RIVER MONKEYS: HOW RIVER TOURISM INFLUENCES PATTERNS OF AGGRESSION IN THE INTRODUCED RHESUS MACAQUES IN SILVER SPRINGS STATE PARK

by

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ABSTRACT

Celeste Lam. River Monkeys: How River Tourism Influences Patterns of Aggression in The Introduced Rhesus Macaques in Silver Springs State Park
(Under the direction of Dr. Lydia Light)

Silver Springs State Park is Florida's largest limestone artisan formation, as well as one of the most popular tourist attractions in the state. The park's popularity began in the late 1870s when the beloved glass-bottom boats were invented (Wolfe & Peters, 1987; Montague et al., 1994). Its notoriety additionally took off with the introduction of the free-ranging rhesus macaques *(Macaca mulatta)* during the 1930's. Despite continual attempts to manage the population, the rhesus macaque numbers have only increased since their arrival. This has led to growing concern over potential conflicts between the monkeys and the other organisms on the river (plants, animals, and humans). To better understand what risks are present, I collected observational data on patterns of aggression in free-ranging rhesus macaques in response to river tourism at Silver Springs State Park, Florida. The goal of this project is to add to biological anthropology and the developing field of ethnoprimatology by using qualitative methods to understand 1) how park policies concerning the anti-provisioning rules and primates are communicated, 2) patterns of aggression between the introduced rhesus macaques on the SSSP river line, and 3) how interactions with passing tourists influence the agonistic behavior of the monkeys within the group. For the collection period, I used all-occurrence focal animal sampling in five-minute observation periods. I collected a total of 865 minutes from June 12-August 25, 2021. I used a Kruskal Wallace test to analyze and compare the proportion of agonistic behaviors in the presence and absence of tourists. I also compared adult males, adult females, and juveniles to each other to determine which age and sex class are more likely to engage humans. I tested two hypotheses related to macaque behavior: 1) adult males would engage in more agonistic

behaviors compared to the adult females and juveniles; 2) the presence of tourists would influence macaque behavior.

I found that agonistic behaviors did not differ significantly between age/sex categories (adult male, adult female, juveniles) but did approach significance [H (2) = 5.146, $p = 0.076$] with rates of aggressive behaviors higher among juveniles. Descriptive statistics (mean ± SE) revealed that on average 7.69% ± 2.53% SE of the recorded behaviors involved some form of agonism. Specifically, among adult males, 3.74% ± 1.08% SE; adult females, 4.56% ± 2.05% SE; and juveniles (both male and female), 21.94% ± 10.98% SE of recorded behaviors were agonistic in nature.

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LIST OF ABBREVIATIONS

CDC	Center for Disease Control
CABI	Center of Agriculture and Bioscience International
IACUC	Institutional Animal Care and Use Committee
SSSP	Silver Springs State Park
SPSS	Statistical Package for the Social Sciences
OTA	The U.S. Office of Technology Assessment

SECTION 1: INTRODUCTION

Primate species have been introduced into novel environments for a variety of reasons, with the earliest documented introduction being around 300 years ago. These animals are released into the wild for a variety of reasons such as tourism, increased biodiversity (by park officials and locals), and accidentally released or escaped from biomedical facilities. One example of this is the introduced rhesus macaques in Silver Springs State Park (SSSP) that have become one of the many tourist attractions to the Silver River. These primates pose a variety of possible risks to the park and park visitors that range from potential contact, disease transmission, and provocation on both sides. With these risks in mind, the goal of this study is to examine 1) how park policies concerning the anti-provisioning rules and maintaining a safe distance from the primates are communicated, 2) patterns of aggression between the introduced rhesus macaques on the SSSP river line, and 3) how interactions with passing tourists influence the agonistic behavior of the monkeys within the group. Macaques (*Macaca* spp) are behaviorally flexible primates that use a variety of behaviors to obtain food from humans. The SSSP monkeys are accustomed to human visitors and are thus not afraid of the passing kayakers and boaters. Due to their familiarity with humans, this population can offer insight into macaques' relationship with humans broadly speaking as well as potential new methods of management for temples and parks that have frequent human-monkey interactions. The broader goal of this study is to contribute to the growing problems at sites of heavy human-macaque interaction and to assist in managing introduced primates to help protect both primates and the people living near them.

SECTION 2: LITERATURE REVIEW

Macaque Sociobiology

The Macaca Lineages. Throughout the geographic ranges of Asia and parts of Africa live one of the world's most adaptive primate taxa: macaques (*Macaca spp*). The genus *Macaca* has developed a status as one of the most successful primate radiations because of their unique ability to adapt to their continually changing environments (Fooden, 1982). There are three primary lineages of macaques based on dispersal waves: *Silenus-sylvanus* (12 species), *Sinica-arctoides* (6 species), *and Fascicularis* (4 species including *Macaca mulatta*). Each of these phyletic groups split from a single lineage that evolved from papionines (large African monkey-like primates) about 7 million years ago in northern Africa. They then spread throughout Eurasia 5.5 million years ago and broke off into the three lineages known today (Fooden, 1976; Delson, 1980). These monkeys are medium sized primates with males ranging from 5.7kg-18.3kg and females between 3.2kg-12.8kg. Regarding this study, rhesus macaque (*M. mulatta*) males are roughly 11kg and females are 8.8kg in size (Singh & Sinha, 2004).

Presently, macaques are primarily found in native populations throughout Asia and parts of Africa and in introduced populations at some European and American locations. The females in these species are philopatric (remain in their natal groups) which typically leads to strong kin-bonds between the mothers and their daughters (Thierry, 2007). The males, on the other hand, disperse from their natal groups and sometimes form bachelor groups until they can join a troop either by overthrowing the current alpha or join groups as low-ranking males. Though all macaques share similarities in their anatomy, diet, and general evolutionary traits, each lineage within the radiation *Macaca* varies in troop dynamics, geographic distribution, and social

behaviors. Some species are more aggressive than others or have stricter matriarchs while others have a mild hierarchy, and some can withstand harsh climates while others cannot.

To be specific, the *silenus* lineage possesses the most scattered distribution with its 11 species being located far from one another. For this lineage, there is little overlap of the geographic ranges and the presence of a relict distribution (an ancestral taxon that was widespread) can indicate an early dispersal of the species (Fooden, 1982). Within the *silenus* lineage and contrary to other macaque species, both *M. sylvanus* and *M. silenus* may attach positive meaning or subordination to the bared teeth display (Preuschoft, 1995). Additionally, species from the *silenus* and *sinica* lineage live in troops that are based on mutual kin-related support and weaker hierarchies of dominance that allow more social tolerance and affiliations between nonrelatives (de Waal and Luttrell, 1989; Thierry et al., 1994; Chapais, 1995). Like *silenus*, the *sinica* lineage has a moderately scattered distribution in south Asia. The species within this lineage are located much closer to one another compared to the *silenus* lineage with the outlier being *Macaca sinica* which resides on the island of Sri Lanka. Unlike the previous two, the *fascicularis* lineage has a more cohesive distribution throughout the equatorial and tropical regions of south Asia. The only outliers for this group are *M. fuscata* in Japan and *M. cyclopsis* in Taiwan. These islands along with Sri Lanka are known as shallow-water islands which at one point (~18000 BP) were all joined to the mainland by land bridges (Worldbath, 2000; Abegg & Thierry, 2002). This played an important role in the distribution of land mammals that evolved into the current native fauna. The water between adjacent islands is swimmable for some macaques and has been recorded occurring between the Japanese islands. This has led to a controlled distribution where most mammals on these islands (who are incapable of swimming between islands) are unable to disperse off the island without human

intervention (Abegg & Thierry, 2002). Within this lineage, *M. mulatta*, the subject of this study, has the largest distribution that stretches from Pakistan through China and into parts of South and Southeast Asia (Fooden, 1982; Thierry, 2004).

Macaque Social Behavior. Across the genus, macaques are highly social primates that live in large communal groups with strong hierarchies and matrilineal bonds. High ranking members can be identified by the dominance they display in their walk and erect tails. The way they carry themselves signals to outsiders and troop members what their ranking is. Lower ranking individuals tend to avoid eye contact with high-ranking members and flee when they approach. They also show more fear and submission through facial expressions such as fear grimacing or barred teeth displays (de Waal & Luttrell, 1985). Across the *Macaca* genus, ranking is passed down from the mother to the offspring. Specifically, a female is born into her permanent position in the troop, but males can climb in status through physical challenges (Kawamura 1958; Datta 1992). Interestingly, since most support goes toward younger female kin, the dominance ranking is reverse ordered by age. Younger daughters always out rank their older sisters. This is only present in large troops with strong matrilines because without the numbers and resources, ranking is less prioritized (Datta, 1992; Hill & Okasyasu, 1995). Rank plays an important part in the maintenance of the troops; it allows for alloparenting for females of similar rank, bonding, and protection against outside threats (Thierry, 2004). Though known for their aggression, macaques can be regularly observed grooming, and playing to express affiliation and recognition of rank. The most notable affiliative behavior is play fighting which can be observed in each age group and is more prominent in species such as *M. fuscata* and *M. mulatta* (Petit et al., 2008).

Intragroup Aggression. Agonistic displays and fights are not uncommon to macaque troops as these primates are prone to aggression (Vandenbergh, 1966; Southwick, 1967; Lindburg, 1971; Fairbanks et al., 1978; Teas et al., 1982; Thierry, 1985). There are various reasons for these behaviors that range from kinship, mating, dominance, sex, age, and resources. Macaques are among the many primate species that maintain strong kin relationships and often this acts as a predictor of outcomes in fights. Individuals with more kin in their troop will have more protection and access to resources (food and social partners), while members without kin have been seen to be more prone to agonistic displays such as fear grimacing and biting (Petit, Abegg, & Thierry, 1996). Macaques have been observed fighting over mates, especially between high-ranking members, as well as hierarchical overthrows where troop members challenge the ranking of dominant members (male and female). Lastly, agonistic displays vary based on sex, ages, and what resources are being fought over.

In explaining the importance of intragroup aggression, Cooper and colleagues (2004) write, "[i]n macaques, within-group competition is strong and appears to have shaped the social organization and female social relationships" (p. 218). Adult males are more likely to engage in disputes over dominance and mate selection while adult females are commonly observed aggressing to protect their kin/offspring, rank in the troop, or resources. Petit and colleagues (1996) observed, "a high proportion of slaps and grabs in crested macaques; manual attacks might be seen as a rough form of aggression that may be used frequently when there is no risk of biting among partners" (p. 424). They also found that the juveniles collectively participate less in fights that lead to injury but rather were more likely to flee from confrontations. Additionally,

they observed that more agonistic interactions were concluded with reconciliation (grooming) between the parties involved. The role of grooming after a fight or altercation is important to any troop because it can strengthen the cohesion between individuals and maintain stability in the group.

Intergroup Aggression. Since macaques (*Macaca spp*) are matrilineal primates (female-focused hierarchies), intergroup aggression is indicative of female tolerance and between-group conflicts (Sterck et al., 1997). As the matriarchs, females will "employ" males to act as resource bodyguards in exchange for reproductive opportunities. This defense strategy is particularly important when outside troops approach or try to steal the protected resource. In these cases, the males would display aggression toward the outside troop and if successful in warding off the intruders, the females would allow the males reproductive access to them (Cooper, Aureli, & Singh, 2004). However, this tolerance cannot be applied to males as they have been observed to form alliances to prevent outside males from mating with troop females. This display of between-group aggression in males is crucial to the structure of macaque societies as it maintains group security and unity. Without the realization of the males, females have been observed to sneak away to partake in "secret" rendezvous with outside males. Intergroup behaviors such as aggression and tolerance are prominent components of macaque troops, however as these adaptive primates continue to integrate into urban areas, occurrences of intragroup aggression become more common, which has caused an increasing need to understand their relationship with humans.

Ethnoprimatology of Macaques

The field of ethnoprimatology is a steadily growing area of academic focus that was developed to bridge the divide between local politics, cultural beliefs, and nonhuman primate welfare (Riley 2005; Sponsel, Ruttanadakul, & Natadecha-Sponsel, 2002; Wheatly 1999). In the modern application, ethnoprimatology examines the impact of social, economic, and political histories on the existence of nonhuman primates (herein "primates") and their relationships with humans (Fuentes, 2012). One of the key messages ethnoprimatology stresses is that environmental problems are cultural because they are problems that directly affect humans. An example of this is seen through habitat loss of various primate species such as baboons (*Papio spp*), vervet monkeys (*Chlorocebus spp*), chimpanzees (*Pan troglodytes*) and macaques (*Macaca spp*) (Boulton, Horrocks, & Baulu, 1996; Hill, 2000). From this we see an increase in crop, property, and market foraging (Hill, 1997) by the primates as well as an increase in using primates as labor workers (Azis et al., 1980; Ruslin et al., 2017; Schowe et al., 2021; Srikulnath et al., 2022). All these issues are areas of focus in ethnoprimatology and are becoming increasingly more important to understand as interactions between primates and humans increase.

Human-Macaque Interactions. The growing concerns of increased contact between macaques and humans has dominated this field as these primates are becoming local pests. When near humans, macaques can monopolize specific vendors or people provisioning the monkeys. To investigate this growing problem, the most prominent and widely studied subjects of ethnoprimatological research have become urbanized macaques. These highly adaptive primates

are now commonly located in human settled areas and are frequently interacting with people. As human-settled areas expand, macaque monkeys are pushed to adapt to their changing environments due to deforestation and the reduction of resources. In a study on the perception of lion-tailed macaques, the researchers write, "many macaque groups that occur in cities, rural settlements, and the forest-agriculture interface have adapted well to human-modified conditions, while sometimes coming into conflict with people due to crop raiding, entering homes in search of food, or injuring people" (Jeganathan et al., 2018, p.205). The perceptions people have for these monkeys have been shown to play a large role in primate conservation and the increasing view of macaques as problems.

In some societies such as Bali, macaques have been deeply rooted in the local religion and as a result are highly revered and respected (Wheatley, 1999). Cultures that have macaques deeply ingrained in their religion viewed these primates not as pests and though the primates displayed similar behaviors as today, the people considered them holy (Riley, 2010; Wheatley, 1999). In some areas, the shifts in attitudes from revering and tolerating macaques to viewing them as vermin appears to be a quickly developed change (Sha, Gumert, & Lee, 2009; Saraswat, Sinha, & Radhakrishna, 2015). It did not start until colonization and once it gained traction, the competition between humans and macaques began to become an issue. Many would not view this as competition but rather the nuisance of a wildlife species, but this is a struggle of survival for macaques. As human-settled areas have expanded, macaque habitats have been destroyed which has led to a drastic decrease in food and home ranges (Lee & Priston, 2005; Sha et al., 2009b; Erinjery et al., 2017). As a result, these primates are forced to adjust to human areas to

survive, which means taking food from people and taking over buildings, temples, parks, and farms. Though macaques have become the most impressive "weed species" (Richard, Goldstein, & Dewar, 1989), found to cause up to 70% of damage in parts of Asia and Africa, this is not completely unexpected. Admittedly, this was more foreseen by researchers and not locals (especially not European colonizers) and it remains no surprise that macaques would use their adaptability to continue surviving (Naughton-Treves, 1998).

The intelligent, adaptable, and opportunistic nature of macaques has led the species to turn to crop foraging for food (Naughton-Treves, 1998; Sillero-Zubiri & Switzer, 2001; Lee & Priston, 2005; Warren et al., 2007). These characteristics of macaques have led them to be labeled as "weed species" (as mentioned above) which is defined as a species competing with humans within a shared space (Richard et al., 1989). Interestingly, the frequency and level of crop damage caused by macaques vary by season. During seasons of food restriction (i.e., winters or dry seasons), macaques are more likely to consume crops on farms as natural foods are in short supply. Coincidentally, these align with human food shortages which lead to the perception of macaques being pests. However, during fertile seasons where wild fruits are in abundance, there is sometimes a decrease in crop-foraging, emphasizing the role in basic nutrition and the balance between wild and cultivated food options (Lee & Priston, 2005; Kasim, Hambali, & Amir, 2017). The issue of viewing primates as pests is a growing problem that needs to be addressed by developing better management skills and further understanding how farmers and locals perceive macaques. If researchers can understand what precisely is causing these negative views, they could begin to develop a new means of benefiting both humans and

primates. However, this is only achievable with the help of locals and how they see change occurring. This can be done through acknowledging the need to understand how humans influence primate life and how primates influence human life (Riley, 2006).

Human-Macaque Conflict. Currently, many macaque species are living in human-settled areas that range from rural farmlands to highly urbanized cities. This is made possible by their generalized diet, high reproductive rates, and troop systems. Despite their affiliative behaviors, macaques are prone to aggression in the presence of humans which has led to an increase in safety issues for both macaques and humans. The risks increase in ecotourism areas where humans are interacting with the monkeys and unknowingly provoking them. The primary cause of negative interactions is the misinterpretation of the social behaviors of macaques.

It is important to note that between-group aggression differs between environmental conditions. Compared to macaques that are not living near humans, macaques that are regularly provisioned by humans or are frequent crop foragers are found to have more intergroup aggression (Southwick et al., 1976; Ruppert et al., 2018). This increased intergroup aggression in urbanized macaques is due to their higher density in human-settled areas (Vessey, 1968; Lindburg, 1971; Hausfater, 1972). The aggression found in urbanized areas occurs not only between the macaques and other wildlife but also with humans.

The increase in conflict over resources is especially pertinent as human-settled areas further expand and macaque habitats decrease. Food patches are reducing at a faster rate and as a result, macaques are forced to adapt to foraging in urbanized areas and farms. The unique adaptability macaques possess is the primary reason for their ongoing survival. It is this

flexibility that allows macaques to adjust their behaviors to survive in human-dominated environments that continue to change (Wong & Candolin, 2015). Due to their generalist diets, high dexterity, and adaptive intelligence, the presence of macaques in human-settled areas presents a list of problems for their human neighbors.

Among the various problematic interactions people have with macaques, the most concerning is the tendency to damage crops, markets, and residential areas. An example of these behaviors can be seen in the macaque populations of Bali, where monkeys damage farms, homes, stores, and markets in response to increasing urbanization (Wheatley, 1999; Solomon, 2013). This behavior is a growing issue as people have begun perceiving the monkeys more as pests than important players in the overall ecosystem. Additionally, primates are deeply rooted in the local religions so seeing them as pests goes against religious teachings (Wheatley, 1999; Sponsel et al., 2002). In a similar case in Indonesia, people may chase, hunt, attack, or capture the monkeys to remove them from their property (Riley & Priston, 2010). However, these responses do not go unaddressed; the monkeys are quite intelligent and have been known to adapt to these responses by developing new ways to evade humans and gather food undetected. Primates have been observed using "tactical deception" where part of a group distracts the farmer while the rest covertly forages from the crops (Maples et al., 1976; Strum, 1986, 2001). This form of crop destruction is highly problematic as it has led to an increase in violence both from humans protecting the economic value of their crops and macaques responding to violence directed towards them (Wheatley, 1999; Hill, 2018). A few examples observed in a study by Sha and colleagues (2009a) found various methods the Singapore macaques took to obtain food: 1)

roaming terraces/backyards to take food from homes, 2) rummaging trash bins, 3) taking food from park visitors, and 4) climbing vehicles to enter stores. In addition to obtaining food from farms and residential areas, macaques are also provisioned in nature parks, temples, and other tourist attractions.

Research on the human-macaque interface examines the relationship, perceptions, and understandings of macaques that local populations of humans have about their primate neighbors. How humans view macaques can fluctuate according to the interactions they have with the monkeys. Peterson and Riley (2013) write, "If macaque populations are frequent and successful crop raiders, this aspect of their behavior is likely to create the most powerful opinions and receive the strongest reactions from local humans" (p.153). These behaviors would invoke strong opinions from locals as their livelihoods would be directly impacted by the macaques as crop-foraging and taking food from residential areas causes the people to lose money. An example of this behavior was observed in a study by Erin Riley (2007) where she found farmers claiming macaques to be the primary cause of crop destruction over non-primate animals, consuming 75% of their cacao crops. However, further research that used camera traps found most of the damage to crops was caused by forest rats and not the macaques. The author states that the most likely reason for this misconception is that the presence of macaques in the fields is easier to detect while rats could invade the crops without the farmers being aware.

Observed countless times by primatologists and ethnoprimatologists, macaques thrive in tourist areas. As macaques become accustomed to tourists and locals feeding them, there is a growing potential for conflict between humans and monkeys (Orams, 2002; Fuentes, Shaw, &

Cortes, 2007; Lee & Davey, 2015). These incredibly smart monkeys have learned to associate these locations with food as many visitors will provision the monkeys and if they do not, the monkeys will aggressively take food from them. These associations and behavioral adaptations macaques form in tourist areas are some of the leading reasons for conflict interactions with humans. In a Hong Kong study by Lee and Davey (2015), some park visitors told the interviewers that they fed the monkeys because they believed them to be starving while others stated they saw no harm in their children feeding the macaques. The most common method of obtaining food is using scare tactics. Interestingly, macaques have conditioned themselves or visitors have unknowingly conditioned the monkeys to associate aggression toward humans with the reward of food (Fuentes, 2006). Lee and Priston (2005) explain, "The monkeys develop a taste for human foods, lose their fear of humans, and then become proactive (and aggressive) in seeking human foods" (p.11). Unfortunately, macaques now expect food from tourists so when they are not provisioned, there is an increase in aggression toward humans (Zhao, 2005; Fuentes, 2006; Lee & Davey, 2015). This dependency on tourist provisioning became a particular concern in 2020 after many countries began their COVID-19 quarantines. The lockdowns have severely decreased tourism and as a result, there has been an increase in aggression from the now starving and desperate macaques in areas like Lopburi, Thailand (The Guardian 2020; Hansen et al., 2021). The issue behind these interactions is that tourists tend to underestimate these wild animals and are often surprised/angry when the macaques attack or aggress toward them. These conflicts are often the result of positive motivation to interact with the monkeys, but the macaques respond with aggression that often leads to bite injuries, food theft, or exposure to

simian viruses (Else, 1991). This is a growing problem especially in areas where macaques are shedding the B Virus virus, the monkey population is getting out of hand, or in areas that are scrutinized by tourists being "attacked" by the monkeys. Additionally, as a response to the increasing "pest" related behaviors, humans tend to respond with open hunting, sterilization, and annoyance toward the animals (Wheatley, 1999).

The desire to engage with macaques at tourist hubs such as temples, beaches, markets, and in some cases residential areas is well-documented. Research has shown most agonistic interactions between humans and macaques are caused by humans initiating the aggression. However, when macaques initiate aggression toward humans it is usually under two circumstances: 1) humans taunt the monkeys and 2) humans attempt non-aggressive interactions with the monkeys (Fuentes, 2006; McFarland et al., 2013; Beisner et al., 2015). The first situation is most seen in today's technologically forward world where "likes" and social media "views" are the leading reason to harass wild animals (Nekaris et al., 2015; Lenzi, Speiran, & Grasso, 2020). People will often showcase food without distributing it to the monkeys or will try to lure monkeys toward them with non-food items such as bags, jackets, or cameras. As for the second circumstance, humans will try to take photos or videos with macaques without the intention of agitating them. These reasons to interact with macaques are not always accepted by the primates especially if the humans persist and unknowingly cause stress to the monkeys. Most agonistic interactions between macaques and humans are prompted by humans practicing behaviors that would insight aggressive reactions. These behaviors consist of "initiating eye contact and physical contact with the macaques, stepping on their tails, teasing them, or allowing

the animals to climb on them" (Fuentes & Gamerl, 2005, p.201). Maréchal and colleagues (2011) suggest that loud sounds such as shouting could cause macaques to initiate aggression toward humans. This study also found that negative interactions between humans and macaques were primarily caused by humans displaying behaviors that caused severe physiological stress to the monkeys.

When people read articles, news, and hear about monkeys attacking tourists, little is ever said about the role of humans in these situations. In a study by Beisner and colleagues (2015), they found that humans initiated 818 instances of aggression toward the monkeys while the macaques only initiated 123 instances. However, about half (42.3%) of the 123 macaque aggression occurrences were in response to previous human aggression but interestingly, the majority (72.1%) of responses to human-initiated aggression were to run away. These findings show that often, the media portrays the monkeys as *violent, wild animals* or *killer monkeys* without any mention of why the monkeys attacked the humans.

As seen in ethnoprimatological and primatological research, humans instigate most human-macaque conflicts and monkeys usually react in fear displays and fleeing behaviors. Only when macaques are pushed too far do they aggress (threaten offspring, dominant members, or steal their food). Despite the outcry of the media, physical injuries from macaques (i.e., bites, scratches, or hits) are rarely observed in areas such as Dehradun, India as macaques do not regularly attack humans to cause injury (Beisner et al., 2015). If anything, macaques will chase humans, exhibit aggression, or small body jolts to communicate they want to be left alone but rarely do they cause injury. However, in locations such as Gibraltar, Bali, and Mt. Emei there are

occurrences of human-macaque conflict that result in minor injuries (barely breaking the skin). Based on hospital records between 1980-1989, Fa (1992) found 248 instances of barbary macaques biting humans in Gibraltar. Then from 1990-1991, 60 macaque bites toward humans were reported. In another Gibraltar study, Fuentes (2006) reported the occurrence of 10 bites out of 808 aggressive encounters out of 5,489 interactions observed in 2004 between barbary macaques and tourists. In Bali, Fuentes and Gamerl (2005) found 48 instances out of 420 aggressive encounters where long-tailed macaques bit tourists. Finally, on Mt. Emei, Zhao and Deng (1992) found 113 instances of conflict between Tibetan macaques and humans that resulted in human injury. As seen, aggression between humans and macaques is not unheard of but the cases of injuries are few compared to the number of conflicts that occur.

In agonistic interactions, humans primarily aggressed toward the macaques when 1) macaques were on human property, 2) macaques stole food, 3) children were involved, and 4) when a human male was interacting with the monkeys (The Humane Society, 2013; Beisner et al., 2015). Interestingly, this study found that humans were more likely to aggress toward the macaques when no food was present and particularly if children were the primary humans involved in the interaction. Unfortunately, the negative interactions between humans and macaques have led to an increase in media labeling macaques as dangerous and killers.

Introduced Species

Introduced Primate Populations. Primate species have been introduced to many places around the world for various reasons that range from ecotourism, the pet trade, to escaping from research facilities. In this section, I will cover three situations of interest in the Western

hemisphere where primates were introduced into a novel environment. The first species to discuss are green monkeys which were introduced to St. Kitts and its adjoining islands, Nevis and Barbados, as a byproduct of the slave trade between West Africa and the Caribbean (Dore, 2017). There is no official record of when the monkeys were brought to the islands, but it is suspected it was during the 17th century. The primary theory of why green monkeys were brought to the islands is for the pet trade. During the 17th century, there was a high demand for pet monkeys, and it was not uncommon for thousands of monkeys to be transported from Africa to the British West Indies (Denham, 1982). By the later 17th century, the primates were established on each island and in 1682, Barbados declared them as pests (McGuire 1974). There is little written about the introduced green monkeys on each of the islands with the primary research being conducted on St. Kitts. As a result, there is still a need for further research to understand the implications of these introduced primates (Dore, 2016). In addition to the introduced green monkeys dispersed throughout the British West Indies, many parts of the United States struggle with similar issues with introduced primate species.

Florida is home to a wide variety of recently introduced species that have ranged from harmless to severe threats. Of these species, three are primates: squirrel monkeys (*Saimiri* sp.), green monkeys (*Chlorocebus sabaeus*), and rhesus macaques (*Macaca mulatta*). The squirrel monkeys were introduced to Florida in the 1960s when they were released into a confined habitat in Silver Springs State Park. Later the monkeys were given access to the entire park but in the 1970s were no longer found in Silver Springs (Maples et al. 1976). The second introduction date is uncertain; there is speculation that the monkeys were introduced in the 1970s into Ft. Lauderdale but there is no record of this (Wheeler, 1990). To date, only one of the introduced populations remains in Florida, and is confined to Ft. Lauderdale (C.J. Anderson, Hostetler, &

Johnson, 2017). The squirrel monkeys have not thrived as well in Florida, perhaps due to trapping for the pet trade, hunting, or inhospitable environmental conditions. Unfortunately, there is a great deal of uncertainty surrounding the disappearance of these monkeys in areas throughout Florida (Maples et al., 1976; Dorcas et al., 2011; Mazzotti et al., 2011; C.J. Anderson et al., 2017).

The green monkeys (*Chlorocebus sabaeus*) were introduced into Dania Beach (south of Ft. Lauderdale) during the 1950s and to date, there has only been one population brought to Florida. These primates can still be found in the Dania Beach area and are suspected to have escaped or were released from the Anthropoid Ape Research Foundation, a biomedical research facility (Williams, Almanza, Sifuentes-Romero, & Detwiler, 2021). By 2015 the population had expanded into four groups (35 individuals total). Some attempts to keep the population from dispersing to other parts of Florida have been taken but overall are not heavily enforced. Due to how habituated the monkeys are, they have gathered a great deal of local support which has helped protect the thriving population in Dania Beach (C.J. Anderson et al., 2017).

Rhesus macaques are the only introduced primate species at Silver Springs State Park. As will be discussed in detail below, these primates were introduced to the park to increase tourism but as the years have progressed, they have caused significant changes to the natural ecosystem of the park. Florida is not the only location with introduced macaques, these species of monkeys are some of the most widely introduced primates in the world. They are the primary primate models used in biomedical research, often bought as pets, and can be found in zoos and sanctuaries (CABI, 2019). Due to unintentional releases from these conditions, several non-native locations around the world have struggled with an increase in issues caused by these introduced primates. Under the invasive species compendium produced by the Center of

Agriculture and Bioscience International (CABI) (2019), introduced rhesus macaques have displayed the potential to cause severe harm to natural resources. The potential risks from the introduction of this highly adaptable primate species consists of shoreline erosion from mangrove destruction, decreased island bird populations from nest predation, and bacterial contamination to water sources.

Unfortunately, as we have seen, introduced and native macaque populations run the risk of causing severe economic damage to the environment if the populations surpass what their habitats can support. To help maintain the balance in these populations, management in introduced ranges has included euthanasia and trapping and removal (CABI, 2019). In addition to these threats, rhesus macaques have the potential for pathogen transmission to humans, animals, and plants (M.C. Anderson et al., 2004a). According to the Center for Disease Control and Prevention (CDC), 70-80% of macaques carry the B Virus. This contagion is particularly concerning because if pushed under immense stress that leads to immunity decline, they can transmit the B Virus virus to humans (Ostrowski, Leslie, Parrott, Abelt, & Piercy, 1998). Beyond macaques, other pathogen threats from introduced species consists of: 1) pathogens that were previously considered harmless that evolved virulency due to the environment; 2) pathogens that went extinct in a region but could reemerge as a result of changing environmental conditions; and 3) pathogens that previously only affected animals but are recently contagious to humans because of exposure to fluctuating activity patterns and environmental conditions, or due to the introduction of a new factor that causes transmission to humans (Dobson & Foufopoulos, 2001; M.C. Anderson et al., 2004a). The threat of disease is one of the most dangerous risks caused by introduced species. It can lead to the outbreak of an epidemic or pandemic that can have terrible consequences on the economy and the human lives of these afflicted countries.

The U.S. Office of Technology Assessment (OTA) estimated that in 1993, 79 introduced species caused $97 billion in damages over the span of 85 years. Then in 2000, a study by Pimentel et al. estimated the yearly damage expenses from a larger set of introduced species to be $137 billion. The total cost of introduced species is overwhelming and has only risen since the mid 19th century. Introduced primates have proven to cause major economic expenses throughout the world. For example, between 2002-2006 the total economic costs in damages for farmers caused by rhesus macaques grew from $1.13 million to $1.46 million each year. In Puerto Rico, rhesus macaques caused $300,000 in direct damages and $1 million in efforts to manage the primates (USDA & PRDA, 2008; CABI, 2019). These expenses consist of direct damages, management costs, and impacts of alien species on the host ecosystem and human populations. They also can influence the interactions and socioecology between humans and wildlife/environment (Perrings et al., 2002). For example, the protocols that involve culling, sterilization, and/or relocation of introduced macaques are incredibly expensive and due to the costs, can sometimes be unavailable as an option. This causes a new layer of trouble for areas that are trying to combat the harm caused by these introduced primates and other species.

Park Ecology

There is an abundance of research done in parks around the world focused on how people interact with nature or how they perceive wildlife (Bath & Enck, 2003; Ogra, 2008; Gandiwa, et al., 2013). Examining how county and national park visitors perceive and interact with wildlife is incredibly important, because in order to preserve local wildlife and maintain the ecosystem within the parks, the rangers, researchers, and visitors need to understand how their presence, opinions, and actions can either positively or negatively impact every organism within the park.

In a 2009 study, Kretser and colleagues examined how the preconceived perceptions of wildlife influence human-wildlife interactions in residential areas, likelihood of reporting interactions to authorities, and any possible conservation implications. They found that perceptions around wildlife were generally high except for specific species that generally live around homes (rodents and insects). Unfortunately, those that had poor interactions with wildlife were less supportive of land and wildlife conservation (Kretser, Curtis, Francis, Pendall, & Knuth, 2009).

In a study focused on wildlife welfare, Sterl and colleagues (2008) examined the awareness of recreational disturbances imposed on wildlife of park visitors at the Donau-Auen National Park in eastern Austria. They wanted to determine the level of awareness in each visitor of how their presence and activities in the protected areas impacted the welfare of the wildlife. They found that most participants did not consider their activities to be higher disturbances than others because all humans bring a level of disturbance with their presence. Visitors were aware of wildlife disturbances by many recreational activities but exempted their own such as dog walking. This notion of awareness but exemption is one that frequently reoccurs within this literature. Most people know that their presence disrupts or impacts the environment, but they do not consider their actions to be harmful. Taylor and Knight (2003) found that to understand the different degrees in which wildlife responded to various forms of recreation such as mountain biking, hiking, camping, and other types of activities. They studied the responses of bison, deer and antelopes toward humans visiting the Antelope Island State Park in Utah by recording alert distance, flight distance, and the distance of movement. Taylor and Knight found that all studied species displayed a 70% probability of fleeing from on-trail visitors within 100 meters of the trails. Additionally, the deer displayed a 96% probability of flushing from off trail visitors within

100 meters. This study found that Antelope Island State Park was mostly unsuitable for wildlife as recreational activities continue to expand (Taylor & Knight, 2003).

Silver Springs State Park

Silver Springs State Park (**SSSP**) is in Marion County in central Florida. The park is home to a wide variety of endemic and introduced species: both rare (see Table 1) and common. Many of these species can be found on or around the river line of the Silver River during various seasons of the year (see Table 2). As a result of this, many of these species have an increased likelihood of interacting with the introduced primates that inhabit various parts of the river line. The diverse ecosystem of the park has also led to its popular tourism and human visitations.

Park & Macaque Tourism History. Silver Springs was established shortly after the end of the Civil War as a destination for steamboat trips (Hollis, 2018). After a century of popularity and becoming one of Florida's iconic gems, the area was established as the Silver Springs State Park once the Florida Park Services obtained the property in 2013 (SSSP, n.d.).

Of the many species that live along the river and throughout the park, the introduced rhesus macaques (*Macaca mulatta*), have become one of the most popular tourist attractions. To date, there is no written record of how the macaques were introduced to the park, but several theories have circulated throughout the years. The most popular is that a man named Colonel Tooey obtained six adult rhesus macaques with the intention to enhance his Jungle Cruise boat tours. After obtaining the monkeys, Tooey released the macaques on an island on the Silver River, but unbeknownst to him, macaques were adept swimmers. The monkeys immediately swam from the island to the banks of the Silver River that connects to the park where they quickly settled in. Tooey was concerned the monkeys were not breeding properly so in 1948 he

obtained and introduced six more individuals to the park which led the population to explode (Concha-Holmes, 2015; C.J. Anderson et al., 2019). His tours eventually brought an increase in tourism as well as a rise in provisioning. As a result, one of the current issues for the park is when tourists attempt to feed the juveniles but are met with hostility from high-ranking adults. Tourists then become frustrated that the food they intended for the younger monkeys was being stolen. Despite interactions like these, the population of macaques continued to grow and with this expansion, population control has become a primary issue for park management.

Management. In the years between 1948-1984 the population of introduced rhesus macaques had expanded to 400 individuals (Concha-Holmes, 2015). This high rate of reproduction is believed to have caused severe damage to the natural ecosystem of the park and led to the use of various modes of population management. To address this growing issue, the park implemented a trapping and relocation program to control the population, but this was quickly ended because of a lack of local support. In 1984 the park was able to remove 225 macaques and sold them to a biomedical research supplier. This too was met with disapproval by the locals and was subsequently terminated (C.J. Anderson et al., 2016; Montague et al., 1994; Wolfe, 2002). Between 1984-1993 the introduced macaque population became such an issue that about 500 monkeys were removed by any means necessary (lawfully and unlawfully). From 1998-2012 the population had once again expanded to an ecologically devastating number which prompted the park to capture and sell 832 individuals to a biomedical research supplier. This caused a myriad of protests from local animal rights groups. To reduce the number of primates being sold to research facilities and to avoid culling, 2,000 locals signed a petition to implement a sterilization program; however, it is unclear if any action has been taken (C.J. Anderson et al 2016). The exact number of individuals currently inhabiting the park is unclear, but the park

management estimates it to be around 550-600 individuals (five identified troops) (C.J. Anderson et al., 2018; Roth, 2018). Over the years, the rhesus macaque population has increased with many efforts to contain it. The management of these introduced primates has become a priority for the park because of their adaptability, threat, and volatile nature toward humans and other wildlife.

Primatological Studies. While there are few studies published about the macaques of SSSP, those studies primarily focus on their interactions with humans, the monkeys' habitat, risk of disease transmission, and feeding behavior. In a study by Riley and Wade (2016) they examined how the macaques had adapted to the river line since their introduction. They looked at the interactions between the monkeys and boaters as well as between the monkeys and kayakers. They examined the feeding behaviors and the general travel patterns of each macaque troop. They found that boaters were more likely to provision the monkeys while kayakers were likely to approach the monkeys. They did note that provisioning was not a common occurrence with only 11.5% of the 566 boats partaking in it. Riley and Wade also found the macaques consumed a total of 31 plant species which was about 30% of the plant species in the floodplain swamp. Most of their diet consisted of vegetation with only one 1% being insects. Of the feeding records collected, 87.5% of them involved the macaques eating wild foods while 12.5% were tourists provisioning the monkeys. In addition to the vegetation, researchers have also observed the macaques preying on bird nests.

In 2016, Anderson and colleagues placed 100 artificial bird nests along the Silver River to test whether the monkeys would consume the eggs. This was done to clarify prior contradicting findings where Wolfe and Peters (1987) reported no nest predation despite records of the macaques consuming bird eggs. They found the SSSP macaques to be opportunistic with

bird eggs. They did not see a regular behavior of nest predation but if the monkeys found a nest, they were observed to consume the eggs. All the studies that have focused on the diet of these introduced primates have provided insight into where the macaques will likely occur as well as how they could be impacting the natural ecosystem of the park.

In another study on the habitat range of the monkeys, Anderson and colleagues (2017) determined the winter home ranges of one of the Silver Springs rhesus macaque troops. They habituated, trapped, and placed a GPS color on an adult female macaque that was set to record locations every two hours. This study was intended to be yearlong (December-December) but was halted after three months (December-February) when the researchers realized it was causing abrasions to the subject's neck. Attempts were made to release the color without trapping the subject again, but each attempt failed. As a result, Anderson and colleagues trapped the macaque and manually removed the collar. From the data they were able to collect, they found the macaques preferred locations with a wider variety of resources (i.e., food, water, and canopy cover) like the floodplain swamps rather than other parts of the river that yielded fewer benefits. In addition to the difficulties met during data collection, the researchers were the subjects of animal rights groups and public scrutiny over the harm to the subject. This was an unforeseen risk that provided insight into what kind of research to do and how the public could respond to it.

In 2018, Wisely and colleagues conducted a study on the prevalence of B Virus shedding in the rhesus macaques at Silver Springs State Park. Saliva and fecal samples were collected and analyzed to identify whether the macaques A) had B Virus antibodies and B) if they were shedding the virus. They found that 2.5% of the swabs used to collect saliva samples tested positive for the B-Virus antibodies. They then were able to estimate that 4-14% of macaques were shedding the B virus which indicates a potential risk of transmission to tourists. Since they

were unable to control for how many monkeys interacted with a single swab, they could not provide an exact percentage of macaques that carried the B-Virus antibodies. The transmission is avoidable so long as tourists continue to keep a safe distance from the monkeys and follow the anti-provisioning laws.

In 2017 Johnson examined how female macaque social relationships are affected by novel environments and feeding ecology in a group of macaques that had moved beyond the Silver Springs State Park into the Ocala National Forest. Over the course of 38 days, he observed 88 occurrences of agonistic behaviors performed by 11/12 females in the group. He found there to be a positive correlation between the expression of agonism and ranking. High ranking females were more likely to engage in non-physical aggressive encounters compared to the lower ranking females. This research pertains to the present study because it is the only study that focused on the expression of agonism. However, of the research conducted at Silver Springs, none of the published studies have examined patterns of aggression in response to park tourism. Understanding how interactions with humans can affect agonistic behaviors between group members as well as between humans and macaques could provide insight into how to manage these situations and ensure the safety of both primates and humans around the world.

Research Objectives, Questions, and Hypotheses

The proposed research will expand on Riley and Wade's findings from their 2016 study as well as help answer questions that emerged through conversations with the park manager. Riley and Wade (2016) examined how the macaques interact with humans and found that provisioning occurred more in boaters while kayakers were more likely to approach the monkeys. When searching the park's website, there was little communication that would define

park policies concerning the monkeys. There is a brief mention that visitors are prohibited from disturbing the wildlife, but there are no anti-provisioning rules displayed on the website. In the present study, I examine how policies concerning the monkeys are communicated as well as how interactions with tourists affect intergroup and intragroup macaque aggression. I ask the following questions:

1. How does Silver Springs State Park communicate their policies about the monkeys?
    a. Does the park communicate to park visitors the dangers of provisioning?
    b. Does the park communicate to park visitors the dangers of encountering the monkeys?
2. How do tourists influence the patterns of aggression of the introduced rhesus macaques?
    a. How frequently do tourists and macaques participate in aggressive behaviors with one another?
    b. Does the presence of tourists influence agonistic behaviors within the group?

I test the following hypotheses:

Hypothesis 1: Park policies will be communicated through effective signage.

Prediction 1.1: Park policies will be communicated on signs placed in high-traffic areas or in places where monkeys are known to visit frequently.

Prediction 1.2: Signage will include accurate information including images to help park visitors identify macaques.

Prediction 1.3: Signage will explain the dangers of interacting with wildlife.

Hypothesis 2: Agonistic behaviors will differ between age/sex classes.

Prediction 2.1: Adult males will display more agonistic behaviors than the adult females or juveniles.

Hypothesis 3: The presence of tourists will influence macaque behavior.

Prediction 3.1: Proportions of agonistic behavior will be higher in the presence of tourists.

Prediction 3.2: Threat and protective agonistic behaviors will be higher among adult males than juveniles and adult females in the presence of tourists.

Prediction 3.3: Threat and protective agonistic behaviors will be higher on the Fort King Paddle Trail compared to the main river because it is easier to approach the monkeys.

Prediction 3.4: Agonistic behaviors will be higher in the presence of tourists who provision the monkeys.

SECTION 3: METHODS

Ethics Statement. Understanding our place in the environment and how we, as humans, impact the natural world is crucial to the preservation of all species. This was one of my goals with this project and to do it, I obtained permits to conduct this research through SSSP. Due to the strictly observational nature of this research, I did not need to obtain IACUC approval. I did not approach macaques or swim in the river. When tourists asked me about my research, I told them what I was doing and the reasons for it. I provided them with an honest and transparent answer which was well received. The purpose of this study is not to find the errors in the macaques but to analyze how they, as an introduced species, are influenced by human-macaque interactions.

Study Site. This study was conducted on the five-mile-long banks of the Silver River at SSSP. I specifically spent most of my time on the Fort King Paddle Trail, head spring, and by the primitive canoe launch. I found these locations to be frequently visited by both a large troop and a bachelor male group. The first two weeks of the study were used to familiarize myself with the river and determine the feasibility of using the different sites as well as how to differentiate and identify the groups and individuals. In addition, I determined which groups to observe, based on location and interactions with tourists. Sites were selected based on the presence of rhesus macaques and tourist visitation. As anticipated, the macaques changed locations during my observations, and as a result, I followed the groups rather than focused on a specific location.

Subjects. The primate subjects are the free-ranging population of rhesus macaques (*Macaca mulatta*) located in SSSP. During initial observations, I recorded the age and sex of the macaques. I assigned troop IDs (Group C, Group D, and Group E) to each group I observed based on Riley and Wade's (2015) article and group identifications. I then finalized my ethogram

in the first two weeks of the study by conducting ad libitum observations. In the tables below, I have provided my full ethogram of behaviors I observed between macaques (Table 3), and between macaques and tourists (

Table 4). I primarily focused on observing Group D as they regularly visited the same locations on the river. This helped ensure tracking and observing the monkeys as well as their interactions with visitors.

Data Collection. This project was conducted over three months between the week of June 12th and August 25, 2021. I began by collecting data about park policies through searching what is available on the park's official website, asking the rangers about the policies, locating signage at the launch sites, and walking around the park (trails, boardwalk, and main area) to find primate related signage.

Every week, I spent five days in the park and located the monkeys on 2-3 days out of five days. Once I located a troop on the river, I followed and observed one subject (adult male, adult female, or juvenile of either sex) for as long as they were on the river line and within sight using an all-occurrence focal animal method with 5-minute observation periods. If the individual was still in sight when I completed the 5-minute period, I continued with another 5-minute period and then pulled these data into one observation of varying duration (see Table 5). During observations, I recorded behaviors of the animal who was located closest to the river line when I began the observation period. If the subject was lost during the interval, I attempted to locate it for 2 minutes but if I could not locate the subject, I switched to a different individual. When the groups were moving, I made all attempts to continue the observations but if I lost sight of the groups, I ceased recording to follow or relocate them. Infants were not observed except as social partners to focal animals. Due to the aggressive nature of rhesus macaques, I conducted observations from my kayak, keeping a minimum distance of 10 feet. As I was restricted to the river, I was not able to follow the monkeys if they left the river. The only location in which I was able to collect data from land was at the primitive area canoe launch. As a result, my

observations were collected opportunistically. From my observations, I found that the monkeys stayed on the river for up to 4-5 hours on each of the days that I found them but were not always in sight. Additionally, I would check in with the river patrol and rangers to see if there were any troop sightings on my days off, and usually there were none. Occasionally, I would receive a call from the rangers or river patrol on my days off that there was a sighting on the trails far from the river.

The behavioral observations of the monkeys involved observations of one adult or juvenile, rotating through focal subjects each day to record interactions, age/sex identification of primate and human social partners, troop coordinates when the groups moved location, and the number of macaques/humans/animals participating in the interaction. I made all efforts to record an equal ratio of observations for both sex (male: female) and age (adult: juvenile) but this was not achievable since adult males were the primary subjects on the river line for a consistent length of time. Most of the adult females and juveniles spent short amounts of time on the river line and primarily stayed just out of sight.

I recorded how the macaques interact with passing tourists, how the presence and absence of tourists influenced responses from the monkeys, what the tourists did to encourage a response from the monkeys (such as provisioning or splashing the monkeys), and how the interaction with humans influenced the behavior of the macaques after the encounter. Each behavior was categorized as non-agonistic (includes neutral and affiliative behaviors) and agonistic. I additionally used a specifically designed map interface made for my research by a team at EarthRanger (Vulcan, The Allen Institute for Artificial Intelligence 2021) to record sightings and locations of the troops on the river. I then used the platform to map the travel patterns of the groups I observed.

Data Analysis. To evaluate the difference in agnostic and non-agonistic behaviors across three separate subject groups (adult male, adult female, and juveniles) I used a Kruskal Wallace test. To quantify my data, I calculated a percentage of agonistic behaviors recorded by adding up the number of agonistic behaviors recorded and dividing by the total number of behaviors recorded for each observation. I then used nonparametric modeling in the Statistical Package for the Social Sciences (SPSS) (IBM Corp. Released 2020. IBM SPSS Statistics for Macintosh, Version 27.0. Armonk, NY: IBM Corp) to investigate (i) the proportions of agonistic interactions between the introduced rhesus macaques and tourists; and (ii) which subject type (adult male, adult female, and juveniles) were more likely to engage in agonistic and non-agonistic behaviors in the presence of humans.

SECTION 4: RESULTS

Park Policy Communication. Silver Springs State Park conveys their primate related policies in various ways. The first being a broad statement on their website (https://silversprings.com) that prohibits the feeding of any wildlife. Rangers and river patrol will also intervene and notify visitors not to provision or interact with the wildlife. Lastly, they also have signage posted around the park that is either primate specific (see Figure 1) or more broadly about wildlife (see Figure 2). During my time at Silver Springs, I recorded the coordinates for every anti-provisioning sign I found around the park (see Figure 4-6). Most of the signs provided detailed reasons why tourists should not feed the monkeys which include:

- Provisioning monkeys is a second-degree misdemeanor that is punishable by a fine of $500 and 90 days in jail.
- Potential for disease transmission, specifically the passage of the B Virus.
- Provisioning the monkeys can increase cross-species conflict between them and humans.

On each of these signs is a picture of a rhesus macaque as well as an image of an adult vervet monkey. The latter primates do not visit the park but are commonly found in Southern Florida, more than 250 miles away. I found that all the signage was posted on trails around the park but not on the river. The only signs that can be found "on the river line" are at the canoe launch at mile 2.5 but these signs are only visible to hikers or river tourists that dock and walk toward the outhouse or the nearby trails. There is a general "PLEASE DO NOT FEED WILDLIFE" sign on the canoe launch at mile 2.5 (see Figure 2) but to see the primate-specific one, tourists would have to walk off the launch. The only primate signage on the river I found was at Ray Wayside

(canoe/boat launch at mile 5.5), but this sign is not the most accurate. It shows a picture of a vervet monkey but says not to feed the rhesus macaques (see Figure 3a and 3b).

In terms of provisioning the monkeys, I only observed two occurrences of this: 1) at mile marker 2.6 with Group E and 2) on the Fort King Paddle Trail with Group D. Group E was fed chips by a family on a boat and displayed no agonistic behaviors toward the tourists nor members of the group. Group D was provisioned almonds by a single kayaker and displayed no agonistic behaviors until the kayaker tried to dock near the group to take a picture. In both locations there are no primate specific anti-provisioning signs visible to tourists on the river. The only way to see the signs is to notice the sign at the head spring canoe launch or dock at the canoe launch at mile 2.5.

Patterns of Aggression. I collected a total of 45 observations (see Table 6) that differed in period length based off how long the subjects were visible. Proportions of agonistic behaviors were determined by dividing the number of agonistic behaviors recorded by the number of all behaviors recorded for each observation. Descriptive statistics (mean ± SE) revealed that on average 7.69% ± 2.53% SE of the recorded behaviors were agonistic in nature. Among adult males, on average 3.74% ± 1.08% SE of the recorded behaviors were agonistic in nature. For the adult females, on average 4.56% ± 2.05% SE of recorded behaviors were agonistic in nature. Lastly, for juveniles (both male and female), on average 21.94% ± 10.98% SE of recorded behaviors were agonistic in nature. According to the Kruskal Wallis test, the total proportion of agonistic behaviors did not statistically differ but did approach significance [$H(2) = 5.146$, $p = 0.076$].

Effects of Tourism on Macaque Aggression. When comparing agonistic behavior between age-sex groups when no tourists were present, descriptive statistics (mean ± SE)

revealed that 12.88% ± 8.19% of recorded behaviors included some type of agonism. Among males, 3.72% ± 1.97% SD of recorded behaviors contained agonism. For the adult females 10.53% ± 10.53% of recorded behaviors were agonistic. Lastly, for juveniles 12.88% ± 8.19% of recorded behaviors were agonistic. There were no significant differences [H (2) = 3.683, *p*. = 0.159] in the display of agonistic behaviors among the three subject groups.

For the observations with tourists, descriptive statistics (mean ± SE) revealed that 1.75% ± 1.96 % of recorded behaviors were agonistic in nature. During the adult male period, 3.75% ± 1.31% SE of recorded behaviors were agonistic. For the adult females 3.37% ± 1.65% SE of recorded behaviors were agonistic in nature. Lastly, for juveniles 12.23% ± 5.72% SE of recorded behaviors were agonistic in nature. There were no statistically significant differences [H (2) = 3.434, $p = 0.180$] in the display of agonistic behaviors in response to tourists among the three subject groups. I also found that even when tourists played loud music or passed the monkeys on motorboats or jet skis, the monkeys were unaffected by the noise. The only time noise deterred the group was when a ranger truck drove through an area where the monkeys were foraging.

SECTION 5: DISCUSSION AND CONCLUSION

This project was designed to examine 1) the effectiveness of park policies concerning the monkeys, 2) the patterns of aggression and interactions between the introduced rhesus macaques and river tourists, and 3) how these interactions influence agonistic behaviors in the monkeys at Silver Springs State Park. Generally, the primate-specific signage is very informative and shares good ways to limit provisioning. The only issue I found was that most provisioning is on the river where there are no signs. The lack of signs on the river is not the fault of the park but rather a county issue and responsibility. When I inquired about the signs, I was told that many people launch from outside the park boundaries and come upstream to the park. The issue with this is that it is more difficult for the park to regulate visitors and make sure everyone knows about the anti-provisioning rules. General signage that prohibits feeding wildlife can be found sparsely on the river but aside from Ray Wayside, there are no monkey-specific signs on the river.

The primate-specific signage and communication of the park policies are both effective methods of warning visitors about the potential risks. But because there is a lack of signs on the river, the potential for human-primate altercations is still a large concern. With that said and when I examined the patterns of aggression in the macaques, I found that the adult males, adult females, and juveniles displayed similar amounts of agonistic behaviors. In fact, both adult females and juveniles exhibited slightly higher proportions of agonistic behaviors than adult males. For Hypothesis 2, I had predicted that adult males would display more agonistic behaviors than adult females and juveniles. However, I found there was little difference in the display of agonistic behaviors between the three subject groups.

For Hypothesis 3, I found that the presence of tourists did not negatively influence macaque behavior. I had predicted that intragroup aggression would be higher after interacting

with tourists, but I found interactions had minimal effect on the monkeys. I also predicted that agonistic behaviors would be higher in the presence of tourists who approached the macaques, but aside from a few instances, there were little reactions to the people. I predicted that adult males would display more agonistic behaviors than adult females and juveniles, but interestingly, I found that juveniles were more likely to react negatively toward humans than the adult subject groups. My next prediction was that food related agonistic behaviors would be higher in the presence of tourists that provisioned the monkeys. When the monkeys were provisioned, there was little change in the group behaviors. No fighting nor hiding occurred in the two instances of provisioning I observed. Finally, my last prediction related to Hypothesis 3 was that agonistic behaviors would occur more than non-agonistic behaviors. This was found to be false, with most of the observed behaviors being neutral or affiliative in nature. The monkeys primarily ignored the river tourists and were generally unaffected by them.

From the history of the introduced monkeys at SSSP and the previous research done on them, we know that these macaques are highly habituated to human interactions. I anticipated the monkeys to be less fearful toward the humans but still aggressive if approached or provisioned. However, once I began observing their behavior, I found that the monkeys primarily ignored tourists or calmly watched them while foraging, grooming, and eating the wild elderberries and wild grapes on the river line. The only instances of aggression toward the tourists were in the rare cases where a human attempted to touch a monkey, approach an infant or juvenile, or mimic threat displays thinking the monkey was "playing." As stated in the results, even when tourists played loud music or loudly passed the groups, the monkeys were not bothered by the noise. In the occurrences of agonism, juveniles displayed the most agonistic behaviors (12.23% ± 5.72% SE) in the presence of tourists while adult males and adult females displayed similar amounts of

agonistic behaviors (adult male = 3.75% ± 1.31% SE and adult females = 3.37% ± 1.65% SE). Adult males were more likely to be on the river line watching the tourists rather than showing aggression toward tourists. They would only engage in fights if the entire group was involved, and they only displayed warning behaviors at tourists if they were approached by humans who attempted to hand feed or touch them (this was a rare occurrence that happened only once). Juveniles, on the other hand, were also more likely to engage with tourists and display milder forms of agonism (e.g., barred grin, head bob, agonistic vocalization) when playing with one another or displaying fear toward the tourists. The adult females and their infants primarily stayed further from the river line to likely avoid tourists and potential threats.

Unexpected findings. While collecting my data, I observed several unexpected behaviors in the monkeys. Firstly, I found that the adult females (10.53% ± 10.53% SE) and juveniles (12.88% ± 8.19% SE) were more likely than the adult males to display agonism when no tourists were present. These agonistic behaviors were typically directed at juveniles or other adult females within the group that either got too close to a baby or were doing something that upset most of the group (i.e., playing too rough, pushing, or stealing food). It is important to note that for this study, I had a very small sample size for females compared to males. If the sample size for females was larger, my findings may be different. I also found the monkeys to show little aggression when provisioned by tourists. One situation involved an adult male human provisioning the troop on the Fort King Paddle Trail with almonds. He was able to approach the troop and get about a meter from them without any agonistic reactions. He continued tossing almonds and once he was close enough, he started taking several "selfies" with the monkeys. They did not seem to care until he tried to land his kayak, at which point several adults made defensive gestures and the man backed away.

In addition to this, I also observed the monkeys consuming large quantities of wild elderberries and the young leaves of cabbage palm trees (see Table 7). All these plants are highly nutritious and can provide immune support and natural protection to viruses, diseases, and parasites (Sidor, & Gramza-Michałowska, 2015; da Silveira Agostini-Costa, 2018). During my observations I found that each of the monkeys appeared very healthy with no visible injuries, scars, or alopecia spots (balding caused from stress) (Chen et al., 2021). The quality of coat, appearance, and behaviors suggests that the frequent consumption of these plants could influence the health and immunity of these monkeys. Their diet may also contribute to their overall calm demeanor and disinterest in fighting with tourists, in turn reducing the risk of disease transmission and potential conflict between park visitors and rangers. As seen in Nile Tilapia, elderberry extract can help relieve stress by lowering an organism's cortisol levels in situations where it would normally increase (Khan et al., 2022). The frequent consumption of elderberries and cabbage palm also allows further plant growth because the monkeys are dispersing their seeds throughout their environment. This is an interesting topic that should be studied further as it could provide new insights into primate adaptation to novel environments such as Florida.

In addition to the plants they consumed, I observed a juvenile catch and eat a Cuban brown anole (*Anolis sagrei*) which is an invasive species of lizards in Florida. This species has spread throughout the state and pushed the native green anole (*Anolis carolinensis)* out of its environment, making it a rare sighting (Bush, Ellison, & Simberloff, 2022). The consumption of the brown anole was worth noting because the rhesus macaques are viewed as a harmful invasive species to the river's ecosystem, but because of their omnivorous diet, they could be reducing the presence of invasive species. Since there are now more Cuban brown anoles on the river, the monkeys catching and eating them could help lower their effects on the ecosystem.

Limitations. While the results discussed here offer promising paths forward for future research, I recognize that there are limitations with this study. First, while planning the project, it was difficult to locate resources that reported accurate information about where to find the monkeys. Had I been introduced to the river patrol before starting data collection, their knowledge of the monkeys could have made it easier for me to locate the troops. Specifically, Dennis Gilkey would have been a beneficial informant to have because of his extensive knowledge and records of monkey sightings on the river. Mr. Gilkey informed me that there are considerable seasonal differences in when the monkeys visit the river and previous knowledge of these patterns could have allowed me to adjust my timeline to collect data in January-March when they visit the river the most often.

As a result of the limited published literature on the park, I was unable to fully predict the maneuverability of the river and the difficulty of both tracking and staying with troops. I was greatly restricted by both speed and visibility because when the troops would travel upstream on the main river, my kayak was unable to move at a speed that would allow me to stay with them. I also was restricted to the river and could not pull my kayak off on non-official canoe launches, which meant that if the monkeys went inland during observations, I could not follow. This caused many of my observations to end abruptly and eventually led to me switching to opportunistic sampling and reducing my overall dataset. For future projects, I suggest researchers talk to the river patrol volunteers about the best kayaks to have for the river, the most opportune time of year to see the monkeys, and the possibility to bring a pontoon boat on to the river to study the monkeys.

Tumultuous and unpredictable weather frequently forced me to leave the river for my safety. As a result of the weather, I found that the monkeys did not visit the river on stormy days

and were only on the river during a storm a few times. This occurred every time I was on the river observing monkeys when a storm began. However, during a storm, the monkeys would hide in the trees out of observable sight. I was also instructed by the rangers to leave the river if the weather became dangerous and even after a storm ended, I was unlikely to find any monkeys. The rain mixed with the thick foliage on the river often obscured the visibility of the troops and made it nearly impossible to keep track of an individual.

Recommendations for management. As history has shown, every attempt to manage the primate population at Silver Springs was met with great difficulties both from the primates themselves and the local activist groups. With the issues the rangers have had, and years of frustration toward the introduced macaques, there was a general atmosphere of dislike for the primates. This was especially evident in how the rangers would talk about the monkeys, their existing knowledge of the monkeys, and their lack of records concerning them. From the short time I spent at the park and working with the park staff, I agree that managing the primate population is a multifaceted task that requires a great amount of consideration to keep each party involved at ease. However, to improve the park's understanding of the macaque's behavior and ecology, keeping and maintaining better records of macaque sightings, human-macaque interactions, travel patterns, group sizes, group IDs, and what they are primarily consuming on the river would facilitate future research efforts. With detailed records, the park can better identify what damage (if any) the rhesus macaques are causing to the river as well as the risk of conflict between the primates and tourists.

In addition to this, there were a wide array of information shared with visitors by the rangers, river patrol, and tour guides that differed greatly from one another. A standard training for park employees could provide an opportunity for everyone to A) be on the same page when

teaching visitors about the monkeys, and B) learn the most accurate facts pertaining to the introduced rhesus macaques. I suggest having a primatologist come to the park or host a virtual workshop regularly to inform staff on macaque ecology and social behaviors. This can help decrease confusion about the primates and a better insight into these animals as members of the park's ecosystem.

Lastly, though there is signage about primate policies posted around the park, there is little located on the river. I also found some signs at Ray Wayside (the boat/canoe launch at the 5-mile marker) that had pictures of vervet monkeys rather than rhesus macaques (see image 1). This can cause confusion in tourists that launch from Ray Wayside and could lead to misunderstandings of the policies. There needs to be more signage on the river, specifically in the areas the monkeys frequently visit. I have observed boaters and kayakers passing signage about fishing and either disregarding it or not even seeing it. I know it is likely more signage would yield a similar result but I do not think the warnings of the dangers on the river are clear. Many boaters and kayakers launch from Ray Wayside or even farther down the river and likely do not see the signs about the monkeys. Additionally, there needs to be clear policies listed on the Silver Springs Park website about the monkeys and the potential risks. The reality is that these monkeys come to the river frequently and people do interact with them, so the policies need to be readily accessible.

Significance. In the last 20 years primate attacks have become an interesting story for journalists and have led to dramatized versions of the encounters. By spreading the message that macaques and other primates are "killer monkeys or herpes infected monkeys", the media is inducing a state of panic and fear that often results in more violence against the *dangerous monkeys*. As a result, people interact with these primates with negative assumptions about the

animals and may act defensively, fearfully, or antagonistically. My goal with this project is to understand how policies concerning the introduced rhesus macaque at SSSP are communicated to tourists, and how patterns of aggression are influenced by river tourism. Understanding the interactions and potential displays of aggression from both macaques and humans is particularly important because of the growing number of urbanized primates and discarded unwanted primate pets. With habitats shrinking and primates continually introduced into foreign areas, the concern of management and ecosystem preservation becomes increasingly more difficult. I hope my findings will aid in the effort to further manage the introduced primate species both abroad and here in the United States.

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TABLES

Table 1. List of rare land and river line vertebrates documented within the Silver River, head springs, and associated wetland communities.

Name		**Location**
Latin name	**Common Name**	
Alligator mississippiensis	Common alligator	Stream-edge
Aramus guarauna	Limpkin	Stream-edge
Egretta caerulea	Little blue heron	Stream-edge
Eudocimus albus	White ibis	Stream-edge, Floodplain swamp
Egretta thula	Snowy egret	Stream-edge
Nyctanassa violacea	Yellow-crowned night-heron	Stream-edge
Pandion haliaetus	Osprey	N/A
Pseudemys concinna suwanniensis	Suwannee cooter	Stream-edge, Floodplain swamp

Sources: Herring & Davis, 2004

Table 2. List of rare land and river line vertebrates potentially occurring within and along the Silver River May-September

Name		Location	Active Seasons
Latin name	**Common Name**		
Accipiter cooperii	Cooper's hawk	Bottomland hardwood forest	Any season
Crotalus adamanteus	Eastern diamondback rattlesnake	Floodplain swamp	March-October
Drymarchon couperi	Eastern indigo snake	Floodplain swamp	Any season
Elanoides forficatus	Swallow-tailed kite	Floodplain forest, Floodplain swamp	April-October
Mustela frenata peninsulae	Florida long-tailed weasel	Floodplain forest, Floodplain swamp	April-October
Picoides villosus	Hairy woodpecker	Deciduous forest, Floodplain swamp, Floodplain Forest	Any season
Neofiber alleni	Round-tailed muskrat	Floodplain swamp	Any season
Ursus americanus floridanus	American black bear	Floodplain forest, Floodplain swamp	Any season

Sources: Herring & Davis, 2004

Table 3. Macaque Ethogram

Behaviors	Description
Agnostic Vocal	Vocal howls, gargles, or sounds of distress or aggression after interaction with boater
Agnostic Vocal	Vocal howls, gargles, or sounds of distress or aggression after interaction with kayaker
Agnostic Vocal	Vocal howls, gargles, or sounds of distress or aggression after no interaction
Attack Boater	One or more individuals quickly/aggressively jolt or hit at a boater (contact)
Attack Kayaker	One or more individuals quickly/aggressively jolt or hit at a kayaker (contact)
Avoid Boat	Individual(s) intentionally moving away from boater when they approach.
Avoid Kayaker	Individual(s) intentionally moving away from kayaker when they approach.
Chase Conspecific	To run aggressively or playful after another macaque
Defecate	Discharge feces from one's body
Dominance mounting	Two individuals display mounting positions.
Eating	Consuming vegetation or insects orally.
Fear	fear grimace, the bared teeth grin, and abrupt crouching or flinching.
Fight	Aggressive physical contact between two or more individuals that appear to or cause harm. This could result in one of the individuals retreating or displaying fear.
Fight	Aggressive physical contact between two or more individuals that appear to or causes harm after interaction with boater
Fight	Aggressive physical contact between two or more individuals that appear to or causes harm after interaction with kayaker

Table 3 continued. Macaque Ethogram

Fight	Aggressive physical contact between two or more individuals that appear to or causes harm after no interaction
Fighting over food	Aggressive physical contact between two or more individuals over food that appear to or causes harm. This could result in one of the individuals retreating or displaying fear.
Follow Boat	Moving with boater(s) up or down river to continue watching or interacting with them
Follow Kayak	Moving with kayaker(s) up or down river to continue watching or interacting with them
Foraging	Searching for vegetation or insects to consume orally.
Jump on Boat	Leap or move on top of a boat
Jump on Kayak	Leap or move on top of a kayak
Lip Smacking at dog	Pressing the bottom and upper lips together directed toward a dog
Play	Two or more individuals swinging in trees or non-aggressively chasing each other.
Resting	Reclined and relaxed in seated or laying position. Asleep or awake and not moving.
Scratching	Repetitive swiping at body after the presence of boaters
Scratching	Repetitive swiping at body after the presence of kayakers
Scratching	Repetitive swiping at body when no kayakers or boaters are present
Self-Groom	Picking, shifting, or manipulating one's own hair to clean it
Shake	to move to and fro in a stationary position
Social Groom	Two or more individuals picking at each other's hair or combing hands through hair.
Social Vocal	Howling or affiliative sounds that are not aggressive.

Table 3 continued. Macaque Ethogram

Threat Display	Ears are forward, the brow is lowered or neutral, with eyes open and staring at the interactant, and the mouth is open (the teeth may or may not be exposed). The head may be lowered with both head and body pulled forward. Directed toward boaters.
Threat Display	Ears are forward, the brow is lowered or neutral, with eyes open and staring at the interactant, and the mouth is open (the teeth may or may not be exposed). The head may be lowered with both head and body pulled forward. Directed toward kayakers.
Urinate	Discharge urine from one's body
Watching Boaters	Observing boaters for the entirety of their presence and interactions.
Watching Kayakers	Observing kayakers for the entirety of their presence and interactions.
Yawn	Exaggerated opening of mouth. Full display of teeth indicates threat or tension but yawning without full display indicates tiredness.

Table 4. Human behaviors directed at macaques

Agitating Macaques	One or more humans attempting to invoke a response from the macaque(s) by poking, touching, taunting with food/items, or other means of annoyance.
Approaching Macaques	One or more boaters moving toward a macaque(s).
Follow Troop	Moving with a troop up or down river to continue watching or interacting with the monkeys
Hand feed	Extending open hand with food on it to provision a monkey
Has Dog	A dog is on the boat
Honking	Pressing on the boat horn to get the attention of the monkeys or cause a startled reaction
Mimic Behavior	Copying the gestures and facial expressions of the monkeys
Move back	Putting some distance between themselves and the monkeys if the monkeys aggress toward the humans.
Picture	Using a camera or phone to record or snap photos of the monkeys
Playing music	Loudly playing music on a speaker in the presence of the monkeys
Pointing	gesturing with one or more fingers at the monkeys
Provisioning	Feeding the monkeys by handing or tossing food
Screaming/talking loudly	Loud projecting talking, hollers, or shrill vocalizations that may cause disruptions
Talking	One or more people conversing at a low volume that is not disruptive
Try to Touch	Extending arm or hand to contact a monkey
Whistle	Making a high pitch sound with mouth to get the attention of the monkeys

Table 1. Observation Durations

Observation Number	Age/Sex Class	Duration (minutes)
1	Juvenile	15
2	Juvenile	5
3	Juvenile	10
4	Juvenile	85
5	Juvenile	5
6	Juvenile	15
7	Juvenile	10
8	Juvenile	5
9	Juvenile	20
10	Juvenile	10
11	Adult Male	20
12	Adult Male	25
13	Adult Male	15
14	Adult Male	5
15	Adult Male	5
16	Adult Male	5
17	Adult Male	15
18	Adult Male	10
19	Adult Male	20
20	Adult Male	40
21	Adult Male	40
22	Adult Male	10
23	Adult Male	5
24	Adult Male	25
25	Adult Male	15
26	Adult Male	10
27	Adult Male	35
28	Adult Male	10
29	Adult Male	30
30	Adult Male	20
31	Adult Male	15
32	Adult Male	45
33	Adult Male	15
34	Adult Female	15
35	Adult Female	40
36	Adult Female	15
37	Adult Female	20
38	Adult Female	25
39	Adult Female	10
40	Adult Female	35
41	Adult Female	25
42	Adult Female	15
43	Adult Female	25
44	Adult Female	10
45	Adult Female	15

Table 6. Observations per Subject Group

Subject Group	Observations with Tourists	Observations without Tourists	Total Number of Observations
Adult Male	14	9	23
Adult Female	10	2	12
Juveniles (Male and Female)	8	1	9

Table 7. Superfoods Consumed by Macaques

Plant Name	Nutritional Characteristics
Elderberry (*Sambucus nigra*)	proteins, unsaturated fatty acids, antioxidants, vitamins, and amino acids
Young Palm Leaves	Omega-3 fatty acids

Figure 1. The primary primate signage used at SSSP.

Figure 2. The general wildlife signage used at SSSP.

Figure 3. The primate signage at Ray Wayside with the incorrect species image close up (A) and the view of the primate signage at Ray Wayside from the canoe/boat launch (B).

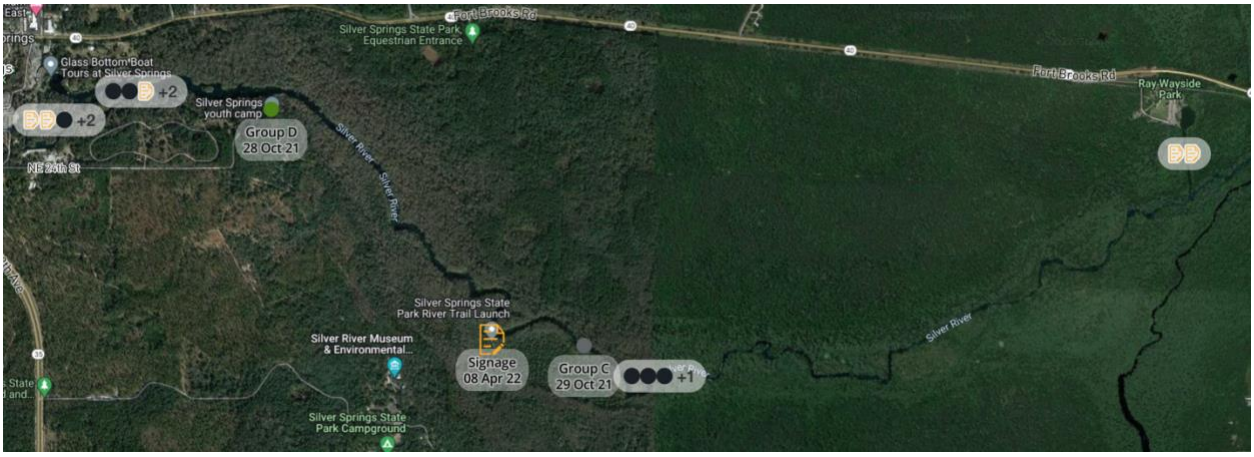

Figure 4. This is a map view of the entire Silver River and the locations of Signage (yellow notebook icon) and macaque sightings (black, green, and grey dots) at Silver Springs State Park from the week of June 12th to August 25, 2021. The black dots represent groups that were found in the same area (at separate times). EarthRanger cannot differentiate colors if groups are clustered in the same areas and the map is zoomed out more than a km.

Figure 5. Map image of the section of the Silver River that encompasses Silver Springs State Park with locations of signage (yellow notebook icons) and Group D macaque observations (green dots) on the Fort King Paddle Trail. This map shows the locations near the top of the river where Group D appeared the most. They would move upstream from the primate campground launch to the Fort King Paddle Trail then back down. The black dots represent groups that were found in the same area (at separate times). EarthRanger cannot differentiate colors if groups are clustered in the same areas and the map is zoomed out more than a km.

Figure 6. Signage (yellow notebook icon) and macaque sightings (Group D on the Fort King Paddle Trail and a Bachelor Group on the main river) from the head spring to the primitive campground launch.

Figure 7. Location of macaque (bachelor male red dot and Groups C and E as grey dots) sighting near mile marker 2.6. Groups C and E do not differ in color because EarthRanger did not have other colors available. I also observed Groups C and E in the beginning of my study but were unable to locate them after the first few weeks.