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Renata J. Platenberg

US Virgin Islands Division of Fish and Wildlife, St. Thomas, Virgin Islands, USA

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IMPACTS OF INTRODUCED SPECIES ON AN ISLAND ECOSYSTEM: NON-NATIVE REPTILES AND AMPHIBIANS IN THE US VIRGIN ISLANDS

RENATA J. PLATENBERG, US Virgin Islands Division of Fish and Wildlife, St. Thomas, Virgin Islands, USA

Abstract: Island ecosystems are highly sensitive to the impacts of introduced species. Non-native invasive snakes, lizards, and amphibians can introduce diseases into native populations and have other deleterious effects through predation, competition, and habitat manipulation. The United States (US) Virgin Islands are situated on the Puerto Rican Shelf in the Caribbean Sea and have a long history of human impacts and species introductions. Two species, the green iguana (*Iguana iguana*) and the red-legged tortoise (*Geochelone carbonaria*) were historically introduced and have become naturalized with little apparent impact to the local ecosystem. Recent years, however, have seen the introduction of several highly invasive species that have proved to have severe impacts when introduced elsewhere, specifically the Cuban treefrog (*Osteopilus septentrionalis*), cane toad (*Bufo marinus*), and the red-eared slider (*Trachemys scripta*). The distribution of non-native herpetofauna has been documented on all main islands of the US Virgin Islands and potential routes for introduction and dispersal have been identified. Additional species are still being identified, having arrived via cargo shipments from other Caribbean ports.

Key Words: colonization, dispersal, herpetofauna, island conservation, invasive species, US Virgin Islands.

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INTRODUCTION

Situated near the eastern terminus of the Greater Antillean chain of islands in the northern Caribbean Sea, the United States (US) Virgin Islands (USVI) comprise four major inhabited islands and more than 50 smaller offshore cays. St. Thomas, St. John, and Water Island are the three main inhabited northern islands, located on the Puerto Rican Shelf to the east of Puerto Rico, while St. Croix is on a separate shelf to the south. The islands are mostly volcanic in origin, with steep slopes and irregular coastlines, surrounded by coral reefs and seagrass beds. The terrain is characterized by these steep hillsides with thin soils and a low permeability of underlying rock dominated by dry tropical forest. The highest elevation is on St. Thomas (474 m), which has an area of 74 km² and is the most densely populated of the islands (USDA-NRCS 1998). St. Croix (217 km²) is more rural with extensive agriculture, and St. John (50 km²) enjoys the protection of the US National Park Service over approximately two-thirds of its area. Combined, all offshore cays comprise about 3% (12 km²) of the territory's area, most of which are designated wildlife refuges (Platenberg et al. 2005). The mild subtropical climate is influenced by easterly trade winds with little variation in average seasonal temperatures (Rogozinski 1999).

Historically, the Virgin Islands have been important for human colonization and settlement. The first inhabitants are dated to about 1500 BC and limited agriculture was in practice by Pre-Taino Indians by about 600 AD, with a heavy reliance on marine resources for food (Brewer 2005). They likely brought familiar and reliable food sources (e.g., tortoises and iguanas) from island to island as they made their way along the Antillean chain. By the time Columbus "discovered" the islands in 1492, the Island Caribs had already become established on St. Croix and throughout the region (Rogozinski 1999). The ensuing centuries saw the elimination of the local inhabitants with an expansion of European colonists and extensive deforestation to make way for sugar cane plantations. Control of the Virgin Islands passed from the Danish to the US in 1917, who established a naval base active through World War II. Tourism took off in the 1950s, and the USVI has become a major tourist destination noted for tax-free shopping and marine recreation.

The demands for space by a rapidly growing population of over 100,000 people have resulted in extensive loss and degradation of natural ecosystems in the USVI, especially on densely populated St. Thomas (Platenberg et al. 2005). Sprawling residential communities and commercial

centers have replaced or fragmented much of the native forest. Resorts, condominiums, and marinas have been constructed on coastal wetlands and marine recreational activities have damaged fragile mangrove swamps, coral reefs, and seagrass beds. Human development has led to increased pollution, particularly non-point source pollution that ultimately contaminates wetlands and marine environments. The introduction of exotic and feral animals and the spread of exotic landscaping plants have had a major impact on wildlife and habitats. Moreover, the natural ecosystems are subject to the effects of short- and long-term wet and dry climatic cycles, and to periodic disturbances from hurricanes. Most of the land within the USVI is divided into small privately-owned parcels that make survey and implementation of conservation measures difficult.

The Spanish and subsequent European colonizers introduced plants, animals, and pathogens from Europe, Africa, and South America (Rogoziński 1999); the most detrimental to native wildlife being the ship rat (*Rattus rattus*) and the small Indian mongoose (*Herpestes javanicus*). Some species arrived unnoticed during this early period of international trade, such as the house gecko (*Hemidactylus mabouia*). Other widespread species undoubtedly took advantage of the increased dispersal opportunities to colonize new areas within the region. Recent improvements in shipping, along with increasing human populations and demands for non-regional produce and landscaping and building materials, have enabled the dispersal of another group of opportunistic invaders (e.g., corn snake, *Elaphe guttata*, and Cuban treefrog, *Osteopilus septentrionalis*).

HERPETOFAUNAL INTRODUCTIONS

A full 25% of the extant native terrestrial herpetofauna in the USVI consists of non-native species (Platenberg and Boulon 2006). Identifying the impacts of non-native reptiles and amphibians on native communities is measurable in some cases, as in the case of the brown treesnake (*Boiga irregularis*) in Guam (e.g., Rodda and Fritts 1992, Fritts and Rodda 1998), the coqui frogs (*Eleutherodactylus* spp.) in Hawaii (e.g., Kraus et al. 1999, Beard and Pitt 2005), and the cane toad (*Bufo marinus*) in Australia (Phillips et al. 2003), among others. However, in many situations, identifying the impact of these invaders is difficult. Most of these species are easily overlooked and as such their date of establishment is generally

unknown. They may have been quietly eating up all their competitors for some time before anyone noticed. These invaders are almost always accompanied by other compounding effects, such as habitat loss and fragmentation from development and agriculture, climate change, pollution, and other direct and indirect influences. Although there may be considerable anecdotal evidence attributing native species declines to a particular invader, actually proving this can be complicated.

The non-native herpetofauna in the USVI can be grouped into three categories according to their ostensible effect on native populations: high impact, presumed low impact, and unknown impact. Each of these categories are discussed in turn.

High Impact Species

High impact species are those recently introduced, deliberately or accidentally, via human mechanisms from outside the region, and that share ecological niches or otherwise interfere with native species. Potential impacts include direct predation of native species, competition for limited resources (e.g., breeding sites, prey), and disease transmission. These species may also present other dangers to naïve species, through toxicity or other impacts. Examples of high impact species in the USVI include the Cuban treefrog, cane toad, and corn snake.

The Cuban treefrog has been present in the USVI since the 1970s (MacLean 1982) and is distributed across all three main islands (St. Thomas, St. John and St. Croix). This species is native to Cuba and nearby islands, and is thought to have invaded Florida, from where it has dispersed across the Caribbean. It arrived in the USVI as a stowaway in horticultural plants and construction materials, most likely from Florida. It exhibits remarkable abilities for colonization, hitch-hiking on a variety of transportation methods (Meshaka 1996b) and surviving under suboptimal and even harsh conditions (Townsend et al. 2000). It is omnivorous, and will eat anything it can shove into its mouth, including lizards with lengths exceeding that of the frog itself (personal observation). Diet studies of the Cuban treefrog have shown that it eats a wide variety of invertebrate species and will also take lizards, frogs and even conspecifics (Meshaka 1996a, Babbitt and Meshaka 2000, Owen 2005). This highly adaptable frog inhabits forests, woodlands, scrub, wetlands, and around human habitations, including cisterns and swimming pools (Meshaka 1996a). It requires freshwater for

reproduction, into which females can lay thousand of eggs per spawning occasion. Although there is little direct evidence of Cuban treefrog impacts on native herpetofauna in the USVI, there are considerable anecdotal assertions that where established, the native frogs and anole lizards have declined (E. Miles and several St. John residents, personal communication). The tadpoles likely interfere with the native white-lipped frog (*Leptodactylus albilabris*), the only native frog species to produce tadpoles (the others are direct developers), with which it shares ephemeral pools for breeding (personal observation).

The cane toad has been present since late 1800s or early 1900s, located primarily around agricultural areas on St. Thomas and St. Croix. This species was deliberately introduced to control agricultural pests, specifically beetle grub particularly damaging to crops (Van Volkenberg 1935). The cane toad is omnivorous, and will take any food available. This species requires a reliable fresh water source for reproduction, which restricts it in the USVI to man-made freshwater systems in disturbed habitats. The impact to native herpetofauna is unknown, although the tadpoles likely compete for limited freshwater resources with the white-lipped frog.

The corn snake was first reported in the territory in 2003 (Perry et al. 2003), although it has been present on St. Thomas since at least the mid 1990s, when an individual was collected and maintained in captivity (D. Griffin and R. Gomez, personal communication). This species was previously thought to be localized around the container port on the south-central side of St. Thomas to the west of the main commercial center of Charlotte Amalie, and until recently all sightings were restricted to this area. However, a road-killed gravid female was collected in a commercial area on the east side of the island in the summer of 2006, indicating some level of dispersal. The diet of this species in its native environment includes small mammals, frogs, birds, and lizards, and it is likely these snakes are taking advantage of the abundant anole lizards. They also pose a potential threat to the endangered USVI tree boa (*Epicrates monensis granti*) by direct predation and competition.

Presumed Low Impact Species

Presumed low impact species are those that do not share an obvious ecological niche or otherwise interfere with any native species. These species are often historically introduced, commonly as a food source, and tend to be herbivorous. They are

generally novel, i.e., there is no ecologically similar native species. They present little competition for resources, although they may have indirect impacts through habitat alteration, disease introduction, or competition with non-similar species of other taxa. They may have other incidental and unknown impacts. Examples of these species in the USVI include the green iguana (*Iguana iguana*), red-footed tortoise (*Geochelone carbonaria*), house gecko, and freshwater turtles.

The origin of the green iguana in the USVI is unknown. It may be a deliberate 20th century introduction through the pet trade or well-intentioned attempts at conservation, or it may have been brought in by pre-Columbian Indians as a food source. It also may have dispersed naturally by rafting up the Antillean island chain. The green iguana is native to Central and South America, and is widely distributed across the West Indies (Schwartz and Henderson 1991). There is no documentation of the earliest specimens in the USVI. While there are iguanid fossil remains in prehistoric middens on St. Thomas (Pregill 1981, D. Brewer, personal communication), there is no evidence that there were any wild populations at that time. There are two species of the endemic West Indian iguanas on the Puerto Rico Bank (*Cyclura stejnegeri*, on Mona Island west of Puerto Rico, and *C. pinguis*, on Anegada at the eastern side of the British Virgin Islands; Schwartz and Henderson 1991); there is no evidence that these species ever occurred on the USVI, and, therefore, were not impacted by the arrival of the green iguana there. This large lizard is herbivorous and able to inhabit a wide variety of habitat types. They are very abundant on St. Thomas, particularly around resorts and open-air restaurants, where they feast on handouts and ornamental plants and lounge by the swimming pools, much to the dismay of the resort managers. They are often observed in association with the common ground lizard (*Ameiva exsul*), which may have discovered the benefits of following around a messy eater (personal observation). They were once considered locally endangered in the territory, and efforts were made to establish and augment populations on the main islands and even some of the satellite cays (Perry and Platenberg, In Press). They are still afforded special protection against killing and harm under local legislation (USVI Code Title 12).

The origin of the red-footed tortoise in the USVI is also a mystery. It is widely believed to have been introduced by pre-Colombian Indians as a food source. It inhabits dense forest and scrub habitat

and is seldom observed, and therefore its distribution in the territory is unknown. It is primarily herbivorous, and appears not to overlap ecologically with any similar native species.

The house gecko has been present in the USVI since 1700-1800s, likely having arrived via slave ships from eastern Africa. It is widely distributed across the Caribbean and into the southern US (Schwartz and Henderson 1991). It occurs on all the main islands and several satellite cays within the territory, although is most commonly found in association with human habitations; it feeds on insects attracted to lights at night. Although territorial, it can occur at high densities (Meshaka 2000). Its potential impact on native populations is through competition for invertebrate prey, although the nocturnal insects attracted to lights may not be readily available to diurnal native foragers.

Freshwater turtles, most commonly red-eared sliders (*Trachemys scripta elegans*), were not reported in the territory prior to the mid 1980s (MacLean 1982). They were most likely introduced into water bodies as unwanted pets. Long-time residents recall being able to buy them in pet shops (along with other exotic pets such as caiman). This species is highly aquatic, and as such have a very limited and human-influenced distribution. They inhabit nearly every freshwater body on St. Thomas and St. Croix, including agricultural ponds and ornamental pools at resort and golf courses. Almost all of these freshwater ponds are man-made because steep slopes and non-porous shallow soils preclude the natural formation of these systems. As such, there are no native species of freshwater turtles in the USVI. For the same reason, the native freshwater fish are amphidromous and restricted to stormwater drainages with occasional connection to the sea (Loftus 2003, Nemeth and Platenberg 2007), which are uninhabited by these turtles. The turtles may predate small waterfowl taking advantage of the rare freshwater resources, although they are observed to cohabit with little discernable effect (personal observation).

Unknown Impact Species

Species with an unknown potential impact are not native to the USVI, but are native within the region. They are species that have recently arrived, and their colonization may have resulted from a natural dispersive range extension, although in most cases the arrival of these species is human-mediated in a general trend for globalization. These species often have very similar counterparts present among the native fauna, and while their impacts are

as yet unknown, they are likely to be significant. They are often “weedy” invaders, highly prolific and able to survive in a variety of habitats and under adverse conditions. Their impact on native populations has not yet been determined, although they are likely to impact native species through displacement of populations by direct competition for limited resources (prey and breeding sites), and may pose hybridization threats. There is also a highly likelihood of these individuals introducing diseases into a naïve population. Examples of these species in the USVI include the Puerto Rican coqui (*Eleutherodactylus coqui*), the Lesser Antillean whistling frog (*Eleutherodactylus johnstonei*), and the common ground lizard on St. Croix.

The Puerto Rican coqui is a recent immigrant to the USVI, presumed to have been introduced as recently as the 1990s in horticultural material from Puerto Rico. During its early years on St. Thomas, it appears to have been localized around the agricultural areas and garden centers at the highest elevation on Crown Mountain. In recent years, which have been moister than usual (USVI Division of Fish and Wildlife, unpublished data), the coqui has established populations in several locations on the island. Its habit of burying itself in potted plants enhances its dispersal (personal observation). These frogs can live at high densities from around 2000 to 20,000 individuals ha⁻¹ (Stewart and Woolbright 1996, Woolbright et al. 2006). It appears that they are displacing the native frogs (particularly, *Eleutherodactylus antillensis*) on St. Thomas, although this observation may be a seasonal artifact and requires further monitoring. The coqui has introduced the chytrid fungus (*Batrachochytrium dendrobatidis*), a significant cause of amphibian decline world-wide, to Hawaii (Beard and O’Neill 2005). The potential of this occurring in the USVI, which likely has temperatures considered too high for the survival of the fungus, requires investigation.

The Lesser Antillean whistling frog is native to many islands in the Lesser Antilles and is widely introduced across the West Indies and northern South America (Schwartz and Henderson 1991). Several specimens arrived in 2004 in cut flower shipments arriving from St. Vincent (unpublished data), but they appear not to have become established. The main concern is competition and hybridization with native frogs, as there is considerable overlap in habitat and diet (Ovaska 1991).

The common ground lizard is native to the Puerto Rican Shelf, where it is widespread,

abundant, and highly adaptive on main islands and satellite cays. This species has recently been introduced to St. Croix, where it previously never occurred. It is believed that the lizards were introduced through a shipment of car tires from either St. Thomas or Puerto Rico (W. Coles, personal communication), and they have since become established in one locality in the center of the island. The concern is that the lizard may make its way to the satellite islands (Ruth, Green, and Protestant cays) that harbor the only populations of the highly endangered St. Croix ground lizard (*Ameiva polops*), which has been extirpated from the main island and exist only in small, isolated populations (McNair 2003, McNair and Lombard 2004, McNair and Mackay 2005, Platenberg and Boulon 2006). It may also have an impact on the naïve St. Croix anole (*Anolis acutus*).

ORIGIN AND MODE OF INTRODUCTION

The current demand for a “lush tropical” environment around resorts and upscale housing developments, instead of the scrubby dry subtropical vegetation native to the USVI, provides a continuous opportunity for species introductions. Produce and landscaping materials regularly arrive from Puerto Rico, Hispaniola, Florida, and other localities. There are two major container shippers in the USVI, as well as a plethora of other shipping companies servicing the US, West Indies, and beyond. One shipper visits 28 ports weekly across the Caribbean, as well as Canada and Florida (www.tropical.com). The residents of St. John assert that the coqui frog arrived on a single barge containing landscaping plants from Puerto Rico during the construction of an upscale resort on that island; a similar event occurred more recently (2006) when chorusing landscaping plants, also from Puerto Rico, were imported during the construction of a new marina on St. Thomas (personal observation). There are currently no provisions for inspecting cargo arriving from Puerto Rico or the US mainland, as these are considered “inter-state” transports and not subject to customs regulations. Only cursory inspections are carried out for goods arriving from other countries, although invasive vertebrate stowaways are not on the inspection radar. There are also no requirements for plant importers to inspect and monitor for non-native pests.

RECOMMENDATIONS

It is acknowledged that many of the detrimental impacts to native wildlife by introduced species have already taken place, such as the extirpation of the Puerto Rican racer (*Alsophis portoricensis*) from the main island and the extinction of the St. Croix racer (*Alsophis sanctaecrucis*) by mongooses (Henderson and Powell 2001, Powell and Henderson 2005, Platenberg and Boulon 2006). It is also difficult to garner financial and staffing support for eradication of non-native species and prevention of new introductions, especially in the face of the more severe detrimental impacts of habitat loss and fragmentation, unregulated pesticide use, chemical contaminants, and other sources of environmental degradation. However, there are still native herpetofauna species that warrant protection from the threat posed by invasive species, and considering unknown impacts to other taxa a response is required. Some steps can be taken to reduce the incidence of introductions. Examples from the coqui invasion of Hawaii and the brown treesnake in Guam include increased inspection and showering landscaping plants with hot water (www.ctahr.hawaii.edu/coqui/shower.asp). Regulations can be imposed to require landscapers and importers to inspect and monitor shipments. Stricter permitting can limit the importation of exotic pets that inevitably end up free-roaming. A rapid response team could be established. However, the single most effective mechanism would be to educate the public and merchants as to the consequences of the non-native species and to enlist their vigilance and stewardship.

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