Prioritizing Management and Research Actions against Invasive Reptiles in Florida:

A Collaboration by an Expert Panel

Report prepared by

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The invasive reptile and amphibian situation in Florida

Florida has more introduced animals than any other region of the U.S. and also ranks high in this respect globally. Given Florida's climate, it is no coincidence that a large proportion of Florida's invasive vertebrate species are reptiles and amphibians. Exotic snakes, lizards, frogs, turtles, and crocodilians are all breeding in Florida. The largest snakes in Florida are constrictors from other continents, and the five largest lizard species breeding in Florida are from Africa, South America, and Central America. Establishment of non-native reptiles and amphibians has been documented in Florida for over 135 years, and the rate of invasive reptile species establishment has been accelerating in the last half century. Florida currently has 16 native lizard species compared to 43 invasive species of lizard established and breeding in the state.

Florida's subtropical climate in the south, its major ports of entry for many wildlife species to the U.S. (both legal and illegal), its thriving captive wildlife industry, and its location in an area of destructive hurricanes that can release captive animals make the state particularly susceptible to the introduction and establishment of a wide range of species. Moreover, Florida is isolated from land with similar climates, resulting in the state's vertebrates typically originating in the southeast U.S. at the southern extremes of their range. Invaders to Florida therefore find relatively fewer native species to contend with than in most tropical/subtropical locations.

To this end a collaboration of scientists and managers was organized (APHIS cooperative agreement 13-7412-0965-RA) to review the invasive reptile and amphibian species posing the greatest threats for ecological harm in Florida, and to identify the circumstances and scales for which research and management actions would be most productive. A primary focal point for these evaluations concerned the negative impacts of invasive reptile species to endangered species and the potential for successful mitigation. The key products from this collaboration were: 1) to identify which invasive reptile species pose the greatest threats in Florida, 2) to identify the circumstances and geographic scales where threats from invasive reptiles are most likely to have a practical and successful mitigation, and 3) to identify practical research directions most likely to rapidly produce useful control tools.

Prioritizing the threats

The invasive reptile species situation in Florida is severe, and the breadth of invasive reptiles in Florida that arguably merit management action is extensive. In recognition that potential resources for managing invasive reptiles in Florida

will fall considerably short of addressing all problems, our collaborative group first re-evaluated all known species of reptiles and amphibians established in Florida on the basis of the risk they pose for ecological harm (with an emphasis on threats to endangered species), and the potential for successful actions against them (at various scales), including research to develop management techniques. The first step was to identify factors that affect the level of threat posed by the invasive species. These factors were then structured into risk criteria, with each criteria sub-classified according to ordered levels of risk.

Risk assessment approach

Assessment of risk was based on the following criteria that encompass the threats for range expansion, negative impacts to native, especially rare species, and circumstances where management actions are highly needed and would likely be successful given the existence of appropriate tools and strategies:

1. Habitat versatility (i.e., narrow or broad
2. Eradication potential (i.e., no chance, local extirpation, eradication)
3. Impacts to endangered species
4. Potential Florida/U.S. range limits (narrow or broad based on physiological tolerances and mobility)

We also considered the stage of invasion of each of the species, following the scheme of Coalutti and McIsaac (2004), as adapted for Florida invasives by Krysko et al. (2011):

stage II - transported and released; introduced.
stage III - established in a novel environment (localized and numerically rare).
stage IVa - widespread but rare.
stage IVb - localized but dominant.
stage V - widespread and dominant.

Risk assessment results

Thirty-seven invasive reptile species were evaluated, scored and discussed (Table 1). From those results seven species were identified as having a “highest impact concern” and are listed in order here:

1. Argentine giant tegu lizard (*Salvator merinae*)
2. Burmese python (*Python bivitattus*)
3. Nile monitor lizard (*Varanus niloticus*)
4. North African python (*Python sebae*)
5. Spectacled caiman (*Caiman crocodilus*)
6. Black spiny-tailed iguana (*Ctenosaura similis*)
7. Yellow anaconda (*Eunectes notaeus*)

Focusing on the future, identifying most useful rewarding research and management actions

Developing recommendations for action

The seven species identified as “highest impact concern” formed the bases for further evaluations aimed at determining where the greatest potential rewards would be obtained from potential funding directed at combatting invasive reptiles in Florida. A variety of considerations entered into the discussions for identifying species that might be practical to target for action and the geographic scales and circumstances where such actions would be successful. Among the considerations were what research and management efforts were already in place against some species, and also the legal and physical potential for actions to take place. The following urgency and practicality criteria were used to identify applications with the most potential for success and therefore meriting effort (funding) against invasive species:

1. Urgency of need for action – impacts if action not taken
2. Potential for success
3. Manageability of geographic scale

Recommended management actions

Problems with several large reptile species in recent years have received public/media attention, a factor sometimes serving to catalyze action. To date, large constrictor snakes have received the vast majority of the attention, although a variety of other species occasionally have been highlighted in the media.

Nevertheless, species outside the media spotlight appear to be in circumstances where sustained management actions would be most useful and could obtain the desired effect.

1. **Cape Coral Nile monitors**
   Established populations of Nile monitors are currently found in Homestead (Miami-Dade County), West Palm Beach (Palm Beach County), and Cape Coral (Lee County). The Cape Coral population has been firmly established since at least 1990. Its range around Cape Coral is expanding into neighboring wild-lands, including nearby islands where it would be a threat to endangered sea turtles and shore birds. The Nile monitor can rapidly outgrow many, if not most, potential predators, and this large-bodied carnivore is capable of eating a wide variety of vertebrate prey, potentially impacting a number of threatened and endangered species in the process. For example, the Florida burrowing owl (*Athene cunicularia floridana*), a Florida Species of Special Concern, has already been observed as a prey item. In Cape Coral these large predatory lizards are known to take residents' pets such as cats and small dogs. The Nile monitor is a prolific species capable of reaching high densities. Based on its native range, this lizard could expand its range and pose severe threats to native fauna throughout Florida, and possibly beyond. Limited control has been applied in Cape Coral, which may have served to prevent maximum population growth, but there has not been funding for an intensive effort that might contain and ultimately eradicate the Cape Coral population. Some useful information for the management of the species has been obtained and used in the limited control efforts to date. Initiating a sustained, intensive control effort with methods currently known to capture Nile monitors would help contain and reduce the population. As additional control tools are developed, especially those that would be less labor-intensive and less costly, the removal of these lizards could be greatly expanded and expedited.

2. **Gasparilla Island black spiny-tailed iguanas**
   Also commonly called ctenosaurs, these large lizards have been recorded at several locations in south Florida. They became established on Gasparilla Island on Florida's west coast when three individuals were brought from Mexico and released on the southern end of the island in 1979. These iguanas have tremendous reproductive potential, and their population rapidly saturated the terrestrial habitats on the island in high numbers, including all residential and commercial areas. On the Island, black spiny-tailed iguanas eat expensive landscape plantings and invade houses, causing monetary damage and aggravating homeowners. Beyond

causing problems for residents, black spiny-tailed iguanas also threaten sensitive native flora and fauna. Although these iguanas are primarily vegetarian, they are opportunistic and will eat other lizards, small birds, rodents and invertebrates. Their predatory behavior potentially jeopardizes various Florida bird species such as the least tern (*Sterna antillarum*), snowy plover (*Charadrius alexandrines*), and burrowing owl (*Athene unicularia floridana*). This lizard feeds on the same native plants as does the gopher tortoise (*Gopherus polyphemus*), inhabits gopher tortoise burrows, and is known to prey on juvenile gopher tortoises. They feed on the fruit of invasive plants and distribute the seeds, making invasive plant control more difficult. They also exhibit agonistic killing behavior towards snakes, a concern if they might interact with listed native species like the eastern indigo snake (*Drymarchon corais couperi*).

To combat the growing population of black spiny-tailed iguanas on Gasparilla Island, an intensive control program is underway. This represents the first such management effort specifically targeting an invasive reptile in Florida. Trappers, using an integrated control approach of trapping and shooting, have removed tens of thousands of black spiny-tailed iguanas. Due to the mixture of habitats, including natural, residential and other developed areas, as well as the behaviors of the animals and restrictions imposed by community residents, great flexibility has been required to integrate tools and strategies while optimizing human and material resources for maximizing ctenosaur removal. The ctenosaur population has been markedly reduced and there has been anecdotal evidence of improved gopher tortoise hatchling survival. As the population declines through management, the level of effort and cost per lizard removed will rise. At this time, if the control effort is reduced, the management gains would be jeopardized as the population would likely rebound in short order, given the high reproductive potential of the species.

3. Hillsborough and Polk County Argentine giant tegus

Relatively new to the scene of established exotic reptiles in Florida is the Argentine giant tegu (aka Argentine black and white tegu), a large omnivorous lizard native to South America. Tegus are the largest lizards in the New World, and invasive populations are now established in Miami-Dade County in south Florida and in Hillsborough and Polk counties in west-central Florida. The Argentine giant tegu is a fecund species, laying annual clutches of 20-45 eggs and appears to have rapidly populated the area with its range expanding. Tegus have been observed using gopher tortoise burrows, and tortoise eggs and hatchlings

are likely prey items. Like spiny-tailed iguanas, tegus could disperse seeds of invasive plants and also could prey on a similar suite of native animals, including listed species. Its burrow use likely excludes gopher tortoises and burrowing owls from their burrows, in addition to the predation threat. Like the spiny-tailed iguanas, tegus have also been observed to exhibit agonistic killing behavior towards native snakes. The omnivorous diet and burrow usage suggest that tegus may present the combined spectrum of threats to the environment as from both Nile monitors and iguanas. Limited control measures have taken place in south Florida and Hillsborough County, primarily live-trapping, using chicken eggs as bait (followed by euthanasia). Experimentation with captive animals has focused on trap and lure development, but to date, dedicated resources have not been available for effective population control, nor for the development and testing of more efficacious control tools.

Recommended research actions

Invasive species often present novel control situations for managers, requiring the acquisition of biological knowledge focusing on potential vulnerabilities, and the development and testing of control technologies and strategies. Only then can an effective, efficient, and cost-effective control program be implemented with optimistic prospects for success. This is especially true for reptiles where relatively few broad programs have been applied around the world to develop and implement control methods for reptiles. To achieve a satisfactory end, suitable control methods must be available, or developed in the case of reptiles, and then applied in a systematic and sustained integrated pest management program. The methods in place for the recommended management actions above tend to be labor-intensive or otherwise inefficient. New, more efficacious tools can dramatically increase application and ensure the feasibility of an integrated pest management approach.

1. **Development of control tools and techniques for tegus**

   Development of effective control tools could help contain the species' range, reduce populations, and create the possibility of localized eradications. The limited trapping in the field uses cage traps with chicken eggs as bait. Pilot studies on trap designs and baits/lures have been conducted and methods to detect/monitor tegu populations are in development. Control efforts would be greatly boosted with less cumbersome and less costly traps. A less fragile and longer lasting replacement for chicken eggs as bait would reduce trap maintenance and make field work easier. A pilot study for developing practical field

methods to detect/monitor tegu abundance has been conducted, but methods need validation and evaluation. Clearly, the greater the ease and efficacy of trapping coupled with lower costs for traps would allow many more traps to be deployed and greater efficacy for reducing populations. Having a reliable and practical method to detect/monitor tegu populations would allow managers to: detect and control incipient populations, identify where control is most needed, determine optimal timing of control, assess control efficacy, and recognize reinvasion.

2. **Improving and developing control tools and techniques for Nile monitor lizards**

   New, improved control tools should (1) reduce time and labor costs in the field, (2) allow more intensive control efforts, (3) raise the probability of population reduction or local extirpation, and (4) reduce the likelihood of range expansion. Some basic information on diet, baits, and trapping technology exists for the Nile monitor. The traps used are large, unwieldy cage traps (two cage traps combined). Development of new lightweight designs along the lines of the trap recently patented for the capture of large constrictor snakes would contribute to the feasibility of a broad-based control effort. Considerable testing and refinement of additional baits, attractants, and capture methods applicable to large-scale removal are needed. Pilot bait matrix preference trials have been conducted for Nile monitors and indicated that multiple commercially available bait matrices might be promising for development for use in traps or toxicant delivery. Trials built on the successful development of acetaminophen as a toxicant for brown tree snakes showed this human medicant to be an effective toxicant for Nile monitors, but substantial development and testing would be needed to ascertain dosage, appropriate bait(s) and delivery mechanisms to target Nile monitors specifically. Despite a reasonably high profile and some media attention, funding has not yet materialized for general development of the needed control technologies, nor for initiating a general control or eradication effort. Without prompt action, the likelihood for successful eradication or containment diminishes as the species colonizes new places where it will be more physically and logistically difficult to manage.

Not prioritized species

Burmese pythons and other large constrictor snakes in south Florida have captured substantial media attention, often in sensational fashion. The panel of experts discussed these species intently but decided for several reasons that they did not constitute the best application of management or research

resources. First, a number of agencies and organizations are already conducting some degree of research into methods development for controlling Burmese pythons (and applicable to other pythons and boas). Second, python removal activities of limited efficacy outside Everglades National Park are carried out under state auspices. Third, the primary population and source for possible post-control reinvasion outside the park lies within Everglades National Park exclusively under National Park Service authority. Last, extensive recent empirical and modeling evidence strongly indicates the species are climate contained within the southern tip of Florida with little prospect for significant northward range expansion. Within the current range, should practical control methods become available along with resources to implement effective intensive control, then such control operations would become a cost-effective priority.

Final thoughts

The negative impacts inflicted by exotic species on native species and ecosystems are only exceeded by human-caused habitat destruction. Exotic species have played a role in the listing of more than 40% of the species protected by the U.S. Endangered Species Act. The species we have focused on here all pose threats to native species, including listed species. Additionally, they cause other forms of damage to human interests including property damage, destruction of domestic animals, and spreading invasive plants.

Strong value exists in examining the life history of an invasive species within the context of understanding why it is successful, and what its vulnerabilities might be. Such information provides predictive power concerning its colonization in other kinds of habitats or regions and also puts to the test the types of biological characteristics associated with successful colonizing species. The identification of vulnerabilities that might be exploited for control underscores the importance of results that directly assist in the removal of the species. Research directly facilitating eradication tools and projects should be of highest priority. Consequently, developing the information and technologies from which control strategies can be developed and implemented should be considered an essential component in the control of invasive species, with priority given to the most problematic circumstances where a management program could be considered practical with a high probability for success. Even a widespread, highly entrenched species might be intensively controlled on a localized scale, managed, excluded, or eradicated in situations of greatest priority.

In general, the non-native reptile species in Florida pose unprecedented difficulties for management, or have other characteristics making effective management challenging. Moreover, initiation of management action requires

more than recognition by experts that a potentially harmful species has become established. It also requires the political will along with concomitant resources and appropriate personnel to develop effective methods and apply them.

References

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Table 1. Evaluation of Florida's invasive herpetofauna for potential impact and management concern.

Common name	Scientific name	Stage	Habitat	Habitat breadth 1=narrow 2=broad	Eradication 1=no chance 2=local extirpation 3=possible	Endangered prey 1=no 2=maybe 3=yes	Range potential 1=narrow limits 2=broad limits	Research needed for control methods 1=no 2=yes	Total	Potential impact and management concern
Argentine tegu	*Salvator merianae*	4b	urban and natural	2	2	3	2	2	**11**	high management concern and high impact concern
Burmese python	*Python bivitattus*	5	natural and urban	2	2	3	1	2	**10**	high management concern and high impact concern
Nile monitor	*Varanus niloticus*	5	urban and natural	2	2	3	1	2	**10**	high management concern and high impact concern
North African python	*Python sebae*	3	natural and urban	2	3	2	1	2	**10**	high management concern and high impact concern
Spectacled caiman	*Caiman crocodilus*	4b	natural and urban	2	2	3	1	2	**10**	medium management concern, high impact concern
Black spiny-tailed iguana	*Ctenosaura similis*	5	urban	1	3	3	2	1	**10**	medium management concern, high impact concern
Yellow anaconda	*Eunectes notaeus*	2	unknown	2	3	2	1	2	**10**	high management concern and high impact concern
Brown anole	*Anolis sagrei*	5	urban and natural	2	1	2	2	1	**8**	low
Carpet python	*Morelia spilota*	2	unknown	1	3	2	1	1	**8**	unknown

Oustalet's chameleon	*Furcifer oustaleti*	5	agriculture	1	3	2	1	1	**8**	medium management concern, high (but unknown) impact concern
Boa constrictor	*Boa constrictor*	3	urban	1	2	2	1	1	**7**	low management concern, debatable impact concern
Caiman lizard	*Dracaena guianensis*		urban	1	3	1	1	1	**7**	unknown
Cane toad	*Rhinella marina*	5	urban	1	1	2	2	1	**7**	low
Cuban treefrog	*Osteopilus septentrionalis*	5	natural and urban	2	1	2	1	1	**7**	low management concern, but high impact concern
Green iguana	*Iguana iguana*	5	urban and some natural	2	2	1	1	1	**7**	high management concern
Greenhouse frog	*Eleutherodactylus planirostris*	5	natural and urban	2	1	2	1	1	**7**	low
Other monitors	*Varanus spp.*	2	urban	1	2	2	1	1	**7**	high management concern and high impact concern
Panther chameleon	*Furcifer pardalis*	2	urban	1	3	1	1	1	**7**	low
Red and gold tegus	*Tupinambis rufescens & teguixin*	2	urban	1	1	2	2	1	**7**	high management concern and high impact concern
Red-eared slider	*Trachemys scripta elegans*	5	natural and urban	2	1	1	2	1	**7**	low management concern, but high impact concern
Veiled chameleon	*Chamaeleo calyptratus*	4b	urban	1	3	1	1	1	**7**	low
African rainbow lizard	*Agama agama*	5	urban	1	2	1	1	1	**6**	low
Ball python	*Python regius*	2	urban	1	2	1	1	1	**6**	low management concern, low impact concern
House geckos	*Hemidactylus spp*	5	urban and natural	2	1	1	1	1	**6**	low

Rainbow whiptail	*Cnemidophorus lemniscatus*	4b	urban	1	2	1	1	1	**6**	low
Tokay gecko	*Gekko gecko*	5	urban and natural	2	1	1	1	1	**6**	low
Bloodsucker lizard	*Calotes versicolor*	4b	urban	1	1	1	1	1	**5**	low
Brown basilisk	*Basiliscus vittatus*	5	urban	1	1	1	1	1	**5**	low
Brown mabuya	*Eutropis multifasciata*	4b	urban	1	1	1	1	1	**5**	low
Butterfly lizard	*Leiolepis belliana*	3	urban	1	1	1	1	1	**5**	low
African clawed frog	*Xenopus laevis*	2		0	3	1	0	1	**5**	low for Florida
Curly-tailed lizard	*Leiocephalus spp.*	5	urban	1	1	1	1	1	**5**	low
Giant ameiva	*Ameiva amieva*	5	urban	1	1	1	1	1	**5**	low
Giant day gecko	*Phelsuma grandis*	5	urban	1	1	1	1	1	**5**	low
Giant whiptail	*Aspidoscelis motaguae*	4b	urban	1	1	1	1	1	**5**	low
Knight anole	*Anolis equestris*	5	urban	1	1	1	1	1	**5**	low
Wall geckos	*Tarentola spp*	3	urban	1	1	1	1	1	**5**	low