Monkey Management Project

Towards a Resilient and Environmentally Sustainable Island by Improving Management of the Invasive Monkey Population on St. Maarten

Monkey Management Project

"RESEARCHING THE MONKEY POPULATION TO DEVELOP A MANAGEMENT PLAN"

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Abstract

The Monkey Management Project was developed by the Nature Foundation St. Maarten and funded by Resources for Community Resilience (R4CR). The project focused on researching the abundance and status of the invasive vervet monkey (*Chlorocebus pygerythrus*) and to establish sustainable and humane solutions to manage the invasive monkey population to protect St. Maarten's native species and local agriculture. The project was guided by the results from the preliminary online survey conducted in August and September 2020 which included the areas the monkeys are most likely seen by respondents. Field research was executed in January and February 2021, to collect data from the monkeys on the island, using a rapid assessment of 10-minute instantaneous scan sampling. A Management Options Survey was conducted to further educate St. Maarten residents on the monkeys and the possible management solutions, and to allow them to provide their opinion on which of these solutions should be implemented on St. Maarten. Observations from the field research reflected data that differed from expected results, including lower numbers of monkeys recorded than expected to be seen during the early morning and evenings. This indicates underestimated numbers of monkeys sighted during the field research. The research shows that most monkeys are located in Point Blanche hill area, but also Guana bay, Sentry hill and Dawn beach hill areas showed high amounts of sighted monkeys. Over half of the respondents from the Management Option Survey decided eradication was the best option for St. Maarten, and a third of respondents decided that sterilization was the best option. Based on the results from the field research, and Management Options Survey, it is estimated that 6 up to 9 troops are located on the Dutch side of the island and each troop existing of 10 up to 50 monkeys. Due to this information collected, the Nature Foundation St. Maarten recommends humane euthanasia to be applied to effectively manage the invasive vervet monkey population. The Foundation recommends making the funds available and starting the process as soon as possible to prevent deterioration of the monkey situation or have residents take matters into their own hands.

Acknowledgements

The Nature Foundation St. Maarten would like to acknowledge and thank Resources for Community Resilience and the World Bank for funding the Monkey Management Project within the Irma Trust Fund. Without the funding, and the dedication from R4CR and their staff, this project would not have been made possible. This project would not have been successful without the generous support and advice from Dr. Kerry Dore and Gilbert (Sully) Gordon from St. Kitts, Mark Yokoyama, and Dahlia Hassell from DCNA. The Nature Foundation thanks all St. Maarten residents who reported sightings of the monkeys and answered our surveys. I would like to thank my family members for supporting me and the Nature Foundation with donating their time and residences for the monkey surveys. I would also like to thank the primary staff and team members.

Primary Staff: Project Coordinator; Alice Manley, Nature Foundation Manager; Melanie Meijer zu Schlochtern, Educational Outreach Officer; Leslie Hickerson

Staff and Intern Team Members: Nature Foundation Ranger; Etienne Lake, Nature Foundation Ranger Trainee; Ray-Angel Boasman, Intern; Sabrine Brismeur and Intern; Lynn Martina.

Table of Contents

1. Introduction

1.1 Nature Foundation St. Maarten

The Nature Foundation is a non-profit organization that aims to preserve and enhance the natural environment of St. Maarten for generations to come. The Nature Foundation manages and maintains the St. Maarten *Man of War Shoal Marine Park*, the only designated nature park area of the island, the 30+ dive sites located on the Dutch side of the island, and is the scientific authority for both the marine and terrestrial ecosystems of St. Maarten. The mission statement of the Nature Foundation is thus as follows:

"To preserve and enhance the natural environment of St. Maarten through proper management, education, public awareness, law enforcement, scientific research and monitoring relating to all aspects of the terrestrial, wetland and marine surroundings."

1.2 Monkey Management Project

The Monkey Management Project was introduced by the Nature Foundation St. Maarten and funded via the Resources for Community Resilience (R4CR) grant scheme. The R4CR program is a grant scheme that focuses exclusively on financing and strengthening of local Civil Society Organization (CSOs). The program is financed by the Government of the Netherlands via the St. Maarten Trust Fund. The latter is administered by the World Bank, implemented by the NRPB (National Recovery Program Bureau) and executed by VNGI (the Vereniging van Nederlandse Gemeenten International) in close cooperation with Foresee Foundation-NPOwer and other local partners.

1.3 Introduction Project Research

A non-native organism that negatively affects and alters a new environment is called an invasive species (Davis and Thompson., 2000). Invasive species are known to cause economic and environmental damage to native ecosystems, as well as protected flora and fauna (Ehrenfeld., 2010; Lakićević and Mladenović., 2018; Campagnaro, Brundu, and Sitzia., 2018). On an annual basis, 1.4 trillion dollars are spent globally to manage invasive species (Amstutz., 2018). Without such controls, many non-native species would have an irreparable population growth (Amstutz., 2018).

Removing invasive mammals is considered a first step in ecological restoration, and such actions can directly benefit threatened species and their habitats. (Kappes and Jones., 2014). Holmes *et al*. (2019) studied invasive mammals on islands globally and the socio-political feasibility of an eradication process and found that such management processes can aid 151 populations of 80 species of highly threatened native vertebrates.

For a small island, St. Maarten has quite a high amount invasive species, such as the green iguana, mongoose, lionfish, and vervet monkeys (*Chlorocebus pygerythrus*). This monkey species is originally from South-eastern Africa but has quickly spread across the globe. The vervet monkey is the largest invasive mammal species on St. Maarten and has quickly naturalized its population. The vervet monkey can also be found on other Caribbean islands such as St. Kitts, Nevis and Barbados (Dore., 2016).

Like all invasive animals, vervet monkeys can have a large effect on St. Maarten's agriculture and ecology. The vervet monkeys are destructive and without predators on the island, therefore resulting in the population having the ability to double in size within one year. Without a natural predator, the

vervet monkey population can continue to grow, and damage the local agriculture and the native flora and fauna. From an ecological perspective, their growth negatively impacts the island's biodiversity and resilience. Vervet monkeys also threaten human livelihood by consuming of food crops, an issue not easily solved given their intelligence. Many St. Maarten residents have expressed that they feel frustrated, threatened, and irritated by the continuous growth of the vervet monkey population and their effects environmentally and personally.

1.4 Research Aim

This project aims to determine the abundance and status of vervet monkeys on St. Maarten, and to establish sustainable and humane solutions to manage their invasive population. Through these efforts, the Nature Foundation hopes to support local agricultural activities and reduce the negative impact of invasive species on St. Maarten's environment to create a more sustainable, resilient and healthier island.

In order to reach the goal of the project several research questions regarding the invasive vervet monkey population are established:

1. What is the estimated population abundance of the vervet monkeys on St. Maarten?
2. What issues can arise within the future if no measures are taken against the invasive vervet monkey population now?
3. Which possible management solutions is favored by St. Maarten residents to effectively reduce and manage the invasive vervet monkey population?

The Nature Foundation, St. Maarten considers the invasive vervet monkey population to be a serious concern. In this study, the Nature Foundation will explore possible solutions to manage the invasive species, and how to reduce their population through sterilization or eradication. The study will develop an insight and estimate of the monkey population on St. Maarten through trapping, sightings, and reporting's.

2. Literature Review

2.1 History

Located in the Leeward Islands of the Caribbean, Saint Martin/Sint Maarten is the world's smallest inhabited island shared by two countries (Hillebrink., 2013). The island of St. Martin/St. Maarten is a total of 87 square kilometers (Yokoyama., 2019), with 34 square kilometers encompassing the 'Dutch side' of the island, otherwise known as St. Maarten.

The natural characteristics of the Caribbean's Leeward Islands vary drastically. The weather, climate and ecosystems can differ vastly between these islands. One factor each island has in common, however, is that most non-native species were introduced from a mainland. Whether introduced on purpose or inadvertently, in cages or as stowaways, or even from animals swimming ashore from a shipwreck, the non-native species located in the Caribbean have found their way to the islands by anthropocentric means.

St. Maarten lacks both historical and contemporary biological data regarding the invasive vervet monkeys. Historians only know the basic background of the invasive vervet monkeys' arrival in the Caribbean. In the 17th and 18th centuries, vervet monkeys were introduced as pets from Southeastern Africa to the Caribbean islands of St. Kitts, Nevis and Barbados (Denham, and Denham., 1987; van der Kuyl *et al*., 1995). The exotic pet trade drove their importation and is ultimately responsible for their establishment. Escaped or released vervet monkeys formed the basis for St. Maarten's wild monkey population.

In relation to the exotic pet trade, local residents have stated that vervet monkeys have been kept as pets for decades, with the first reported wild sighting of a vervet monkey only in the 1970's (Hoogerwerf., 1977). Most observations of the islands' wildlife have come from residents who compare the current environment to how it appeared in their youth, or when they first arrived on the island. Recently, the Nature Foundation has received reports from residents stating that the monkeys were a common household pet found on St. Maarten in the early 1950's and prior, however, some residents who similarly have family generations dating back to the 1800s on St. Maarten say that they have never heard of monkeys on the island.

Additionally, news reports and common hearsay have claimed that vervet monkeys escaped from the St. Maarten Zoo after Hurricane Louis in 1995 and Hurricane Irma in 2017. However, previous board members from the zoo have refuted such reports. These conflicting accounts make it difficult for the Nature Foundation to determine precisely when the wild vervet monkey population came to be in St. Maarten.

2.2 Biology, Ecology and Behavior

Characteristics

Vervet monkeys are abundant, non-endangered, and one of the least specialized Old-World monkeys (Palmour *et al*., 1997). Five subspecies are found throughout Southeastern Africa and several have been introduced to the Caribbean and southern United States of America (Groves., 2018; McQuire., 1974). Adult vervet monkeys are characterized by their black face, which is surrounded by a white fringe of hair. The rest of their body is a discolored grey. The physical characteristics of the vervet monkey can be

seen in image 1. Baby vervet monkeys have a pink face and a black coat until they are approximately 12 weeks old (North., 2018). An average male weighs 5.5 kg (12lb), with an average female weighing 4.1 kg (9.0lbs) (African Wildlife Foundation., 2020; Skinner and Chimimba., 2005).

Reproduction and Population Structure

Image 1. A vervet monkey on St. Maarten.

Females can reach sexual maturity as early as three years old, while males reach sexual maturity at five to six years old (Vervet Monkey Foundation., 2018). Their gestation period is approximately five and a half months, with the ability to produce offspring every one to two years (North., 2018). After reaching sexual maturity the males will migrate to another troop nearby while the females remain in the same troop they were born into (Vervet Monkey Foundation., 2018). The vervet monkey troops can range between 10-70 individuals (African Wildlife Foundation., 2020) dependent on their habitat and food abundance (vervet Monkey Foundation., 2018).

Diet

Studies have shown that the daily distance that vervet monkeys move is highly dependent on the availability of their food resources (Thatcher, Downs, and Koyama., 2019). While such resources vary for the vervet monkey, their primary diet is mainly herbivorous. These monkeys are often seen in agricultural areas due to fresh, readily available fruit and vegetables. However, vervet monkeys occasionally eat birds, bird eggs and insects, making the species omnivorous (African Wildlife Foundation., 2020; North., 2018; Skinner and Chimimba., 2005). These monkeys are considered agricultural predators (Palmour *et al.*, 1997) due to their adaptability in urban environments that supply their broad diet. Vervets are well known to raid crops of local farmers in populated areas (North., 2018).

Range

The home range patterns of vervet monkeys are relatively unknown in urban areas. However, they appear to exhibit effortless adaptability to thrive in these urban settings (Thatcher, Downs, and Koyama., 2019; Patterson, Kalle, and Downs., 2019). Thatcher, Downs and Koyama (2019) found their home range was more extensive when correlated with more positive human encounters, such as food abundance and non-threatening interactions. Given that St. Maarten has a very pronounced dry season, it is likely that their home range will shift further into urban environments to capitalize on human gardens and agricultural areas.

Adaptability

Vervet monkeys have adapted exceptionally well to the type of vegetation found on St. Maarten. The island consists mainly of secondary vegetation that has adapted from seasonal formations and some dry evergreen formations (Rojer, Carmabi and Curaçao., 1997). Stoffers (1956) wrote that St. Maarten was home to seasonal formations, vegetation derived from seasonal formations, evergreen formations, vegetation of the rock pavement, mangrove woodland, strand vegetation, hippomane woodland (manchineel trees), and combinations of two vegetations in one area.

Conflicts

St. Maarten agriculturists have struggled with the vervet monkey population for many years, but the issue has become more pronounced in the last year. In April 2020, the Covid-19 pandemic resulted in government lockdowns across St. Maarten. Stuck at home, residents began growing various fruits and vegetables in their gardens. Given the dry season, vervet monkeys were particularly attracted to these agricultural products, resulting in abundant monkeys around residences.

3. Methods

The Monkey Management Project was conducted in St. Maarten over a six-month period between December 1, 2020, and May 31, 2021. It consisted of three chronological core elements, including 1) preliminary survey, 2) field research, and 3) the social survey 'Management Options Survey'.

3.1 Preliminary Survey

Prior to receiving funding from the R4CR grant scheme, the Nature Foundation introduced and published a preliminary survey. This survey was designed to collect data that would help guide the Monkey Management Project. The preliminary survey was published on social media on August 25, 2020 and closed on September 23, 2020 one month later. The survey was automatically shared across multiple social media platforms by users. The survey consisted of six questions, which asked: where the residents lived, if they saw monkeys around their residence and how many they saw, if the resident participated in agriculture, and if so, how many people their crops feed, and if the monkeys affect their crops. The respondents could also include their email addresses to allow the Nature Foundation to reach out with more questions if needed. The results from this survey were used to assist the development of the methods for the field research (element 2).

3.2 Field Research

121 field surveys were conducted between January 26, 2021, and February 14th, 2021, along those roads and paths that correlated with the natural habitat of the vervet monkey species. Most of the surveys were done in the morning hours 6am until 10am and several surveys were done in the afternoon from 4pm until 6pm. The field research team consisted of two people: Alice Manley, Project Coordinator and was joined by other staff members on rotational basis: Melanie Meijer zu Schlochtern or Leslie Hickerson. The Dutch side of St. Maarten was separated in five districts based on the preliminary survey monkey sightings reported and the desirable vegetative habitat for the vervet monkeys. These five areas were as follows: Pointe Blanche, Dawn Beach, Sentry Hill and St. Peters Hill, Williams Hill, and Belair/Little Bay. Each location was visited at least twice by Nature Foundation staff, morning and evening, with most locations being visited three times.

The specific GPS locations were chosen based on accessibility from the road and walking paths and ease of viewing, as bush vegetation is very dense on St. Maarten. Each survey consisted of a 10-minute instantaneous scan sampling at every GPS location. During the scan, the field research team monitored the area along a 10 meters-long path. With a maximum distance of sight of about 200 meters from the GPS location, the vegetation was scanned using eyesight or binoculars. The following guidelines were followed during the field research for safety and the success of the project: long sleeves and pants with sturdy close-toed shoes were worn, no bright colors or logos on clothing, silence when in the field and manchette and first aid kit were present.

During the field research the following data was taken (see table 1): GPS location and number of samples, general location name, time sample recorded, date, group composition of monkeys recorded (Adult Male, Adult Female, Infant and Juvenile). Table 1 shows an example of the data sheet in the field research which was used to ensure systematic data collection.

Table 1. Example of the Vervet Monkey Group Composition field research data sheet. This data sheet collected the time, location, GPS location, and group composition of the monkeys.

Vervet Monkey Group Composition									
Date				Time Start		Time End		Observer	
AM - Adult Male, AF - Adult Female, IN - Infant, JV - Juvenile									
#	Time	Location	GPS N	GPS W	Total Seen	AM	AF	IN	JV

3.3 Management Options Survey

The Management Options Survey presented to St. Maarten residents had the primary focus of determining if the population understood the risks of the invasive monkey population and what the general public would prefer to be done to combat these risks. This survey was conducted between the dates of April 20th, 2021 and May 17th, 2021. The Management Options Survey asked St. Maarten residents to offer their opinions on the possible Management Solutions for the invasive vervet monkey population on the island. Staff and Interns, Alice Manley (Project Coordinator), Leslie Hickerson (Education Outreach Officer), Dahlia Hassell (DCNA), and Sabrine Brismeur (Intern), visited numerous different locations around Dutch St. Maarten. This survey was conducted throughout different 'hotspots' such as supermarkets, hardware stores and gardening centers, to provide the highest probability of receiving responses from different demographics. The survey was intended for Dutch side residents alone, however, many French side residents were encountered and therefore a decision to include them was made at that time. The location for all French side residents was made 'French side' instead of using their exact areas of residence.

The survey consisted of several questions, which asked: age, gender and ethnicity, where the residents lived, if they saw monkeys around their residence, if they are afraid for monkeys, and if they know the monkeys are invasive. At the end, the survey described three viable management options and listed the pros and cons for each to provide the residents with a comprehensive background of their environmental, societal, and agricultural effects, seen in table 2. To ensure that the residents were fully informed and conclusive with their decision, they were then asked to confirm their opinion with the Nature Foundation staff repeating the information while being shown the Mangement Options table (table 3). The results from this survey were organized into Excel and displayed in graphs to reflect what a sample of St. Maarten residents would like to occur.

Table 2. Shown as a guide of information during the Management Options Survey. Respondents were shown this table to assist them in making an educated decision.

Management Options				
Methods	**Estimated Time**	**Cost $$**	**Outcome**	**Pros & Cons**
Nothing	0 years Population will continue to increase	No management costs Increase of costs for SXM	Monkey population ↑ Dangerous for humans No agriculture opportunities	Pros - No initial investment Cons - Monkeys will continue to **increase** - Future **economic distress** - Monkeys will become more comfortable and dangerous with humans - Will **not protect** native species
Eradication	5 years (full time project)	Basic Costs: Trapping, humane euthanasia, disposal	Monkey population ↓ Increase in agriculture opportunities and native species	Pros - Cheapest and fastest - Will effectively **protect** native species Cons - Initial investment - Euthanizing healthy animals
Sterilization	15-20 years	5x more than eradication	Population slowly ↓ Outcome will be visible in a long-term effect	Pros - Most **humane** option - Will **protect** native species in the future Cons - More time and effort - Possible failure

4. Results

4.1 Preliminary Survey

A total of 70 respondents participated online in the preliminary survey.

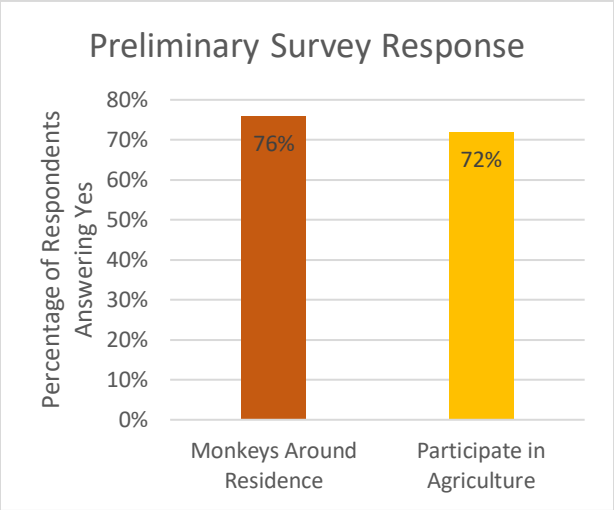

Figure 1. Results of the preliminary survey displaying the percentages of respondents answering yes on the following questions: Have you seen monkeys around your residence? (red bar), and do you participate in agriculture? (yellow bar).

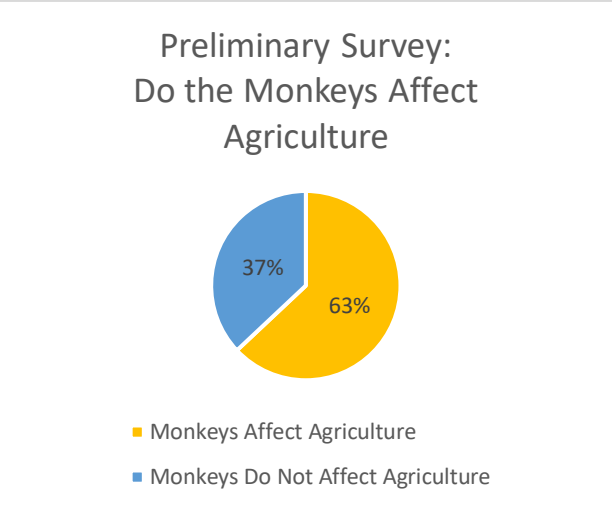

Figure 2. Results from the preliminary survey question: Do monkeys affect your agriculture? Percentage of respondents answering Yes (yellow) or No (blue) is shown. The percentages displayed are out of the 72% of respondents who answered yes to participating in agriculture.

Figure 1 shows that a total of 76% of the respondents answered yes to the question if they have seen monkeys around their residence, a total of 72% of the respondents answered yes to the question if they participate in a form of agriculture. Figure 2 shows the results to the question: Do monkeys affect your agriculture? 63% of the respondents who answered yes to participating in agriculture have stated that monkeys affect their agriculture. 37% of the people who participate in agriculture stated to have no affects from the monkeys on their agriculture activities.

Figure 3 displays results from the preliminary survey question: How many monkeys do you see at a time? Respondents who answered yes to seeing monkeys around their home were able to answer this question. A total of 49 respondents answered this question, with 53% seeing 1-5 monkeys at a time. 21% of the respondents usually see 6-10 monkeys around their residence at a time, and 16% of respondents see 11-19 monkeys at a time. 10% of the respondents stated they see 20 or more monkeys around their residence at once. The areas such as Pointe Blanche, Guana Bay and Dawn Beach had the highest respondence rate of monkey sightings around the residence. These results from the preliminary survey guided the field research with suggested areas to conduct the scan samples.

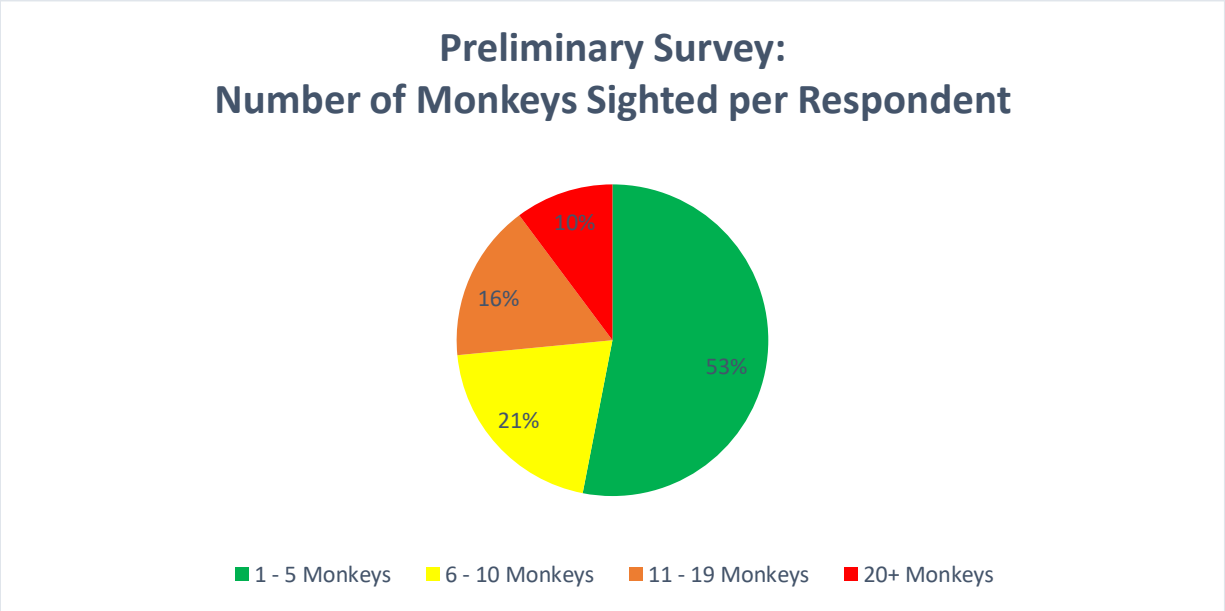

Figure 3. Pie chart from preliminary survey – How many monkeys do you see at a time? People who answered yes to seeing monkeys around their residence.

4.2 Field Research

A total of 20 sightings of vervet monkeys were recorded during the field research, which consisted of a total of 121 sites surveyed.

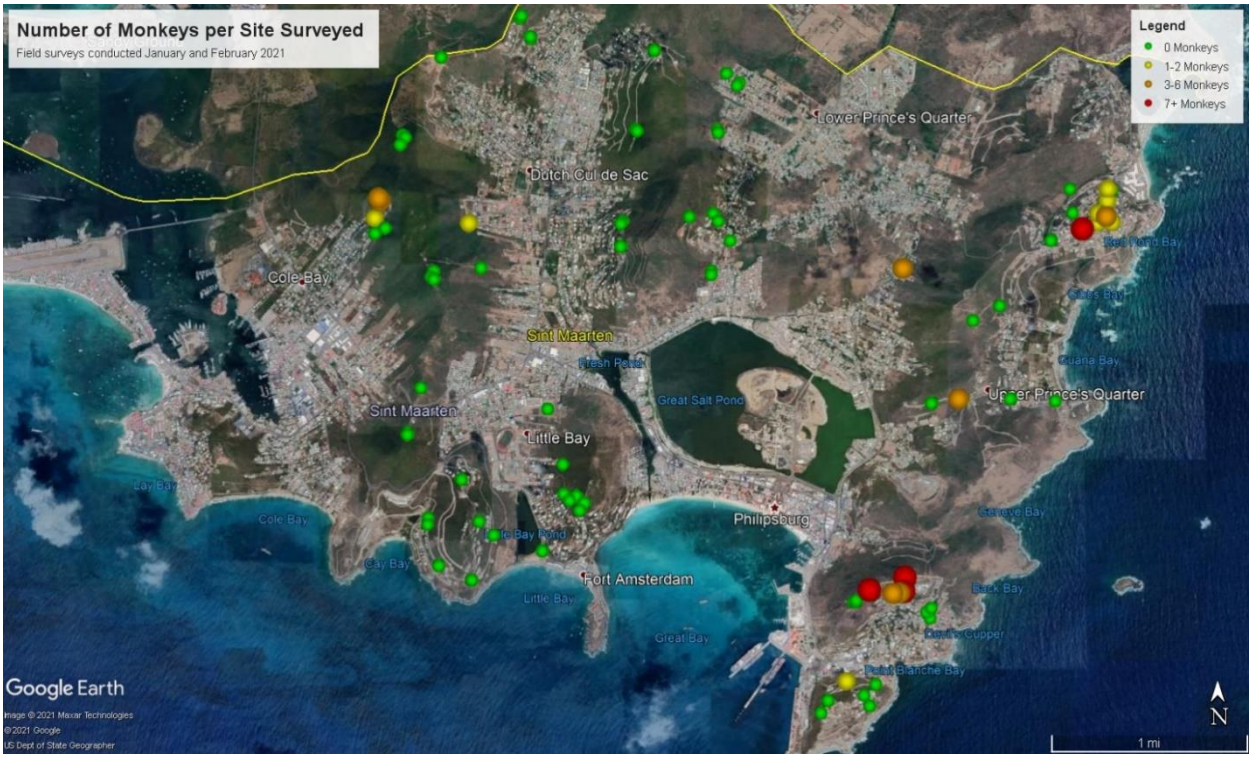

Image 2. Google Earth image showing the number of monkeys recorded per site surveyed during the field research in St. Maarten. Green dots represent no monkeys sighted on that site, yellow dots represent 1-2 monkeys sighted, orange dots represent 3-6 monkeys sighted and red dots represent 7 or more monkeys sighted.

Image 2 shows that the individual sightings of monkeys were mostly recorded in Pointe Blanche, Sucker Garden, Guana Bay, Dawn Beach and Sentry Hill. Image 2 visually shows the number of monkeys per sample site surveyed, with the highest recording of monkeys sighted in Pointe Blanche. As seen in image 2, also Dawn had a high number of sightings of monkeys. Further data on the monkey sightings can be seen in table 4 in the *Supplements*.

Image 3 visually shows the average number of monkeys per area. Pointe Blanche displays a red dot, with an average of 7 monkeys seen in the area. Guana Bay and Sucker Garden displays an orange dot with an average of 5 monkeys seen in the area. Dawn Beach displays a yellow dot with an average of 3.1 monkeys seen in the area. Sentry Hill displays a yellow dot with an average of 2.6 monkeys seen in the area. Cay Hill and Williams Hill display green dots with no monkeys sighted in the area during the field research.

Image 3. Google Earth image showing the average number of monkeys recorded per site surveyed during the field research in St. Maarten. Green dots represent no monkeys sighted in the area, yellow dots represent 1-2 monkeys sighted in the area, orange dots represent 3-6 monkeys sighted in the area and red dots represent 7 or more monkeys sighted in the area.

Figure 4 displays the average number of monkeys recorded and standard deviation per area. The standard deviation is the quantity of how many individuals sighted can differ from the mean value of the group. Figure 4 shows that Pointe Blanche had the highest average number of monkeys per area, and Guana Bay and Sucker Garden had the second highest average. Williams Hill and Cay Hill and Belair have an average of zero monkeys due to there being no monkeys seen during field surveys.

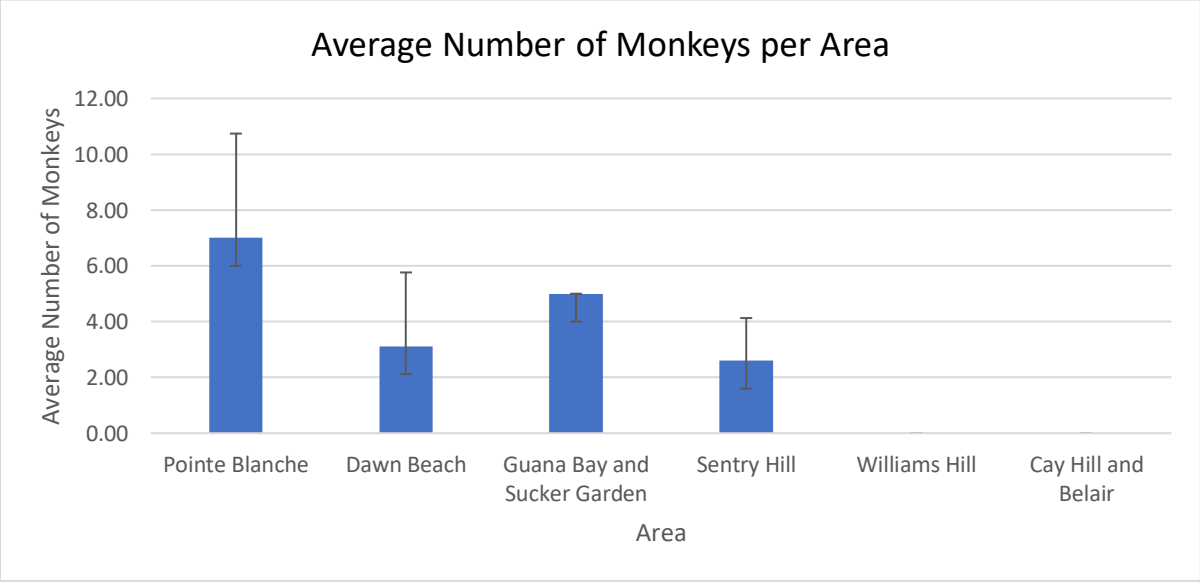

Figure 4. Average number of monkeys and standard deviation recorded per area during the field research in St. Maarten.

4.3 Management Options Survey

The demographics data from the Management Options Survey can be seen in tables 5 and 6 in the *Supplements*. A total of 143 respondents participated in the Management Options Survey, most respondents were between the ages of 30-39 and from Williams or Sentry Hill. Figure 5 shows that over 90% of the respondents were aware that there are invasive monkeys found on St. Maarten with nearly 50% of the respondents responded to having the monkeys around their home. Over 40% of respondents stated they were afraid or wary of the invasive vervet monkeys.

Figure 6 displays the locations of where the respondents reside who have answered yes to the question if they see monkeys around their home. The respondent's locations have been grouped together in larger areas to display a general census. Pointe Blanche has the highest recording of respondents who have seen monkeys around their residence, and Simpson bay and Cupecoy have zero recordings of respondents who have seen monkeys around their residencel

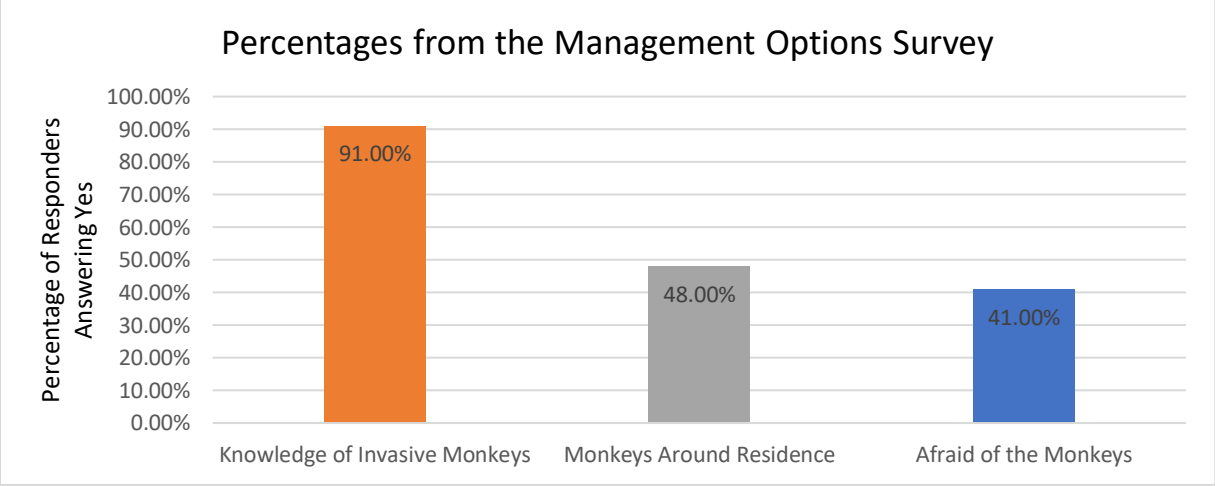

Figure 5. Results of the Management Options Survey displaying the percentages of respondents answering yes on the following questions: Are you aware there are invasive monkeys on St. Maarten? (orange bar), do you have monkeys around your home? (gray bar), and, are you afraid of the monkeys? (blue bar).

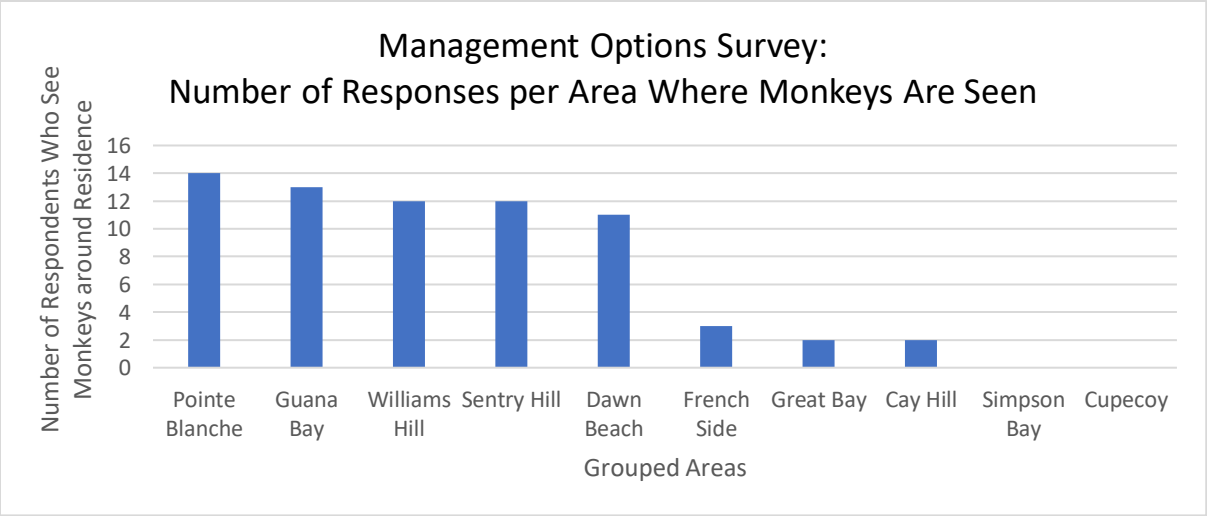

Figure 6. Number of responses for positive monkey sightings from residents from the Management Options Survey recorded per area of residence.

Management Solutions

The final question in the Mangement Options Survey was: What do you think needs to happen to the monkeys? Figure 7 shows that a total of 77 of the respondents chose eradication (55%), 46 respondents chose sterilization (32%), and 19 respondents chose that doing nothing would be the best course of action (13%). After confirmation about the chosen option, 12.6% of respondents later changed their opinion after receiving the information again.

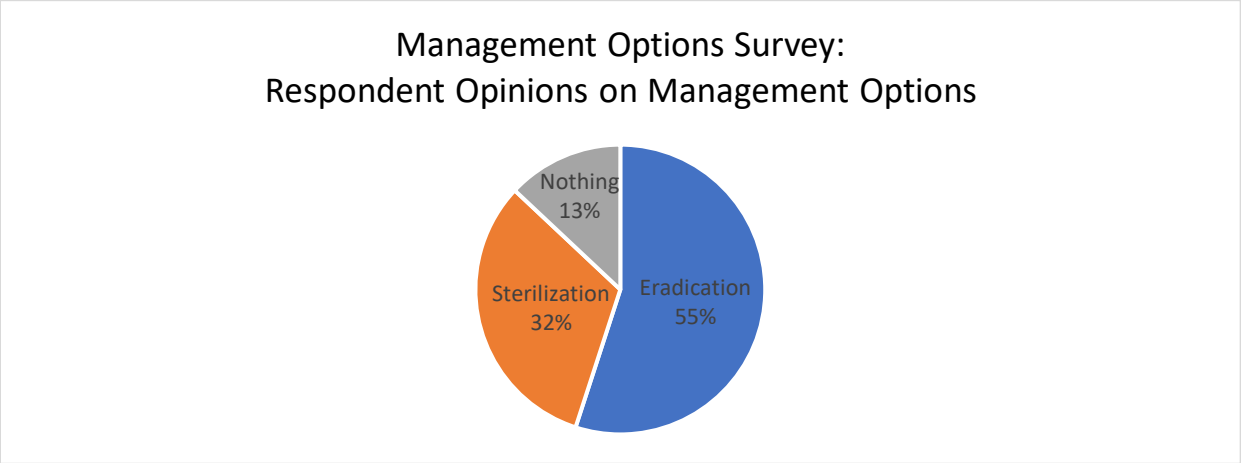

Figure 7. Percentage of respondents displaying the prefered monkey management option for the invasive monkey population on St. Maarten.

4.4 Population Estimation

The results from the field research, Management Options Survey and literature research, indicate for six to nine troops located on the Dutch side of St. Maarten. The field research shows smaller troops than literature research shows, with a maximum 10 individuals seen per site. Therefore based on this information it is estimated to have 10 – 50 individual monkeys in each troop. The estimated approximate locations of the troops are shown in image 4. These areas are distributed between Upper Prince Quarter, Williams Hill and Sentry Hill.

Image 4. Google Earth image displaying the estimated areas that monkey troops could be located.

5. Discussion

5.1 Preliminary Survey

The preliminary survey results indicated that the monkeys on the island needed to be studied and eventually managed in order to increase the agriculture on St. Maarten. The survey also indicates that most of the respondents participate in agriculture, which is not an accurate representation of the St. Maarten community. This survey was spread through social media, it was mainly shared through agricultural groups. While it is understood that these percentages do not accurately describe the St. Maarten population, those who did answer have shown that the monkeys are a large issue when participating in agriculture, and the community may take things in their own hands if nothing is done. The results of the survey also indicate that a majority of residents living on St. Maarten see monkeys around their home, with some residents from Pointe Blanche, Guana Bay, and Dawn Beach having the likelihood of seeing 20 or more monkeys at a time.

5.2 Field Research

When examining the results from the field research, it is clear to see that there are multiple troops of this invasive primate around St. Maarten. The research shows that the area of Point Blanch has the highest concentration of monkey sightings, followed by Guana Bay, Dawn Beach and Sentry Hill. However, the field data also suggests that the vervet monkey population is more off road than initially expected and visit residential areas only during certain times of the day. The population is maybe more elusive during field research, as only 20 of the 121 survey sites had recorded sightings of vervet monkeys. The number of monkeys seen during the field research was lower than expected, especially compared to the concerning monkey reports received from residents. This indicates that the field research shows an under estimation of the monkeys present in St. Maarten.

The literature shows that Vervet monkey activity peaks between 06:00 – 10:00 and 14:00-19:00 during the day (Menbere and Balakrishnan., 2016; Peres., 1999; Struhsaker., 1967), due to the cooler temperature. High temperatures accelerate water loss in primates, affecting their activity. To combat this, primates generally rest during the hottest parts of the day (Menbere and Balakrishnan., 2016; Peres., 1999). This is contradicting to our field research, as the vervet monkeys were often absent during the morning and afternoon periods of the field research, however residents would sent sighting reports in the same area later in the day. This indicates that the vervet monkeys their activity hours on St. Maarten may differ from other islands and studies. In a future research, it would be recommended to conduct monkey surveys during different frames times, including noon, afternoon and night.

Vervet monkeys have an average daily range of 1600 feet to 8200 feet, or 0.5-1.5 mile of distance daily (Dunbar., 1974; Richardson., 1990; and San Diego Zoo., 2021). The result of the researched area and results in this study shows that it is expected to have a minimum of one troop per area. Based on the results from the field research alone, there are at least four distinct troops on the Dutch side of the island, however, when including the results from the preliminary survey and the Management Options Survey, residents living on or around Williams Hill, and Cay Hill have also reported monkeys around their residence. This indicates that even though there were no monkeys seen during the field research, there is likely to still be a troop in each location. Therefore, it is predicted that in addition to the four troops surveyed by the Nature Foundation, there are at least two more troops on the island. Due to the distance between the monkey populated areas, it is a possibility for there to be three additional vervet

monkey troops. The areas that have the possibility of having two monkey troops are Upper Prince Quarter, Sentry Hill and Williams Hill. Leading to the prediction of six to nine distinct troops on St. Maarten. An exact population estimate has not been done as within one vervet monkey troop there can be 10 – 70 individuals (African Wildlife Foundation., 2021). However, based on the field research collected and the results from the surveys, it is believed that the troops on St. Maarten have a maximum of 50 individuals.

5.3 Management Options Survey

As the preliminary survey did not show an even demographic of respondents, the Management Options Survey was not published online. It instead was distributed around local supermarkets, gardening centers, hardware stores, etc. in an effort to even the distribution of respondents. The Management Options Survey shows similar results as the preliminary survey and field research, the areas with monkeys sighted by respondents are located in the Upper Prince Quarter area.

The results indicated that most residents are aware of invasive monkeys and that half of them have monkeys around their residence, showing large area cover of the monkeys on St. Maarten. A significant number of residents are afraid of the monkeys (41%), which shows action need to be taken in order to have more residents live comfortable around their residence. When conducting the Management option surveys it was noticed that most of the respondents who answered “no” to having monkeys around their home, were thankful that they did not have an issue with the monkeys. A large portion of the residents who said they were not afraid of monkeys added that they would not be afraid, as long as the monkeys kept away from them. However, during the project Nature Foundation often received reports of monkeys coming close to residents their house, children and pets, showing the possible increase of danger and decrease of comfort for residents due to monkeys.

During the survey, over half of the respondents chose eradication as the best solution, and a third of the respondents chose sterilization. Indicating that the residents of Dutch St. Maarten prefer to handle the monkey situation by applying eradication. According to research, euthanasia is also the most cost-effective, humane, and practical option that would have immediate positive effects for St. Maarten’s native wildlife and local agriculture (Baker and Bode., 2021). Eradication by human euthanasia of the monkeys is also being applied on St. Kitts and have showed to be an option which actually makes an impact on the population and decreases the numbers of monkeys. However, the size and timeline of an eradication project will determine the success of decreasing the monkey population.

6. Recommendations

6.1 Future Field Research

To improve further monkey research, it is recommended that the monkey management team is expanded to include more researchers. This will allow the team to carry out surveys throughout the entire day around several areas in St. Maarten at the same time. This recommendation includes areas for adjustment for the difference in the vervet monkeys' peak hours of activity. It should also be considered to included access to the bush area and drone surveys to access bush area.

The Nature Foundation also suggests that the team use motion-sensor field cameras to survey areas that are not being monitored by researchers. Possible drone use, or transit paths, would additionally be extremely useful for any future field research. With these suggestions, future field research on the vervet monkeys will have more precise population estimations.

6.2 Implementing the best Management Option

The island of St. Maarten is in need of a viable solution to take place as soon as possible regarding the invasive vervet monkey population. It is recommended to apply the eradication management option, as it has received most support from residents and has most success based in other parts of the world. Any option that would be implemented would be improved with a collaboration with French Saint Martin, as there is no physical border between the two countries. Without this collaboration repopulation or reintroduction of the invasive monkeys from the French side to the Dutch side would be highly likely.

The reinvasion probability for the invasive vervet monkey is low if the management solution is conducted on both sides of the island. This is due to the fact that St. Maarten is an island with no connecting land mass and keeping wild animals as pets is illegal without a permit on St. Maarten. Besides, import permits are needed to bring monkeys on the island.

If no future management option is instituted, the monkey population can quickly increase and cause irreparable damage to especially agriculture activities. Such damage includes endangering native flora and fauna, a detrimental effect on the local agricultural farms, causing future economic issues and safety issues. The vervet monkey population can double in size within a year, resulting in an overpopulation of an invasive species with no natural predator present. Management solutions are being explored and should be introduced now in order to slow down the overpopulation and prevent worse. This will limit damages to the native flora and fauna and help promote successful agricultural practices on the island. If the situation worsens, residents taking actions themselves can be expected, this likely includes inhuman and cruel procedures and treatment.

Based on this information, this research and the survey responses, eradication is the strongest management solution available, and it is recommended to make funds available to start implementing this management option as soon as possible.

6.3 Recommendation for implementing eradication

The euthanasia process would involve catching the monkeys by trap or dart to be humanely euthanized at a local veterinary clinic. The original quote from the St. Maarten Veterinary Clinic was $60 per monkey. However, this price did not include the cost of capture, nor the added costs of sedatives. The euthanasia solution is predicted to take approximately five years based on the 2021 troop number estimates from this research. However, this prediction is based on the current staffing situation at the Nature Foundation and also needs additional funding covering the costs, materials and time to execute the project. While it is possible for a mass eradication of the species to occur within a shorter time period, the team focused on this project would need to be larger and have the necessary hunting and darting experience or training and a higher amount of additional funding will be needed.

6.4 Recommendation for implementing sterilization

In case sterilization is chosen, it is recommended to focus the sterilization process exclusively on female monkeys, who would be trapped or darted and taken to the veterinary clinic to perform a sterilization surgery. Sterilization and euthanasia techniques, procedures, challenges and details were discussed with Dr. Singh of the St. Maarten Veterinary Clinic. The sterilization surgery is safe and straightforward, however with possible complications arising from tissue sensitivity or temporary trauma from capture. Dr. Singh confirmed that it was possible to sterilize monkeys of all ages, including juveniles. After a 24-hour recovery period to monitor possible reactions and allow the wound to begin to heal, the monkey would be released into the same area that it was caught. The recovery period would be the most challenging portion, as the monkey would need to be re-sedated for transport and released into its own troop.

The short gestation period and young sexual maturity of females makes them ideal candidates for sterilization. Females would be easier to sterilize at a younger age than males due to testes not being fully developed yet. Non-viable candidates for surgery (males, infants, heavily pregnant females, or nursing females) would be immediately released. The original quote for the sterilization was $300 per operation, not including the cost of capture or the added costs of sedatives. While this solution can be considered the most humane if successful applied, it would likely take a minimum of 5-10 years to complete with another 10-15 years until the population size begins decreasing. This option is likely to have a high percentage of error rate as all females would need to be sterilized to ensure the population would not continue to reproduce. Trapping and sterilization activities would become increasingly difficult as the remaining unsterilized females will be in areas that are more difficult to access.

The females can reach sexual maturity as early as two years old, while males only reach at five to six years old (Vervet Monkey Foundation., 2018). Vervet monkeys have a lifespan of approximately 12 years old but have been known to live up to 24 years in captivity (North., 2018). It would take approximately 10 years for the sterilized females to die, at which point the population size may begin decreasing.

7. Conclusion

The preliminary survey concludes that most people who participate in agriculture see the monkeys as a large issue, and it affects their agriculture activities. This research concludes that the highest number of monkeys is present in Point Blanche hill area, but also in the Guana bay, Sentry and Dawn beach hill areas, high amounts of monkeys can be seen. The numbers of monkeys sighted in the field surveys are expected to be an underestimation of the monkeys present, due to the difficulty of the monkey sightings in the dense bush area and differences in residential activity time of the monkeys during the day. It is concluded that there is an estimated number of 6 to 9 separate troops of Vervet monkeys on the Dutch side of St. Maarten, the troops are estimated to have 10 up to a maximum of 50 individuals.

If nothing is done within the near future, the vervet monkey population on St. Maarten can rapidly increase causing further issues with native species, agriculture and safety. Over half of the respondents from the Management Option Survey decided eradication was the best option, and a third of respondents decided that sterilization was the best option to manage the monkeys. Based on this survey, literature research and the collected data from the field research, the Nature Foundation advises to initiate the management solution human euthanasia. This solution would be the most time and cost effective and receives most support from residents. The Nature Foundation St. Maarten highly advises for a the eradication management option to be taken into consideration and initiated in the very near future, to prevent deterioration of the monkey situation or have residents take matters into their own hands.

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9. Supplements

Figure 8 displays the average number of monkeys seen in the morning versus the evening.

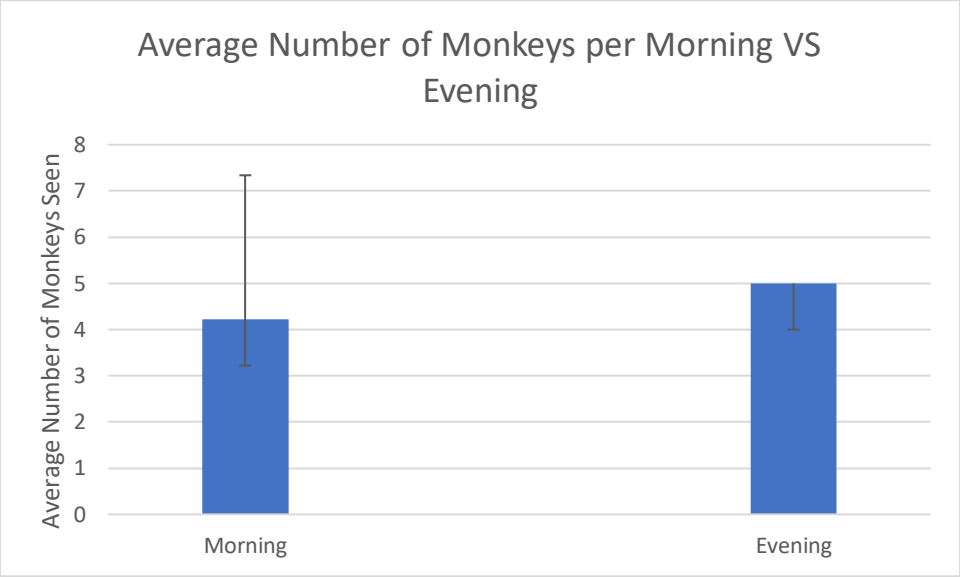

Figure 8. Bar graph showing the average number of monkeys seen in the morning and evening, with the standard deviation.

Table 4 displays the identifiable information describing each monkey sighting during the samples. In the table, the date, time the sample started, location, GPS coordinates and the group composition of the monkeys seen is included. Each sample was continued for 10 minutes after the starting time. The following abbreviations for the total seen are as follows: UK – unknown, AM – adult male, AF – adult female, IN – infant, JV – juvenile. Adult males and females can be easily identifiable by the body size and characteristics. Juveniles and infants are identified by size, body characteristics and color, and infants typically stay within arm's reach of an adult female.

Table 4. Data from the Monkey Management Project field research. The data includes date, time the sample started, location, GPS coordinates and total seen.

Date	Time	Location	GPS N	GPS W	Total Seen
27/01/2021	7:17	Almond Grove	18°02.777	63°04.571	4UK
27/01/2021	7:27	Almond Grove	18°02.764	63°04.564	3UK
27/01/2021	7:37	Almond Grove	18°02.692	63°04.593	1UK
28/01/2021	8:10	Pointe Blanche	18°00.667	63°02.420	1AM
29/01/2021	7:26	Sucker Garden	18°02.478	63°02.154	1AM,1AF,1IN,2JV
29/01/2021	7:50	Dawn Beach	18°02.680	63°01.186	2AM
29/01/2021	8:17	Dawn Beach	18°02.831	63°01.195	1UK
29/01/2021	8:42	Dawn Beach	18°02.777	4.303	2UK
29/01/2021	9:00	Dawn Beach	18°02.719	63°01.250	1UK
29/01/2021	9:11	Dawn Beach	18°02.705	63°01.213	2AF,4JV
4/2/2021	8:18	St. John	18°02.677	63°04.167	1UK
9/2/2021	6:44	Pointe Blanche	18°01.131	63°02.165	3AM, 2AF, 6JV
9/2/2021	7:15	Pointe Blanche	18°01.068	63°02.168	6AM, 3AF, 1JV
9/2/2021	7:30	Pointe Blanche	18°01.061	63°02.185	1UK, 2AF, 3JV

9/2/2021	7:40	Pointe Blanche	18°01.059	63°02.216	3AM, 2JV
9/2/2021	16:56	Pointe Blanche	18°01.076	63°02.326	3AM, 3AF, 3JV
11/2/2021	7:03	Guana Bay	18°01.904	63°01.904	1AM, 1AF, 3JV
11/2/2021	7:34	Dawn Beach	18°02.651	63°01.321	3AM, 1AF
11/2/2021	7:59	Dawn Beach	18°02.651	63°01.323	2AM, 3AF, 3JV
11/2/2021	17:23	Dawn Beach	18°02.678	63°01.253	1AM

Tables 5 and 6 display the demographic data from the Management Options Survey. Table 5 identifies grouped areas that respondents stated as their residing locations. Table 6 identifies the sex of the respondents as well as their age.

Table 5. Demographics from the Management Options Survey showing the areas residents listed as their home location.

Area	**Number of Respondents**
Williams Hill	30
Sentry Hill	24
Guana Bay, Hope Estate & Sucker Garden	19
Dawn Beach & Defiance	16
Pointe Blanche	15
French Side	12
Pelican Key & Simpson Bay	8
Philipsburg & Great Bay	8
Cay Hill & Belair	7
Cupecoy	4

Table 6. Demographics from the Management Options Survey showing the age and sex of all respondents.

Age Group	**14-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80+**
Number of Male Respondents in the age group	0	10	11	12	17	12	5	2
Number of Female Respondents in the age group	5	12	22	12	7	7	5	4