History and Status of Introduced Non-human Primate Populations in Florida

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Abstract - We validated and synthesized reports of historic and current populations of the 3 introduced non-human primate species in Florida—*Saimiri* sp. (squirrel monkey), *Chlorocebus sabaeus* (Vervet Monkey), and *Macaca mulatta* (Rhesus Macaque)—using systematic review of literature, content analysis of popular media, expert interviews, and site visits. Invasion success varied among the 3 species: only 1 of 5 squirrel monkey populations was still extant, a single Vervet Monkey population showed little change between the mid-1990s and 2015, and 2 of 3 introduced Rhesus Macaque populations grew, but only 1 was extant. Disparities in invasion success appeared to be primarily influenced by natural history and anthropogenic intervention. Understanding introduced species success is critical to determine current and potential impacts and effectively allocate limited management resources.

Introduction

Humans have introduced non-human primate (hereafter: primate) species into novel habitats since at least the 16th century (Long 2003). However, primate introductions began relatively recently in the US and pose a growing and understudied threat to native flora, fauna, and humans. Since the 1930s, at least 10 species of primates have been introduced into the US (Dierenfeld and McCann 1999, Engeman et al. 2010, Feild et al. 1997, González-Martínez 2004, Hall et al. 2007, Hyler 1995, Maples et al. 1976, Mowry et al. 1997, Paterson 1996, Rawlins and Kessler 1983, Taub and Mehlman 1989, Wilson and Elicker 1976, Wolfe and Peters 1987). While some of these were unintentional releases or from unknown sources, those that were intentional varied in purposes including conservation, tourism, and behavioral and/or biomedical research. Although the native ranges of these species vary in climatic and environmental conditions, successful introductions have thus far been restricted to the southeastern US and Puerto Rico. The impacts of these introductions have ranged from seemingly innocuous to extensive destruction of environmental and economic resources. To date, 3 species of primates have established populations in Florida: *Saimiri* sp. (squirrel monkey), *Chlorocebus sabaeus* L. (Vervet Monkey), and *Macaca mulatta* (Zimmerman) (Rhesus Macaque).

Squirrel monkeys are native to Central and South America. Four *Saimiri* species primarily occupy tropical lowland forests throughout the Amazon basin, and *Saimiri oerstedii* Reinhardt (Central American Squirrel Monkey) is native to forests

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along the Pacific Coast of Costa Rica and Panama. Among neotropical primates, Squirrel monkeys are considered habitat generalists, with the capacity to survive in disturbed and edge forests (Kinzey 1997). They are primarily frugivorous and insectivorous, but will supplement their diet with other plant parts, eggs, small invertebrates, and small vertebrates (Baldwin 1985, Kinzey 1997). Squirrel monkey populations have been introduced in the Brazilian Atlantic Forest (Camarotti et al. 2015, Oliveira and Grelle 2012); the impacts of these introductions are not well known, but appear to be altering the behavior of native *Callithrix jacchus* L. (Common Marmoset) (Camarotti et al. 2015).

There are 6 species within the genus *Chlorocebus* (Haus et al. 2013). Spanning sub-Saharan Africa, *Chlorocebus* is one of the most widespread genera of primates (Wolfheim 1983). Species within this genus are habitat generalists and opportunistic omnivores, which allows them to thrive in a variety of environments. They readily adapt to human settlements in rural, suburban, and urban settings (Hill 2000). Across much of their native range, they are regarded as pests because they raid crops (Hill 2000, Saj et al. 2001) and steal food from homes and trash bins in villages (Long 2003, Fourie et al. 2015), which has led to extermination programs in many countries (Long 2003). *Chlorocebus* monkeys were introduced to 3 Caribbean Islands as an unintentional consequence of the Trans-Atlantic Slave Trade (Long 2003, Turner et al. 2016). These populations have caused significant economic losses through crop raiding (Dore 2013) and have historically been controlled through bounty hunting (Turner et al. 2016).

Native throughout eastern and southern Asia, Rhesus Macaques have the largest native range of any non-human primate (Southwick et al. 1996). They are habitat generalists, occupying elevations in their native range varying in elevation from sea level to 2500 m on average (Fooden 2000). They are both arboreal and terrestrial, generalist omnivores, and capable of adapting to a diversity of environmental conditions. Rhesus Macaques are noted human commensals (Richard et al. 1989), with population densities averaging 37.2 individuals/km^2 in forested habitats and 201.1 individuals/km^2 in urban areas and temples (Fooden 2000). Rhesus Macaques arguably represent the oldest, most widespread, and most invasive introduced primate species in the US. In the continental US and Puerto Rico, introduced populations of this species have increased bacteria levels in water bodies (Klopchin et al. 2008), destroyed crops causing millions of dollars in agricultural losses and management expenses (Engeman et al. 2010), eroded shorelines by destroying mangroves (Kruer 1996), and eradicated island bird populations by preying upon eggs and chicks (Evans 1989).

Prior to this study, very little research had been conducted or published on populations of introduced primates in Florida. Rather, most information had been disseminated through news reports, grey literature, and by word-of-mouth. Given the potential for primate populations to thrive in novel habitats and threaten environmental and economic resources, it is critical to understand their historic and current status as well as their potential impacts. The aim of this study was to compile, validate, and synthesize information on historic and extant free-ranging

primate populations in Florida and to understand variations in success among these populations. For each population, we sought to determine: (1) introduction date and source; (2) whether there have been management efforts to increase or decrease the population; (3) for those no longer extant, how long the population survived and why it is no longer in existence; and (4) for extant populations, current population size, known impacts, and potential future impacts.

Methods

We used 4 methods to assemble data on the history and current status of primate populations in Florida: (1) systematic review of peer-reviewed and grey literature, (2) content analysis of popular media, (3) semi-structured interviews with local experts, and (4) site visits to reported historic and extant populations.

We conducted a systematic review of peer-reviewed and grey literature following the framework described by Pullin and Stewart (2006). We defined our geographic range as the state of Florida and used relevant search terms to query Web of Science© and Google Scholar for peer-reviewed articles and abstracts. We used the search function in Google to locate grey literature. We included peer-reviewed articles, state agency reports, university theses, book chapters, and conference abstracts pertaining to introduced populations of primates in Florida.

We conducted a content analysis (Riffe et al. 1998) of news articles to synthesize information on introductions, population estimates, and management efforts of introduced populations of primates in Florida. To compile popular media articles, we used the search function of Google News. Key words included "monkey" and locations of introductions, as well as the common name of each species with their known introduced locations (e.g., "monkey" AND "Silver Springs", "Rhesus Macaque" AND "Silver Springs"). Only articles from local and national news organizations were included; articles by individuals and special interest groups were not included in analyses. Further, we included only articles referencing primate populations and excluded articles describing free-ranging individuals.

Concurrently with literature review and analysis of media reports, we conducted semi-structured interviews with biologists, land managers, and local experts (n = 19). Interviews were conducted between July 2013 and May 2016. Initial interviewees were selected based on their knowledge and experience in the respective location, and subsequent interviewees were selected through snowball (Goodman 1961) and respondent-driven sampling techniques (Heckathorn 1997). Interview questions included the interviewee's personal experience with local primate populations, length of time local populations were or have been established, whether any local management regimens were currently or historically used to control introduced primate populations, and what local opinions and perceptions were of the respective primate population.

From June 2014 to February 2016, we conducted site visits of locations of reported historic and current primate populations. For populations found to no longer be present, we interviewed local experts and residents to determine the last time that primates were observed and variations in observed population sizes. For

extant populations, we estimated minimum populations size by interviewing local residents and experts and by observing the animals.

Results

Systematic review

We reviewed 13 peer-reviewed articles, 3 university theses, 2 book chapters, 2 peer-edited articles, and 2 conference abstracts. Most of these focused on the Rhesus Macaques of Silver Springs (Hammond 1989; Maples et al. 1976; Peters 1983; Riley and Wade 2016; Sarris 1980; Wolfe 1986, 2002; Wolfe and Peters 1987) or on the Rhesus Macaques in the Florida Keys (Johnson 1989; Johnson and Kapsalis 1995, 1998; Kruer 1996; Lehman et al. 1994; Taylor et al. 1994). Five publications described squirrel monkey introductions, including 3 populations (Elgart 2009, Layne 1969, Leon 1997, Taylor and Lehman 1997, Wheeler 1990). Two publications documented Vervet Monkeys (Hyler 1995, Williams 2015). One book chapter described all 3 species (Layne 1997).

Content analysis

We reviewed 106 news articles published from 1960 to 2016. Most articles described Rhesus Macaques in Silver Springs ($n = 32$) or the Florida Keys ($n = 22$). We only located 2 that described Rhesus Macaques in Titusville. Rhesus Macaque news articles dated from 1977 to 2016. We analyzed 18 articles about Vervet Monkeys dating from 1983 to 2015. Nearly one-third of articles reviewed ($n = 32$) described squirrel monkey populations in Naples, Boca Raton, Ft. Lauderdale, and Lake Wales.

Historic and current populations

Squirrel monkeys. Based on our review, there have been at least 5 introduced squirrel monkey populations in Florida (Fig. 1, Table 1), of which 4 are no longer extant, and a dwindling population remains on a historic property known as the Bonnet House Museum and Gardens in Ft. Lauderdale. The introduction date of the squirrel monkey population on the property is uncertain; Wheeler (1990) suggested the population came from 2 pairs released from captivity in a local bar in the 1970s, but Leon (1997) and Taylor and Lehman (1997) suggested the population was introduced on the site in the 1940s. Researchers consistently identified this population as *Saimiri sciureus* (L.) (Common Squirrel Monkey; Leon 1997, Taylor and Lehman 1997, Wheeler 1990). Studies of the population reported 43 individuals in 1988 (Wheeler 1990) and 39 animals in 1995–1996 (Leon 1997). The animals are not confined to the property; researchers from the 1990s routinely observed the animals traveling into the nearby Hugh Taylor Birch State Park (L. Taylor, University of Miami, Miami, FL, pers. comm.). During our site visit in 2014, we found only 3 individual monkeys remaining on the property. Researchers from the 1990s confirmed a trapper was removing animals from the perimeter of the property during the time of their observations, perhaps for sale into the pet industry (L. Taylor, pers. comm.). It is unknown how many animals were trapped and removed. Bonnet House property staff reported 2 monkeys disappeared (L. Schaller, Bonnet House Museum and Gardens,

Fort Lauderdale, FL, pers. comm.) during a particularly cold winter in 2009–2010 (Dorcas et al. 2011, Mazzotti et al. 2011), although it is unclear if they succumbed to the weather. At the time of our site visit, the animals were provisioned daily with food and fresh water. Property staff reported the population consisted of 3 individuals in December 2016 (L. Schaller, pers. comm.).

Squirrel monkeys are reported to have been introduced around 1960 in what is today Silver Springs State Park. It is unclear which species of *Saimiri* occurred in this population (Maples et al. 1976). The animals were initially contained within an enclosure near the headspring, but were later intentionally released into the surrounding forests (Maples et al. 1976; Michael Summers, Silver Springs State Park, Silver Springs, FL, pers. comm.). In 1961, the population numbered ~12–15 animals (Layne 1969). Tourists would frequently hand-feed the animals (Michael Summers, pers. comm.). They were no longer in the park by the early to mid-1970s (Maples et al. 1976). The reason for their disappearance is uncertain. Maples et al. (1976) reported the animals may have moved towards the Ocklawaha River, and it is likely they did not survive. It is possible they were driven out of the area by introduced Rhesus Macaques (see below), as Rhesus Macaques are aggressive and prone to attack unfamiliar individuals (Maestripieri and Hoffman 2012).

The introduction date and source of squirrel monkeys in Masterpiece Gardens, a tourist attraction in Lake Wales, is unknown. The specific species of *Saimiri* within this population is also unclear. The earliest record of the population we located was

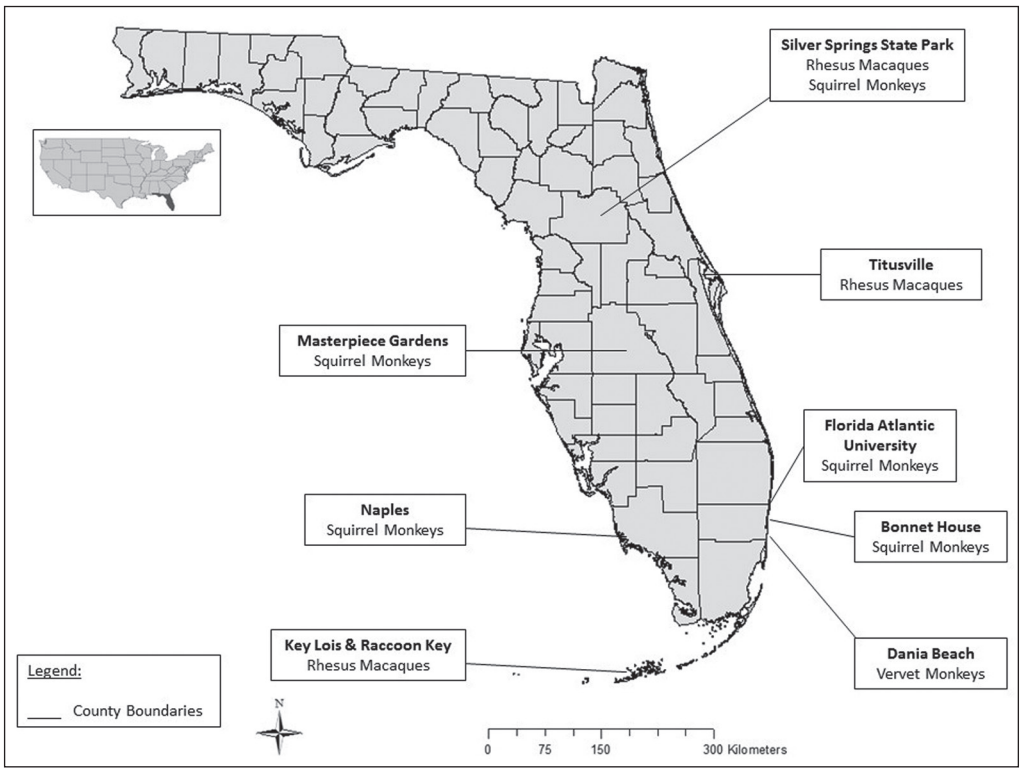

Figure 1. Approximate locations of introduced non-human primate populations in Florida.

Table 1. Sites of known introductions in Florida for 3 primate species, with introduction date, number of animals introduced, and the most recent estimate of the population size. For populations believed to have been extirpated or removed, the respective date is listed.

Species	Location	Introduction date	Date of last observation or removal[A]	# animals introduced	Most recent population estimate[B]
Squirrel monkey	Bonnet House Museum and Gardens, Ft. Lauderdale, Broward County	1940s or 1970s	N/A	Unknown	3 (2016)[C]
Squirrel monkey	Silver Springs State Park, Silver Springs, Marion County	~1960	1970s	Unknown	N/A
Squirrel monkey	Masterpiece Gardens, Lake Wales, Polk County	~1960s	Mid 1980s	Unknown	N/A
Squirrel monkey	Naples, Collier County	~1960s	2010	Unknown	N/A
Squirrel monkey	Florida Atlantic University, Boca Raton, Palm Beach County	1970	Late 1970s	~65	N/A
Vervet Monkey	Dania Beach, Broward County	1950s	N/A	Unknown	35 (2015)[C]
Rhesus Macaque	Silver Springs State Park, Silver Springs, Marion County	1930s –1948	N/A	~12	175 (2015)[C]
Rhesus Macaque	Titusville, Brevard County	1976	Early 1990s	Unknown	N/A
Rhesus Macaque	Key Lois and Raccoon Key, Monroe County	1973 and 1978	1999 –2000	1350+	N/A

[A]For populations no longer present in site.
[B]For extant populations.
[C]Parentheses indicate date of most recent population estimate.

from 1971 (Florida State Library and Archives 2016), suggesting the population may have been introduced in the 1960s. It is unclear whether the introduction of these animals was intentional. A 1981 news article stated the owner of the property was attempting to trap the animals to sell them at auction (Bair 1981); however, we were unable to obtain records on the success of this trapping effort. Another local newspaper article from 1983 reported the population was dwindling and suggested predation and cold weather were the primary causes (Bair 1983). Property managers reported occasionally hearing monkeys in the surrounding forests in the late 1980s (P. Blackburn, Masterpiece Gardens, Lake Wales, FL, pers. comm.). In the winter of 1989, dead monkeys were found on the property; there have been no reported observations since that time (P. Blackburn, pers. comm.). No formal population estimates were published during the ~20-year span of this population. News articles suggested there were hundreds of animals (Bair 1981, 1983), but these numbers should be considered with caution because untrained observers have been found to overestimate primate population sizes (Malaivijitnond et al. 2011).

A population of squirrel monkeys was introduced along the Gordon River in Naples, FL. This population was confirmed to be *S. sciureus* (A. Elgart, Florida Gulf Coast University, Ft. Myers, FL, pers. comm.). City records indicate the population was introduced in the 1960s (City of Naples 2012), but the exact date and source are unknown. In the late 1990s–early 2000s, several reports were made of individuals trapping the monkeys, potentially for the pet trade or research industry (A. Elgart, pers. comm.). In 2002, city council members proposed a local ordinance to protect the monkeys from trapping, but the ordinance was denied in 2003 (City of Naples 2012). In 2009, the population consisted of only an adult male, a juvenile male, and a female that was either a juvenile or adult (A. Elgart, pers. comm.) occupying an area of ~4.77 km^2 (Elgart 2009). There have been no reported sightings since ca. 2010 (J. Schmid, Conservancy of Southwest Florida, Naples, FL, pers. comm.).

In 1970, a captive colony of squirrel monkeys on the campus of Florida Atlantic University was released by animal rights activists (FAU 2016, Tarrant 1976). The animals persisted as a free-ranging population on the campus, with some supplemental provisioning. The release was believed to include around 65 animals. By 1976, the population was reported to include only 3 animals (Tarrant 1976); we did not locate any records of the population after this date.

Vervet Monkeys. To date, there has only been 1 reported population of Vervet Monkeys in Florida (Table 1, Fig. 1). Vervet Monkeys were introduced into Dania Beach, south of Ft. Lauderdale, in the 1950s. It is believed these animals escaped or were intentionally released from the Anthropoid Ape Research Foundation, a facility which imported primates for use in biomedical research (Williams 2015); the number of animals originally released is unknown. A study conducted in the early 1990s found there to be ~36 Vervet Monkeys split between 2 groups (Hyler 1995). In 2015, the population was estimated to be 35 animals split between 4 groups (Williams 2015). Hyler (1995) reported the animals were *Chlorocebus aethiops* or a hybrid; however, more recent evidence suggests they are likely *Chlorocebus sabaeus* (D. Williams, Florida Atlantic University, Boca Raton, FL, pers. comm.).

In 2013, two Vervet Monkeys separated from the main population in Dania Beach and moved south into Miami-Dade County (J. Ketterlin Eckles, Environmentally Endangered Lands Program, Melbourne, FL, pers. comm.). The Florida Fish and Wildlife Conservation Commission trapped a Vervet Monkey, believed to be one of the separated individuals, ~33 miles south of Dania Beach and placed it with an individual permitted to hold captive primates; the fate of the other animal is unknown. Aside from the capture of the individual animal, there have been no efforts by the state to control the Vervet Monkey population (Jennifer Ketterlin Eckles, pers. comm.). A 2013 news article (Nolin 2013) stated that ~7 Vervet Monkeys had been trapped and sold in the early 1990s. There are reports that several of the monkeys were trapped in the early 2000s by a private citizen for sale into the biomedical industry, but no reports of trapping since that time. The animals in this population are extremely habituated to humans and have extensive support from the local community (D. Williams. pers. comm.). Local officials previously considered a local ordinance to protect the monkeys, but to date no policies have been implemented (J. Ketterlin Eckles, pers. comm.).

Rhesus Macaques. From our review, 3 populations of Rhesus Macaques have been introduced in Florida (Table 1, Fig. 1). A population of Rhesus Macaques was introduced in Titusville in 1976 when they either escaped (Layne 1997) or were intentionally released (Zimmerman 1977) from a tourist attraction known as Tropical Wonderland. It is unclear how many individuals were included in the initial introduction. The animals occupied a wooded area near the attraction after their escape (Layne 1997). A 1977 news article suggested there were between 35–75 animals and that state wildlife officials planned to trap and remove the animals (Zimmerman 1977); however, no state records confirm or deny whether this occurred. In the early 1980s, an individual trapped ~6 Rhesus Macaques from Titusville and released them into the area occupied by an introduced Rhesus Macaque population in Silver Springs (Mike Legare, US Fish and Wildlife Service, Titusville, FL, pers. comm.); it is unknown whether these animals survived. A 1987 article reported the monkeys in Titusville harassed motorists (Rose 1987). The last reported observation of Rhesus Macaques in Titusville was in the early 1990s (Layne 1997).

In 1973, Charles Rivers Laboratories, a subsidiary of Bausch and Lomb, introduced over 1200 female and 150 male Rhesus Macaques to Key Lois (historically known as Loggerhead Key), a 39-ha island in the Florida Keys. From 1978 to 1980, the company moved over 500 of the animals to Raccoon Key, an 81-ha island 15 km north of Key Lois (Johnson and Kapsalis 1998, Lehman et al. 1994). The company acquired the islands to develop a breeding colony of Rhesus Macaques for biomedical research. The animals were provisioned daily with food and provided with veterinary care, which allowed the population on each island to quickly increase; 1524 births were recorded on the islands during 1988–1990 (Lehman et al. 1994). It is believed the animals were free of predators on Key Lois, but may have experienced some mortality due to *Crotalus adamanteus* Palisot de Beauvois (Eastern Diamondback Rattlesnake) on Raccoon Key (Johnson and Kapsalis 1998). Both islands were predominately vegetated by *Rhizophora mangle* (L.) (Red Mangrove)

and *Avicennia germinans* (L.) L. (Black Mangrove). The macaques consumed the new growth of these trees, which was reported to have led to the destruction of over 30 acres of Red Mangroves on Key Lois alone (Kruer 1996) and potentially decreased bird populations on Raccoon Key (Enge et al. 2002).

Controversy ensued as environmental activist organizations called for a removal of the animals from both islands. The State of Florida brought a regulatory action against Charles Rivers Laboratories in 1988 as a result of the environmental damage on the islands, and civil litigation followed (State of Florida 1988, 1992). An agreed Final Judgment was entered following mediation in 1992, wherein the company agreed to remove all Rhesus Macaques and give the deed of Key Lois to the state of Florida by 2013, and remove all macaques from Raccoon Key and give the island to the federal government to be included in the National Wildlife Refuge System by 2014. The order also stated the company must revegetate the islands with mangroves, monitor fecal coliform levels in the waters around the islands, and pay the state $75,000 for damages (State of Florida 1992). The macaques were removed from the islands during 1999–2000 (C. Kruer, Coastal Resources Group, Sheridan, MT, pers. comm.). In 2003, Charles Rivers Laboratories and the State of Florida signed a Settlement Agreement, wherein it was agreed the company had met its aforementioned requirements and would also donate $200,000 to the state's Conservation Trust (State of Florida 2003).

The oldest and, at present, the largest population of primates in Florida is that of Rhesus Macaques in Silver Springs State Park (SSSP) in central Florida. The population was initially introduced in the 1930s, when the captain of a glass-bottom boat placed a small number of Rhesus Macaques on an island in the Silver River in an effort to increase tourism. It is unclear how many he released, but a local report in 1938 speculated there were 6 in the park (Wolfe and Peters 1987). Rhesus Macaques are proficient swimmers, and they promptly swam from the island to the mainland. The monkeys proved popular among tourists, and the boat captain purchased and released ~6 additional animals around 1948 (Wolfe and Peters 1987). A 1968 study estimated the population had grown to 78 individuals spread between 2 groups (Maples et al. 1976), and a 1979 study reported the population to be in excess of 150 animals (Sarris 1980). By the mid-1980s, the macaque population had grown to nearly 400 animals in SSSP and had spread to forests along the Ocklawaha River and Ocala National Forest (Wolfe 2002, Wolfe and Peters 1987). In 1984, short-term trapping was initiated in an attempt to reduce the population; ~225 were captured and sold for biomedical research (Wolfe 2002). This practice incited extensive public protest and was subsequently halted. In the following years, ~60 individuals were removed without permit and others were sent to a zoological park (Wolfe and Peters 1987). While specific removal records were not maintained, Wolfe (2002) estimated 500 macaques were removed during 1984–1993. In the late 1980s, 13 female macaques were sterilized by hysterectomy in an effort to decrease population growth (Wolfe 2002). From 1998–2012, a private trapper, permitted by the state, captured ~630 Rhesus Macaques on SSSP and ~200 on lands along the adjoining Ocklawaha River and sold these animals to biomedical research facilities

(State of Florida 2013). It is likely the trapper's efforts single-handedly controlled this population in a habitat where they have few terrestrial predators and have previously exhibited substantial population growth. In 2012, this trapping effort was halted after extensive pressure from the public and special interest groups. A spring 2013 study estimated the population to be 118 individuals (Riley and Wade 2016). The estimated population in Fall 2015 was ~175 macaques in SSSP (C.J. Anderson, pers. observ.) and unknown along the Ocklawaha River.

Discussion

Non-native species may be categorized along a gradient of introduced to established to invasive (Colautti and MacIsaac 2004, Lockwood et al. 2007). The 3 species of primates with reported populations in Florida—squirrel monkeys, Vervet Monkeys, and Rhesus Macaques—appear to span this spectrum. Despite having the most reported populations throughout the state (n = 5), squirrel monkeys have demonstrated the least success in Florida. Although the Vervet Monkey population in Dania Beach has persisted for several decades, it has changed very little in size. Rhesus Macaques have demonstrated a propensity for survival and population growth in both the Florida Keys and central Florida.

Variation in persistence among the primate species in Florida may be attributed to disparities in human intervention. Trapping and removing animals may decrease population growth or survivorship. Conversely, provisional feeding by humans may have allowed some populations to persist and/or grow. Provisional food is often higher in caloric value, available in larger proportions (therefore requiring less energy expenditure for foraging), and is more predictable than natural foods, and consequently has been demonstrated to decrease generation time, increase survivorship, and increase population sizes and densities among primates (Sengupta et al. 2015). Ecological factors may also explain variation in survivorship, such as adaptability to novel environmental resources and climate, ability to survive in human-dominated landscapes, tolerance of genetic depression, and capacity for interspecific competition (Lockwood et al. 2007).

Despite some reproductive success, squirrel monkey populations have never survived more than a few decades in Florida. Trapping and removal likely decreased the Ft. Lauderdale population (Linda Taylor, pers. comm.) and may have influenced the extinction of the Naples and Masterpiece Gardens populations; we are not aware of any trapping efforts of the other 2 populations. The population in Ft. Lauderdale is the only one reported to have had daily provisional feeding, which may have allowed the population to persist longer than the other populations in Florida.

Inability to tolerate cold temperatures may have limited squirrel monkey survival in Florida. Squirrel Monkeys are susceptible to cold stress and have been observed to experience negative eye, nose, and respiratory effects when housed in settings with low relative humidity (Abee 1985). Ambient temperature of 26–27 °C (78.8–80.6 °F) is believed to be the lower critical temperature, or temperature below which an individual must use energy above its normal metabolic rate, for

squirrel monkeys (Adair 1985). Southern Florida experienced an unusually cold winter in 2009–2010 (Dorcas et al. 2011, Mazzotti et al. 2011); in January 2010, air temperatures remained at or below 10 °C (50 °F) for at least 48 hours (Mazzotti et al. 2011). This cold snap corresponds with the last observations of the squirrel monkeys in Naples in 2010 (J. Schmid, pers. comm.) and the time period during which 2 individual monkeys were identified to have disappeared from the population in Ft. Lauderdale (L. Schaller, pers. comm.). In February 1989, ambient temperature in Polk County reached -2.2 °C (28 °F) (Weather Underground 2016); around this time, squirrel monkeys are believed to have succumbed to cold weather at Masterpiece Gardens (Paula Blackburn , pers. comm.). If winter climate extremes did increase squirrel monkey mortality, it is possible animals succumbed both to sustained cold periods and to acute, extreme events.

The stability of the Vervet Monkey population in Florida is surprising given that Vervet Monkeys have demonstrated increased population densities in areas with human-provisioned food (Brennan et al. 1985, Saj et al. 1999) and that there has been little documented trapping pressure. The persistence of the population over several decades confirms there is reproduction and suggests they are capable of surviving in the local climate. It is unlikely population growth is limited by density in Florida, as *Chlorocebus* populations of over 200 individuals/km^2 have been reported elsewhere (Harrison 1983, Pasternak et al. 2013). It is possible a genetic bottleneck due to a small founder population and lack of immigration may be precluding population growth (Kolbe et al. 2004, Lee 2002). The small and seemingly stable population size may suggest this population has had fewer negative impacts than other *Chlorocebus* populations, both native and introduced. However, the economic damage and human conflict of an introduced population of *Chlorocebus* monkeys in the Caribbean (Dore 2013), coupled with the ability of these species to act as nest predators (Patterson et al. 2016) and carry zoonotic pathogens (Legesse and Erko 2004), suggests the Florida population should be continually monitored and studied.

Rhesus Macaques have demonstrated appreciable population growth throughout their introduced range in the continental US and Puerto Rico (Evans 1989, USDA 2008). This successful establishment is likely a product of their plasticity in environmental requirements (Fooden 2000). The growth of the SSSP population despite a small founder population suggests they are resilient to genetic depression.

The propensity of survival in Rhesus Macaques, and related high population growth rates, may lead to population densities that threaten native natural resources as well as human health and livelihood. As previously mentioned, Rhesus Macaques in introduced habitats outside of Florida have increased bacteria loads in water bodies (Klopchin et al. 2008), increased mortality of native birds through nest predation (Evans 1989), and caused substantial agricultural damages (USDA 2008). Little research has evaluated potential environmental impacts of introduced primates in Florida. The population of Rhesus Macaques in Silver Springs was found to consume quail eggs placed in artificial nests (Anderson et al. 2016), indicating they will consume bird eggs located in their habitat. Hoffman (1996) reported *Setophaga petechia*

gundlachi (S.F. Baird) (Cuban Yellow Warbler), a mangrove specialist, was absent on Raccoon Key in areas where the mangroves had been destroyed by Rhesus Macaques and that only a few solitary males were located in areas where mangroves were damaged but still standing; the author did not specify the abundance of the birds on the island prior to the macaques (Hoffman 1996).

In addition to potential ecological impacts, introduced Rhesus Macaques may threaten public health and safety. From 1977 to 1984, the Florida Game and Fresh Water Fish Commission—now the Florida Fish and Wildlife Conservation Commission—documented 31 monkey–human interactions, and 23 of these incidents included human injury; the agency stopped maintaining primate conflict reports after this time (Montague et al. 1994). These reports are concerning as the population of Rhesus Macaques in SSSP and along the Ocklawaha River has tested seropositive for Herpes B Virus (Montague et al. 1994); transmission from macaques to humans is extremely rare, but can be fatal (Huff and Barry 2003, Jones-Engel et al. 2006). From 2013 to 2016, there were a minimum of 4 road mortalities of Rhesus Macaques within 10 miles of Silver Springs State Park; because the virus is transmitted through exposure to bodily fluids, these carcasses may represent a threat for those charged with their removal.

Public sentiment makes management of charismatic invasive species challenging (Verbrugge et al. 2013); however, public support can be critical to the success of environmental management programs (Jacobson 2009). Despite potential ecological and public health threats, public support of introduced primate populations in Florida has remained high. In 1992, the Ocala Star Banner, a central-Florida newspaper, solicited readers to respond to the question, "Do you want free-ranging monkeys to stay along the Silver River?" Of the 625 respondents, 615 responded "yes" (Montague et al. 1994). As previously mentioned, local officials in both Dania Beach and Naples considered local ordinances protecting the cities' introduced monkey populations. An adult male Rhesus Macaque, colloquially known as the "Mystery Monkey of Tampa Bay", wandered the Tampa Bay area and eluded capture from 2009 to 2012. The story got over 75,000 "likes" on a dedicated Facebook page and was featured on a recurring segment called "Monkey on the Lam" on the national comedy program The Colbert Report. Because the public has displayed support for introduced primate populations in Florida (Montague et al. 1994, Wolfe and Peters 1987), wildlife managers must prepare for potential public backlash of management decisions and consider outreach and education initiatives.

Developing policies for the captive maintenance of non-native and potentially invasive species is also difficult and controversial. In Florida, *Chlorocebus* species and macaques are listed as Class II wildlife, indicating they pose a potential threat to people. Individuals wishing to keep these animals in captivity must obtain a Class II permit, which requires previous experience with the species as well as specific caging and facility requirements. Squirrel monkeys are classified as a Class III wildlife species, which requires a permit for possession but with fewer restrictions than a Class II species. In June 2016, there were ~225 commercial facilities (e.g., zoos, animal trainers) permitted to keep primates for commercial use and ~450

individuals permitted to keep captive primates for personal use in the state (State of Florida 2016a). Potential escapes of these animals are concerning, as escapees could potentially migrate into small, extant populations and increase likelihood of survival (Brown and Kodric-Brown 1977, Lockwood et al. 2005). During 1989–2016, the Florida Fish and Wildlife Conservation Commission recorded nearly 200 reports of escaped or free-ranging primates, including over 250 individual animals; at least 115 of these were escapes from captive settings, about 75 of which had permits (State of Florida 2016b).

Herein, we provide the first comprehensive review of introduced primate populations in Florida. Managers and researchers of invasive species must understand when to classify individual populations as simply introduced rather than invasive, and for those classified as invasive, how to designate threat levels (Colautti and MacIsaac 2004). We suggest management of Rhesus Macaques should be prioritized over the other 2 introduced primate species in Florida, as they have demonstrated faster population growth as well as potential environmental, economic, and public health threats.

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