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CHALLENGES OF INVASIVE REPTILES AND AMPHIBIANS

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Abstract: Although worldwide distributions of many amphibians and reptiles are declining, a handful of species are spreading rapidly throughout tropical regions of the world. The species that have the greatest effect tend to be generalist feeders, have high reproductive rates, attain large population sizes, and often due to their behavior and or small size, are easily transported or are difficult to detect. The most notable of these species include the coqui frog, cane toad, bullfrog, brown tree snake, and Burmese pythons. The effect of a few individuals typically is small but the combined effect of large populations can be devastating to ecological communities and agriculture. Currently, there are few methods available to effectively remove established populations. However, invasive species management capabilities are developing, with more effective methods in detecting incipient populations, improved control methods, more stringent restrictions on movement of nonnative animals, and increased public support.

Key words: amphibians, brown tree snake, bullfrog, Burmese pythons, cane toad, coqui frog, invasive species, reptiles

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INTRODUCTION

In the last 20 years, worldwide declines of many amphibian and reptiles have been well documented. At the same time, a growing number of species have invaded new habitats and have reached population levels that have had negative consequences on native flora and fauna, agriculture, and local economies (Mooney and Hobbs 2000). Five of the 24 vertebrate species listed as the worst invasive species are amphibians and reptiles (Lowe et al. 2004). Invasive amphibians and reptiles generally have a high reproductive rate, which facilitates rapid population growth and recovery from stochastic events. They have generalized diets that effectively utilize locally abundant resources. Typically, successful invaders are small or secretive, which allows undetected

movement in transportation networks. These cryptic behaviors also allow the development of incipient populations that are difficult to detect until the animal is well established. Species that exhibit all of these attributes tend to be most successful at colonizing new environments .

The probability of a successful invasion is also dependent on the qualities of the ecosystem invaded (Simberloff and Von Holle 1999). Beyond a suitable climate and habitat, ecosystems with a limited assemblage of resident species have fewer potential competitors and predators and, therefore, enhanced probability of successful colonization. Lastly, as the frequency of invasion events by a species increases, the likelihood that the species will successfully establish increases. Insular areas are

generally more susceptible than mainland areas, as islands support few predators or competitors, often receive heavy air and sea traffic, and typically provide a favorable climate for many potentially invasive species (Elton 1958, Simberloff 1995). Currently, 33 non-native amphibians and reptiles have been established in Hawaii and more species continue to arrive (M. Wilkinson, Hawaii Department of Land and Natural Resources, personal communication). For example, six snake species have been intercepted in transportation networks in the Pacific and at least six species of frogs have established populations in Guam in the past three years (D. Vice, personal communication). While the mechanism for arrival differs among locales and species, the rapid and expanding colonization of invasive reptiles and amphibians is affecting ecological and economic systems worldwide.

The pathways that transport invasive species are varied and likely increasing. Rapid increases in global transportation networks move people and commodities to previously remote destinations, increasing the homogeneity of global floral and faunal communities (Mack et al. 2000). Generally, species are either accidentally or intentionally transported. Accidental movements include stowaways in air and sea cargo, shipping containers that hold cargo, or vessels that move people and commodities (e.g., brown treesnake), hitchhikers on agricultural products (e.g., coqui frogs, geckos, blind snakes) and pet escapes (e.g., pythons and Jackson chameleons). Intentional releases include those that were intended to provide food for people (e.g., bullfrogs and turtles), to combat other species (e.g., cane toads and poison dart frogs), or for aesthetic reasons (e.g., veiled chameleons). Although many intentional releases are altruistic in intent, some are for insidious or financial reasons.

Species smuggled and released for the pet trade are increasing threats, especially in tropical environments and difficult to prevent as border security measures and the realignment of customs inspections are not focused on invasive species.

HIGHLIGHTED SPECIES

Several species have become widely publicized for their overall effect as invasive species or as successful invaders in multiple regions. To understand the effects of invasive amphibians and reptiles and potential problems with control efforts, we provide a brief summary of several noteworthy species. Further, we provide a brief discussion regarding the social, biological, and political complexity of the invasive species issue.

Coqui Frogs

The coqui frog (*Eleutherodactylus coqui*) was introduced into Hawaii during 1988-1995, likely from infested plant shipments from Puerto Rico (Kraus et al. 1999). Sizeable populations are now found on the islands of Hawaii, Maui, Oahu, and Kauai. The super-abundant terrestrial frog threatens Hawaii's multi-million dollar floriculture, nursery, real estate, and tourist industries, as well as its unique ecological systems (Beard and Pitt 2005). Effects from the coqui are predominantly associated with the frog's piercing call (80-90 dBA at 0.5 m) and the extremely high population densities that have exceeded 50,000 individuals ha in Hawaii. Beyond the noise nuisance, the loud nighttime choruses of male frogs has affected real estate values, as people desire coqui free property (A. Hara, University of Hawaii, unpubl. data). The floriculture industry may also be affected through the refusal of export shipments, reduced sales, and increased costs associated with control and quarantine efforts. Further, the frogs may affect native insect populations, forest

nutrients, compete with native birds and bats, and alter ecosystem processes (Beard and Pitt 2005). Due to the high densities of frogs and their present range, few options exist for control of wild populations. Mechanical controls include hand capturing, habitat alteration, and trapping. These methods have limited effectiveness, as the logistic constraints in applying across a large, complex environment with heavy frog populations preclude large-scale application. Some success has been documented using hot water treatments for quarantine efforts in ornamental plant shipments (M. Wilkinson, pers. comm.). Biological control or the release of organisms to combat the frog likely will have little success and could have many unintended consequences. Unfortunately, disease organisms have a low potential for controlling coqui frogs in Hawaii, primarily because viruses and diseases are most effective when applied to small populations of species with low reproductive capacity (Brauer and Castillo-Chavez 2001, Daszak et al. 2003). In large populations, diseases may induce temporary population declines, but surviving individuals may develop resistance, resulting in population levels similar to those pre-treatment. As most of the major frog diseases infect tadpole stages (Daszak et al. 2003), coqui, which develop directly into tiny frogs inside terrestrially-deposited eggs, are less likely to be affected by disease organisms. Although many frogs are quite susceptible to a variety of chemicals, the terrestrial coqui frog has been unaffected by a wide range of potential pesticides. Currently, only citric acid and hydrated lime have proven to be effective and registered for use to combat the frogs (Pitt and Sin 2004a, Pitt and Doratt 2005). Although these chemicals are effective if sprayed directly on the frogs, there are limitations with these products, including varying efficacy affected by weather conditions,

potential phytotoxicity to plants, high costs associated with repetitive spraying of large areas, access to remote or private land, and other factors (Pitt and Sin 2004b).

Burmese Pythons

Burmese pythons (*Python molurus bivittatus*) became established in Everglades National Park during the 1990s as the result of unwanted or accidentally released pets (S. Snow, National Park Service, pers. comm.). Burmese pythons, native to Southeast Asia, are large snakes (>7 m) with high reproductive rates and are common pets in the United States (Pough et al. 1998). Pythons may compete with native snake species, prey on many native mammals and birds, transmit disease to native reptiles, and disturb visitors due to their large size. The number of snakes removed has quickly increased in recent years and may represent a rapidly increasing population (S. Snow, unpubl. data.). Sources of mortality for the snakes in the Park include motor vehicles, mowing equipment, fire, and possibly alligators (S. Snow, unpubl. data.). Currently, management actions center on direct control and education efforts to prevent further introductions. Control techniques include trapping, hand capture, and early detection using dogs.

Bullfrogs

Bullfrogs (*Rana catesbeiana*) from the eastern United States were widely introduced from 1900-1940 into many western states, including Hawaii, as a food resource. Bullfrogs are responsible for significant ecological effects and have been difficult to control as they are highly mobile, exhibit generalized eating habits, and have high reproductive capacity (Moyle 1973). Bullfrogs may cause the extirpation of other species due to intense predation and competition (Kats and Ferrer 2003), and may be a primary predator of several

federally endangered waterbirds in Hawaii. Management of bullfrog populations is difficult, in part due to commingling with native species in aquatic habitats. Adult frogs are removed by trapping or hand captures and tadpoles are destroyed by draining ponds or chemical treatment with limited success. Fencing may also be used to limit frog movements away from infested habitats.

Cane Toads

Giant neotropical (*Bufo marinus*) or cane toads were widely introduced from Central America into sugar cane producing regions worldwide to control beetles causing damage to crops (McKeown 1978). However, the effort had very limited success, as the beetles could climb into the vegetation to escape foraging toads. Cane toads may compete with native species for food, compete with native amphibians for breeding sites, and prey on a variety of invertebrate and vertebrate species (McCoid 1995, Catling et al. 1999, Williamson 1999, Boland 2004). Further, native species preying on cane toads may be poisoned by the toad's parotoid glands (McCoid 1995). The frogs also may be a nuisance when large numbers congregate for breeding in ponds or water features and may foul water sources. Australia has been aggressively pursuing control options but has had little success in developing effective methods (Luntz 1998). Currently, the only effective strategies are pond drying, hand capture, and trapping.

Brown Treesnakes

Brown treesnakes (*Boiga irregularis*; BTS) were accidentally introduced into Guam shortly after World War II from their native range in Australia and Papua New Guinea. The slender arboreal snakes average approximately 1 m in length, with large individuals capable of exceeding 2.5 m. They have reached extremely high

population levels (> 20 per acre) on Guam, in part because of abundant food and the lack of predators and ecological competitors. The extreme densities of BTS have resulted in the extirpation of most of Guam's native forest birds (9 of 11), reductions in native lizard populations, and extirpation of two of the three native bats (Savidge 1988, Rodda and Fritts 1992, Vice et al. 2005b). Beyond the severe ecological effects, brown treesnakes threaten human health and safety, agriculture, poultry production, and pets.. The snakes are poisonous and may cause trauma to small children, with numerous bites treated by medical facilities annually (Fritts et al. 1994). The largest economic impact from the snakes is the disruption of power systems. The aboreal snake frequently climbs utility poles, power lines, and other structures, searching for birds and lizards. Snakes occasionally disrupt these systems when they cross from grounded to live structures, causing an estimated 1.4 million (U.S. dollars) in damages from power outages (Fritts et al. 1999). The cryptic, nocturnal snake is especially adept at stowing in cargo and dispersing off Guam via commercial and military traffic (Vice and Vice 2004), creating substantial risk to surrounding islands. A variety of methods are employed to control snakes and restrict their access to aircraft and cargo leaving the islands, including hand capture off fences (Engeman and Vice 2001), trapping (Vice et al. 2005a), and inspection of outbound cargo using detector dogs (Vice and Engeman 2000, Vice and Pitzler 2002) . Other developing and potential methods include the use of oral toxicants, repellents, reproductive inhibition, and barriers.

Curious Skink

Often the effects of invasive species are not predictable, and the combined effects of two or more invasive species may result in synergistic effects that exceed the sum of

the individual species effects. Such is the case of the curious skink (*Carlia ailanpalai*), skink, a small terrestrial lizard that was introduced to Guam in the 1960s (Zug 2004). This lizard has reached extremely high population densities, (approaching 10,000 acre in snake-free areas) on Guam both in forested habitats and near human habitation (Campbell 1996). Due to sheer number of lizards, they may compete with native lizards for food and physically displace other native terrestrial skinks through territorial interactions. However, this is only a small part of the overall effect on Guam. The high population levels of the lizards have exacerbated other problems, as the skink serves as the primary food source supporting the abundant BTS population on island. The abundance of skinks in close proximity to human habitation brings snakes into contact with cargo facilities, power generation and distribution stations, and agricultural production, increasing the risk of snake-caused damages associated with these activities. The invasive skink has now colonized the remainder of the populated Northern Mariana Islands, and may increase the probability of successful colonization by the BTS, as the skink will provide an abundant ectothermic food source for juvenile snakes, should they reach the currently snake-free islands. Further, the skink population has facilitated growth in Guam's population of native yellow bittern (*Ixobrychus sinensis*). Increasing bittern populations near Guam's airport has created an aviation safety risk, as bitterns frequently forage for skinks in the manicured turf around the airfield and are subsequently struck by aircraft (Vice and Pitzler 1999). Thus, a small invasive species with few predictable effects may cause a myriad of significant emergent effects.

PRIORITIES OF INVASIVE SPECIES

The priorities of invasive species management are generally divided between prevention and control. Prior to establishment, research and funding should go to prevention and early detection to decrease the potential for species becoming a problem. To increase the effectiveness of limited funding, a risk analysis should be performed to promote awareness of species that could cause significant effects. Further, coordination and cooperation among state and local agencies decreases the potential for duplicated efforts and increases the response efforts for incipient species. After a species has become established, research and funding is shifted to documenting effects of the species on ecological services, agriculture, and local economies. Development of control strategies and public awareness area are priorities after establishment to control the effects of the new species.

It is widely accepted that prevention is the preferred means of dealing with invasive species, as post-colonization eradication efforts require massive funding and resource commitments. Additionally, complete eradication of vertebrate species has rarely been accomplished in large landscapes. Unfortunately, the line that separates the priorities before and after establishment dictates the amount of funding available and the cost of the eradication effort. Prior to species establishment, the cost of controlling a species is low and the probability of success is high. However, the amount of funding and public interest in dealing with the potential problem is generally low at this time. Federal funding for research and interdiction efforts prior to species establishment is typically not a part of congressional funding. Funding for research and interdiction efforts is usually only secured with public support and congressional backing. After the species is

established, funding typically becomes more available and public interest in dealing increases. Conversely, the costs of control and/or eradication efforts sky rocket and the probability of successful eradication drops after a species is established. This same scenario has been repeated in many areas with many species. A recent example is the above-mentioned case of the coqui frog in Hawaii. Although the species became established by the early 1990s in parts of some islands, no funding was available, even though the potential to eradicate was still high. The primary public opinion was that this was not a major problem and there were likely to be few negative consequences associated with this introduction. Ten years later, public opinion is extremely supportive of dealing with the issue and several studies have documented the effects of the frogs on ecological communities, real estate, agriculture, and human health (Kraus and Campbell 2002). To highlight this change, in March 2004, the Mayor on the island of Hawaii declared a state of emergency in dealing with the coqui situation. Unfortunately, this response occurred once the frog had populated massive tracts of habitat on the island, rendering eradication unlikely.

In conclusion, invasive amphibians and reptiles are an increasing worldwide problem, causing a diverse array of problems that cannot be easily predicted. Invasive reptiles and amphibians may cause more significant problems on island systems than mainland areas. The number of new introductions is likely to continue escalating, as many pathways of invasion are not subject to stringent quarantine and/or control. Currently, there are few effective options in controlling established invasive reptile and amphibian species, and the cost for control efforts is often extreme once a species becomes widespread. Although politically challenging, the most cost

effective approach to invasive species management is to secure funding for research and interdiction efforts to prevent establishment.

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