THE ROLE OF EARLY DETECTION AND RAPID RESPONSE IN THWARTING AMPHIBIAN AND REPTILE INTRODUCTIONS IN FLORIDA

TODD S. CAMPBELL, Department of Biology, University of Tampa, Tampa, Florida, USA

Abstract: Prevention is the best policy for dealing with introduced species. However, biologists often spend an inordinate amount of time studying their spread and impacts rather than focusing on what should be done to thwart their establishment in the first place. Amphibian and reptile introductions are reaching epidemic proportions in Florida, largely due to irresponsible behavior by pet owners and the pet industry, but also due to ineffective preventive policies and actions. Prevention of additional amphibian and reptile introductions in Florida will require a comprehensive approach involving legal restrictions of certain problematic species, a massive public education effort, and a well-funded and staffed Early Detection and Rapid Response (EDRR) program. EDRR is not a novel concept, but it needs to be newly applied to amphibian and reptile introductions where pathways are firmly established and propagule pressure is intense. An effective EDRR program in Florida will require (1) significant funding and political will, (2) a comprehensive stakeholder education and public outreach program, (3) a vast network of expert early detectors, (4) a team of talented rapid responders, and (5) rigorous post-project assessment. Knowledge gained from such a program in Florida could easily be extended to other taxonomic groups and locations.

Key Words: amphibian, early detection, eradication, Florida, introduced, invasive species, prevention, rapid response, reptile.

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INTRODUCTION

Introduced species are a form of biological pollution; however, they represent a problem for which dilution is not a solution. Unlike most chemical pollutants, introduced species often become established long before their presence is known, and they also may expand exponentially, resulting in a problem that worsens over time. Once they are firmly established, the range of options for dealing with non-indigenous species changes considerably (Simberloff et al. 2005). As a result, prevention is widely considered the most effective, efficient, and economically viable policy for dealing with introduced species (Pimentel 2002).

Effective prevention requires a multifaceted approach, including (1) legal restrictions on the import, breeding, ownership, and sale of problematic species, (2) quarantine of illegally imported problematic species, (3) effective public education about introduced species problems, (4) early detection of incipient populations, (5) swift, decisive action to eradicate incipient populations, and (6) risk assessments for potential future invaders. Specific protocols for dealing with many introduced species in the early stages of their establishment are surprisingly underdeveloped (Myers et al. 2000), especially when multiple populations and import pathways are involved (Lockwood et al. 2007). This is particularly true for amphibian and reptile introductions, which have reached epidemic proportions in Florida due to irresponsible behavior by the pet industry and their customers, delays in reporting and lack of follow-up by scientists in the field, and ineffective governmental policies and actions for preventing new introductions. In this paper, I will (1) summarize the extent of the problem, (2) identify some of the roadblocks that prevent us from finding solutions, and (3) provide a framework for an Early Detection and Rapid Response (EDRR) program that could help thwart the establishment of additional non-native amphibians and reptiles in Florida and beyond.

WELCOME TO FLORIDA!

Florida's sub-tropical climate makes it an ideal place for the establishment of non-native amphibians and reptiles from all over the world. The Sunshine State is also a haven for the amphibian and reptile pet industry, private herpetoculturists, and pet owners, many of which

house their pets in outside cages and open enclosures. While hurricanes and careless import and husbandry practices result in some accidental releases, well-intentioned pet owners often release unwanted pets into suitable habitats, and unethical breeders may release multiple individuals in order to establish new populations as a future source of animals. As a result, Florida is one of the most invaded places on Earth.

Along with over 2,000 introduced pathogens, plants, invertebrates, fish, birds, and mammals (Simberloff et al. 1997), at least three amphibians and over 40 reptiles are now established in Florida (Meshaka et al. 2004). Notorious species include the cane toad (*Bufo marinus*), Cuban treefrog (*Osteopilus septentrionalis*), Cuban brown anole (*Anolis sagrei*), green iguana (*Iguana iguana*), Mexican spiny-tailed iguana (*Ctenosaura similis*), Nile monitor (*Varanus niloticus*), and Burmese python (*Python molurus*). In fact, there are now more non-native lizards established in south Florida than there are native lizards in the entire southeastern United States (US), and whole assemblages of non-native lizards (anoles, geckos, iguanids, and teiids) can be observed at some locations (e.g., most botanical gardens in Miami). With so many introduced amphibians and reptiles using mainly introduced plants as habitat and consuming mainly introduced plants, arthropods, and vertebrates, Florida is a grand example of invasional meltdown (Simberloff and Von Holle 1999). How did we get to this point?

NERO IS FIDDLING WHILE FLORIDA IS BURNING

The first introduced amphibians and reptiles (IAR) arrived in Florida over a century ago, and early publications on the herpetofauna of Florida contained information about 7 established species (Carr 1940, Carr and Goin 1955, Duellman and Schwartz 1958). King and Krakauer (1966) wrote the first comprehensive summary of the problem, identified the pathways and potential impacts of 13 species (10 lizards and 3 anurans), issued a stern warning that the native fauna would suffer if introductions continued, and even called for preventative measures. Twelve years later, Smith and Kohler (1978) discussed the IAR problem throughout the US and for 16 species in Florida. By the early 1980s, Floridians had anecdotal evidence their native green anole (*Anolis carolinensis*) was being replaced by the Cuban brown anole in urban and residential areas (Campbell 2000). Wilson and Porras (1983) included detailed accounts of newly established species and lengthy discussions of potential impacts, but underplayed the impacts of IARs relative to habitat alteration. Moreover, they argued that eradication was not morally defensible, and even suggested that Floridians should accept them as part of a new urban herpetofauna (their emphasis), utilize them for biological materials, establish a quota system for their harvest, document their arrival, and conduct more research on their impacts and competitive effects, rather than develop prevention, eradication, or management plans.

By the 1990s, hundreds of new distribution records and natural history notes documenting new IARs and numerous studies revealing impacts of established species were published in Herpetological Review and other peer-reviewed journals. Meanwhile, the popularity of amphibians and reptiles as pets increased rapidly due to advances in medicine and husbandry techniques and heavy promotion by the pet industry and private breeders, and the number of introductions accelerated. Dalrymple (1994) revealed the extent of the growing IAR problem on public lands in south Florida, and Butterfield et al. (1997) summarized the overall problem in detail, but like Wilson and Porras (1983), they touted IARs as merely a symptom of habitat alteration, and even predicted that IARs would not invade or negatively affect native species or natural habitats in Florida.

Unfortunately, the erroneous perception that IARs in Florida were either benign or would only colonize and affect human-altered landscapes was repeated so often that it became common knowledge. Certainly, one would expect invasions to be more common in areas populated by humans, but it was probably reckless to assume, without supporting data, that no IARs of any consequence would expand beyond human habitation or affect native species. There was even a general reluctance to view the establishment of small, abundant species (e.g., *Anolis*) as potentially problematic (Butterfield et al. 1997), despite the extraordinary densities and biomass of the brown anole (Campbell and Echternacht 2003), the near complete replacement of the green anole in urban areas despite its long association with even the most urban landscapes (Campbell 2000), and its dramatic effects on Bahamian food webs (Schoener and Spiller 1999). Decades of peer-reviewed and popular publications about IARs in Florida merely instigated more basic studies of their distribution,

abundance, impacts, and evolution, rather than steer biologists towards applied questions such as prevention, eradication, or management.

To-date, no established IAR species has ever been eradicated from Florida. In fact, only 6 IARs have been the subject of organized eradication or management efforts of any kind. Burmese pythons have spread widely in the Everglades, but biological studies and trapping efforts have only just begun (S. Snow, personal communication). Argentine tegu lizards (*Tupinambis rufipunctatus*) are established near Tampa, but their impacts are unknown, and preliminary trapping efforts have been unsuccessful to-date (B. Kaiser, personal communication). Green iguanas are abundant throughout south Florida, and localized trapping and management efforts have not measurably reduced iguana populations (Krysko et al. 2007). Mexican spiny-tailed iguanas are a serious problem on the beaches of Gasparilla Island (Krysko et al. 2003), and the County government instigated a massive trapping effort, bounties, and even an "iguana tax", but the effort is on-going and thousands of lizards remain. Nile monitor lizards are widespread and problematic in Cape Coral (Enge et al. 2004) and results from a preliminary trapping study and eradication effort are encouraging (Campbell 2005), but thousands of lizards remain, the population is rapidly expanding into natural areas, and new populations have been discovered elsewhere. Finally, results from two assessments of the utility of PVC pipe refugia in reducing Cuban treefrog populations (Rice et al. 2003, T. Campbell, unpublished data) are encouraging, but in terms of the operational viability of managing this widespread, abundant species using PVC pipe refugia in natural areas, the jury is still out. Ultimately, all six of these species were firmly established when management efforts began, and none of these efforts have received the level of funding, agency attention, or political support that would ensure success.

In summary, agency, industry, and academic biologists have known about the worsening IAR problem in Florida for over 6 decades, but the warnings issued every decade since 1940 were muted and have gone largely unheeded. Until the recent arrival of a few large predatory species, IARs were simply not seen as a problem worth our attention beyond basic biological and population studies. Indeed, there is a limit beyond which further biological studies of an introduced species do not assist in its eradication (Simberloff 2003). Given decades of complacency and misdirected research, it is no surprise that a recent comprehensive summary of the IAR problem in Florida (Meshaka et al. 2004) required a bound volume and painted a very dreary picture. As invasional meltdown proceeds in Florida, biologists are beginning to understand that the Emperor has no clothes; that IARs of all taxa and sizes potentially represent significant threats to the native species that nature preserves were designed to protect, and that future invasions should be thwarted whenever possible. But how might this be accomplished?

EARLY DETECTION AND RAPID RESPONSE: A PARTIAL SOLUTION

Despite our best intentions, prevention efforts will never thwart all introductions. Aggressive, coordinated intervention is often necessary to prevent incipient populations from spreading beyond the point where eradication is economically and logistically feasible (National Invasive Species Council 2001, 2003). This is where Early Detection and Rapid Response (EDRR) comes into play. Success of an intervention depends on the speed and veracity of the response, which is in turn dependent on coordination of stakeholders. Effective EDRR requires careful coordination of two separate but interrelated phases. Early Detection (ED) reveals the extent of the problem and assesses the potential for a rapid and successful eradication. Early detection and reporting is critical given the speed with which many IAR populations expand numerically and spatially. Rapid Response (RR) is a carefully planned, decisive action designed to eradicate the incipient population. Together, these efforts ultimately serve to prevent an incipient population from expanding beyond the point where it can be eradicated quickly and efficiently (National Invasive Species Council 2001, 2003). However, EDRR is not a long-term management or control strategy. If an EDRR effort is unsuccessful, the response team should provide information to another group of managers for long-term management or control and quickly move on to the next incipient species.

There is no need to reinvent the wheel when designing an EDRR program for IARs in Florida. A plethora of EDRR programs, networks, and initiatives have been mandated or established for many taxa at the international, federal, regional, state, and local levels all over the world. These templates could be easily altered to fit the special problems of IARs and unique operational issues in

Florida. I review a sample of government reports, peer-reviewed publications, and web sites that describe EDRR efforts in the US, critique their efficacy, and make suggestions for improvements. A much more detailed, but potentially dated, review of these programs is provided in Worrall (2002), and important documents are available at www.invasivespecies.gov.

Starting primarily with the Lacey Act in 1900, the US has a long history of introduced species prevention, eradication, and management. Over 20 federal agencies have at least some responsibilities for introduced species management (General Accounting Office 2001). However, the need for a national system for detecting, responding to, and monitoring incipient populations has only recently been realized. Executive Order 13112, issued by President Clinton in 1999, requires federal agencies to detect and respond to incipient populations in a cost-effective manner. The National Invasive Species Council (NISC) generated a National Invasive Species Management Plan with specific recommendations for EDRR in the US (NISC 2001). Still, the obstacles hindering rapid response efforts at the federal level are extensive (General Accounting Office 2001). Rapid response to introduced agricultural pests is often intense and effective, but the response to invasive species in natural areas has been minimal (General Accounting Office 2001). In FY 2000, nearly $150 million was spent on RR efforts in the US. Over 90 percent of these funds was spent on species that affect agricultural and silvicultural species and pests of native trees, and for a number of aquatic nuisance species, but no amphibians, and only one reptile, the brown treesnake (*Boiga irregularis*, BTS), appears on the list. Although agricultural and food pests have been a high priority for good reason, a more balanced approach is now clearly warranted.

The Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) published a conceptual design for a national EDRR system for introduced plants in the US (NISC 2003). This document was the result of 5 years of planning with extensive agency, industry, and public input. Although the proposed EDRR System is specific to plants, it has vast applicability to IARs in Florida. They elaborate on 5 specific EDRR System elements: detection and reporting, identification and vouchering, rapid assessment, planning, and rapid response (including post-response assessment). They also provide a framework for coordination, support, oversight, information management, stakeholder involvement, and outreach, and identify the resources that are needed to establish their proposed system.

The Aquatic Nuisance Species (ANS) Task Force is an interagency committee charged with developing and implementing a program to prevent the introduction and dispersal of non-native aquatic species in waters of the United States (Parker and Keeney 2004). The ANS Program document and ANS Strategic Plan include a number of prevention strategies and established 5 committees with species-specific Working Groups. The Communication, Education, and Outreach Committee approaches this problem from the perspective that aquatic introduced species are not readily observed, thus, their negative effects are not realized until their populations are firmly established. This is also true for IARs in Florida. Also, the ANS Task Force Control Committee is one of the agencies charged with controlling the BTS in Guam and other areas where it has been introduced, and preventing its introduction to the North American mainland (Parker and Keeney 2004). Thus, the ANS Task Force already has experience dealing with at least one terrestrial reptile from an EDRR perspective.

The ANS Task Force is also charged with educating the public about the problems of introduced species and empowering people to actively prevent their establishment; both essential elements of a successful EDRR program. The ANS Task Force's Stop Aquatic Hitchhikers!™ campaign has a vast infrastructure of partner organizations and a consistent educational message that is broadcast in many different formats (Parker and Keeney 2004). The ANS Task Force's Habitatitude™ campaign (www.habitatitude.net) recruits the aquarium and aquaculture industry, governmental agencies, and academia to proactively educate aquarists and consumers of ornamental aquatic plants about the risks and negative effects of aquatic introduced species, and provide alternatives for releasing unwanted species into the wild (Parker and Keeney 2004). The Habitatitude™ campaign has more recently incorporated IARs into their message, and has been proactive in working with agencies, industry, academia, reptile wholesalers and breeders, and private herpetoculturists in Florida. The educational and outreach components of these programs mainly address prevention of releases, but will be essential for the establishment of an effective EDRR program for IARs in Florida.

In Florida, many iterations of EDRR have long been practiced by exotic plant and agricultural pest managers, but this concept was rarely mentioned as an operational strategy in a comprehensive volume published only a decade ago (Simberloff et al. 1997). In fact, while 9 state agencies are responsible for prevention and management of invasive non-native species, only 3 have regulatory authority (NISC 2003), there is no interagency coordination mechanism for prevention or management (NISC 2003), and there is no state agency charged with the operational aspects of non-indigenous wildlife management (Ferriter et al. 2006). However, recent developments are encouraging.

Florida's Invasive Species Working Group (ISWG), formed in 2001 by personnel from a number of agencies, included rapid response as an action item in their Statewide Strategic Plan for Florida (ISWG 2003). They committed to recommending RR procedures and improved coordination with federal and local agencies. In 2004, the Florida Invasive Animal Task Team (FIATT) was formed by the South Florida Ecosystem Restoration Task Force to deal with introduced species issues affecting the Comprehensive Everglades Restoration Project (CERP). They generated species list for each taxon from which priorities can be set by triage. On a positive note, 2 mammal invasions may have been recently thwarted by effective EDRR programs (R. Engeman and B. Constantine, personal communication). These kinds of successes will be extremely valuable for generating funding for EDRR efforts in Florida (L. Williams, personal communication).

Despite the vast number of vertebrate EDRR programs in place worldwide, very few have been initiated for IARs. Much can be learned from the rich literature on the well-funded, multi-agency efforts to eradicate the BTS from Guam and thwart its spread to other South Pacific islands, Hawaii, and beyond (Rodda et al. 1999, Parker and Keeney 2004). Efforts to control the Puerto Rican coqui frog (*Eleutherodactylus coqui*) in Hawaii resemble EDRR on a local scale, but this species spread beyond EDRR due to a lack of funding, governmental delays, and disbelief in the problem (Kraus and Campbell 2002). In Florida, despite decades of warnings and the rapid accumulation of nearly 50 IARs, only a handful of management programs have been initiated, and all were clearly well beyond EDRR, but much can be learned from those efforts.

Stakeholder involvement and coordination efforts involving EDRR have gained momentum in Florida in recent years. Prevention and management was featured during the "Introduced Amphibians and Reptiles: From Case Studies to Solutions" Symposium at the 2005 Joint Meeting of Ichthyologists and Herpetologists in Tampa, Florida. Specific strategies were developed by the Early Detection and Rapid Response Working Group at the 2005 Invasive Snake/Reptile Management and Response Workshop in West Palm Beach, Florida. Pet industry and Habitatitude! representatives, agency personnel, legislators, managers, academics, herpetoculturists, and other stakeholders gathered at the 2006 All-Florida Herpetology Conference in Gainesville, Florida, to discuss EDRR and pending legislation restricting ownership of large reptiles. Soon after, I vetted these ideas at a Central Florida Herpetological Society meeting, and received mostly positive feedback. Recent meetings of the ISWG and FIATT featured specific discussions about potential EDRR program funding, staffing, and infrastructure. Many of the key participants of the above meetings and workshops continue to place EDRR high on their priority list and are working hard to generate interest and obtain funding.

AN EDRR PROGRAM PROPOSAL FOR INTRODUCED HERPS IN FLORIDA

Detection, assessment, and response are generally viewed as the minimum components of any successful EDRR program (NISC 2003). I propose that an effective EDRR Program for IARs in Florida will require (1) significant political will, long-term funding, and governmental agency infrastructure, (2) a comprehensive stakeholder education and public outreach program, (3) a network of informed early detectors, (4) a team of talented rapid responders, and (5) rigorous post-project assessment.

Political Will, Long-Term Funding, and Infrastructure

Stakeholders should be responsible for generating the motivation and political will to implement such a program. This will require frequent interactions with legislators and agency personnel and a massive public education campaign. Because the EDRR task at hand is immense and potentially never-ending, it will require significant funding, in perpetuity.

Government agencies generally have experience with the operational aspects of pest management and have the funding and required tools. Thus, I believe the funding and infrastructure for an EDRR program should be established by a collaborative group of federal and state agencies, such as the ANS Task Force, ISWG, Florida Fish and Wildlife Conservation Commission (FWCC), Florida Department of Environmental Protection (FDEP), and FIATT.

Once the political will is generated, it will be up to the agencies to determine how to obtain funds, set up the infrastructure, and partition the workload. Funds should be used to establish an infrastructure that includes at least (1) a dedicated 1-800 phone number, (2) an informative, interactive web site, (3) a centralized information repository, (4) a network of early detectors and taxonomic experts, and (5) a team of rapid responders. However, this infrastructure will only be effective if it is linked directly to an aggressive education and outreach campaign.

Stakeholder Education and Outreach

An effective education and outreach campaign is critical to the success of any EDRR program. Examples of proactive strategies with eye-catching, positive messages include the ANS Stop Aquatic Hitchhikers! and Habitatitude campaigns, the BTS campaign (N. Hawley and C. Martin, personal communication), the Burmese python campaign (S. Snow, personal communication) and Hawaiian Ecosystem At Risk (HEAR) project. This paper is not intended to discuss the creation and administration of introduced species education campaigns in general. Rather, with regards to EDRR, results from these programs suggest stakeholders must (1) understand the problem and have a reason to care, (2) know that an EDRR program exists and is worth using, (3) have at least a rudimentary knowledge of which species are native and which are introduced, and (4) know who to contact to report a sighting or capture of something they cannot identify.

The first line of defense against the establishment of new herpetiles will be information and images provided by informed observers and early detectors, including the public (e.g., hikers, birders, photographers), professional field biologists (e.g., agency, NGO, and industry biologists), and academic biologists. However, not everyone can be expected to correctly identify an amphibian or reptile they have not seen before. They may only believe it to be somehow different than anything they have ever seen. Most often, the observer will only be able to manage a vague description of the critter (e.g., "a big, dark, stripped lizard walking across my yard"). On balance, the proliferation of cell phone cameras may benefit our cause, but in my experience the images usually resemble the Sasquatch on the National Enquirer. It will be up to the experts to filter out the noise.

To accurately identify non-native species, stakeholders and experts must have access to information about native and introduced species. Meshaka et al. (2004) is the most recent comprehensive source for identification and known localities of existing IARs in Florida, but despite their Herculean effort, it was out of date by the time it was published. Rapid senescence will be a problem for any information source published on paper. Bio-profiles (K. Enge, personal communication) made available in electronic format on-line are a powerful way to disseminate information, and may even result in published manuscripts (Enge et al. 2004). It might be more helpful to establish a centralized repository of information about the native and introduced amphibians and reptiles in Florida (e.g., the current FWCC web site). Ideally, the repository would also include information about popular pets that might escape or be released. In any event, a team of herpetologists should be available to verify the accuracy of sightings by the public.

For EDRR to work, informed observers, early detectors, and the general public must either know or be able to easily determine how to use the infrastructure to report a sighting. First, a toll-free phone line should be established for reporting sightings, and this phone line should have a live operator recording information and routing calls or an automated message system that is checked regularly. Phone contact information should be routed to the appropriate entities which the public is most likely to contact, including federal agencies, state agencies, and all county-level animal control and law enforcement agencies.

More importantly, the public should be able to easily find out how to report a sighting using an Internet search engine. Search results should take the observer directly to a central web site established specifically for this effort. A talented web writer will be able to insert a series of "meta tags" that will help to bring the Amphibian and Reptile Rapid Response Group (ARRRG) site to the top of the list of search results. The site itself should be very user-friendly in order to minimize frustration by less Internet-savvy users. It should

not only provide key EDRR team member contact information (e-mail and phone numbers), it should enable observers to directly enter their sightings and submit images using an on-line observation form, and those submissions should be reviewed on a regular basis. This web site should be mounted on a state-level server (e.g., FWCC) to ensure stability.

The media, which includes newspaper, magazines, television, Internet, and radio, can be a very powerful tool for education and outreach when used properly. I utilized local newspapers and television with much success to inform the public about Nile monitor lizards in Cape Coral and generate sightings (Campbell 2005). The fact that the story reached many media outlets beyond Cape Coral was an unintended, but largely beneficial consequence. Of course, there are many down-sides to the active use of the media in science; however, the benefits will generally outweigh the costs. We should not expect the general public to be experts. Rather, we should empower them to learn which species are non-native and problematic, and give them the means to contact the experts that are trained to deal with those species.

The Amphibian and Reptile Rapid Response Group (ARRRG)

A network of early detectors, taxonomical experts, and rapid responders will be required to thwart the establishment of incipient populations of IARs in Florida and beyond. Although the ISWG already has their FIATT, that team is specific to the South Florida region, is administered by CERP, and deals with any invasive animal taxa. I propose the establishment of the ARRRG, a team that works specifically on IARs. With its pirate connotations, this acronym has a high probability of being remembered by stakeholders, an important aspect of any outreach program (N. Hawley, C. Martin, and D. Vice, personal communication). Although the ARRRG would initially be specific to Florida issues, Florida was left out of the team name because I envision this group will eventually work nationwide.

The ARRRG should be composed of a network of individuals ranging in taxonomic and conceptual expertise from expert laypersons (hobbyists) to professional biologists. Professionally, the ARRRG should be populated by relevant personnel from government agencies, non-governmental organizations, academia, and industry, as well as the public. University of Florida Institute for Food and Agricultural Sciences (UF-IFAS) Extension Offices are present in nearly every county in Florida, already deal with exotic plant issues, possess the infrastructure to coordinate and share information among stakeholders, and directly involve the public in many activities and courses, so could play an important role in the IAR-EDRR Program (S. Johnson, personal communication).

To increase efficiency, the ARRRG should be partitioned into overlapping functional groups including early detectors, taxonomic experts, and rapid responders. Early detectors are the informed observers at the front lines of the EDRR effort. They must have their eyes and ears continually trained on the field, must possess just enough background in natural history and taxonomy to quickly detect the arrival of a non-native species, must be able to photograph, capture, or otherwise document their observations, and must know exactly how to report their observations. Suitable spatial coverage is important for early detection, so informed observers must be present in higher densities at locations where pathways are established (e.g., near ports, wholesalers, and breeding operations), but should also be present in more remote areas. Early detectors might include agency, NGO, industry, and academic biologists, bird watchers, fishing guides, landscapers, fire fighters, or anyone that regularly works outside. Given the establishment of an effective education and outreach program, the general public may even serve as part of this network.

Once a novel species is detected and either photographed or captured, taxonomic experts from agencies, natural history museums, academia, or the pet industry should be recruited to verify the early detectors' identification before proceeding with a response. Ideally, these experts would have the knowledge or access to pertinent literature to generate a brief synopsis of the problem, including the potential for establishment, numerical expansion, spatial spread, and feasibility of eradication of the incipient population. The synopsis could range in style from a simple e-mail to a formal agency report, bio-profile, or draft manuscript for publication. Most importantly, this information should be immediately disseminated to a team of biologists that stand ready to quickly assess the problem and formulate a rapid response plan.

The rapid response team should be responsible for operational aspects, including finding the population, assessing the magnitude of the problem, and attempting to capture, trap, or otherwise quickly eradicate the incipient population. The

time it takes to complete these tasks will depend on many biological characteristics of the pest species, including the population size, fecundity, behaviors and activity periods, movements, and ease of capture and handling. Hundreds of specific rapid response protocols and manuals have been developed for many species worldwide. Short-term evaluation and monitoring by the team will help to ensure that time is not wasted on a population that has spread beyond rapid response capabilities.

The funding required to manage or eradicate all the new IARs in Florida would be economically and politically prohibitive. In fact, the “tens” rule dictates that we do not need to thwart all invasions (Williamson 1996). Instead, we must develop a system to prioritize which species to eradicate in the face of limited funding. In prioritizing which introduced species to eradicate or manage, there is a stark contrast between small insectivores (e.g., anoles) and large conspicuous predators (boas, pythons, monitors, and other "charismatic megafauna") when determining which species will get attention and funding. In the past, Florida has mainly suffered introductions of small, seemingly insignificant species (e.g., small lizards). Small species such as the brown anole are often extremely abundant (Campbell and Echternacht 2003). Eradication of these species would be nearly impossible once firmly established, and any good cost-benefit analysis would contraindicate eradication unless it could be done very early in the invasion or involves small, isolated populations (T. Campbell, unpublished data). However, the playbook has changed dramatically with the establishment of large herbivores, omnivores, and carnivores. Because large introduced predators often inflict significant direct impacts on native species, the urgency to prevent their establishment is dire, and justification for their eradication is almost incalculable.

Species identity also matters, in that charismatic megafauna will generate very different responses, and some of the large, sexy species are more equal than others. For instance, people tend to like herbivorous green iguanas much more than carnivorous Nile monitors, and often defend iguanas vigorously; however, even their opinions about green iguanas changed when they became pests (Krysko et al. 2007). Location also matters, in that species in residential areas or expensive waterfront property (e.g., iguanas on Gasparilla Island) will get more attention and funding. It is also more difficult to educate the public, and have eyes on the situation, in rural areas (Argentine tegus in rural Tampa versus Nile monitors in residential Cape Coral). Responders must take these things into account when mounting an eradication attempt.

Finally, Rapid Response efforts should be defined as, and confined to, those species that can be eliminated in a short period of time, hopefully before successful breeding occurs. Initially, the new population is influenced by the Allee effect, where individuals occur at such low densities that they never or rarely find each other, and the population grows very slowly. This lag phase occurs before the rapid exponential or geometric growth phase, and is the best time to mount a rapid response effort from economical and logistical standpoints. A good threshold for Rapid Response may be to determine whether or not the population could be eradicated quickly (days or weeks) or will require a major effort (months or years).

Post-Project Evaluation and Reporting

Post-project assessment is critical to the success of any EDRR program (ISWG 2003). It is up to the entity administering the EDRR program to set a priori guidelines for program review. Program administrators must periodically assess the IAR-EDRR program in general and individual response efforts in particular. For instance, proper data collection and analysis will be required to index or estimate the size of an incipient population being diminished by trapping (Engeman 2005). Without such analyses, it will be difficult if not impossible to demonstrate whether or not RR efforts had any effect. Sufficient post-project assessment will provide accountability and generate a roadmap for improvement of future EDRR efforts.

A Hopeful Case Study

I recently embarked on a pilot EDRR program to keep Nile monitors from becoming established on Sanibel Island, a barrier island less than 10 km from the core Nile monitor population in Cape Coral. Sanibel Island is home to the J. N. Ding Darling National Wildlife Refuge, one of Florida's most important bird sanctuaries. The propagule pressure from Cape Coral is intense, a few Nile monitors have been observed on the island, and concern is mounting. I am currently working with the USFWS (W. Thomas, personal communication), the City of Sanibel (J. Zimomra, personal communication), and the Sanibel-Captiva Conservation Foundation (B. Smith, personal communication) to determine the extent of the problem and formulate an EDRR protocol to keep

the lizards from becoming established on the island. Hopefully, their program will be successful in thwarting the establishment of this species, will serve as a model for a larger EDRR program in Florida, and will even instill a bit of badly needed encouragement that we have the political will, funding, and expertise to thwart the establishment of the most devastating IARs in Florida.

CONCLUSION

The extinction of the passenger pigeon (*Ectopistes migratorius*) shows that Americans can accomplish extraordinary eradication feats when they put their minds to it. In the face of limited resources, managers must carefully choose which species could and should be eradicated and which species are destined for management in perpetuity. While massive eradication efforts will be required to eliminate certain firmly established species, and management in perpetuity will be necessary for others with no hope of being eradicated, prevention is the only viable mechanism for stemming the tide of newly introduced amphibians and reptiles in Florida. What will it take to prevent additional non-native amphibians and reptiles from becoming established in Florida?

First, our attitude about IARs is important. The main solution is to stop studying them in such great detail (Simberloff 2003) and start (1) preventing them from becoming established, (2) eradicating recently established species before it becomes logistically and economically prohibitive, and (3) developing management tools to ameliorate the effects of species that cannot be eradicated. Although the “tens” rule predicts that few of those species that become established go on to be pests (Williamson 1996), we cannot yet predict their impacts in the future, so introduced species should be considered guilty until proven innocent (Van Driesche and Van Driesche 2001). EDRR is a logical extension of the GUPI philosophy in that we should eradicate first and ask questions later.

The most effective preventive policy will include a combination of multiple strategies. First, legislation restricting ownership and sale of certain problematic species is warranted. The first steps have already been taken, in the form of a law restricting sale and requiring a permit for ownership of certain large reptiles which goes into effect on January 1, 2008. Sufficient regulations of the pet industry, education of the public, and incentives for good behavior will be crucial. An example is the recently established Pet Amnesty Day, where pet owners are able to donate unwanted pets, for free and with no questions asked, in the hopes they will be adopted instead of released into the wild (S. Hardin, personal communication).

Given the new regulations, we must assume that some pet owners will avoid fees and regulations and simply release their pet into the wild. Others will arrive accidentally. Considering the myriad unrestricted pathways currently in place, the intense propagule pressure from the pet industry, the high fecundity of many amphibians and reptiles, and the excessive cost of dealing with them after they become established, an effective EDRR program will be necessary to thwart the establishment of incipient IAR populations in Florida and beyond. Such a program has applicability to species of invertebrates, fish, birds, and mammals that are popular in the pet trade. However, EDRR is but one element of a comprehensive prevention program.

Beyond EDRR, stakeholders must work proactively with the pet industry, herpetoculturists, and hobbyists to identify species that might become established in the future. Risk assessments based on which species are most popular and which species would be most likely to thrive in Florida's habitats and climate (using climate matching and GAP analysis) will enable specialists to predict the next problematic species.

Interest in establishing an EDRR program for IARs in Florida is gathering steam. Now we should determine who will fund and implement such a program in Florida and beyond, obtain funding, and hit the ground running. I hope this paper provides a solid foundation on which an effective EDRR program can be built.

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