

Invasive Exotic Species Strategic Action Framework

Case Studies: Authors & Contact Information

PREVENTION	
Tropical Bont Ticks & Heartwater Disease	<p>Carlos Pages, Wildlife Inspector, US Fish and Wildlife Service carlos_pages@fws.gov</p> <p>David Arronte, Pest Management Officer, US Department of Agriculture David.Arronte@aphis.usda.gov</p>
Exotic Pet Amnesty Program (EPAP)	<p>Jennifer Eckles, Nonnative Wildlife Management, Florida Fish & Wildlife Conservation Commission Jennifer.Eckles@MyFWC.com</p> <p>Liz Barraco, Public Information Coordinator, Florida Fish & Wildlife Conservation Commission Liz.Barraco@MyFWC.com</p> <p>Tylan Dean, Biological Resources Branch Chief, Everglades and Dry Tortugas National Parks, South Florida Natural Resources Center tylan_dean@nps.gov</p>
ERADICATION THROUGH EDRR	
Sacred Ibis	<p>Tony Pernas, Coordinator, National Park Service, Florida/Caribbean EPMT tony_pernas@nps.gov</p>
Gambian Pouched Rat	<p>Jennifer Eckles, Nonnative Wildlife Management, Florida Fish & Wildlife Conservation Commission Jennifer.Eckles@MyFWC.com</p> <p>Liz Barraco, Public Information Coordinator, Florida Fish & Wildlife Conservation Commission Liz.Barraco@MyFWC.com</p> <p>Tylan Dean, Biological Resources Branch Chief, Everglades and Dry Tortugas National Parks, South Florida Natural Resources Center tylan_dean@nps.gov</p>
Fruit Fly	<p>Eduardo M. Varona, State Operations Support Officer, US Department of Agriculture/Animal and Plant Health Inspection Service eduardo.varona@aphis.usda.gov</p>

CONTAINMENT	
Argentine Black & White Tegu	<p>Jennifer Eckles, Nonnative Wildlife Management, Florida Fish & Wildlife Conservation Commission Jennifer.Eckles@MyFWC.com</p> <p>Liz Barraco, Public Information Coordinator, Florida Fish & Wildlife Conservation Commission Liz.Barraco@MyFWC.com</p> <p>Tylan Dean, Biological Resources Branch Chief, Everglades and Dry Tortugas National Parks, South Florida Natural Resources Center tylan_dean@nps.gov</p>
LONG-TERM MANAGEMENT	
Burmese Python	<p>Bryan Falk, Invasive Species Science, South Florida Natural Resources Center, US Geological Survey bfalk@usgs.gov</p> <p>Michelle MacEachern, Invasive Species Science, South Florida Natural Resources Center, US Geological Survey mmceachern@usgs.gov</p>
Lionfish	Tom Jackson , Research Fisheries Biologist, Southeast Fisheries Science Center, National Oceanic and Atmospheric Administration tom.jackson@noaa.gov
Shoebuttan Ardisia	Miami-Dade County Environmentally Endangered Lands Program, Regulatory and Economic Resources Dept., Division of Environmental Resources Management eel@miamidade.gov
Ambrosia Beetle & Laurel Wilt Disease	Barry Rosen , Biologist, SE Regional Director's Office, US Geological Survey brosen@usgs.gov
Melaleuca	<p>LeRoy Rodgers, Lead Invasive Species Biologist, South Florida Water Management District lrodgers@sfwmd.gov</p> <p>Francois LaRoche, Vegetation Management, South Florida Water Management District flaroche@sfwmd.gov</p> <p>Tony Pernas, Florida/Caribbean Exotic Plant Management Team, National Park Service tony_pernas@nps.gov</p> <p>Dan Thayer, Chief, Land Resources Bureau, South Florida Water Management District dthayer@sfwmd.gov</p>

South Florida Ecosystem Restoration Task Force

7500 SW 36th Street, Davie, FL 33314

(954) 377-5971, (954) 377-5901 fax

www.EvergladesRestoration.gov

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Prevention Case Study: Tropical Bont Ticks & Heartwater Disease

Heartwater is a tick-borne disease of domesticated (cattle, sheep, goats) and wild (deer) ruminants caused by a bacteria transmitted by ticks belonging to the genus *Amblyomma*. The most important of these vectors is the tropical bont tick (*Amblyomma variegatum*) due to its widespread distribution. Heartwater is historically endemic to sub-Saharan Africa, Madagascar, and more recently several islands in the Caribbean. If heartwater is introduced to the South Florida Ecosystem, this often fatal disease could cause devastating impacts on native ruminants and the agricultural industry.

Case Presentation

In countries where heartwater is established, indigenous wild and domestic ruminants have had many years of exposure to the disease therefore gaining resistance to its effects. The concern lies in geographic areas in which heartwater was never before present.

Species that contract heartwater experience symptoms that include prolonged high fever, listlessness, diarrhea, shortness of breath, and death. Heartwater disease is often fatal with mortality rates of up to 80% in non-African cattle, sheep, and goats. The white-tail deer population has also been shown to be very susceptible to the disease in laboratory settings and can also serve as a reservoir in the wild. If the disease becomes established in the United States, there are two species of *Amblyomma* tick (*A. maculatum* and *A. cajennense*) that are native and have proven to be able to transmit the disease in laboratory settings.

The potential for heartwater gaining a foothold in South Florida Ecosystem is further increased due to the favorable climate for the vector (*Amblyomma* ticks) and the large volume of African reptiles that are imported weekly into Miami International Airport. The reptiles prone to carrying the ticks include land tortoises, monitor lizards, and snakes (pythons and old world boas). Another risk of introduction comes from the proximity of the Caribbean islands and the migration patterns of cattle egrets.

Management Actions and Outcome

In 2000, the U.S. Department of Agriculture (USDA) passed two emergency rules banning the import (9 CFR 93.701(c)) and the interstate movement (9 CFR 74.1) of three species of African land tortoises: African spurred tortoise, leopard tortoise, and Bell's hingeback tortoise. The interstate movement rule was later amended to allow these tortoises to travel between states with a health certificate endorsed by an accredited veterinarian. These emergency rulings were in response to the discovery that there was evi-

A Deadly Hitchhiker

Heartwater is an often fatal tick-borne disease historically endemic to sub-Saharan Africa, Madagascar, and more recently several islands in the Caribbean. Mortality rates can be up to 80% in non-African cattle, sheep, and goats.

The potential for Heartwater gaining a foothold in south Florida is increased due to the favorable climate for the ticks and the large volume of African reptiles, often carrying ticks, imported into the region's ports.



Photo: USDA.

dence of the causative agent for heartwater disease in a tick collected from a leopard tortoise and the interstate movement of leopard tortoises from infested premises to noninfested premises. The African spurred and Bell's hingeback tortoises were included in these rulings due to the prevalence of *Amblyomma* ticks found on them upon importation.

The USDA received appropriated funds to create two positions that would be responsible for inspecting reptile shipments imported into the U.S. In 2003, USDA's Animal and Plant Health Inspection Service (APHIS) Veterinary Services (VS) created the Pest Management Officer (PMO) position. There is currently only one PMO in the country (stationed at Miami International Airport). The PMO relies on the U.S. Fish and Wildlife Service (USFWS) for notification and inspections of reptile shipments imported into the airport (with an emphasis on inspections for shipments of African origin).

This officer collaborates with USFWS Wildlife inspectors on reptile shipment inspections. Upon discovery of a tick infestation in a reptile shipment, the USDA PMO places the importer's facility under USDA Quarantine and notifies the Florida Department of Agricultural and Consumer Services (FDACS) of the infestation so that the quarantine can be enforced until all ticks have been identified. If the identification of the tick comes back as a heartwater carrier species, FDACS directs the importer to treat the reptiles for ectoparasites and follows up with site inspections.

To date there have been two recent importations of reptiles from Africa (Ghana) that have had tropical bont ticks identified in the shipment. Both times the same reptile importer's facility was quarantined and the animals were treated for ectoparasites. In both cases the wildlife infested were savannah monitor lizards. In both situations the quarantines were lifted after confirmation by FDACS that the facility was tick free.



The USDA APHIS VS has had several workshops/meetings with the reptile industry in light of the two infested shipments. The reptile industry has expressed concern over possible future bans on imports of specific species and has taken a constructive approach by becoming proactive. Several reptile importers have traveled to Africa and have put pressure on their suppliers to treat their stock for ectoparasites and improve their animal husbandry practices to prevent tick infestations in their facilities.

Key Recommendations

- Hire more Pest Management Officers.
- Amend current regulations to add inspection authority for USDA Pest Management Officers. Currently they can only inspect reptile shipment when USFWS is present.
- Continue to engage and include the reptile industry. They can exert influence overseas to correct the issue before it arrives in the U.S.
- Continue to monitor cattle egret populations and expand efforts by conducting random trapping and sampling of ectoparasites.

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Prevention Case Study: Exotic Pet Amnesty Program

The Exotic Pet Amnesty Program is an innovative effort by the Florida Fish and Wildlife Conservation Commission (FWC) that provides exotic pet owners with an opportunity to surrender or re-home their exotic pet. The goals of the Exotic Pet Amnesty Program are to reduce the number of exotic pets released in Florida and provide amnesty for animals that require permits, including conditional species such as the Burmese python. The program also serves to provide education and outreach regarding responsible pet ownership and invasive exotic species in Florida.

Case Presentation

The Exotic Pet Amnesty Program was started in 2006 as periodic one-day-only events across the state of Florida where people could come and surrender their exotic animals, no questions asked. Surrendered animals were then looked over by volunteer veterinarians and all healthy animals were held for adoptions later that same day. These events were linked with multiple exhibitors providing people with the opportunity to learn more about invasive exotic species and animal care. In later years, events were combined with existing festivals and outreach events. Avoiding the responsibility of long-term housing of the animals allows the Exotic Pet Amnesty Program to be successful with a low budget. This program also relies heavily on volunteers from outside organizations.

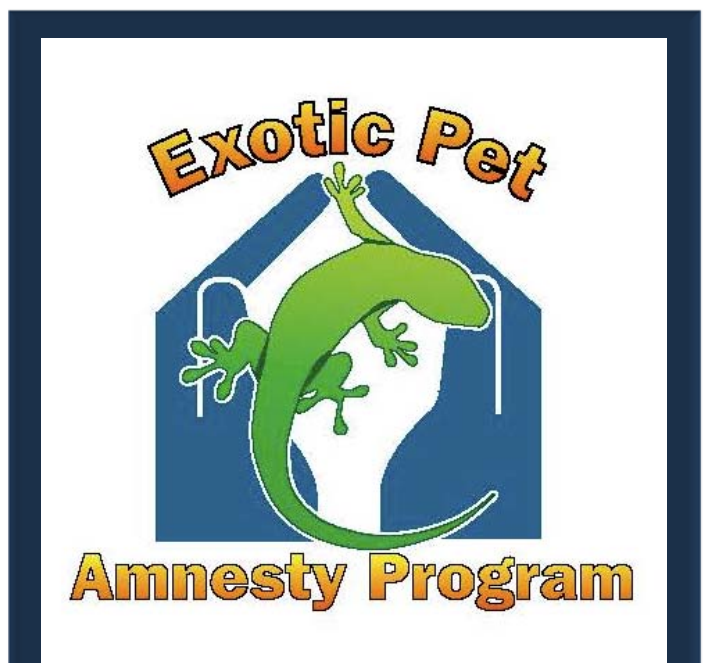
The occurrence of Exotic Pet Amnesty Program events has been increased over the last few years with 15 of the 25 total events taking place in the last 3 years. Additionally, the distribution of the events has been expanded with the first Florida panhandle event in 2013. With the increased number and location of Exotic Pet Amnesty Program events, the number of animals placed into new homes through the program has also increased. Since 2006, 2,340 animals have been placed into new homes through the Exotic Pet Amnesty Program. Over 1,000 of those animals were placed within the last 3 years.

Also, the increase in event number and location has allowed the Exotic Pet Amnesty Program to act as a

catalyst to inform the public about the dangers of releasing nonnative animals into the wild. The ability to reach the public through this program has been widely successful.

Management Actions and Outcomes

The Exotic Pet Amnesty Program has evolved and improved over the program's history. For instance, at early events, animals were adopted by people vetted that same day. As the program has grown, the adopter application process has become more sophisticated. Now a database is kept of approved Exotic Pet Amnesty Program adopters across the state of Florida. This database allows the FWC to search specific counties for adopters interested in specific categories of animals and helps to make adoptions outside of amnesty events possible. Having online applications and time to vet adopters before events allows the FWC to verify an applicant's permits and check for any wildlife violations prior to approving them as an adopter with the program.



For more information:

<http://myfwc.com/wildlifehabitats/nonnatives/amnesty-program/> OR
888-lve-Got1 (888-483-4681)

Interested in Adopting an Animal?

- Fill out and submit an application at www.MyFWC.com/Nonnatives.
- Complete an “adopter information form” along with the “animal information forms” for the animals you are interested in adopting.
- Applicants who are approved as adopters will receive a letter of acceptance from the FWC and will be informed of upcoming Exotic Pet Amnesty Days in their area.
- All adopters must apply and be approved before adopting an animal at an Exotic Pet Amnesty Day event.

Additionally, in October of 2010, a grant from the National Park Service (NPS) increased dedicated funding to the Exotic Pet Amnesty Program which facilitated the introduction or improvement of key factors including the hiring of a new staff member and the purchase of an amnesty specific trailer.

Using funding from the NPS grant, a part-time (20 hours per week) operator was hired to answer the Exotic Species Reporting Hotline (1-888-Ive-Got1). As part of the program, the operator would also facilitate amnesty adoptions through the hotline as they were received. With the addition of the hotline, and staffing to monitor the hotline, the number of animals placed through the program increased dramatically. Since the hotline has been in operation as an Exotic Pet Amnesty Program tool, 687 animals have been placed into new homes through the hotline. It should be noted that during this same time period, 986 animals were placed into new homes through Exotic Pet Amnesty Program events. Thus, the effectiveness of the program more than doubled with the addition of the hotline and staff to facilitate adoptions through it.

Using grant funding, a trailer was purchased to comfortably house surrendered animals safely and securely during an event. This trailer was created specifically for the Exotic Pet Amnesty Program making it very useful for the program’s unique needs. The trailer contains multiple ‘snake racks’ along one wall which can

be used to house animals in a low stress and comfortable environment throughout an event. On the opposite wall the trailer has shelving which allows space for larger cages to be stored during the event. The rear door of the trailer becomes a ramp so people can enter through the rear and exit through the front side door, improving the flow of an event during the adoption period. The trailer also has aero roof vents and a quiet, induction generator which allows the vehicle to be cooled or heated as needed to keep the animals comfortable during an event. The trailer is mobile and can be transported across the state to be used at all Exotic Pet Amnesty Day events. Additionally, the size of the trailer makes it a usable billboard to promote the program while it is being transported from one event to another.

Key Recommendations/Issues

The Exotic Pet Amnesty Program has been successful as a tool for preventing the release of exotic pets in Florida by facilitating the adoption of 2,340 animals since 2006. Additionally, 86 conditional constrictors were placed into permitted facilities through this program, including 79 Burmese pythons. As with all programs and projects, improvement would be possible particularly with the addition of dedicated staff and increased outreach campaigns to attract potential adopters and expand to areas that haven’t yet hosted an Exotic Pet Amnesty Day event.

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EDRR Case Study: The Sacred Ibis Project

Sacred ibis are colonial wading birds indigenous to African wetland regions. The bird is classified as an invasive species in Europe where it escaped from numerous zoological parks (Clergeau and Yésou 2006). The presence of sacred ibis in south Florida may threaten the integrity of the Everglades ecosystem by directly competing with native wading bird populations. Their opportunistic feeding habits, ability to colonize numerous habitats, and tendency to compete with and prey upon native species in Europe illustrate the potential of sacred ibis to establish viable invasive populations in other regions of the world, including south Florida (Herring & Gawlik 2008).

Sacred ibis escaped captivity following the devastating effects of Hurricane Andrew in 1992. In the following years, numerous sightings were reported in the region. Recognizing the risks of this species' expansion in Florida and the still limited distribution, members of the Everglades Cooperative Invasive Species Management Area (ECISMA) developed a sacred ibis Early Detection and Rapid Response (EDRR) plan to incorporate monitoring networks, coordinated invasive species control programs, trained rapid responders, and prevention and education plans. Staffing and funding to implement the plan were provided by the Everglades Foundation, the U.S. Department of Agriculture Wildlife Services (USDA-WS), and Zoo Miami.

An EDRR Success Story

Sacred ibis are wading birds indigenous to African wetlands that would directly compete with native wading birds if they became established in south Florida. Zoo Miami and the USDA Wildlife Services led a successful interagency Early Detection and Rapid Response (EDRR) program to eradicate 75 sacred ibis from Miami-Dade and Palm Beach counties.

Case Presentation

Staff at Zoo Miami (formerly Miami Metrozoo) began live-trapping birds at the Zoo and the USDA-WS began lethal take on Zoo grounds and in the surrounding area in 2008. A variety of live trapping techniques were strategically employed to maximize sacred ibis catch rates and minimize native bycatch. The USDA-WS released live-captured sacred ibis equipped with GPS transmitters (see photo below left) to determine if the birds would locate and join other populations of sacred ibis (see photo below right). This detection strategy, combined with outreach and reporting initiatives, led to the detection and eradication of sacred



Above left: A transmitter is secured to a sacred ibis using a backpack style harness. Above right: Two sacred ibis fitted with wing tags and satellite transmitters. Photos: Zoo Miami.



ibis at landfills in both Palm Beach and Miami-Dade counties. Satellite tracking of the released sacred ibis helped determine that the population of ibis living at the zoo never left the immediate area. They followed a general daily routine, moving from feeding areas to loafing and roosting areas located around the zoo (see photo above). While the transmittered birds being used for tracking purposes continued to utilize the zoo as their main base, they were visiting wetland areas located in close proximity to the zoo, including a mixed-species rookery site at the Calusa Country Club about 7 miles north of the zoo (see photo on page 3).

All birds trapped by Zoo Miami were surgically pinned and placed with other accredited facilities with signed agreements of their invasive potential and need for containment.

The USDA-WS continued to monitor bird networks in the region for sacred ibis sightings following the initial detection and removal project phase. Outreach efforts targeted natural resource management personnel conducting field work who could possibly observe and report sacred ibis. In addition, partnerships were cre-

ated with several birding groups and individuals to increase awareness and establish an observational network for sacred ibis. As a result, a variety of public and private cooperators assisted with detection efforts and reported a number of sightings in the region.

The EDRR framework used in the Sacred Ibis Project yielded positive results in terms of identifying a newly introduced invasive species, developing a thorough and efficient detection system, implementing control/eradication measures, effectively coordinating action among multiple government agencies, achieving short-term eradication goals, and promoting scientific research and public education.

Management Outcomes and Actions

The Sacred Ibis Project prevented sacred ibis range expansions and successfully controlled populations while they remained localized and extirpation was still feasible. Threats posed by the sacred ibis to native flora and fauna, particularly to endangered wetland species, have declined. Considerable progress was made in determining habitat preference, geo-



graphic distribution, and daily routines of the sacred ibis. Overall, 75 sacred ibis were located and removed from the wild by USDA-WS and Zoo Miami staff during the project.

The rapid response paradigm is best illustrated by the two most recent sacred ibis removals. On May 8th, 2011, the Florida Fish and Wildlife Conservation Commission alerted the USDA-WS to the presence of an adult sacred ibis at the Palm Beach County Landfill. The USDA-WS dispatched personnel to the site who successfully removed a single adult sacred ibis from that location. On November 2nd, 2011, a single adult sacred ibis was sighted at the National Park Service building on Old Cutler Road, Palmetto Bay, Florida. As before, this information was relayed to USDA-WS biologists, and the bird was removed that day.

Much of the success of the program relied on multiple agencies and landowners granting access to property

and voluntarily monitoring and reporting sightings. For successful lethal take, the birds had to be located in open and accessible locations where firearms could be safely discharged. A large factor in the removal of the Zoo Miami population was due to the birds having been habituated to the close proximity of people, aggressive scavenging behavior at feeding areas for the collection, and existing infrastructure that aided capture. Satellite tracking allowed for the discovery of roosting locations, daily migration patterns, and a rookery site for continued monitoring and evaluation of removal efforts.

Challenges included misidentification of similar looking endemic juvenile white ibis and wood storks. Adaptation was exhibited by individual birds that developed aversions to roost locations and trap areas, types, and techniques if a capture was unsuccessful or if a lethal take had occurred in the proximity.

Key Recommendations/Issues

- Interagency communication and cooperation is essential for efficient, timely response to control invasive exotic species.
- Availability of trained competent personnel greatly increases the chance for success.
- Telemetry is a useful tool for helping to define the scope of the problem, at least for birds.
- There is abundant habitat for a mobile species like the sacred ibis in south Florida. Remnant individuals likely remain in the wild and vigilant monitoring is needed to avoid the resurgence of this species in Florida.

Literature Cited

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EDRR Case Study: Gambian Pouched Rat

Gambian pouched rats (GPR) are large rodents native to Africa, weighing an average of 3 pounds and measuring 20-35 inches from the head to the tip of the tail. GPR primarily eat fruit and grains, but they have been known to eat insects, crabs, and snails. GPR are a vector of a number of serious diseases, including monkey pox; however, several GPR captured in Florida have been tested and all were negative for this zoonotic disease. Due to the somewhat isolated nature of the infestation, it was determined that eradication is possible and remains the ultimate goal.

Case Presentation

GPR were bred in captivity by an individual on Grassy Key, north of Marathon, in the Florida Keys. Between 1999 and 2001, eight rats apparently escaped and subsequently established a reproducing population, which was reported to the U.S. Fish and Wildlife Service (USFWS) in 2004. The State of Florida is concerned about potential impacts to agriculture should they spread to mainland south Florida, as well as potential interactions with native Florida rodents in the Keys and elsewhere.

The GPR infestation is currently centered around the escape location on a key that is mixed residential, hardwood hammock, and salt marsh. The population had also spread west to Crawl Key where eradication efforts seem to have been successful. The majority of management activities take place on private properties and require coordination between multiple state and federal agencies and the city of Marathon. A number of innovative control measures have been employed and success was even declared in 2010 after trapping had produced no rats for one year. Unfortunately, this declaration was premature and in 2011, the Florida Fish and Wildlife Conservation Commission (FWC) received a credible rat report by a reliable citizen in the area and subsequent trapping confirmed a hold-out population remained.

The Wildlife Impact Management Section (WIM) of FWC continues to lead efforts to eradicate this species by conducting monitoring and trapping activities. In

2015, WIM hired staff to carry out monitoring and trapping on Grassy Key monthly through June. There were no GPRs trapped or observed in cameras during these efforts which were made possible by a Florida Fish and Wildlife Conserve Wildlife Tag Grant. Although funding from the grant ends in July 2015, WIM will continue to monitor for GPRs using camera traps and by screening reports from the public via the Exotic Species Hotline and the IveGot1.org website. The project will be considered a success after five years of monitoring have passed with no credible sightings or captures.

Management Actions and Outcome

The USFWS, FWC, and a student at Texas A&M began trapping efforts soon after GPRs were reported to the USFWS in 2004. In 2005, FWC held a multi-agency meeting to create an eradication plan. The pilot eradication project began on Crawl Key in June 2006 with USFWS and FWC funding the U.S. Department of Agri-

Gambian Pouched Rats

Gambian pouched rats are large rodents native to Africa that are a vector for serious diseases, including monkey pox. Efforts to eradicate this species from the Florida Keys are being led by the Florida Fish and Wildlife Conservation Commission (FWC).



Photo: FWC.

culture Wildlife Services to conduct trapping and toxic baiting for GPRs. Rats were also tracked using radio telemetry to determine regular movement patterns. A large-scale eradication effort began in January 2007 consisting of the deployment of 1,000 toxic bait stations, live trapping, and further testing of toxicants. Remote cameras were used for monitoring throughout the project. Initial efforts attempted to saturate the area with traps and bait stations and as the project continued, efforts became more targeted based on results of monitoring.

During the project, different baits were tested and attempts were made to get access to more properties throughout the neighborhood. Adjustments were made to the bait station designs and toxicants to increase effectiveness and limit effects on non-targets. As this project took place both within and in close proximity to private homes, the concerns of residents were a constant consideration. Residents were especially concerned about impacting non-targets, including raccoons and feral cats. Live trapping was used more around private homes to address this concern. In general, live trapping GPRs is not difficult and does not require sophisticated baits. However, there were some individuals who refused access to their property and that may have contributed to the lack of complete success. Radio telemetry confirmed that rats were frequently traveling to these “no access” properties. More mature rats also seemed to become trap-shy.

There was an attempt to create a “Judas rat” with a mature female that was trapped, sterilized, and released with an implanted transmitter. It was hoped that she would attract breeding males but this did not seem to be the case and it was discovered that live trapping around the coral island was difficult due to the false signals given when the signal was bouncing off of the hard coral formations.

Overall this project demonstrated excellent inter-agency coordination and cooperation with local government and private residents. A declaration of success in 2010 was premature but there have been no

Have you Seen a Gambian Pouched Rat?



Gambian pouched rats are gray to brown in color with a paler belly and feet that are off-white. Most of the tail is dark gray while the final third is off-white. This rate can be 20-35 inches in length and weighs 3 lbs. on average. These rats have been sighted on Grassy Key.

REPORT SIGHTINGS:

1-888-IVE-GOT1

ExoticReports@MyFWC.com

confirmed sightings since 2013. Over the course of the project, funds have been made available through grants, operational budgets, and in-kind services both from agencies directly involved with management activities and agencies with a vested interest in the success of the project. GPRs have since been listed as prohibited by the FWC making personal possession illegal in Florida, although they are still allowed as pets in much of the U.S.

Key Recommendations/Issues

As with other rapid response projects, early action, significant efforts and funding, and a directed plan were needed to assess and target eradication efforts. Follow up assessment was important even after the initial findings were concluded. In this case, agencies were able to find available monies to do this work, aided by the fact that a large agricultural interest was involved. However, funding has not been consistent and this case illustrates the need for a dedicated source of funding to be available for rapid response efforts and follow-up.

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EDRR Case Study: Tephritid Fruit Flies

Since 1997, the Tephritidae species of fruit flies has been detected in Florida 22 times. Early detection and rapid response (EDRR) activities conducted jointly by the United States Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) and the Florida Department of Agriculture and Consumer Services (FDACS) have successfully eradicated each introduction.

Tephritid Fruit Flies: A Severe Threat to U.S. Agriculture

Fruit flies in the family Tephritidae are considered the most destructive pests of fruits and vegetables, attacking more than 400 different plants. The genera, *Anastrepha*, *Bactrocera*, and *Ceratitis*, pose the greatest risk to U.S. agriculture and are the focus of APHIS' Exotic Fruit Fly Strategic Plan and Fruit Fly Exclusion and Detection cooperative programs. The permanent establishment of these pests in the U.S. could cause significant economic losses as a result of the destruction and spoilage of a number of commodities, the costs associated with implementing control measures, and loss of market share due to restrictions on domestic and export shipment of affected commodities. In addition, the establishment of exotic fruit flies in Florida could indirectly impact natural systems as a result of an increased need for treatments to control established infestations in agricultural and/or urban areas near wild lands and/or tribal lands. APHIS employs a number of regulatory and non-regulatory actions to prevent the entry of fruit fly species and to address outbreaks when outbreaks occur.

Recent History of Detections and Emergency Response in Florida

APHIS' emergency response to fruit fly detections involves two actions: delimitation and eradication. Delimitation includes early detection of a new population and ongoing monitoring to ensure permanent establishment does not occur. Eradication includes measures to control or eliminate the population. A number of factors trigger eradication activities, including the total number of adult fruit flies detected during delimitation, the number or type of life stages detected, or the presence of a mated female fruit fly. Since 1997, there have been multiple detections in Florida of the Mediterranean Fruit Fly, Oriental Fruit Fly, Guava Fruit Fly, Peach Fruit Fly, and Mexican Fruit Fly. In each case, APHIS' emergency response led to delimitation and/or eradication.

Actions to Prevent the Introduction or Establishment of Fruit Flies in Florida

The ever-growing volume of international trade and travel places constant pressure on the safeguarding system designed to prevent the introduction of fruit flies in Florida. The APHIS/FDACS Cooperative Fruit Fly Exclusion and Detection Program (FFED) addresses the potential risk of fruit fly introductions associated with global commerce and travel through continual pest monitoring and sterile insect release. With approximately 56,000 traps distributed in 43 Florida counties covering more than 8,354 square miles, the FFED continuously monitors the environment to detect new populations.

Under the Medfly Sterile Insect Technique Preventative Release Program, FFED releases sterile Medflies by air over

A Danger to Agriculture

Tephritid fruit flies are considered the most destructive pest of fruits and vegetables, attacking more than 400 different plants. Since 1997, the Tephritidae species of fruit flies has been detected in Florida 22 times. Early detection and rapid response activities conducted jointly by the United States Department of Agriculture's Animal and Plant Health Inspection Service and the Florida Department of Agriculture and Consumer Services have successfully eradicated each introduction.



Photo: USDA-ARS.

the highest-risk urban areas of the state (approximately 633 square miles). The release rate is 125,000 flies per square mile per week. These sterile male flies compete with wild male flies from a potential exotic incursion to cause any new wild population to die out. In addition, new traps, lures, and protocols are always in development to increase efficiencies in an ever increasing risk situation compounded by globalization, liberalized trade, and increase passenger traffic.

A World-Class Safeguarding System

The U.S. has developed a safeguarding system that uses a number of exclusion and response strategies to mitigate the plant health risks that come with global trade and international travel. It is a dynamic, data-driven operation that considers and addresses risk not only at ports of entry, but at every point in the risk spectrum.

Offshore strategies:

- Monitor pest data from around the world to uncover potential new pathways
- Harmonize quarantines, exclusion strategies, and other safeguarding initiatives with countries in the Greater Caribbean Region to guard against the introduction of high-risk pests
- Maintain a line of defense along Mexico's southern border to prevent the northern movement of fruit flies from this region through the production and release of sterile flies and the use of bait sprays
- Inspect and treat commodities in their country of origin to mitigate pest risks prior to export to the U.S.
- Assess the trapping protocols of countries that export commodities known to host fruit flies

Strategies at the border:

- Conduct pest and commodity risk assessments to determine the level of risk associated with specific commodities and measures that can be used to mitigate the risk
- Assess and analyze risks through our Port Risk Committees (which include representatives from USDA APHIS, U.S. Department of Homeland Security's Customs and Border Protection, and FDACS) to focus port-of-entry inspection activities to target what is truly risky in an ever-changing global trade environment
- Develop import policies and procedures to ensure that adequate safeguards, such as inspections or treatments, are applied to prevent the introduction of plant pests and diseases
- Inspect live plants and propagative plant material and direct the inspections of commercial vessels, trucks, aircraft, railcars, cargo, and international passenger

baggage (conducted by the U.S. Department of Homeland Security's Customs and Border Protection) to intercept pests before they can enter the U.S.

- Develop, conduct, and monitor treatments to eliminate viable pests from agricultural goods and commodities entering the U.S.
- Provide high-quality and time-sensitive identifications of fruit fly specimens found during port-of-entry inspections
- Develop molecular diagnostics for fruit fly specimens to better identify the source of incursions so we can work with trading partners to minimize risk
- Develop methods with key partners to expand the tools available to us to mitigate risk from fruit fly pests

Strategies inside the U.S.:

- Conduct joint USDA and FDACS trapping programs in accordance with the USDA APHIS National Fruit Fly Strategic Plan
- Release sterile insects to prevent incursions from becoming established
- Collect and manage trapping data to focus trapping on the highest risk areas and manage delimitation and eradication activities in an efficient manner
- Provide high-quality and time-sensitive identifications of fruit fly specimens found during delimitation programs
- Conduct aggressive and coordinated emergency and eradication responses based on the USDA Action Plans and New Pest Response Guidelines when a wild fruit fly is detected
- Coordinate public communications between FDACS Public Information and USDA Public Affairs staffs to ensure public awareness and cooperation during responses to fruit fly incursions

In fiscal year 2013, the cost to operate the Fruit Fly Exclusion and Detection program and the Sterile Insect Technique Preventative Release Program was \$9.5 million. From an internal APHIS report, each dollar APHIS invested in these programs yielded approximately \$120 in cost benefits to the U.S. citrus industry alone. This cost benefit ratio increases significantly when you consider the fact that fruit flies affect a wide variety of fruits and vegetables. Benefits of an aggressive and proactive fruit fly exclusion and eradication program include sustainable crop yields, continued access to domestic and foreign markets, and lower production costs for producers who don't have to implement additional pest management measures. On a larger scale, society benefits from the abundant availability of a wide array of fruits and vegetables at a reasonable cost.

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South Florida Ecosystem Restoration Task Force

Invasive Exotic Species Strategic Action Framework

Containment Case Study: Argentine Black and White Tegu

The Argentine black and white tegu is a large, invasive lizard native to South America that has established in southern Miami-Dade County. In their native range, tegus are habitat generalists and eat a wide variety of fruits, insects, small vertebrates, and specialize in eating the eggs of ground-nesting animals. Their reproductive capability (30 - 40 eggs per year), lack of potential predators, and adaptability to a wide variety of food sources, habitats, and environmental conditions make them a threat to a Florida's wildlife and environment. From their current location, tegus are dispersing west towards the sensitive habitats in Everglades National Park (ENP), south toward the Florida Keys, and east towards Biscayne National Park and American crocodile nesting habitat at Florida Power and Light's Turkey Point power plant. Since they are already widely established, the goal is to contain them to their current range and decrease the population.

Case Presentation

A breeding population of tegus was discovered in Florida City, a town just west of ENP, in 2008 by members of the Everglades Cooperative Invasive Species Management Area (ECISMA). The following year, more investigation and limited trapping efforts confirmed multiple size classes present in the area, indicating that the tegus were breeding. There were no dedicated staff from any agency to trap these animals at the time. The National Park Service (NPS) and Florida Fish and Wildlife Conservation Commission (FWC) were able to hire one trapper and utilize members of their fire crew to develop trapping methods and track five telemetered animals, including one female that led to the discovery of the first tegu nest in Florida. The stomach contents of 30 animals were analyzed to determine diet.

During subsequent years, volunteer trapping efforts by more ECISMA partners enabled the continued assessment of tegus, but did not appear to limit the expansion of the tegu population. There was no dedicated funding for trapping efforts until 2011. Private trappers had also become involved with trapping te-

gus, and many of their captured tegus are re-sold into the pet trade. The exact number of tegus removed by private trappers and their ultimate fate is not available; however, the general number given by at least one trapper is that hundreds of individuals have been taken out of the wild and placed back into the pet trade.

From the first reports of tegus in 2008 in Florida City through 2013, the tegu population has continued to grow and expand its range, despite trapping efforts. Currently, tegus occur across over 100 square miles, including many natural areas and conservation lands. Despite being readily trappable, there is a consensus that eradication now appears unlikely, and containment is the appropriate objective. No permit is required to possess tegus in Florida.

The Tegu Curtain

The Argentine black and white tegu is a large, invasive lizard native to South America that has become established in southern Miami-Dade County. The goal is to protect sensitive habitats, including nearby national parks and crocodile nesting areas, by containing them within their current range and decreasing the population.



Photo: Dennis Giardina.

Management Actions and Outcome

After their discovery, ECISMA members and partners quickly put together whatever resources they could to begin trapping and removing tegus. Members of the Miami-Dade County Venom One Team began responding to calls in residential areas and provided traps to neighborhood associations that citizens could use.

Different traps and baits were tested, and telemetry was conducted to learn about dispersal patterns and behavior. Stomach contents were analyzed to determine what native species might be at risk. These initial efforts led to relatively rapid determination of effective trapping methods and confirmation that the tegu may represent a significant threat to wildlife. These studies were conducted within 1-2 years of discovery.

In 2012, a brochure was created to inform citizens living in areas with tegus on how to prevent them from taking up residence on their property and how to report sightings. FWC and Venom One have given several community presentations to inform the public and conducted media outreach to improve awareness. The IVE-GOT1 hotline and Early Detection & Distribution Mapping System (www.EDDMapS.org) have also been advertised to improve tegu reporting. These outreach efforts have increased public awareness and reporting of tegus, leading to broader documentation. However, they have also indicated the need for greater capacity to respond to the public and to tegus in more areas.

After initial trapping efforts, ECISMA partners expanded on previous efforts by increasing trapping locations and season, more animals were tracked using radio telemetry, and new methods for monitoring were added including camera trapping and driving surveys. The University of Florida, Zoo Miami, South Florida Water Management District, and the U.S. Geological Survey began providing staff to trap and track tegus starting in 2011, with FWC providing staff specifically to support tegu removal in 2012. In 2013, the idea of creating a "Tegu Curtain" was proposed, which includes utilizing camera traps and driving surveys to monitor the perimeter of the population and conduct intensive

trapping in core areas that would expand to correspond with seasonal dispersal. The U.S. Department of the Interior provided support for this effort and NPS provided additional staff and volunteers in the field. This containment effort, coordinated among many partners was expanded in 2014. Although each participating organization is contributing available resources, it still lacks dedicated funding.

The dedication and persistence of ECISMA members and cooperators has led to increased efforts and larger numbers of tegus removed every year. The tegu population may well have been larger and more widespread without these efforts. The knowledge base about the species and control options and methods has also been significantly improved.

Key Recommendations

- Outreach to the public promoting early reporting can lead to more discoveries of newly established populations, possibly in time to eradicate them.
- Dedicated resources are needed to successfully respond, and resources must be consistent with the scale of the threat. Potentially significant threats warrant application of all available resources.
- A pre-existing coordination framework among agencies, researchers, and partners would be helpful to expedite response and increase effectiveness.
- When new species are identified, it is possible to prioritize removal/eradication while still collecting valuable research information.
- If eradication is not possible, an assessment should be conducted to determine possible impacts and inform next steps and develop strategies to protect key resources.
- Time is of the essence – developing methods and initial assessments should be quick, because incipient populations may grow rapidly, leading to larger costs and effort.
- Volunteer efforts are valuable but dedicated staff/work would likely be more effective.

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South Florida Ecosystem Restoration Task Force

Invasive Exotic Species Strategic Action Framework

Long-term Management Case Study: Burmese Pythons

Burmese pythons are giant constricting snakes, native to Asia, that have an established invasive population in southern Florida. Adult pythons are large predators with little risk of predation themselves, and the Florida population has the potential to negatively impact a multitude of native wildlife species. Management of the invasive python population has proven very difficult, and the population continues to grow despite an increasingly coordinated effort of several governmental agencies and academic institutions. Burmese pythons are an unfortunate yet apt example of how eradication of established invasive exotic species is costly and problematic.

Case Presentation

Founded by animals from the pet trade, a population of Burmese pythons colonized Everglades National Park probably 20-30 years ago. Since then, the snakes have spread well beyond the park to become established in at least three counties. We do not yet have a population-size estimate, but approximately 1,400 pythons were removed from the park between 2000 and 2014, and more pythons were removed from the park in 2014 than in any previous year.

Burmese pythons have a remarkable potential for reproduction and growth. Females lay a single clutch of typically 30-50 eggs in the spring, and clutch sizes of over 80 eggs have been recorded in Florida. Like many other python species, the female tends to her nest, protecting her eggs from predation and shivering to keep them warm. The self-sufficient young are roughly 50-80cm in length upon emerging, and exhibit growth rates of up to 20cm/month. Most pythons collected in Florida are reproductive adults and 3.0-3.25m in length, with few individuals exceeding 5m.

The size and eating habits of these giant constrictors lead to a potentially giant ecological impact. The pythons are feeding generalists, capable of eating many appropriately sized terrestrial vertebrate species, with larger snakes eating larger prey. Documented prey items include over 40 species of mammals and birds, as well as American alligators. Some of these

prey items (e.g., wood storks, Key Largo wood rat), are at risk of extinction because of their already low population sizes or limited geographic distribution, and it is unclear how these populations will respond to increased predation pressure. Evidence suggests that many prey populations (e.g., marsh rabbits, raccoons) have declined dramatically since the python's introduction. Research into the effect of the pythons on their prey populations, and the effect of competition on other predator populations, is ongoing.

An Infamous Invader

Perhaps south Florida's most recognized invasive exotic species, Burmese pythons have become established in at least three counties. The pythons are large predators, dining on a wide variety of native mammals and birds—and even alligators—with little risk of predation themselves. Efforts are now focused on long-term management in order to control the geographic spread and density of these snakes. Lessons learned may help prevent the establishment of other giant constrictors in south Florida.



Photo: Bryan Falk, Everglades National Park.

Management Actions and Outcome

Currently, there is no evidence to suggest that the Burmese python population in Florida can be eradicated by management activities. Each potentially promising management tool has limitations, and primary among these is a high financial investment into research and/or high maintenance costs. Nonetheless, a suite of well-researched management tools may help control the geographic spread and density of these snakes.

A major hurdle for Burmese python research and management is the extreme difficulty of finding pythons. The probability that a human searcher will detect a python present in the area is 1% or less (i.e., searchers pass by at least 99% of the pythons present in the area they are searching). Furthermore, visual searching is labor-intensive (i.e., costly) and constrained to human-accessible terrain. Some approaches may improve detection probabilities, but each of these has limitations. For example, dogs improve detection probabilities, but training and maintenance is expensive and time-consuming. Moreover, detector dogs may show aversion to pythons after a negative interaction (i.e., an attempted or successful snake bite), which also increases costs if a trained dog can no longer be used to search for pythons. Likewise, employing Forward Looking InfraRed (i.e., heat vision) is of limited benefit because the snakes generally have a similar thermal profile as their surrounding environments. Overall, the factors that contribute to detection probability, and the ways in which it may be improved, are poorly understood and research in this area is ongoing.

Approaches to locate snakes other than visualization have also been employed, but again with limited success. The use of “Judas” snakes (where a captured individual is fitted with a radio transmitter, released, and tracked in order to find other pythons) is an example. Judas-snake activities generally recover only a few additional individuals at a substantially increased cost in both labor and equipment.

Trapping is another common management tool and has been successfully used in the control of other invasive exotic species. Trapping Burmese pythons presents several challenges, however, and principal among these is that pythons are ambush predators (i.e., they sit-and-wait for food, as opposed to active foraging). Since they do not forage, it’s unlikely that they would enter a trap baited with prey. Thus far, strategies to compel the pythons to move (e.g., drift fences, noise deterrents) and thereby increase the probability of trapping success have been, by and large, impractical or ineffective.

Some management tools show potential, but the underlying science is underdeveloped and in need of much additional research. Pheromone attractants are a good example. Male pythons congregate around females in relatively large numbers during the breeding season and are presumably signaled to do so via pheromones. Such an attractant may be an effective bait for trapping pythons (at least adult male pythons) but, unfortunately, the science of chemical signaling in snakes is in its infancy. The isolation and synthesis of python pheromones for use in management, while potentially effective, may be a long way off.

Key Recommendations/Issues

Whereas eradication of the Burmese python population in Florida may be impossible, and effective management is costly, the lessons learned may help prevent the establishment of other invasive exotic species. Other giant, non-native constrictors (e.g., African rock pythons, reticulated pythons) are imported to Florida via the pet trade and have a similar potential for establishment with a large ecological impact. Given what we know about the difficulties in managing Burmese pythons, any steps taken to prevent the establishment of other giant constrictors are steps well-taken.

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South Florida Ecosystem Restoration Task Force

Invasive Exotic Species Strategic Action Framework

Long-term Management Case Study: Lionfish

Lionfish, predatory reef fish with venomous spines native to the Indo-Pacific, have invaded and established breeding populations in the waters off Florida. Since first observed off Florida in the 1980s, two lionfish species (*Pterois volitans* and *Pterois miles*) have populated the Caribbean, Gulf of Mexico, the Southeastern U.S. coastline, and the Bermuda coastline. Lionfish pose a threat to the integrity of the food web and are capable of impacting commercial fisheries, tourism, and overall coral reef health. There are no suitable traps ready for deployment, nor are any other cost effective collection strategies available. Currently, lionfish are only removed by hand by divers or caught as bycatch of fisheries. Barring some unforeseen emerging technique or natural control, lionfish will be permanent neighbors requiring long-term management to lessen their impacts on Florida's native aquatic habitats and species.

Case Presentation

Lionfish entered the ornamental trade in the 1970s and some of these pets were released into the tropical Atlantic Ocean in the 1980s. Without native predators, and having year round reproduction of up to 20,000 eggs every three days, lionfish have flourished in the region and are now found from Florida's shallow estuaries to off-shore waters over 300 meters in depth.

Lionfish invasions have direct and indirect impacts, from local to ecosystem level effects. Lionfish are efficient predators in direct competition with many recreational and commercial native species and those of special concern. They consume over 130 species, primarily fish, crustaceans, and mollusks. With invasion densities up to eight times those of native range populations, lionfish outcompete native predators and have reduced small native fish populations by up to 90% in some locations. Cascading effects include food web changes on reefs from reducing herbivores, causing algal proliferation on both shallow habitats to deep reefs. Algal proliferation reduces habitat for coral settlement and space for existing coral colonies.

Management Actions and Outcome

Lionfish are now a management issue for 37 countries in the Caribbean, western Atlantic, and Gulf of Mexico regions. Alliances are developing among the nations and between resource managers and non-governmental conservation organizations. Management actions within the United States have included the development of strategies by federal and state agencies as well as efforts by a number of nongovernmental entities such as Reef Environmental Education Foundation (REEF) who have been a means of furthering research, coordination, and outreach on lionfish.

An Invasion Below

Since first observed in the 1980s, two predatory species of lionfish have populated the Caribbean, Gulf of Mexico, the Southeastern US coastline, and the Bermuda coastline. This has led to a loss of herbivorous fish species on reefs and the resulting dominance by algae and coral death. Currently, there are no suitable traps ready for deployment, nor any other cost effective collection strategy for control.



Photo: Rich Carey, REEF.

Management actions currently involve a combination of regulatory efforts and development of fisheries strategies. The focus of management efforts are on marine protected areas and other areas relating to commercial species or species of special concern. Management efforts need to be continuous and long term because lionfish have a high rate of reproduction, are found much deeper (> 300 m) than present diving removal methods can target (< 50 m), and new arrivals are continuously travelling on currents from outside Florida's waters.

Successful regulatory actions include the easing of permitting requirements for lionfish capture in Florida. The Florida Fish and Wildlife Conservation Commission (FWC) does not require a recreational fishing license for divers using certain devices (e.g., pole spears, Hawaiian Slings, handheld nets). The FWC has also removed size and daily bag limits on lionfish and sponsors lionfish derbies to increase recreational lionfish removal. FWC encourages recreational divers to "Be the Predator" as part of its lionfish removal campaign.

Lionfish trap development is the most promising strategy because it would allow removal of deeper populations, however there are many difficulties in designing the perfect trap. Lionfish are not widely mobile if food is present, and a high trap density might be needed for effective control, possibly impacting bottom habitat. Furthermore, present trap designs allow significant native bycatch. Research and funding is needed to promote trap design and devise attractants or other capture methods that would allow the reduction of lionfish at depths.

Most invaded countries are involved with artisanal and bycatch capture of lionfish as a food fish. In Florida, lionfish is the second most common bycatch of the spiny lobster fishery. The National Oceanic and Atmospheric Administration has partnered with REEF on an "Eat Lionfish" campaign to promote consumption of lionfish and commercial development of a lionfish fishing industry.

Cumulative lionfish sightings as of February 11, 2013.



SOURCE: USGS NAS.

Key Recommendations/Issues

Lionfish are impacting the tropical Atlantic from species specific to ecosystem levels. The development of effective controls is stymied by lionfish depths, densities, rapid reproduction, and early survival success, as well as problems limiting native bycatch.

Strategies for long-term management include:

- Persistent local/recreational removal efforts,
- Continued efforts to develop effective capture methods and trap designs,
- Development of local markets and market strategies for export of lionfish as a food fish, and
- Application of lessons learned to help prevent or eradicate other invasive exotic marine species.

Resources

For more information and resources on lionfish, please visit <http://www.evergladesrestoration.gov/content/ies/goal4.html>.

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Invasive Exotic Species Strategic Action Framework

Long-term Management Case Study: Lionfish—RESOURCES

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An Invasion Below

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Photo: Rich Carey, REEF.

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Invasive Exotic Species Strategic Action Framework

Long-term Management Case Study: Shoebutton Ardisia

Shoebutton ardisia (*Ardisia elliptica*) is an evergreen shrub/small tree native to Asia. Originally imported as an ornamental plant in the early 1900s, it has become a prolific invasive species that is very expensive to control. Shoebutton Ardisia is now commonly found in short hydroperiod wetlands, hammocks, and tree islands in Miami-Dade, Broward, West Palm, St. Lucie and Brevard Counties (UF/IFAS). In the 1980s, shoebutton Ardisia was found in to be invasive within Everglades National Park. Since then, the extent and range of shoebutton Ardisia has expanded as it displaces both native and invasive exotic plant species. Because it impacts community structure and ecological function of native habitats, shoebutton Ardisia is a Category 1 invasive on the Florida Exotic Pest Plan Council's Invasive Plant List. The desired outcome in managing this invasive exotic species is to find and implement a cost-effective control.

Case Presentation

Shoebutton Ardisia is a summer-flowering, fall-fruiting species that is closely related to the native marlberry (*Ardisia escallonioides*), an uncommon shrub found in south Florida hammocks. The native marlberry is not abundant because there is a native seed predator which renders up to 90% of its seed non-viable. There is no known seed predator in south Florida for *A. elliptica*. Shoebutton Ardisia seeds are known to be dispersed by birds and raccoons.

First spotted outside Everglades National Park during vegetation mapping in 1990, shoebutton Ardisia expanded to several hundred acres by 1996. Today, there are approximately 4,000 acres of shoebutton Ardisia within and adjacent to the Miami-Dade County South Dade Wetlands Preserve, an important wetland system in the southern part of the county. Land in this area is targeted for acquisition and management by the county's Environmentally Endangered Lands (EEL) Program because of its strategic location between two national parks (Everglades and Biscayne national parks) and within the watersheds of Florida Bay, Biscayne Bay, Card Sound, and Barnes Sound.

Managing at the Wrong End of the Invasion Curve

An evergreen shrub/small tree that is native to Asia has invaded short hydroperiod wetlands, hammocks, and tree islands in south Florida. It impacts both the community structure and ecological function of native habitats. Miami-Dade County's Environmentally Endangered Lands (EEL) Program is working to identify cost-effective controls to manage this invasive species.



Hand treatment of shoebutton Ardisia by Miami-Dade County EEL crew.
Photo: Miami-Dade County EEL Program.



Shoebutton *Ardisia* is also known to extend up the coast within Miami-Dade County, especially in coastal wetlands that are already impacted by Brazilian pepper or in areas that have been farmed in the past. Shoebutton *Ardisia* spreads rapidly in nutrient enriched soils such as those that have been altered by farming, and also tolerates longer hydroperiods than Brazilian pepper.

Beginning in 2002, the EEL Program implemented a concerted effort to treat shoebutton *Ardisia* within the South Dade Wetlands Preserve, and that work continues today. The control effort is limited because not all of the land with the preserve has been acquired, and invasive exotic species present on private lands (including *A. elliptica*) are not being treated, so the private parcels act as a seed source. Control of shoebutton *Ardisia* is further complicated because field identification is difficult as the invasive strongly resembles the native marlberry and dahoon holly (*Ilex cassine*). Field crews must undergo training and gain practical experience so they can properly identify species to treat.

Management Actions

In controlled studies, Garlon 3A® (triclopyr, amine salt form) was over 90% effective at reducing cover of shoebutton *Ardisia* with one application. The effectiveness rate of Garlon 3A is diminished in the field when plants in dense stands are inadvertently missed during treatment. Resprouting plants and massive seed germination with increased light after initial treatment requires repeated follow-up treatments. Arsenal® (imazapyr) has been used as an alternative supplement to Garlon 3A®, but Arsenal® is not appropriate for all habitats and can result in high non-target damage to some plants like buttonwood (*Conocarpus erectus*) and white mangrove (*Laguncularia racemosa*). Detection of shoebutton *Ardisia* by aerial review is not effective, so finding infestations can be difficult in remote areas and requires ground verification.

On average, initial control of shoebutton *Ardisia* has cost up to \$11,000 per acre for selective hand treatment by a crew of 6 individuals walking an area look-



Brontosaurus treatment of shoebutton *Ardisia* in Miami-Dade County. Photo: Miami-Dade County EEL Program.

ing for and treating seedlings, saplings, and trees. After initial treatment opens up the canopy, the shoebutton *Ardisia* seed bank responds to increased light levels and second year treatments can cost up to \$9,000 per acre to address all the new seedlings. By the third year, most of the seed bank is exhausted and the cost decreases to less than \$6,000 per acre, with subsequent annual maintenance treatments averaging between \$1,000 to \$1,500 per acre. In native dominated wetlands, treatments must occur every three to four years because shoebutton *Ardisia* is co-located with listed and rare species that will be displaced if the habitat is not maintained free of invasive exotic species. The EEL Program has treated over 350 acres through selective hand treatment and follow-up maintenance activities.

With selective hand treatment by crews, the control costs for shoebutton *Ardisia* were too high to be sustainable over 4,000 acres. To reduce costs in areas that are dominated by invasive vegetation, treatment efforts are now being used to manipulate the habitat to make it less suitable for *A. elliptica*. In dense stands of *A. elliptica*, the current strategy is use a gyrotrack or brontosaurus mulcher to mulch both native and exotic woody material, with follow up mowing and aerial spraying. The land is allowed to convert to prairie, which then can be maintained through the application of prescribed fire. The EEL Program has successfully converted 26 acres to prairie, with another

22 acres in process. This treatment method has averaged about \$3,000 per acre for mulching, and not more than \$300 acre for mowing or aerial spraying. In three years, there has been significant recruitment of native grasses. While not yet applied, prescribed fire is expected to cost less than \$100 per acre. As a side note, it is important to use proper phytosanitation/ equipment decontamination practices when bringing in heavy equipment. Some exotic grasses can be brought in unintentionally, especially on mowers. Additionally, mulching is preferable to land clearing and grubbing because soil disturbance may also result in new infestations of nuisance species like cattails.

A primary management goal of the EEL Program is to reduce the amount of exotics-dominated forested wetlands to provide for a diverse ecological community, including habitat for listed ferns, bromeliads, and orchids. A critical component of this management goal is to reduce coverage of shoebuttton *Ardisia* to make control cost-effective and feasible in the long-term. This is especially important because there is no biocontrol currently being developed and development of a biocontrol would be complicated by the presence of an

uncommon native in the same genus. In total, the EEL Program has spent almost \$5 million to control shoebuttton *Ardisia* and other associated invasive exotic species in the South Dade Wetlands since 2000.

Key Recommendations

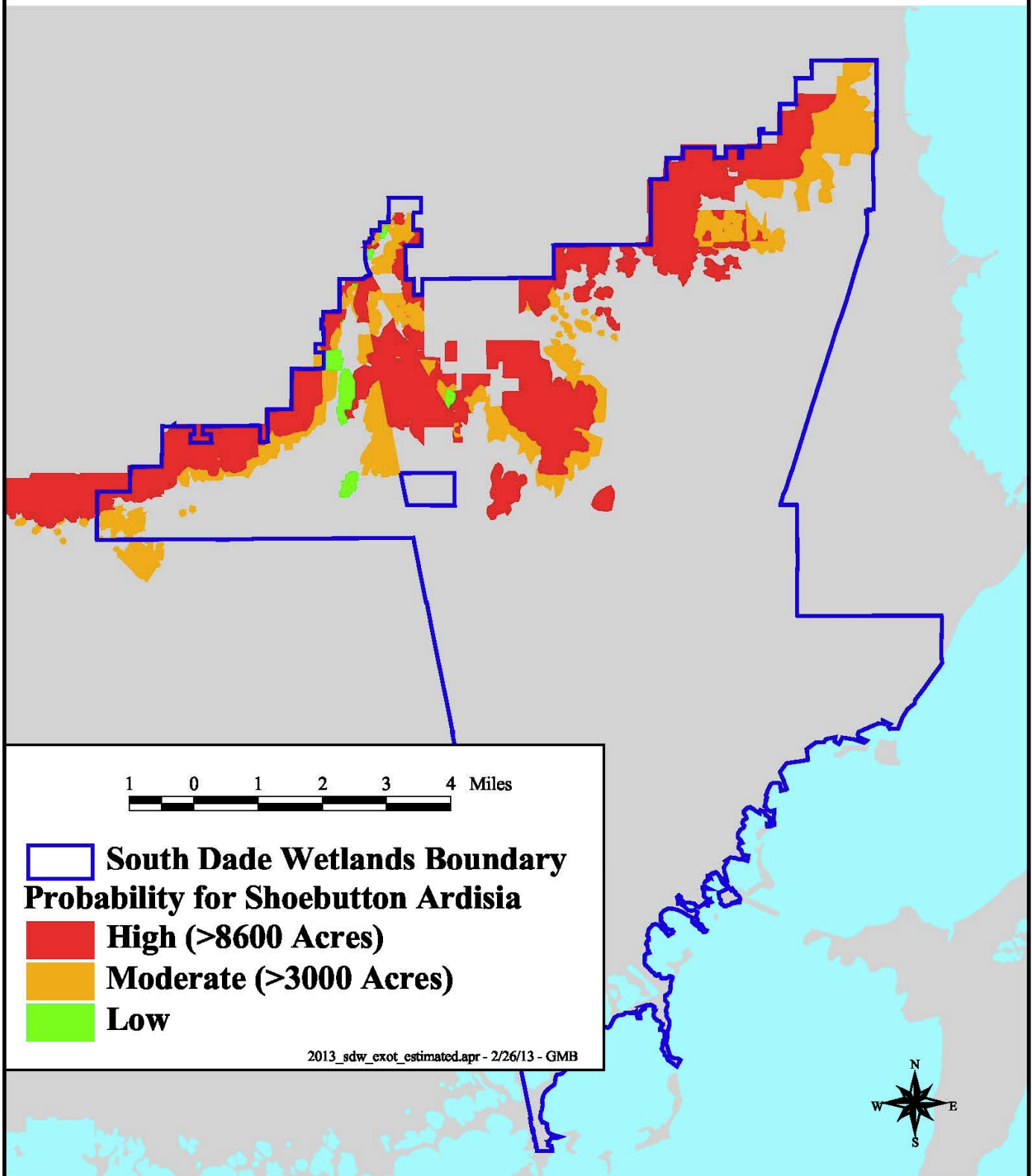
More research on the demographics and life cycle of shoebuttton *Ardisia* is needed. Specific information on the relationship to soil nutrient characteristics, response to prescribed fire, seed banks, and vectors can all inform management decisions and help to reduce management costs. Most importantly, consistent and sustained funding is needed to help bring this species under permanent control. Funding comes in cycles, but the invasion doesn't stop or slow without active management. Lacking sustained and sufficient funding, land managers are forced to prioritize their management strategies, which often means choosing whether to maintain what has already been restored or respond to new or expanding threats.

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South Dade Wetlands Shoebutton Ardisia - 2013 Estimated Distribution



South Florida Ecosystem Restoration Task Force

Invasive Exotic Species Strategic Action Framework

Long-term Management Case Study: Ambrosia Beetles & Laurel Wilt Disease

Laurel wilt disease threatens to cause the extinction of native redbay trees (*Persea borbonia*) and swamp bays (*Persea palustris*) in the Everglades, as well as seriously impact commercial avocado (*Persea americana*) groves in south Florida. This has implications for the structural integrity of tree islands in the Everglades. Additionally, bay trees are one of the most important cultural resources to the Miccosukee Tribe of Indians of Florida and the Seminole Tribe of Florida.

The disease is caused by a fungus (*Raffaelea lauricola*) transmitted by an exotic insect, the redbay ambrosia beetle (*Xyleborus glabratus*). The beetle bores into healthy trees creating tunnels in the wood and introducing the fungus. The tree's reaction to the fungus blocks water, which results in wilting of leaves and quickly leads to the death of the tree. The beetle was introduced in Port Wentworth, Georgia in 2002, spread rapidly down into Florida, and was first detected in Miami-Dade County in March 2010. Laurel wilt disease was discovered in swamp bays in February 2011 and by late 2013 dead swamp bays were observed throughout the southern Everglades.

Swamp bay is a shrub or small tree that is a major component of many Everglades tree islands and is found in swamp forests, hammocks, and pinelands throughout the region. Swamp bay fruits are consumed by bears, deer, and many songbirds and the foliage is the larval food plant for the palamedes swallowtail butterfly. While the mammalian and avian frugivores are generalists, the only host plants for the swallowtail larvae are swamp bay and redbay, both of which are very susceptible to laurel wilt.

In areas with redbay ambrosia beetles, populations of redbay and swamp bay have experienced almost 100% mortality of mature trees within a few years of the first appearance of laurel wilt symptoms. Given the rate of spread, it is expected that within a few years most, if not all, mature swamp bays within the Everglades ecosystem may be killed. Although the mature trees are likely to be killed, swamp bay often reacts to injury by basal sprouting, which should lead to

young trees that initially won't attract the redbay ambrosia beetle. It is possible that the basal sprouting of swamp bays will create shoots from its roots that will allow the species to survive for an extended period, much like the American chestnut continues to survive as small resprouts.

Can the Issue be Resolved by Management?

Management of redbay ambrosia beetles and laurel wilt in the Everglades will not be easy, and may not be possible. Only one beetle is necessary to introduce the fungi that will cause the death of a tree. Insect

Ambrosia Beetle

Laurel wilt disease threatens to cause the extinction of native redbay trees, swamp bays in the Everglades, and seriously impact commercial avocado groves in south Florida. This has implications for the structural integrity of tree islands in the Everglades and one of the most important cultural resources to the Miccosukee Tribe of Indians of Florida and the Seminole Tribe of Florida.



Photo: Courtesy of Sun Sentinel.

control, such as preventative insecticides, might be effective in an agricultural setting, but is not feasible in the Everglades. Given the current abundance of dead and dying bay trees already in the Everglades, it can be assumed that a large numbers of beetles are already finding their way to uninfected trees. Given enough time, the chances are that a beetle will find all the existing bay trees. Therefore, it seems that no practical way can prevent the spread of redbay ambrosia beetle or any feasible way to treat plants in the natural areas against the fungal pathogen.

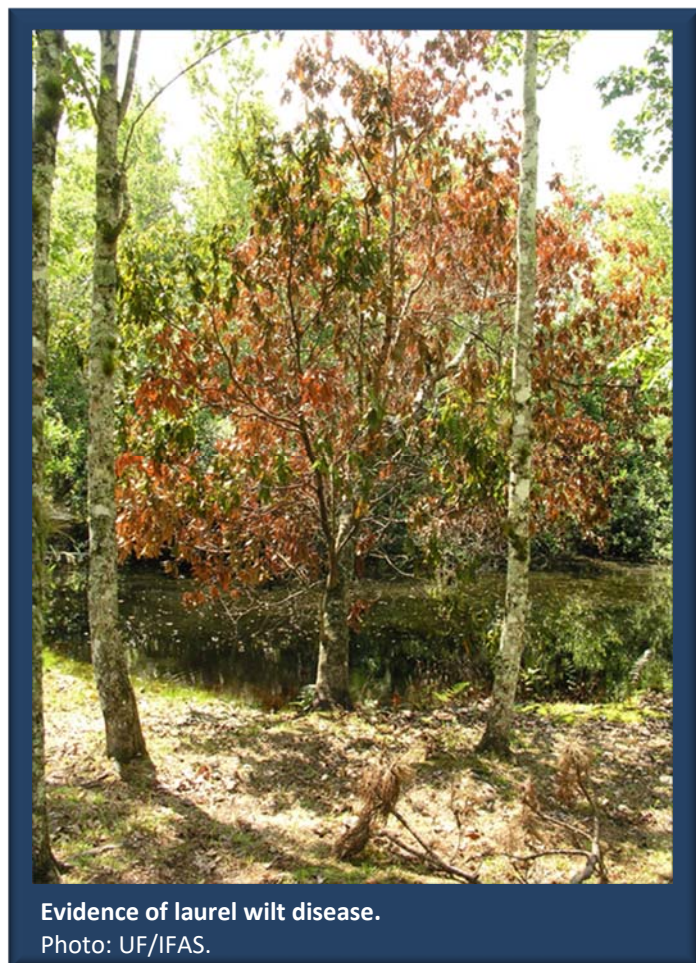
What Would be the Facilitating Factors Needed for Success?

Success in the sense of slowing or reversing the effects of this invasive exotic species are not likely, however, efforts can be focused on developing a recovery strategy. The first important step in a recovery strategy would be to find individual trees that are resistant to the redbay ambrosia beetle. This effort is underway for the redbay and needs to be extended to swamp bay. Two hypotheses are: 1) the tree may not be producing the appropriate chemical signal to attract the redbay ambrosia beetle; or 2) the tree is resistant to the fungal pathogen.

A recovery strategy would include efforts to document the spread of laurel wilt by aerial surveys and reporting from individuals in the field. It is recommended that a network of permanent plots be established throughout the Everglades to follow the progression of laurel wilt and search for resistant individuals that can potentially be cultivated.

Key Recommendations/Issues

Efforts to locate and propagate individual swamp bay trees that show resistance to the redbay ambrosia beetle and/or the laurel wilt fungus are recommended. Resident populations of swamp bay in the field will almost certainly disappear and the best chance to reestablish the species in the wild should be addressed through a comprehensive recovery plan. It is



important to develop a comprehensive recovery plan that involves propagating resistant organisms and reestablishing them into the wild.

The Everglades has begun to experience bay tree mortality that will impact tree islands and Tribal cultural uses. This needs to be documented and research initiated to understand the impacts to the natural system including individual tree response, the species in general, and overall ecosystem restoration.

The redbay ambrosia beetle has spread rapidly over the past decade and has led to the mortality of approximately five hundred million trees. Better communication across state, county, and agency boundaries during the initial invasion may have provided more awareness of this important invasive exotic species.

South Florida Ecosystem Restoration Task Force

Invasive Exotic Species Strategic Action Framework

Long-term Management Case Study: Melaleuca

Melaleuca is a fast-growing evergreen tree native to eastern Australia. The plant is a prolific seed producer, is fire-adapted, and is able to thrive in both flooded and well drained soils. First introduced to Florida in the early 1900s as an ornamental tree and soil stabilizer, melaleuca quickly spread throughout south Florida and is considered one of Florida's worst invasive species. Melaleuca successfully invades a variety of habitats in Florida including pine flatwoods, mesic prairies, sawgrass marshes, cypress swamps, roadsides, ditch banks, lake margins, and pastures (Laroche 1999). Once established, melaleuca can significantly alter plant species composition, community structure, alter important ecological processes such as fire behavior and litter production, and reduce the carrying capacity for some wildlife species (Mazzotti et al. 1981, Serbesoff-King 2003, Rayamajhi et al. 2009).

Case Presentation

The introduction of melaleuca to the United States did not initially include its co-evolved predators and pathogens. This release from natural enemies, in combination with its numerous adaptations to south Florida's environment, significantly increased melaleuca's invasive potential. In a short time, the plant spread beyond the areas where it was intentionally planted. By 1970, melaleuca was established throughout the Everglades and by 1993 infested an estimated 488,000 acres in south Florida (TAME 2007). Large tracts of the Everglades *River of Grass* were quickly changing from sawgrass marsh and open water sloughs to dense melaleuca stands with little to no native plants in the understory. Other detrimental changes to ecosystem characteristics and processes such as community structure (O'Hare and Dalrymple 1997) and fire intensity and behavior (Flowers 1991) were also discovered as the melaleuca expansion continued. Without active management of melaleuca, the Everglades and other unique Florida ecosystems would be severely altered or lost completely, regardless of ongoing efforts to restore historic surface water flows to the region.

Mounting evidence that melaleuca was causing substantial impacts to Florida's natural areas, led state and federal agencies to take action in the late 1980s against the spread of melaleuca and attempt recovery of impacted ecosystems. At that time, natural resource managers faced significant obstacles to melaleuca management. In particular, there were very few established control tools, there was no dedicated funding for control or research, melaleuca could still be legally cultivated and sold in Florida, and the public was largely unaware of the plant's harm to Flori-

A Model Plan

Melaleuca is a highly invasive tree native to Australia. First introduced to Florida in the early 1900s as an ornamental tree and soil stabilizer, melaleuca quickly spread throughout the South Florida Ecosystem.

Florida's eventual response to this long-neglected invasive species problem is an exceptional example of cooperative implementation of a comprehensive, long-term strategy. The Florida Melaleuca Management Plan and the initiatives it inspired can serve as a model framework for other invasive exotic species plans. See page 3 for specific recommendations.



Photo: Vic Ramey, UF/IFAS.



An Everglades marsh overtaken by melaleuca.
Photo: SFWMD.

da's natural areas. Early in 1990, the Florida Exotic Pest Plant Council (FLEPPC) and the South Florida Water Management District jointly convened a task force of federal, state, local land managers, scientists, and others to develop a plan for managing melaleuca. The resulting Florida Melaleuca Management Plan (Laroche 1999) became a guiding document for a regional, comprehensive strategy.

Management Actions and Outcome

Implementation of melaleuca management began in the late 1980s and accelerated shortly after the completion of the first edition of the Florida Melaleuca Management Plan in 1990. To address the numerous challenges outlined above, the plan set forth clear management objectives and proposed specific recommendations based on an integrated control strategy. These included:

- Maintain cooperation and collaboration among agencies
- Adopt a regional quarantine strategy, which systematically controls melaleuca from new incipient populations toward the older and more established populations
- Maintain consistent funding to promote efficiency in long-term planning
- Fund research on effective and safe herbicides in natural areas
- Fund biological control research

- Develop integrated weed management techniques to ensure cost effective and environmentally sound management.
- Encourage regulatory actions to prohibit the sale and distribution of melaleuca
- Implement outreach initiatives to inform the public and lawmakers of melaleuca's negative impact on Florida's environment
- Encourage initiatives to remove melaleuca on private lands

A great deal has been achieved towards realizing these objectives and recommendations since the first edition of the plan was drafted. By 1993, melaleuca was included on the U.S.D Department of Agriculture (USDA) Federal Noxious Weed List and was designated a prohibited plant in the State of Florida. Melaleuca was the first non-agricultural weed ever listed as a noxious weed by the USDA. Also in 1993, the Florida Legislature allocated an annual budget of \$1 million to the Florida Department of Environmental Protection (FDEP) specifically for melaleuca control. The allocation of consistent and adequate funding has been a vital component of implementing the plan, because it allows land managers to establish and rely on a long-term, adaptive management strategy.

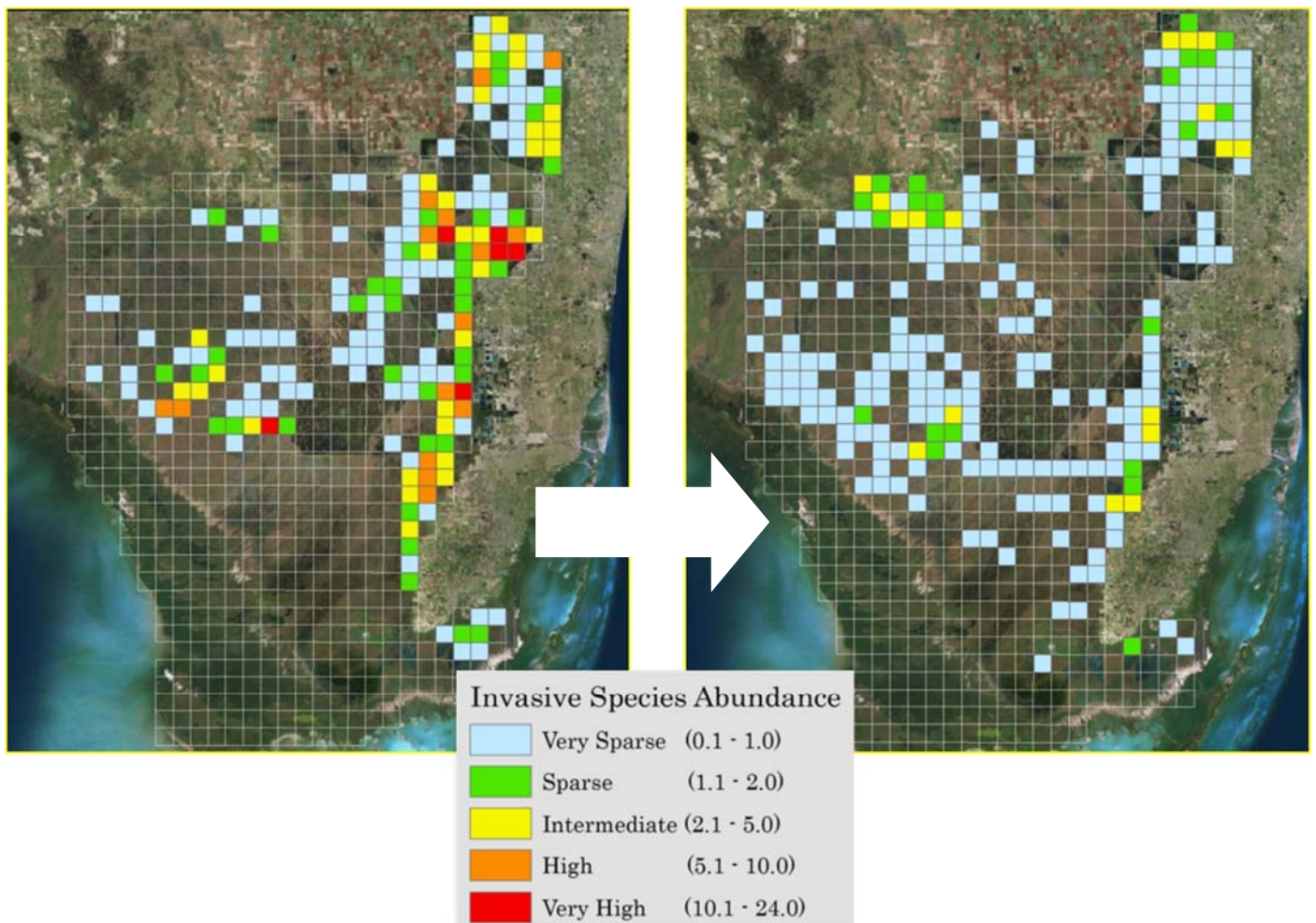
Efforts to develop control tools were fortunately successful. Obtaining approved herbicides for melaleuca in natural areas and initiating research to refine herbicide application techniques greatly enhanced the overall success of the melaleuca program. Careful selection and use of herbicides has resulted in the cost-effective removal of hundreds of thousands of acres of melaleuca. Sustained funding for the development of biological control agents resulted in the approval of four insects for release in the U.S. Three of these insects are now established in Florida and are exerting significant pressure on melaleuca (Tipping et al. 2009). While biological control is not expected to eradicate melaleuca, reductions in melaleuca growth rates and reproductive potential are reducing the rate of reinfestation and thus reducing herbicide control costs.

Large sections of the Greater Everglades have reached or are nearing maintenance-control levels where melaleuca once dominated (Rodgers et al. 2014). However, some portions of the South Florida Ecosystem still contain sizable melaleuca infestations. Limited resource allocation for melaleuca control in some management areas has slowed progress. In these cases, resource managers cite insufficient or unpredictable timing of funding as a major impediment to their success.

While agencies continue to make progress toward achieving maintenance control of melaleuca on public conservation lands in south Florida, many private lands still retain large infestations. In addition to direct impacts to natural resources on those private holdings, those melaleuca infestations provide a continuous seed source for new infestations on adjacent public lands. Unfortunately, there are only a handful of programs to assist private land owners with removal of melaleuca and other invasive plants within the state. Outreach initiatives such as the TAME Melaleuca Project have contributed to increased public awareness of the environmental and economic impacts of melaleuca. In addition to increasing awareness among the general public, TAME and similar outreach programs are actively transferring knowledge to private land owners and small governments seeking to manage melaleuca.

Lessons Learned

South Florida's century-long melaleuca story is an instructive example of the environmental and economic consequences of allowing aggressive invaders to proliferate for decades without management action. Hundreds of thousands of acres of native habitat have been altered or lost, and the effort to reverse this course is costly. The south Florida melaleuca effort (including biological, mechanical, chemical, and physical control efforts) has cost over \$43 million thus far. To place this in perspective, however, FDEP estimates that failing to act against melaleuca would ultimately cost the region \$161 million annually in lost revenues (Laroche 1999). The high cost of managing this aggressive invader calls attention to two important points. First, aggressive action against newly detected invaders could save significant public resources and substantially reduce impacts to natural resources in the long term. Second, eradication of many long established, aggressive invaders like melaleuca is unlikely. A lasting commitment to maintenance control is the most cost effective and environmentally responsible approach to managing these species. Allowing once controlled invaders to re-establish in natural areas is not only poor stewardship of the resource; it is an inefficient use of public resources.



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South Florida Ecosystem Restoration Task Force

7500 SW 36th Street, Davie, FL 33314

(954) 377-5971

www.EvergladesRestoration.gov

This document is part of a series of case studies developed for the Invasive Exotic Species (IES) Strategic Action Framework. This particular case study highlights issues within the Long-term Management Phase of the IES Invasion Curve. 6/1/15