee damage assessments. FWC contracted UF and independent contractors for iguana management and encourages the public to remove iguanas whenever possible. Green iguanas are a priority species for management across agencies.

Regulatory Tools: This species is widely sold in the exotic pet trade. In July 2020, FWC established Executive Order 20-19 which lists green iguanas as a regulated species while new rules are being finalized.

Critical Needs: Research on the economic impacts of green iguanas is needed, as is an evaluation of the effectiveness and long-term impacts of removal efforts on the population.

2020 Status of Green Iguana by Management Region

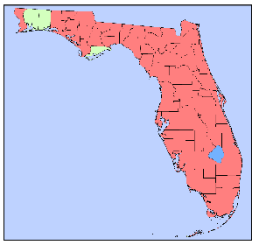
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Laurel Wilt (*Raffaelea lauricola*)

SUMMARY: Laurel wilt (**Figure 7-42**) is a lethal disease of red bay (*Persea borbonia*) and other members of the Laurel family (Lauraceae). The disease is caused by a fungus (*Raffaelea lauricola*) that is introduced into trees by the wood-boring redbay ambrosia beetle (*Xyleborus glabratus*) (FDACS 2020). This Asian beetle was introduced into the United States via infested wood used for shipping crates (Harrington et al. 2011). Once infected, susceptible trees rapidly succumb to the pathogen and die. The disease also impacts other members of the Lauraceae family (Hanula et al. 2009) including swamp bay (*P. palustris*), an important species of many Everglades plant communities.

Figure 7-42. Dying red bay trees in a mixed hardwood forest (photo by UF).

KEY MANAGEMENT ISSUES



Distribution: Laurel wilt disease is now found in every county in 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 SFWMD'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 began at the onset of the disease and workshops were conducted during 2013 to identify research and management strategies. Follow-up meetings have not occurred due to lack of feasible control strategies in natural areas.

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

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

2020 Status of Laurel Wilt by Management Region

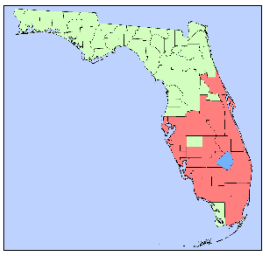
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
		not applicable				not applicable	

Mexican Bromeliad Weevil (*Metamasius callizona*)

SUMMARY: The Mexican bromeliad weevil was originally introduced to Florida via a shipment of bromeliads imported from Mexico. It was first detected in 1989 and is now found in many parts of South and Central Florida (Frank and Cave 2005). Larvae of the weevil destroy bromeliads by mining into their stems (**Figure 7-43**). This damaging insect is documented to attack 12 native bromeliad species, 10 of which are state-listed as threatened or endangered, and one of which occurs naturally only in Florida. Two of these bromeliad species were listed due to damage done to their populations by the weevil. Among the contributions of bromeliads to wildlife is that they catch rainwater, making is available to a variety of animals during dry periods.

Figure 7-43. A tillandsia plant heavily damaged by larva of the Mexican bromeliad weevil (photo by UF).

KEY MANAGEMENT ISSUES



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

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

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

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

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

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

2020 Status of Mexican Bromeliad Weevil by Management Region

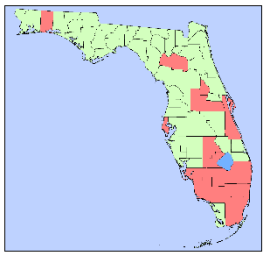
Upper Lakes	Kissimmee	Lake Okeechobee	East Coast Region	West Coast Region	Everglades	Florida Bay & Southern Estuaries	Florida Keys
							

Purple Swamphen (*Porphyrio porphyrio*)

SUMMARY: The purple swamphen (**Figure 7-44**) 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.

Figure 7-44. The purple swamphen (photo by SFWMD).

KEY MANAGEMENT ISSUES



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

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

2020 Status of Purple Swamphen by Management Region

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

FUTURE NEEDS IN MANAGEMENT AND CONTROL

The elements of a comprehensive management program for some nonindigenous plant species—legislation, coordination, planning, research, education, training, and funding—have been in place in Florida for many years. Most plants identified in this chapter as priority species are being managed on public lands by local, state, or federal agencies. This is not true for many nonindigenous invasive animal species, though significant strides have been made in this area in recent years. The threat of nonindigenous animals has become an important ecological and restoration issue for many agencies in Florida. Meaningful legislation to significantly limit new invasions, continued funding for control programs, and coordination at all levels are needed for a comprehensive nonindigenous animal management program for Florida. Recent efforts by FWC, SFWMD, NPS, and others to develop a comprehensive management plan for the Burmese python is an excellent example of the coordination required to effectively address invasive animals in the restoration footprint. 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. Continued 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 many 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 implementing 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, Springborn et al. 2011). Many states struggle with how to implement an EDRR approach because awareness and funding often lag, preventing a real rapid response. For South Florida, groups such as the cooperative invasive species management areas and the SFERTF are attempting to initiate additional EDRR efforts.

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

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

LITERATURE CITED

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

Bankovich, B., E. Boughton, R. Boughton, M.L. Avery, and S.M. Wisely. 2016. Plant community shifts caused by feral swine rooting devalue Florida rangeland. *Agriculture, Ecosystems and Environment* 220:45-54.

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

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

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

Bicudo, D.D.C., B.M. Fonseca, L.M. Bini, L.O. Crossetti, C.E.D.M. Bicudo, and T. Araújo-Jesus. 2007. Undesirable side-effects of water hyacinth control in a shallow tropical reservoir. *Freshwater Biology* 52:1120-1133.

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

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

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

Cole, J.M., J.H. Nestler, J. Ketterlin Eckles, and F.J. Mazzotti. 2017. *How to Infer Absence of Northern African Pythons from the Bird Drive Basin, Miami-Dade County, Florida*. Prepared by University of Florida, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL, and submitted to Florida Fish and Wildlife Conservation Commission, Davie, FL.

Cole, J.M., M.A. Miller, J.H. Waddle, and F.M. Mazzotti. 2019. *Removal of Argentine Black and White Tegus in Southern Miami-Dade County (Annual Report)*. Prepared by University of Florida, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL, and submitted to Florida Fish and Wildlife Conservation Commission, Davie, FL.

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

Cuda, J.P., S.F. Enloe, K.T. Gioeli, C.R. Minteer, and P. Prade. 2019. *Brazilian Peppertree Integrated Management Guide 2019*. Florida Exotic Pest Plant Council. Available online at https://bugwoodcloud.org/CDN/fleppc/publications/BrazillianPeppertree_Final_Oct19.pdf.

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

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

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

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

David, A.S., and E.C. Lake. 2020. Eriophyid mite *Floracarus perrepae* reduces climbing ability of the invasive vine *Lygodium microphyllum*. *Biological Control* 146:104271.

David, A.S., N. Sebesta, A.A. Abdel-Kader, and E.C. Lake. 2020. Colonization by Biological Control Agents on Post-Fire Regrowth of Invasive *Lygodium microphyllum* (Lygodiaceae). *Environmental Entomology* nvaa076. Available online at https://doi.org/10.1093/ee/nvaa076.

Della Torre III, C.J., L. Gettys, W.T. Haller, J.A. Ferrell, and R. Leon. 2017. Efficacy of aquatic herbicides on dwarf rotala (*Rotala rotundifolia*). *Journal of Aquatic Plant Management* 55:13-8.

DEPI 2010. *Invasive Plants and Animals Policy Framework*. Department of Environment and Primary Industries, Victoria, Australia. Available online at https://library.dbca.wa.gov.au/static/FullTextFiles/070191.pdf.

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

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

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

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

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

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

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

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

Ehler, L.E. 2006. Integrated pest management (IPM): definition, historical development and implementation, and the other IPM. *Pest Management Science* 62:787-789

Enloe, S., K. Langeland, J. Ferrell, B. Sellers, and G. MacDonald. 2018. *Integrated Management of Non-native Plants in Natural Areas of Florida*. SP 242, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Available online at edis.ifas.ufl.edu/WG209.

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

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

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

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

Falcón, W., J.D. Ackerman, W. Recart, and C.C. Daehler. 2013. Biology and impacts of Pacific island invasive species. 10. *Iguana iguana*, the green iguana (Squamata: Iguanidae). *Pacific Science* 67(2):157-186.

FDACS. 2020. *Laurel Wilt/Redbay Ambrosia Beetle Detection Update*. Florida Department of Agriculture and Consumer Services, Tallahassee, FL. Available online at http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Pests-Diseases/Laurel-Wilt-Disease.

FDACS. 2013. *Frequently Asked Questions about Metaldehyde for Controling Snails and Slugs*. Florida Department of Agriculture and Consumer Services, Tallahassee, FL. Available online at https://www.fdacs.gov/Divisions-Offices/Plant-Industry/Pests-Diseases/Giant-African-Land-Snail.

FDACS-DPI. 2020. *Giant African Land Snail*. Florida Department of Agriculture and Consumer Services – Division of Plant Industry, Tallahassee, FL. Available on-line at http://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Pests-Diseases/Giant-African-Land-Snail.

FLEPPC. 2019. *Florida Exotic Pest Plant Council's 2019 List of Invasive Plant Species*. Florida Exotic Pest Plant Council, http://www.fleppc.org/. Available online at http://bugwoodcloud.org/CDN/fleppc/plantlists/2019/2019_Plant_List_ABSOLUTE_FINAL.pdf.

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

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

FWC. 2020. *Species Profiles: Nonnatives – Veiled Chameleon*. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. Available online at http://myfwc.com/wildlifehabitats/nonnatives/reptiles/veiled-chameleon/.

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

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

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

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

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

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

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

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

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

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

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

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

Hoyer, I.J., E.M. Blosser, C. Acevedo, A.C., Thompson, L.E. Reeves, and N.D. Burkett-Cadena. 2017. Mammal decline, linked to invasive Burmese python, shifts host use of vector mosquito towards reservoir hosts of a zoonotic disease. *Biology Letters* 13:20170353.

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

Jacono, C.C., S.F. Enloe, K.A. Langeland, and J. Hutchinson. 2011. *Wright's Nutrush: An Invader of Seasonal Wetlands in Florida*. Center for Aquatic and Invasive Plants, University of Florida, Gainesville, FL. Available online at https://edis.ifas.ufl.edu/ag352.

Johnson, S. 2017. *The Cuban Treefrog (*Osteopilus septentrionalis*) in Florida.* Publication WEC 218, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Available online at edis.ifas.ufl.edu/UW259.

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

King, W., and T. Krakauer. 1966. The exotic herpetofauna of southeast Florida. *Quarterly Journal of the Florida Academy of Sciences* 29:144-154.

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

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

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

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

Lake, E.C., M.C. Smith, P.D. Pratt, A.J. Boughton, and R.W. Pemberton. 2014. Dispersal and establishment of new populations of the biological control agent *Floracarus perrepae* (Acariformes: Eriophyidae) on

Old World climbing fern, *Lygodium microphyllum* (Polypodiales: Lygodiaceae). *Florida Entomologist* 97:827-829.

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

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

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

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

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

Loewenstein, N.J., and J.H. Miller (eds.). 2007. *A Congongrass Management Guide: Confronting the Cogongrass Crisis across the South*. From the Proceedings of the Regional Congongrass Conference, November 7 and 8, 2007, Mobile, Alabama, hosted by the Alabama Cooperative Extension System, Auburn School of Forestry and Wildlife Sciences, and United States Department of Agriculture Forest Service.

MacDonald, G.E. 2009. Cogongrass (*Imperata cylindrica*) – A comprehensive review of an invasive grass. Pages 267–295 in R.K. Kohli, S. Jose, H.P. Singh, and D.R. Batish (eds.), *Invasive Plants and Forest Ecosystems*, CRC Press, Boca Raton, FL.

Martin, S. 2015. Researchers identify, name toxic cyanobacteria killing American bald eagles. *University of Georgia News*. Available online at https://news.uga.edu/identify-name-toxic-cyanobacteria-killing-american-bald-eagles-0215/.

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

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

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

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

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

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

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

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

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

Miller, M.A., J.M. Kinsella, R.W. Snow, B.G. Falk, R.N. Reed, S.M. Goetz, F.J. Mazzotti, C. Guyer, and C.M. Romagosa. 2020. Highly competent native snake hosts extend the range of an introduced parasite beyond its invasive Burmese python host. *Ecosphere* 11:p.e03153.

Miller, M.A., J.M. Kinsella, R.W. Snow, M.M. Hayes, B.G. Falk, R.N. Reed, F.J. Mazzotti, C. Guyer, and C.M. Romagosa. 2018. Parasite spillover: Indirect effects of invasive Burmese pythons. *Ecology and Evolution* 8:830-840.

Minogue P.J., J.H. Miller, and D.K. Lauer. 2012. Use of glyphosate and imazapyr for cogongrass management in southern pine forests. *Southern Journal of Applied Forestry* 36:19-2.

MIPN. 2011. *CWMA Cookbook: A Recipe for Success.* Midwest Invasive Plant Network. Available online at https://bugwoodcloud.org/mura/mipn/assets/File/CWMACookbook2011reduced.pdf.

Mississippi State University Extension Service. 2020. *Wild Pig Info*. Available online at http://www.wildpiginfo.msstate.edu/.

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

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

Nafus, M.G., F.J. Mazzotti, and R.N. Reed. 2020. Estimating detection probability for Burmese pythons with few detections and zero recaptures. *Journal of Herpetology* 54:24-30.

National Invasive Species Council. 2003. *General Guidelines for the Establishment and Evaluation of Invasive Species Early Detection and Rapid Response Systems*. Department of the Interior, Office of the Secretary, Washington, DC. Version 1, June 2003. Available online at https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1017&context=natlinvasive.

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

Netherland, M.D., K.D. Getsinger, and D.R. Stubbs. 2005. Aquatic plant management: Invasive species and chemical control. *Outlooks on Pest Management* DOI:10.1564/16jun/02

Norton, D.A. 2009. Species invasions and the limits to restoration: Learning from the New Zealand experience. *Science* 325.5940:569-571.

Orzechowski, S.C., C.M. Romagosa, and P.C. Frederick. 2019. Invasive Burmese pythons (*Python bivittatus*) are novel nest predators in wading bird colonies of the Florida Everglades. *Biological Invasions* 21:2333-2344.

Overholt, W., L. Markle, E.N. Rosskopf, V. Manrique, J.P. Albano, E. Cave, and S.T. Adkins. 2009. The interactions of tropical soda apple mosaic tobamovirus and *Gratiana boliviana* (Coleoptera:

Chrysomelidae), an introduced biological control agent of tropical soda apple (*Solanum viarum*). *Biological Control* 48:294-300.

Overholt, W.A., P. Hidayat, B. Le Ru, K. Takasu, J.A. Goolsby, A. Racelis, A. Racelis, M. Burrell, D. Amalin, W. Agum, M. Njaku, B. Pallangyo, P.E. Klein, and J.P. Cuda. 2016. Potential biological control agents for management of cogongrass (Cyperales: Poaceae) in the southeastern USA. *Florida Entomologist* 99:734-739.

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

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

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

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

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

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

Prokopy, R.J. 2003. Two decades of bottom-up, ecologically based pest management in a small commercial apple orchard in Massachusetts. *Agriculture Ecosystems and Environment* 94:299-309

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

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

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

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

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

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

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

Roda, A., G. Nachman, S. Weihman, M.Y. Cong, and F. Zimmerman. 2016. Reproductive ecology of the giant African snail in South Florida: Implications for eradication programs. *PLoS ONE* 11(11), e0165408. Available online at https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0165408.

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

Rodgers, L., and T. Pernas. 2015. Laurel wilt impacts, expansion and future in the Everglades. Conference on Laurel Wilt Disease and Natural Exosystems: Impacts, Mitigation, and the Future, Coral Springs, FL, June 16 2015. Available online at https://conference.ifas.ufl.edu/LaurelWilt/documents/1350%20Rodgers%20Leroy.pdf.

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

Rolando, C.A, B.R. Baillie, D.G. Thompson, and K.M. Little. 2017. The risks associated with glyphosate-based herbicide use in planted forests. *Forests* 8:208.

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

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

Sellers, B.A., J.A. Ferrell, G.E. MacDonald, and S.L. Flory. 2018. *Cogongrass (*Imperata cylindrica*) Biology, Ecology, and Management in Florida Grazing Lands*. Agronomy Department, University f Florida Institute for Food and Agricultural Sciences Extension, Gainesville, FL. Available online at https://edis.ifas.ufl.edu/wg202.

SFERTF. 2020. *Invasive Exotic Species Strategic Action Framework*. South Florida Ecosystem Restoration Task Force. Available online at http://www.evergladesrestoration.gov/content/ies/.

SFWMD. 2020. *Strategic Plan, 2021–2026*. South Florida Water Management District, West Palm Beach, FL. Available online at https://www.sfwmd.gov/who-we-are/sfwmd-2021-2026-strategic-plan.

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

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

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

Smith, B.J., K.M Hart, F.J. Mazzotti, M. Basille, and C.M. Romagosa. 2018. Evaluating GPS biologging technology for studying spatial ecology of large constricting snakes. *Animal Biotelemetry* 6:1.

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

Snow, R.W., K.L. Krysko, K.M. Enge, L. Oberhofer, A. Warren-Bradley, and L. Wilkins. 2007. Introduced populations of *Boa constrictor* (Boidae) and *Python molurus bivittatus* (Pythonidae) in southern Florida. Pages 416–438 in: R.W. Henderson and R. Powell (eds.), *The Biology of Boas and Pythons*, Eagle Mountain Publishing, Eagle Mountain, UT.

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

Solomon, K., and D. Thompson. 2003. Ecological risk assessment for aquatic organisms from over-water uses of glyphosate. *Journal of Toxicology and Environmental Health, Part B* 6:289-324.

Springborn, M., C.M. Romagosa, and R.P Keller. 2011. The value of nonindigenous species risk assessment in international trade. *Ecological Economics* 70:2145-2153.

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

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

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

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

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

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

UF-IFAS 2020. *Background on the Aquatic Herbicides Registered for Use in Florida*. University of Florida Institute of Food and Agricultural Sciences, Gainesville, FL. Available online at https://plants.ifas.ufl.edu/manage/control-methods/chemical-control/details-about-the-aquatic-herbicides-used-in-florida/.

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

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

USDA 2020. Plant Pest Information. Giant African Snail. United States Department of Agriculture, Washington, DC. Available online at https://www.aphis.usda.gov/aphis/resources/pests-diseases/hungry-pests/the-threat/giant-african-snail/giant-african-snail.

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

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

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

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

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

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

Willson, J.D. 2017. Indirect effects of invasive Burmese pythons on ecosystems in southern Florida. *Journal of Applied Ecology* 54:1251-1258.

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

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

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

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

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

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