

A large green iguana is the central focus of the cover, resting on a bed of vibrant green grass. The iguana's body is covered in detailed scales, and its long, pointed tail extends towards the left. The background above the grass is a dark, textured band, and the background below is a lighter, textured band, both with a painterly, brushstroke-like appearance.

MANAGEMENT OF THE GREEN IGUANA IN SAN JUAN NATIONAL HISTORIC SITE

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Vol. 1

A small, detailed illustration of an iguana's head is positioned in the bottom left corner of the page.

Reviewed by: Kelly Altenhofen

Wildlife Biologist

By: Miguel Angel Naveira

Biological Science Technician



U.S. Department of the Interior

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Produced by:

WILDLIFE PROGRAM STAFF AT THE SAN JUAN NATIONAL
HISTORIC SITE OF THE NATIONAL PARK SERVICE OF THE UNITED
STATES DEPARTMENT OF THE INTERIOR

Collaborators:

USDA APHIS WILDLIFE SERVICES
USDA APHIS VETERINARY SERVICES
USDA FOREST SERVICE INSTITUTE OF TROPICAL FORESTRY
USDOI NPS BIOLOGICAL RESOURCES DIVISION

U.S. Department of Interior
National Park Service WASO - SAJU
San Juan, P.R.

KELLY ALTENHOFEN
WILDLIFE BIOLOGIST
MIGUEL ANGEL NAVEIRA
BIOLOGICAL SCIENCE TECHNICIAN



U.S. Department of Interior
National Park Service WASO - SAJU
San Juan, P.R.

MANAGEMENT OF THE GREEN IGUANA IN SAN JUAN NATIONAL HISTORIC SITE

**KELLY
ALTENHOFEN** Digitally signed by
KELLY ALTENHOFEN
Date: 2026.05.05
10:38:51 -04'00'

Prepared by:

Kelly Altenhofen
Wildlife Biologist

_____ Date

**MIGUEL NAVEIRA
GUZMAN** Digitally signed by MIGUEL
NAVEIRA GUZMAN
Date: 2026.04.29 13:33:14 -04'00'

Miguel Angel Naveira
Biological Science Technician

_____ Date

FELIX LOPEZ Digitally signed by FELIX
LOPEZ
Date: 2026.05.27 13:54:09
-04'00'

Recommended by:

Felix J López
Cultural Resources Program Manager

_____ Date

MYRNA PALFREY Digitally signed by MYRNA
PALFREY
Date: 2026.05.27 19:24:31 -04'00'

Approved by:

Myrna I. Palfrey
Superintendent

_____ Date

501 Norzagaray Street
San Juan, PR. 00901
Email: saju_superintendent@nps.gov



ABBREVIATIONS (Nomenclature)

%	Percent
°C:	Degrees Celsius (Grados Celsius)
°F:	Degrees Fahrenheit
APHIS	Animal and Plant Health Inspection Service
AVMA	American Veterinary Medical Association
BATF	Bureau of Alcohol, Tobacco, Firearms and Explosives
BSA-P7	Baluart de San Antonio
BSE/SF-P5	Baluart de Santa Elena/Batería de San Fernando
BST-P1	Bastión de Santa Teresa
CE	Categorical Exclusion
CPR	Cardiopulmonary Resuscitation
CGT-P6	Contra Guardia de la Trinidad
CO ₂ :	Carbon Dioxide (Dioxide de Carbono)
CSC-P2	Castillo San Cristóbal
Cu.	Cubic (Cúbico)
DE/FA-P4C	Foreign Defense (Fuerte El Abanico)
DE/RSC-P3	Foreign Defense (Revellín de San Carlos)
DOI	Department of the Interior
DRNA	Departamento de Recursos Naturales y Ambientales de Puerto Rico
EA	Environmental assessment
EIS	Declaración de impacto ambiental
Ft.	Feet (Pies)
GCB11	Helicobacter sp.
GPS	Global Positioning System (Sistema de Posicionamiento Global)
In.	Inches (Pulgadas)
m	meter
MS222	Tricaine Methanesulfonate
N	North
NEPA	National Environmental Policy Act
NPS	National Park Service
O.E.	Executive Orders
QEIBP	Queen Elizabeth II Botanical Park
Qt	Quart (Cuarto de Galón)
RAP	Resource Assistants Program
USDA	United States Department of Agriculture
W	West
WS	Wildlife Services



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WORK PLAN:

Iguana Management at San Juan National Historic Site – NPS

1 INTRODUCTION:

The San Juan National Historic Site is the only national park service unit in Puerto Rico. Located in the ancient city of Old San Juan, the park includes the fortifications of Castillo San Cristóbal, Castillo San Felipe del Morro (El Morro), and Fortín San Juan de la Cruz (also known as El Cañuelo), along with bastions, powder houses, and three quarters of the wall that surrounds the city. These structures represent advancements in architecture and military engineering over nearly five centuries (from the 16th to the 20th century) and are the oldest European-designed fortifications in the United States. In 1949, the United States Secretary of the Interior designated these fortifications as a national historic site through the Order of Establishment for the San Juan National Historic Site, and in 1961, they were transferred to the National Park Service and the Commonwealth of Puerto Rico. The walls of the Paseo del Morro follow the western coast of the island, bordering the base of the historic fortification walls and landscapes from the San Juan Gate to El Morro.

INVASIVE SPECIES MANAGEMENT PLAN

The National Park Service is developing a management plan to address invasive species within the park. This plan specifically targets the green iguana (*Iguana iguana*), whose population has grown significantly and now occupies various areas of the park (NPS, 2023; NPS, 2020). The presence of this invasive species poses risks to environmental and public health, as well as damages the structure and landscaping that characterizes the national park. The green iguana is native to Central and South America and is considered an invasive species in the United States. It is believed to have arrived in 1970, and by 1990, there were dense populations in the regions where it was not formerly located, including Puerto Rico. The population is estimated to be around one million in total in Puerto Rico. However, US Department of Agriculture – Forest Service (USDA-FS) biologist Dr. De Jesús (2021) mentions in her studies (2021) that green iguanas were first reported in Puerto Rico in 1964. Both specimens were deposited in the Museum of Zoology at the University of Puerto Rico. By the 1990s, isolated populations had become established in the western part of the Mayagüez Zoo, the northeastern mangrove forest of Carolina-Loíza, and the San Juan metropolitan area.

Green iguanas breed in the dry season from December to June and mating is between January and February. Gestation lasts between 59 and 84 days, with an average of 65 days. They can lay about 3 to 75 eggs, averaging 24 eggs per year. Currently, green iguanas are distributed throughout Puerto Rico in large colonies, in the coastal regions of the main island and on Culebra Island. Green iguanas are considered a harmful non-native invasive species according to Regulation Number 6765 of the Puerto Rico Department of Natural and Environmental Resources (DRNA) (López, 2012). The DRNA has regulatory authority over green iguanas in Puerto Rico and permits damage management activities within the Commonwealth under this authority. Similarly, the US Department of Agriculture - Animal and Plant Health Inspection



Service - Wildlife Services (USDA - APHIS - WS) mentions that Executive Order (EO) 13112 and Executive Order (OE) 13751 direct federal agencies whose actions may affect the status of invasive species to reduce the invasion of these species and associated damages to the extent practicable and allowed by law ([USDA, APHIS WS, 2021](#); [USNARA, 1977](#); [USGI, 1999](#)). A positive aspect that complements the iguana reduction strategies is the intervention of other species, which contributes to the processes of decreasing this invasive species. Studies have identified a total of seven predators in Puerto Rico that feed on iguanas or their eggs: (1) one reptile, (2) three birds, and (3) three mammals. ([Rodríguez, 2013](#)).

The post-1990 expansion and increase of green iguana populations on the island of Puerto Rico are closely related to the haplotypic relationship between iguanas exported from El Salvador for the pet trade and wild iguanas in Puerto Rico, further demonstrating the influential role of the pet trade in species invasion ([De Jesús, et al., 2021](#)). In highly urbanized areas (San Juan metropolitan area, Caguas, Ponce), green iguanas are predicted to be found in vegetation patches (e.g., parks) and adjacent to bodies of water. However, the distribution of green iguanas is irregular in the limestone formations of the northwest ([De Jesús et al., 2020](#)). Since green iguanas are considered a harmful non-native invasive species in Puerto Rico, any reduction in their population could be considered beneficial for the native environment of the Commonwealth of Puerto Rico and the United States of America. The San Juan National Historic Site has not been isolated from the impacts brought by the green iguana. These reptiles have taken over the 500-year-old historic fort, becoming part of the tourist attractions, which detracts from the park's general cultural message. Tourists generally do not know that the green iguanas are not native. Somehow, they have normalized. Their presence has distracted visitors from native natural resources and wildlife. In addition, iguanas damage the internal structure of the fort by utilizing the drain networks and cracks/crevices for living and breeding spaces. Their fecal droppings can potentially carry bacteria that is harmful to humans and the accumulation of feces is unsightly and erodes the limestone mortar. The fortress itself serves as a large area of harborage for the iguanas which leads to not only an increase in the reptile population but also to a decrease in tourist enjoyment. The present large population numbers and their proximity to visitors poses a clear threat to public and environmental health. The National Park Service stipulates in Management Policies ([2006](#)) subsection 4.4.4.2 – Removal of Exotic Species Already Present that *"...All exotic plant and animal species that are not maintained to serve an identified park purpose will be managed, including eradication, whenever: (1) control is prudent and feasible, and (2) the exotic species..."*. This includes, but is not limited to, interfering with natural processes and the perpetuation of natural features, native species, or natural habitats; altering the accurate presentation of a cultural landscape; damaging cultural resources; significantly impairing the management of the park or adjacent lands; posing a public health hazard as recommended by the U.S. Public Health Service (which includes the Centers for Disease Control and Prevention and the NPS public health program); or creating a public safety hazard.

The purpose and need for action have driven the park to create a Resource Management Plan with the implementation of the removal protocol to begin as soon as possible. It is important for the agency to address this issue with full adherence to environmental policy, regulations, and agency guidelines that address invasive species management. Additionally, these actions must be accompanied with the collaboration and support of relevant agencies. Undoubtedly, the removal program could provide a significant contribution to the science of invasive iguana management throughout the National Park Service and other federal agencies. This plan will detail the processes and actions that will form the operational protocol which will be attached to the established management plan. This plan would only



address the green iguana population within the boundaries of the park and would not address green iguanas within Old San Juan or other areas outside the jurisdiction of the National Park Service. This plan will largely reflect some resources on the USDA APHIS WS "Management of damage caused by mammal and reptile species in Puerto Rico", the "Management Policies 2006" by DOI - National Park Service, AVMA Guidelines for the Euthanasia of Animals: 2020 by the American Veterinary Medical Association (AVMA), Managing Damage Caused by Mammal and Reptile Species in Puerto Rico by USDA - APHIS - WS, and the "Comprehensive action plan to control the population of the green iguana" by DRNA and the NPS Plan.

2 OBJECTIVES:

2.1 Protecting archaeological resources and cultural landscapes

- Establish physical barriers and non-invasive control methods to protect archaeological resources and cultural landscapes by reducing iguana burrows or refugees.
- Train staff in specific management and conservation techniques for areas with a high iguana presence.
- Implement regular monitoring and observation of historic structures and archaeological resources to prevent damage caused by iguana burrows, also known as harborage.
- Implement control methods to prevent iguanas from damaging park structures.

2.2 Preventing ecosystem/ecology disruption

- Reduce the density of iguana's population by 85% (percent) per year.
- Conduct pilot environmental impact studies to better understand the effects of iguanas on local wildlife and habitats.

2.3 Conserving biodiversity

- Implement actions to reduce competition and environmental damage by iguanas.

2.4 Minimize economic impacts

- Promote sustainable tourism through the education of visitors about the problem of iguanas and the impact on the ecosystem.
- Reduce damage to historical structures due to iguanas.

2.5 Overlay with native species

- Monitor and manage the interaction between iguanas and native species to avoid overlapping and competition.
- Restore and maintain habitats that favor native species.

2.6 Reducing accidents, stress and illness (Public health)

- Educate the community and visitors on how to safely interact with iguanas.
- Establish health surveillance programs to detect and control diseases transmitted by iguanas through collaboration with other agencies or private entities.

2.7 Protecting the cultural landscape and wildlife

- Implement specific management and conservation actions to protect the cultural landscape and endangered species.



2.8 Promoting environmental education

- Implement environmental education and environmental awareness for all people of interest.
- Reduce misinformation by increasing access to public information early in the planning process.

3 DURATION:

This plan will continue for the foreseeable future depending on staffing and funding commitments. The first 6 years will be vital for the implementation of this project.

4 MISSION:

The Green Iguana Management Program must effectively manage and mitigate the impact of invasive *Iguana iguana* populations through a comprehensive and ethical approach that always reflects proper suitability and sustainability. It must prioritize the protection and conservation of the ecosystem, public health and historical archaeological resources.

5 GOALS:

- Reduction of green iguana harborage, egg laying habitats, hatchlings and further invasive exotic species establishment.
- Reduction of accidents, stress, and illness related to human-iguana interactions.
- Protect and conserve the cultural landscape, endangered species, and other native and endemic wildlife from the effects caused by green iguanas in all spaces of the San Juan National Historical Site.

6 THEORETICAL FRAMEWORK:

There are limited studies currently available as to the effects of iguanas on the historical areas and structures of the fortress and walls that were built to defend Old San Jaun. Park staff will be able to collect data on harvested iguana numbers, sex, age and locational densities through the implementation of the Iguana Management Plan and determine their impacts on the ecosystem at the San Juan National Historic Site. A review of the scientific data and methodologies for removal will become and represent a structured methodology for dealing with this invasive species. In summary, the park must be able to collect site-specific information on iguana control and make detailed comparisons to other studies and efforts conducted in the Commonwealth of Puerto Rico, the United States of America, and internationally to create a cohesive and unified management strategy for the control of this invasive reptile.

The need for a cohesive strategy is apparent at the microscale of the park as iguanas inhabit and are routinely observed in all areas of the park. Although they have not been specifically studied in the National Park Service areas within Puerto Rico, observations recorded between 2008 and 2009 in the Linear Park and the Blasina Canal in San Juan and Carolina, respectively, indicated high densities and reproductive success of green iguanas (De Jesús, 2022). In 2012, the population of green iguanas in Puerto Rico was



estimated at 4 million. Green iguanas are mating and reproducing in park habitats that are conducive for them to lay eggs and dig burrows (López, et. al., 2012). The iguanas cause various impacts to the park, including damage to vegetation, feces generation in highly visited areas (creating health hazards and maintenance issues), and potential displacement of native species such as Caribbean hermit crabs, black-backed land crabs, and various bird species. Additionally, iguanas dig burrows for nesting and shelter, causing erosion and undermining historical fort infrastructure. Green iguanas and cats generally do not coexist unless they can separate by height, meaning that although both species are abundant along the Paseo, they tend to self-segregate (NPS, 2023). Yet iguanas have been seen eating cat food deposited by outside groups and cats are actively utilizing iguana burrows for shelter and harborage along the trail. The large iguanas located along the trail are no doubt benefiting from the continued deposition of and abundance of a commercial pet food source.

Below are some studies, regulations and laws that serve as background for the issue of iguanas as invasive species:

6.1 Summary of Previous Case Studies:

6.1.1 Case 1: Interviews with farmers suggest negative direct and indirect effects of the invasive green iguana (*Iguana iguana*) on agriculture in Puerto Rico (De Jesús, 2021).

Farming communities and crop production are negatively affected by invasive species such as the non-native green iguana. This research focuses on the interactions of the non-native green iguana with native species, with little prior attention to its impact on the agricultural landscape. Through semi-structured interviews with farmers from 20 farms in Puerto Rico, the effect of the invasive green iguana on crop production and the management strategies used by farmers were explored. Of the 55 crop species reported by farmers, 34 were negatively affected by the green iguana. It was found that green iguanas were absent in 20% of the farms, did not consume crops in 10% of the farms, and caused negative impacts in the remaining 70%. Negative impacts included crop loss and damage to infrastructure, which had behavioral, emotional, and economic effects on farmers. Specifically, these effects included loss of income, renovation costs, changes in crop selection, management costs, and emotional distress. Farmers used netting, hunting, and domestic animals as methods to reduce the negative effects of green iguanas on crop production. Interviews with farmers revealed that 34 of the 55 crop species were negatively affected by green iguanas, resulting in substantial crop loss and damage to infrastructure.

6.1.2 Case 2: Preliminary findings of *Salmonella* spp. in captive green iguanas (*Iguana iguana*) and their environment (Mitchell, 2000).

Reptiles kept in captivity are frequently identified as carriers of *Salmonella* spp., and cases of salmonellosis associated with reptiles are on the rise. A limited study was conducted at a green iguana farm in El Salvador to detect sources of *Salmonella* spp. in both the iguanas and their environment. Samples were collected for microbiological culture from iguanas (adult, juvenile and embryo) and their



environment. In this study, *Salmonella* spp. was found to be isolated from the gut of adult (3 out of 20) and juvenile (8 out of 20) iguanas. No evidence of *Salmonella* spp. was found in the reproductive tracts of female iguanas (0 out of 10). *Salmonella* spp. was found on the surface of 40% (7 of 16) of the eggs tested. No *Salmonella* spp. was identified in the externalized yolk sac of the iguana embryos analyzed. However, soil and nest samples tested positive for *Salmonella* spp. In this study, eight different serotypes of *Salmonella* spp. were identified. These results suggest the horizontal transmission of *Salmonella* spp. and confirm that iguanas (reptiles) can act as a disease vector.

6.1.3 Case 3: Efficient nocturnal capture methods for controlling a diurnal and arboreal invasive lizard species (Wasilewski, et al., 2022).

Effective methods for capturing and removing large numbers of invasive green iguanas (*Iguana iguana*) are presented in both the Bahamas and South Florida, USA. Night hunts were conducted, but eliminations were performed during the day using a live trap or snare placed at the entrances of active burrows. The green iguanas were humanely euthanized using Blitz-Kerner stunning equipment and pithing as mentioned in the American Veterinary Medical Association's (AVMA) guidelines for animal euthanasia. With these methods, they resulted in the removal of 22,678 invasive green iguanas. This methodology may be used as a tool for a rapid response to new introductions of green iguanas, as a management tool in areas already infested by these invasive species located in forested environments.

6.1.4 Case 4: The Environmental and Economic Impacts of an invasive Species in South Florida (Rubin, 2022).

Invasive species continue to enter the environment and thereby generate ecological imbalances. This study focused on raising awareness among the public and policymakers about the detrimental effects that invasive species have on the planet. Through specific research on green iguanas in South Florida, this project highlighted the damage iguanas are causing not only to the environment and economy, but also to infrastructure. Erosion from iguana burrowing in surrounding areas of the foundations of various buildings, roads and bridges are making these structures less viable and safe. Although there has been some progress with proposed new infrastructure bills, there is still much to be done to directly address the iguana problem. The study underscores the need for greater awareness and environmental public policy measures to address this problem effectively.

6.1.5 Case 5: Green Iguanas: A Threat to Man and Wild in Fiji Islands? (Shah, et. al., 2020).

Green iguanas are a detrimental invasive species in the Fiji Islands, where they were accidentally introduced as pets. Their presence poses a threat to the islands' unique biodiversity, which includes four species of native iguanas, three of which are endemic. The spread of green iguanas on several islands has been facilitated by both natural and anthropogenic means. Local communities face challenges in



identifying native versus invasive iguanas, complicating management efforts. There is currently a lack of environmental education on the subject of invasive iguanas in Fiji. There is a pressing need for research to inform evidence-based decision-making, particularly about the ecological impacts of green iguanas on native species and ecosystems. This includes studying their foraging behavior, impacts on seed germination, and interactions with native iguana populations. In the Fiji Islands, the biggest challenge is the need to combine research and management strategies to fill the knowledge gap, identify novel tools and technologies, convince decision-makers and funders, and reduce any conflicts of interest among stakeholders. The effectiveness of the plan must go hand in hand in combating education, studying the impact and ordering the methods for greater effectiveness of the program.

6.1.6 Case 6: Systemic *Helicobacter* infection and associated mortalities in endangered Grand Cayman blue iguanas (*Cyclura lewisi*) and introduced green iguanas (*Iguana iguana*) (Conley, 2021).

The Blue Iguana Recovery Program maintains a captive breeding and initiation program for the endangered Grand Cayman blue iguanas (*Cyclura lewisi*) in Grand Cayman, Cayman Islands. During 2015, two wild Grand Cayman blue iguanas were found within the Queen Elizabeth II Botanical Park (QEIBP). Spiral-shaped bacteria were identified in peripheral blood smears from both animals (Cayman blue iguanas and green iguanas), which molecular diagnostics identified as a new species of *Helicobacter* sp. (*Helicobacter* sp. = GCBI1). Between March 2015 and February 2017, 11 Grand Cayman blue iguanas were identified with the infection. Two of them were found dead and nine were treated. In contrast, five of the nine animals treated survived the initial infection. A Taqman qPCR assay specific for *Helicobacter* sp. was performed to examine tissue and/or blood samples from clinical cases, fecal and cloacal specimens from clinically healthy Grand Cayman blue iguanas, including previously infected iguanas. Fecal and/or cloacal swab samples were all negative, suggesting that Grand Cayman blue iguanas are not asymptomatic carriers of this organism, nor do they shed this pathogen by cloaca after infection. However, retrospective analysis of a 2014 mortality event affecting green iguanas from a separate location of Grand Cayman identified *Helicobacter* sp. in two of the three cases. The source by which iguanas become infected has not yet been confirmed. However, analysis of rainfall data reveals that all the infections occurred during a dry period of several years, with most occurring shortly after the first rain at the end of the seasonal drought. In addition, further detection has identified *Helicobacter* sp. GCBI1 from clinically normal green iguana choanal swabs in the QEIBP, suggesting that they could be asymptomatic carriers and a potential source of the pathogen. Green iguanas, like other vectors, could undoubtedly be associated with the transmission of *Helicobacter* sp. bacteria, underscoring the need to reduce/eliminate them through surveillance and control to prevent outbreaks in human populations. The green iguana is also a potential vector to native wildlife (Akhlaghi, 2024; Jalava, 2001).

6.1.7 Case 7: A virulent clone of *Devriesea agamarum* affects endangered Lesser Antillean iguana (*Iguana delicatissima*) (Hellebuyck, et. al, 2017).



This study on other iguanas (*Iguana delicatissima*) on the island of Saint Barthélemy, in the French Caribbean, revealed the presence of a serious skin disease caused by the bacterium *Devriesea agamarum*. This disease poses a significant threat to the conservation of these iguanas, which are in danger of extinction. The research also found that the bacterium was present in healthy lizards who cohabit the island, suggesting the existence of asymptomatic hosts that could serve as reservoirs of the disease. This case highlights how infectious diseases can negatively impact the biodiversity and ecology of reptiles in their natural habitat.

6.1.8 Case 8: Combined per-capita and abundance effects of an invasive species on native invertebrate diversity and a key ecosystem process (Carvalho et al., 2022).

The invasive signal crayfish (*Pacifastacus leniusculus*) negatively impacts the freshwater ecosystems of the Rabaçal and Tuela Rivers (Portugal) by modifying invertebrate communities and leaf litter decomposition processes. An increase in the abundance of these crabs is associated with lower invertebrate diversity and a reduction in functional redundancy, implying long-term ecological consequences. Although these case studies highlight the harmful effects of invasive species, it is crucial to recognize that not all non-native species cause negative outcomes. Some can integrate into ecosystems without causing significant damage, suggesting a complex relationship between invasive species and native biodiversity. The results showed that an increased abundance of crayfish led to a decrease in invertebrate abundance, richness and diversity and to changes in community structures. An increased abundance of crayfish also led to a decrease in invertebrate functional redundancy and an increase in the percentage of invertebrate taxa with resistance forms. For this reason, it is necessary to investigate the potential impact of these species on the spaces where they interact with native species and the flow of ecology.

6.1.9 Case 9: Green Iguanas (*Iguana iguana*) in Puerto Rico: is it time for management? (López-Torres, et. al., 2011).

On the island of Puerto Rico, it is estimated that the green iguana was introduced in the 1970s and has reached very high population densities, with a maximum of 223 individuals per hectare. This invasive species has proven to be successful reproductively and has negatively impacted native biodiversity. Green iguanas have been observed to threaten infrastructure, agriculture, and human biosecurity. The lack of effective predators and competitors has allowed this species to proliferate, underscoring the urgency of developing a management program to control its expansion and mitigate damage to infrastructure. This data is important to have at hand when assessing the impact or implementing pressing issues about the decline of green iguanas.



6.1.10 Case 10: Effect of Animal Burrows on the Vulnerability of Levees to Concentrated Erosion and Impact of animal burrows on earthen levee body vulnerability to seepage (Ceccato, et. al., 2022; Palladino, et. al., 2019).

Concentrated erosion in dikes and dams by burrowing animals, such as porcupines and otters or others can compromise the integrity of these structures. If burrows connect the water side to the land side, the flow of water can cause concentrated erosion which could lead to fatal failures of the structure. A simplified model based on the boundary equilibrium method has been proposed to assess the vulnerability of the dikes to these burrows. Earthen dikes are similarly affected through their vulnerability to filtration. A study of dikes along the Tanaro River in Italy showed that animal burrows increase vulnerability to seepage, which increases the likelihood of internal erosion. This phenomenon translates into a greater risk of long tunnel formation and dam or dike failure due to animal burrowing.

6.1.11 Case 11: Effects of pocket gopher burrowing on archaeological deposits: A simulation approach (Pierce, 1992).

Gophers and their burrows can affect archaeological deposits, and their integrity can cause vertical classification of artifacts, destruction of fragile artifacts, and alteration of sedimentary structures. A simulation study showed that after thousands of years, a zone of stones composed mainly of particles larger than 6 cm develops, suggesting that current notions about certain archaeological horizons may need revision. They appear to be related to situation-specific differences in burrow depth, occupation history, and geomorphological environment. The validity of the patterns of alteration of the strata and depositional structures produced by the simulation cannot be evaluated with the two examples used, since the lack of such layers and structures in the sites may be the result of other pedogenetic processes. However, the rapidity of disturbance caused by gopher burrows is attested by the mixed and discontinuous condition of the strata at one site.

6.1.12 Case 12: Can green iguanas compensate for vanishing seed dispersers in the Atlantic Forest fragments of north-east Brazil? (Maura, et. al., 2015).

In the fragmented Atlantic Forest of northeastern Brazil, green iguanas (*Iguana iguana*) have proven to be effective seed dispersers, partially offsetting the local extinction of important seed dispersers such as primates. During a 20-month study, iguanas were observed to disperse seeds of 12 plant species in fragments of urban forest. This seed dispersal behavior is crucial for the maintenance of plant communities in these fragments, suggesting that iguanas may play an important functional role in the ecology of these fragmented ecosystems. The green iguana in its habitat is an effective dispersal agent. However, its effects on seed or fruit dispersal in Puerto Rico may be mixed due to the introduction of invasive or exotic species such as the green iguana. This invasive species is capable of dispersing seeds beyond the canopy of parent trees, which can be significant for the dynamics of plant communities. Green iguanas, due to their high population density, can alter seed germination timing and rates, as seen in the



case of *Ficus spp.*, by removing the fruit pulp. In species such as *Pterocarpus officinalis*, they may reduce the percentage of seeds that germinate, while also decreasing the germination time. It is worth noting that understanding their ecological role is complex and requires further research to support appropriate management strategies in our region. However, at SAJU NPS, observations have confirmed that native and endemic bird species (not green iguanas) are typically responsible for seed dispersal, although the activity of these bird species has also been impacted by the presence of free-ranging cats in areas near the NPS (Burgos, 2014; Burgos, *et al.*, 2016).

6.1.13 Case 13: A distribution model, nest temperatures, predators and results for a five-year management plan of *Iguana iguana* in Puerto Rico: Chapter III and Chapter IV (Rodríguez, 2013)

The green iguana (*Iguana iguana*) is an invasive species in Puerto Rico, originating from Central and South America. Introduced in the 1970s, this reptile has become a significant nuisance, costing the local government millions annually in infrastructure damage, agricultural losses, and conservation efforts. One major factor that may reduce their abundance is predator release. The study identified seven confirmed predators in Puerto Rico through field observations at Las Cabezas de San Juan Nature Reserve and Guánica State Forest, including one reptile (*Ameiva exsul*), three bird species (*Ardea alba*, *Falco sparverius*, and *Margarops fuscatus*), and three mammals (*Canis familiaris*, *Felis catus*, and *Herpestes javanicus*). In Florida and within iguanas' native range, birds have been identified as the primary predators. This work is the first to report on green iguana predators in Puerto Rico and highlights the potential for unconfirmed predators to aid in population control. Additionally, green iguanas may facilitate population growth of other invasive species, necessitating further research for effective management.

In response to the challenges posed by the green iguana, a five-year management project was implemented at Cabezas de San Juan Nature Reserve (CSJNR) from 2008-2012. The project focused on harvesting green iguana eggs to reduce population densities and gain insights into their reproductive ecology. A total of 7,638 eggs were collected, and various clutch characteristics were recorded. Despite a slight decrease in population density, it remains unclear if egg harvesting was the sole cause, as adult iguanas were also hunted during the project. The study emphasized the need for integrated management techniques, including adult removal, to effectively reduce green iguana populations. The project also demonstrated the value of citizen science and provided important baseline data on the natural history of this invasive reptile.

6.1.14 Case 14: State of knowledge for invasive green iguanas in Florida reveals negative impacts and pervasive research needs (Claunch, *et. al.*, 2025).

The green iguana has significant negative impacts on agriculture, infrastructure, natural resources, and biodiversity, especially in Florida. These effects are attributed to their feeding behavior, which damages crops, and their burrowing, which harms infrastructure like canal walls, roads, and power plants. For instance, repairing damage caused by iguana burrows in South Florida canal walls costs around



\$400 per burrow, with larger projects like a \$1.8 million dam repair in Palm Beach emphasizing the economic strain. Ecologically, iguanas contribute to plant species degradation, including mangroves, vital for ecosystem stability. Their burrowing also threatens endangered species like the gopher tortoise and burrowing owl. While there is some research on the economic impact of iguanas in Puerto Rico, comprehensive data on their effects in Florida remains limited. More research is needed on the economic costs, agricultural damage, and ecological consequences, especially regarding the costs of control methods, and the behavior, diet, and reproduction of the iguana. Such research is crucial for improving management strategies and policies to mitigate the impact of this invasive species, as outlined in this study. This study certainly provides us with clear data on the needs we could address or what we should avoid through our project.

The analysis of previous cases allows us to investigate the importance of managing this species and justify the proposed actions. It strengthens appropriate methodologies for studying and managing green iguanas. Both elements are essential and necessary for effectively designing, implementing, and evaluating management strategies, ensuring sound, adaptable, and sustainable actions in the short, medium, and long term. All the studies and data presented demonstrate the need to address this problem, which we hope to address on the national historic site.

6.2 Environmental public policy and others:

6.2.1 National Environmental Policy Act (NEPA):

The National Environmental Policy Act (NEPA; 42 U.S.C. §§ 4321 et. seq.) requires federal agencies to evaluate the environmental effects of their proposed actions before making decisions. A primary objective is to protect the environment and public accessibility to an environment suitable for human enjoyment. This includes assessing environmental impacts and considering alternatives for actions that significantly affect the environment. NEPA encourages public participation in the decision-making process, which may include the management of invasive species, such as the green iguana.

6.2.2 National Park Service (NPS) Management Policies 2006:

This environmental public policy regulation emphasizes the conservation of the natural and cultural resources of the national parks of the United States of America. NPS is committed to preventing the introduction and spread of invasive (or “exotic”) species that may harm the ecosystem. This includes the removal of invasive species already present and the restoration of affected natural communities.

6.2.3 Managing Damage Caused by Mammal And Reptile Species In Puerto Rico of USDA -APHIS – WS (2021):

This USDA - APHIS - WS environmental assessment focuses on managing the damage caused by mammal and reptile species in Puerto Rico. The focus is to reduce the population of invasive species using integrated control and eradication methods, such as capture and specialized methods of elimination (euthanasia). In addition, it seeks to collaborate with local agencies and communities to implement effective and sustainable



strategies that minimize the negative impact of these species on the ecosystem and the local economy.

6.2.4 AVMA Guidelines for the Euthanasia of Animals: 2020 del American Veterinary Medical Association (AVMA, 2020):

The AVMA's *"2020 Animal Euthanasia Guidelines"* provide guidance for the euthanasia of animals, with a focus on relieving the pain and suffering of animals that must be euthanized. Such guidelines should also be used when dispatching an invasive species, such as the green iguana, in a humane and bioethical manner.

6.2.5 Comprehensive Action Plan to Control The Green Iguana's Population (DRNA; López, 2012):

The Comprehensive Action Plan to Control the Green Iguana Population of the Puerto Rico Department of Natural and Environmental Resources (DNER) focuses specifically on the management and control of the Green Iguana population. The plan includes strategies to reduce the invasive population through methods such as capture and humane killing, as well as public education and collaboration with other agencies to mitigate the impact of this invasive species on the local ecosystem.

6.2.6 Regulation 6765 – Para Regir La Conservación Y El Manejo De La Vida Silvestre, Las Especies Exóticas Y La Caza En El Estado Libre Asociado De Puerto Rico, amparada a la Ley Nº 241 - Nueva Ley de Vida Silvestre del 1999 (GELAPR, 1999):

This regulation establishes the regulations for the conservation and management of wildlife, exotic species, and hunting in Puerto Rico. Its objective is to protect and conserve the state's biodiversity, ensuring that hunting and species management practices are sustainable and ethical. In addition, it promotes education and awareness about the importance of preserving natural resources and encourages collaboration between government agencies and the community to achieve these objectives (DRNA, 2004).

7 NEPA – Categorical Exclusion:

NEPA gives the authority to categorize actions into different levels of environmental review based on their potential impact on the environment. It has been determined that a Categorical Exclusion (CE) may be applied to allow for the management of green iguanas in the park, as actions taken are not expected to cause significant adverse impacts and no extraordinary circumstances exist. The only objective is to be able to catch, remove, and euthanize the iguanas. In this case, the NPS - SAJU has an "Invasive Species Management Plan" for the management of green iguanas.

3.5.E.3 Removal of park resident individuals of non-threatened/endangered species which pose a danger to visitors, threaten park resources, or become a nuisance in areas surrounding a park when such removal is included in an approved resource management plan. These proposed actions are based on executive orders (E.O. 13112 and E.O. 11987). It should be added that consultation with the regional environmental coordinator (REC) must be made before the park unit superintendent approves further actions. (NPS, 2025; Clinton, 1999; Carter, 1977).



It is necessary to take precautionary measures against the spread of the invasive species based on case studies and observations in the park. In addition, an in-depth structural evaluation must be carried out since it is observed that green iguanas use historical and contemporary structure as harborage. This study would determine if iguanas had a significant and detrimental impact on the fort over time. Similarly, it should be part of this process to carry out population census studies of the invasive species and native life, and inventory of the vegetation to study the impacts, during and after the elimination management of the species.

8 EVALUATION CRITERIA FOR THE SPECIES:

8.1 Terrain and ecosystem:

- **Deposits:** Alluvial and other unconsolidated surface deposits (Quaternary) ([Gómez, 2014](#)).
- **Soil Classification:** Prairies ([SJBE, 2020](#)).
- **Soil:** Sandy and stony.
- **Vegetation:** Coastal ecosystem (altered by historical constructions).

8.2 Temperatures and precipitation of the zone:

- Average temperatures in Old San Juan typically range from 24 °C (75.2 °F) to 32 °C (89.6°F) ([Méndez-Lázaro et al., 2015](#)).
- Urban heat islands exacerbate temperature increases, with a recorded increase of 0.41 °C (32,738°F) per decade in metropolitan areas ([González-Cruz, 2004](#)).
- In coastal areas, annual air temperatures vary from an average maximum of 27 degrees Celsius (°C) to an average minimum of 24 °C ([Gómez, 2014](#)).
- Annual precipitation (average) from 1971–2000, 1,256 to 1,630 millimeters ([Gómez, 2014](#)).

8.3 Habitat of the study area:

In this area (park) of study there are no further descriptions of the ecosystem beyond the general information of Old San Juan. It should be added that there is no natural resource assessment in the NPS records of San Juan National Historic Site ([NPS, 2023](#)). However, there are relevant data as mentioned below:

- The soil in and around the fortifications is composed mainly of moist and fertile types, which support diverse vegetation.
- The ecosystem includes broadleaf trees and dense vegetation, which were historically prevalent before urbanization altered land use ([González-Cruz, 2004](#)).
- The fortifications also serve as habitat for several species, contributing to the biodiversity of the area ([Bassols, et. al., 2020](#)).
- The San Juan National Historic Site is within what is known as the National Estuary Program of the United States, which is composed of rivers, canals and lagoons. In addition, 8 species of animals and 17 plants in danger of extinction have been documented, such as the West Indian manatee. Nineteen species of reptiles and amphibians, such as the coquí, have also been identified, as well as 124 species



of fish, including tarpon and snook. In addition, 300 species of wetland plants are recorded (SJB, 2025). This information is general data for all the municipalities located within the estuary.

8.4 Iguana habitat:

- The species prefers 75% humidity and temperatures between 85 and 90°F and become overheated at 100°F.
- Preferred nighttime temperature is approximately 77°F.
- They live on low slopes and areas near water sources.
- They are arboreal lizards but also make large terrestrial burrows (female nesting behavior).
- In temperatures as low as 40 °F their bodies become pallid and balance is unstable (López, 2012).

8.5 Characteristics of Iguanas:

- **Native location:** Central and South America.
- The species that need full-spectrum light.
- **Invasion zone:** United States and Caribbean islands.
- **Genetics of iguana reported:** El Salvador and Colombia.
- **Arrival:** 1970.
- **Population growth year:** 1990.
- **Class:** Reptilia.
- **Domain:** Eukaryota.
- **Kingdom:** Animalia.
- **Phylum:** Chordata.
- **Class:** Reptilia.

8.6 Sex (Iguana) characteristic:

- **Size and length:**
 - They can reach up to 1.75 meters (5.7 feet) in length.
 - Adults weigh approximately 4 to 10 kg.
 - Body width: The widest part of the torso can measure between 15 and 20 cm.
 - Average: between 5 to 10 cm wide at the base of the neck.
- **Dewlap:**
 - **Males:** They have a larger, more prominent dewlap that hangs under their lower jaw.
 - **Females:** The dewlap is smaller and less noticeable compared to males.
- **Dorsal ridge:**
 - **Males:** They have a higher and more pronounced dorsal crest along their back and tail.
 - **Females:** The dorsal crest is lower and less pronounced.
- **Poros Femoral:**



- **Males:** They have larger, more visible femoral pores on the inner thighs. These pores secrete a waxy substance used to mark territory and attract females.
- **Females:** The femoral pores are smaller and less obvious.
- **Hemipenis (in males):**
 - **Males:** They have hemipenis that can be visible at the base of the tail if carefully handled.
 - **Females:** They do not have hemipenis (López, 2012; Watkins, 1997; Aleira, 2007, Ibáñez, 2017).
- **Gestation:** This species breeds in dry season from December to June. Its gestation is from 59 to 84 days with an average of 65 days. It can lay about 3 to 75 eggs, with an average of 24 eggs per year. Currently, green iguanas are distributed throughout Puerto Rico in large colonies (De Jesús, 2020; López, 2012; De Jesús, 2021).

9 METHODOLOGY / ACTION PLAN:

9.1 Implementation/planning strategy:

The strategies will be mainly based on the "*Management of damage caused by mammal and reptile species in Puerto Rico*" of the USDA - APHIS, the "*National Park Service Management - Policies 2006*", AVMA Guidelines for the "*Euthanasia of Animals: 2020*", "*Managing damage caused by mammal and reptile species in Puerto Rico*" of the USDA -APHIS – WS, and the "*Comprehensive action plan to control the population of the green iguana*" of the DRNA. The following methods will be performed:

- **Creation and Implementation of the *Iguana iguana* management protocol:** Develop and maintain the protocol: This protocol will be part of the green iguana management plan. Continuously monitor and review the tasks identified in the management plan, adapting to changes in the iguana population and for development of new methods. This must be started with a population count of invasive species, to locate impact zones and establish the average population to be worked on.
- **Creation of the field plan:** Represents the field protocol, will be attached to the resource management plan and will be the basis of the project.

The park consists of open ground, various grasses and shrubs, trees and fortifications which are constantly influenced and subjected to the wind and salinity of the Atlantic Ocean. Despite being an urban area of historical importance, the surroundings of the fortifications are home to a local biodiversity that adapts to climatic and urban conditions. Even so, there is a lack of data on the vegetation of the area. Old San Juan, San Juan Puerto Rico has a warm and tropical climate. It is an ecosystem adapted to the proximity of the sea, with flora resistant to salinity and other climatic factors and human influence. Therefore, the flora and surrounding cultural landscape should be inventoried along with the native fauna in conjunction with iguana population estimation.



- Population count method:** The population count of the invasive species of the green iguana will begin by means of 10m x 10m plot methods. Visual census will begin within each plot (visits and use of camera). These methods involve observing over 4 to 5 months, in impact areas and ecosystems, to identify and count the number of iguanas observed. The data collected allows estimating population density. In addition, descriptive statistical methods will be used to provide estimates of densities in areas and sizes of these groups. These counts are crucial to evaluate the effectiveness of the control program and to make informed decisions about the management of this invasive species (Muñoz, 2003). Abundance estimates will be used to reinforce the logistic model, generate subsequent population distributions, hunting management parameters, and make future abundance predictions (Rivera, 2020).
- Field techniques:** Methods will be standardized for selecting, counting, and observing sampled individuals from the iguana population coupled to the space, ecosystem, and climate in Old San Juan, Puerto Rico. This process is in addition to the vegetation inventory study (plots), since it is expected to use the same areas of the count. This area is characterized by warm temperatures, with extreme heat events, particularly in the summer months. The urban landscape greatly influences local microclimates, contributing to higher temperatures compared to rural areas. The soil and ecosystem surrounding historic fortifications are shaped by both natural and anthropogenic factors over 500 years of history, resulting in unique ecological conditions (NPS, 2022).

The main steps are outlined below:

- Study Site Selection:** Throughout the San Juan National Historic Site. The habitat observed in each area is varied and ideal for studying the diverse micro-ecosystems and the population of iguanas. In some areas you can see robust vegetation and in others you can see the impacts of human development (see Table 1).

Table 1: Areas where the population sampling plots will be located

Counting Zones		
Zones	Abbreviation	Coordinates
<i>Bastion of Santa Teresa</i>	<i>BST-P1</i>	<i>18.468296, -66.108121</i>
<i>San Cristobal Castle</i>	<i>CSC-P2</i>	<i>18.468040, -66.111231</i>
<i>Foreign Defense</i>	<i>DE/RSC-P3</i>	<i>18.467629, -66.108750</i>
<i>(Ravelin of San Carlos y Fuerte El Abanico)</i>	<i>DE/FA-P4C</i>	
<i>Baluarte de Santa Elena/Batería de San Fernando</i>	<i>BSE/SF-P5</i>	<i>18.469519, -66.124531</i>
<i>Contra Guardia de la Trinidad</i>	<i>CGT-P6</i>	<i>18.466640, -66.110626</i>



*Baluarte de San
Antonio*

BSA-P7

18.471149, -66.123104

Abbreviation: First Letter of the Word + P = Parcel + # = Parcel Number. C = control.

- **Habitat Details:** The soil in and around the fortifications is moist with some dry areas. The soil type is (two ecosystems) sandy and stony. In addition, it has a coastal ecosystem. The study area (park) lacks detailed descriptions of the ecosystem beyond the general information available for Old San Juan. It is important to note that there is no Natural Resources Assessment in the records of the National Park Service (NPS) for the San Juan National Historic Site ([NPS, 2023](#)). In the absence of prior Natural Resources Assessments, this plan aims to gather, expand, and complement the necessary database to provide the required information about the park's resources. However, it should be noted that the areas to be impacted consist of zones with grass, shrubs, trees, and buildings, and they support both micro and macro insects.
- **Vegetation:** As the iguanas are being surveyed, an inventory of plant species presents in the area and their density will be conducted simultaneously (vines, shrubs, trees [monocots and dicots, others], others).
- **Physical characteristics:** Physical characteristics of the area will be described, such as the presence of water, rocks, or human structures.
 - Studies on the impacts of invasive animals on the quality and integrity of soil, water, and/or air, as well as public health risks.
- **Delimitation of study plots:**
 - **Plots:** The plots will be square, and the size will be 10m x 10m.
 - **Number of Plots:** Seven plots, one will be a control, and the rest will be placed in various ecosystems randomly, including areas that have been impacted by historic buildings with grass, and areas with stony ground, sand, or natural foliage. The purpose will be mainly to obtain representative data from each of the plots on the iguana population.
 - **Counting methods:** The visual census or visual contrast encounter survey (VES) will be conducted every 4 days a week ([Zapata, 2020](#); [Narváez, 2020](#); [Rivera-Milán & Conley, 2020](#)).
 - **Data collection:** The iguanas observed in each plot will be counted from all four sides and images will be taken by date and week. Data could be collected during the morning (10:00AM to 11:30AM) and during the afternoon (2:00PM to 3:30PM).
 - **Observation log:** Will be documented in the field notebook and then passed to ArcGIS Survey123, iNaturalist and/or ArcGIS Field Maps. Write down the number of iguanas observed, their location, temperature, behavior, and other relevant characteristics that will be described in the "Monitoring" section, [pages 40 to 41](#).
 - **Data analysis:** The data will be subjected to descriptive statistical tests in software to speed up and improve data management. Before submitting the data, it must be reviewed to reduce the margins of error.



- **Report or documentation:** A detailed report of the finding will be written after the duration of the initial study of the population estimate. Everything will be stored on a driver and an external hard drive.

9.2 Study areas:

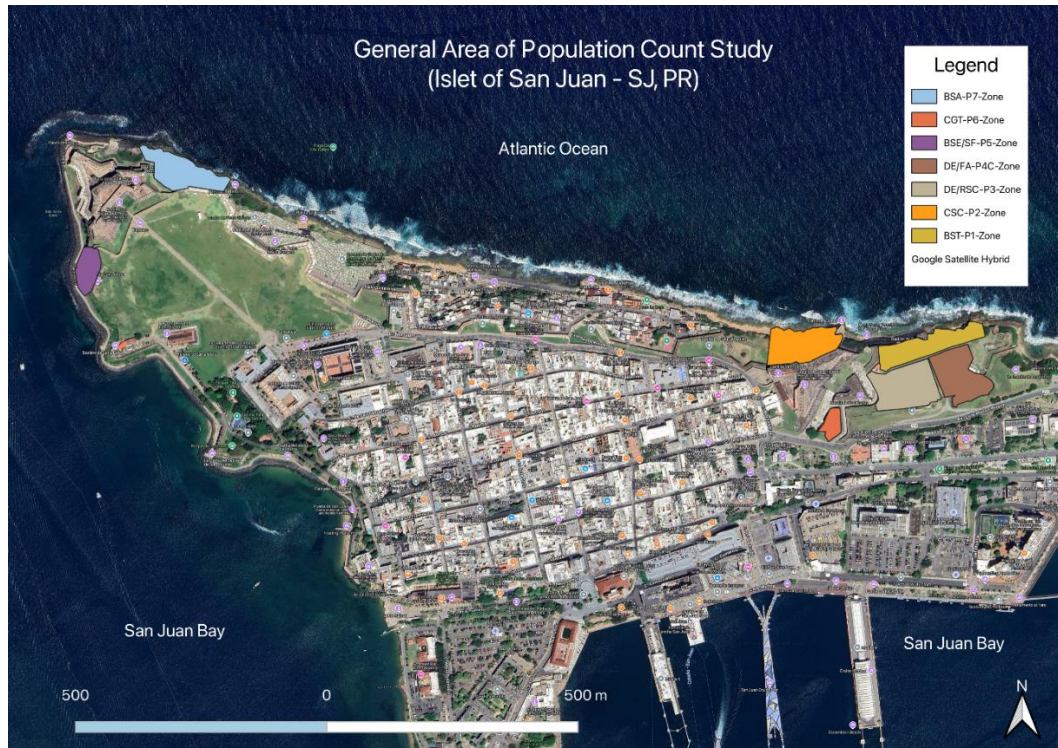


Fig. 1: General areas where the plots will be located on the population count study.





Fig. 2: Cristóbal area where the plots on the population count study will be located.



Fig. 3: Morro area where the plots on the population count study will be located.



9.3 Control Methods:

- **Elimination of resources:**
 - Eliminate breeding areas/harborage: Identify and target potential habitats where iguanas can thrive.
 - Reduce food sources: Identify, reduce, and/or eliminate access to potential food sources as much as possible.
 - Prevent spread: Implement euthanasia measures to prevent iguanas from invading sensitive areas, ensuring public safety and the integrity of physical structures.
- **Hunting and trapping:** Recommended hunting and/or trapping methods used by NPS Wildlife staff will consider this and other legal options for capturing or hunting in order to reduce damage or the threat of damage caused by the target species. In practice, continuous monitoring (2 to 4 times) or remaining near the trap while it is active is recommended. When leaving the field (the park), the trap should be removed or deactivated to avoid capturing native, endemic, or non-target species.

Euthanasia: The Lethal Control of Animals of the WS Directive 2.505 emphasizes that a procedure is an "act" of inducing the humane death of an animal. In addition, it reaffirms that what happens in the field "the conditions that occur in the field" do not excuse or exempt the ethical obligation of the responsible individual to reduce pain and distress to the greatest extent possible during the deprivation of an animal's life ([AVMA, 2020](#); [USDA, 2011](#) and [USDA, 2024](#)).

Several methods can be considered:

- **Use of Pneumatic Rifles (air guns):** This is recommended for the practice of humane euthanasia of animals to manage and control wildlife populations, including reptiles. In addition, it is closely tied to the guidelines set by the AVMA and other relevant policies. The use of firearms or rifles, including pneumatic rifles, is considered a target-specific method with minimal risk to non-target species, including humans and native species. Even so, authorization for use is required, as USDA APHIS - WS personnel are trained and certified in the safe use of firearms, which ensures that operations are conducted in a safe and ethical manner. Similarly, it should be made clear that this section could be subject to change and internal audit in the search for better euthanasia techniques. Based on field needs, it is recommended that they be used exclusively when necessary, for example, when the animal is located on cliffs or steep walls.
 - Rifles and air guns (Pneumatic rifles = Air guns): This method uses compressed air, either from a scuba tank, a CO2 cartridge contained in the rifle, or by pumping the rifle to compress the air (usually from 1 to 7 pumps), to propel individual projectiles, pellets. Air rifles and pistols are generally available in .177 caliber, .22 caliber, and .25 caliber. Air rifles and pistols are quieter than traditional firearms, but the effective firing range is limited in relation to an actual firearm as defined by the Bureau of Alcohol, Tobacco, Firearms and Explosives (BATF). Wildlife personnel primarily use air rifles to eliminate small animals lethally at close range, usually a maximum of 100 yards (300 feet). Since 2000, air rifle technology has improved significantly. Newer model air rifles are more accurate and powerful. Newer models have a rechargeable



cylinder in the front or stock of the rifle, which is reloaded with air from a scuba tank. They can typically fire 30-40 bullets before they need to be reloaded ([USDA, 2019a](#)).

- Recommended pistols/rifles should have the ability to be discreet. Due to the nature of the urban operations area, it is advantageous to have a pneumatically loaded rifle or pellet pistol of compact weight and design. It should have a reach of 5 feet in total length effectively and efficiently. The pellet rifle or pistol is equipped with an air tank that is loaded by a manual pneumatic or electric pump and can also be quickly loaded with a SCUBA cylinder or larger tank. The preferred pellet pistol or rifle should have a multi-shot capability for rapid follow-up shots to increase lethality and efficiency. These must have a sight or optics attached to make rapid shots at 100-meters distance, although the actual shots will probably be less than 20-meters. The pellet gun or rifle must be equipped with .22 or .25 caliber pellets of sufficient lethality to hunt small animals. Refer to [Appendix 3](#) for the recommended design.
- Using pneumatic rifles, during fiscal years 2011 through 2015, USDA – APHIS – WS eliminated approximately 1,044 green iguanas/year throughout the United States and its territories ([USDA, 2019a](#)).
- **Required training and certifications:** The necessary credentials will be met and maintained in the personnel/agency so that they are trained for any hunting activities, wildlife, risk, and safety training that are necessary.
- **Puerto Rico Department of Natural and Environmental Resources (DRNA):** In addition, based on Regulation 6765 – *To Govern the Conservation and Management of Wildlife, Alien Species and Hunting in the Commonwealth of Puerto Rico*, under Law No. 241 – *New Wildlife Law* of 1999. The use of the Special Permit is required for scientific research purposes. The DRNA recommended attending a basic hunting course.
- **Hunting Training:** weapon handling, safety & cardiopulmonary resuscitation (CPR).
- **Euthanasia method (2):** A second method of euthanasia would be a Blitz-Kerner stunning equipment (turbocut Jopp GmbH, Bad Neustadt, Germany) and followed by pithing, decapitation or cervical dislocation (Use Euthanizing Device) ([Wasilewski, et. al, 2022](#)). We are evaluating other methods that are authorized by the USDA APHIS/Wildlife Veterinary Service and the AVMA.
- **Euthanasia method (3):** Injectable Agents – MS-222: The intracoelomic administration of concentrated Tricaine Methanesulfonate (MS-222) is considered an acceptable method of euthanasia for amphibians and reptiles, including iguanas, as outlined in the AVMA Guidelines for the Euthanasia of Animals ([2020](#)). However, intracoelomic injections of 250 to 500 mg/kg of 0.7% MS222 could be administered. This is done to reduce stimulus loss. The use of MS222 would result in loss of the righting reflex and loss of response to painful stimuli. Similarly, with a second injection of 50% (v/v; unbuffered) MS222, hearts could stop beating and exhibit behavioral responses ([Conroy, 2009](#)). It should be studied that other injectable options may be the best option. This method is subject to review and viability.



- This method can be achieved by diluting 0.18 ml of euthanasia solution with 0.82 ml of saline solution or water for injection in a 1 ml syringe. A small gauge needle (25-27 gauge) should also be used to minimize the pain of injection. When administered via intracelomic injection, it must be diluted due to the pH. Agents such as Tricaine Methanesulfonate (MS 222) should be used. There must always be two steps, and it is most important to determine death by auscultation (whenever viable) ([Simpson, n.d.](#)). For its implementation, you must review the Field Work Manual and the protocol according to the study.
- **Euthanasia method (4):** Combine methods similar to those mentioned. Methods of stunning using medication and/or mechanical equipment and then applying euthanasia either by shooting, exsanguination, pithing, decapitation, Injectable agents, Spinal cord severance followed by destruction of brain tissue, CO₂ or lethal injection (Some of them must be secured by applying a secondary lethal procedure).
 - There should always be two steps: (1) Stunning the animal (humane) (2) Humane death.
- **Safety & certifications:** The USDA - APHIS - WS requires training and certification for its employees to use firearms “*Wildlife Service Firearms Handbook and WS Directive 2.615*”. This Agency uses firearms as part of their duties and receives training in the proper and safe use of firearms, including classroom and on-range instruction, followed by an annual continuing education requirement. USDA – APHIS – WS personnel have had accidents and incidents with all uses of firearms, including aerial shooting accidents as well as ground shooting accidents, and most personnel have been injured by accidental shooting. There are many differences with the use of firearms and hunting, but hunters also have accidents. Hunters had an annual average of approximately 275 accidents per year between 2005 and 2012 The National Rifle Association (NRA) and NRA's curriculum for basic pistol, rifle, and shotgun certification is the only officially recognized program for initial firearm safety training for new WS employees (approximately eight hours of training per weapon type of fire). NRA Basic Firearms Course is required. Training and continuing education are documented in the weapons manual guidelines and in USDA-APHIS guidelines ([USDA, 2024 and USDA, 2019](#)). It is necessary to consider safety equipment such as: gloves, boots (always), disinfectants, safety glasses (always), first aid kit, CPR training, cap, sunscreen, water, snack, radio/cell phone, etc. More details can be seen in [Table 3](#).
 - Security training and handling of weapons and hunting
- **Reduce hatching rates:** Remove iguana eggs from the environment to control population growth.
 - **Elimination of Eggs:** One of the first steps should be the removal and disposal of eggs along with the identification of harborage. The process of extracting the eggs must be studied due to the area's historical and archaeological significance. If extraction is possible, the eggs can either be destroyed (broken), placed in water for more than 12 hours or freeze and/or disposed of as per APHIS - WS guidelines.
 - A study conducted in the Las Cabezas de San Juan Nature Reserve, focused on egg collection, showed that a total of 7,638 eggs were collected over a five-year period. However, the population census did not report significant reductions in population densities. Nonetheless, this effort should contribute to reduction measures due to the impact of the invasive species on historic walls and structures. It is essential to consider or evaluate, based on our ecosystem, whether female iguanas migrate up to 3-kilometers during the egg-laying season



to find suitable nesting sites due to their proximity to the sea. Additionally, in our park, based on observations, the common Puerto Rican ameiva lizard (*Ameiva exsul*) plays an important role as they can feed on iguana eggs (Rodríguez, 2013).

This section requires verification from the Division of Biological Resources, Wildlife Veterinarian.

- **Work schedule:** Semi-annual plans will be drawn up outlining the work to be carried out in the field, in the office and the administrative procedures required for this project. A copy will be given to the supervisor and attached to the annual report (project status).
- **Monitoring and management:** The implementation of comprehensive measures to control the iguana population and monitor population fluctuations will be monitored. A part will be created exclusively to detail the information required; the processes will be recommended as provided in the monitoring section on [pages 40 to 41](#). This will include:
 - **Population census:** Carry out regular population censuses of iguanas and any other species that is affected by the introduction of iguanas.
 - **Elimination census:** Keep detailed records of iguana removals (weight, numbers of iguanas caught per day/week/month, temperature, among others). It will be detailed in the protocol.
 - **Weighing and measurement:** The animal must be weighed and measured and documented as part of the monitoring and data collection process.
 - **Documentation of work performed and report:** This consists of creating a data sheet for the creation of detailed reports and the establishment of a solid database for this study. In addition, a field notebook and the necessary software for data management and analysis will be used.
- **Public awareness and environmental education:** Implement educational campaigns to increase public awareness of iguana control and historic preservation efforts. Implement and carry out the visualization of the works under strict ethical and regulatory criteria, in addition to making the community part of the events in this cultural center.
- **Disposition:** Will be managed through the USDA APHIS or private entity as part of the collaboration and management of the iguanas. Disposal Services-Carcasses will be frozen and delivered to a landfill or approved agency disposal site in conjunction with agreement with USDA APHIS WS. However, based on the manuals, the following disposition management will be carried out if necessary:
 - **Leave the corpses in the field:** Most of the field areas are not accessible and have little visibility for visitors. However, if one or more dead iguanas are found in areas frequented by visitors, they will be removed. If there are one or two specimens, it will be left in the field if it is a risk to hand lift (for safety) and the environmental conditions allow it.
 - **Composting:** Carcasses could be composted between layers of carbon-rich organic materials.
 - **Incineration:** This is another option for the disposal of corpses, ensuring that there is no hazardous waste.

9.4 Schedule:

The schedule design provides a structured and detailed guide for the effective management of introduced exotic species, such as the *green iguana*, over the course of a year. It can be adjusted according



to the specific needs and circumstances of the Wildlife project. However, the key is to maintain constant planning and adapt to the changes that arise during the year and more so on the population of the species and in the climatological environment. Details on the schedule can be found in [Appendix 1](#).

The breakdown of tasks, duties and frequencies are listed below. The calendar will include (January to December) following is the work schedule (Excel preferred):

Table 2: Representation of the Work Schedule

Administrative Management	Purchasing and Sourcing of Materials
• <i>Planning meetings (2 times a month).</i> • <i>Review of policies and procedures (quarterly).</i> • <i>Coordination with agencies (monthly).</i>	• <i>Shopping/Stocking Days (1 time a month).</i> • <i>Inventory of materials and equipment (quarterly/at the beginning each season).</i>
Certifications and Training	Monitoring
• <i>Training in the management of invasive species (2 or 1 times a year).</i> • <i>Certifications required for staff (annual/every 2 years).</i>	• <i>Daily Monitoring: Observations and field records.</i> • <i>Daily/Weekly Monitoring: Population field observation.</i> • <i>Weekly Monitoring: Inspection of traps and control areas.</i> • <i>Monthly Monitoring: Evaluation of impacts on the ecosystem.</i> • <i>Quarterly Monitoring: Consolidated reporting of monitoring data.</i>
Data Analysis	Report Writing
• <i>Review and analysis of data collected (monthly).</i> • <i>Comparison with historical data and trends (quarterly/annual).</i>	• <i>Monthly report: Report of activities and results.</i> • <i>Semi-Annual report: evaluation of the effectiveness of the plan.</i> • <i>Annual report: Detailed summary and future recommendations.</i> • <i>Population Inventory/Census report.</i>
Fieldwork/Weekly Office	Collaborative Projects/Outreach
• Monday and Wednesday: <i>Count/inventory or hunt and capture days. (Administrative or Planning).</i> • Tuesday: <i>Administrative work, writing and reading. Collaborations and environmental education or Plot Monitoring.</i> • Thursday: <i>Disposal of dead iguanas and preparation of traps, monitoring, hunting and capture.</i>	• <i>Coordination with other entities and agencies (ongoing).</i> • <i>Participation in research projects (quarterly/annual or continuous).</i> • <i>Outreach and awareness events (2/3 times a year).</i>



- **Friday:** Follow-up and planning meetings. Collaborative activities and environmental education.

9.5 Resources needed:

This list is neither exhaustive nor exclusive, some of the materials have already been purchased. In addition, it will depend on the protocols that will be carried out, the area, the number of cages, among others. Even so, this is an estimate to visualize the cost of this iguana management program. You may double the total presented in this list of necessities.

Table 3: Breakdown of Required Resources

Article	Cost	Product Description	Comments
Durable Resin Plastic Storage Shed	\$1820.15	15 ft. x 8 ft.	A location may be required.
Multi-purpose Plastic Garage Storage Shelving	\$54.98	36 in. W x 74 in. H x 18 in.	
Defrost Chest Freezer	\$948.00	24.8 cu. ft.	Adjustable Temperature Control
Commercial Canopy Tent Waterproof with Adjustable Legs,	\$145.60	10 x 10	
One Hand Adjustable Height Fold-in-Half Resin Table	\$34.88	4 ft.	
Earth Tan Plastic Seat Outdoor Safe Folding Chair	(\$19.88) 39.76		2 Chairs
MaxCold Gray 60 qt Cooler	\$87.00	60qt	
Coyote/Fox/Armadillo Trap-10	\$150.00		
Small Mammal Wire Snares with Swivels and Clamp One Dozen	\$50.00		
One Roll 550 Parachute Cord (green) 500 Feet	\$50.00		
Air Rifle-Pneumatically Charged with Scope, .25 caliber-1	\$500.00		
High Compression Pump-PCP for Air Rifle-1	\$100.00		
Air Pistol, Hand Compression Pump-.22Cal.-2	\$70.00		
Pellets-.25 cal.-250 count per tin-4 tins	\$10.00		
Pellets-.22 cal.-250 count per tin-4 tins	\$10.00		
Gloves, Dual Layer Nitrile, Large-80 Count-5 boxes	\$10.00		
Batteries-AA-50 Count/pack-5	\$15.00		
Click Counter-2-	\$10.00		
Galvanized Wire-2 spools-	\$20.00		
Fencing Wire-6 rolls.	\$20.00		
Hanging Scale-50 pounds-1 @	\$20.00		
Animal Restraint Noose Pole-1	\$50.00		



Gloves, Welder-2 Pair	\$20.00	
Tool Set-Carpentry and Repair-1	\$50.00	
Paint, Spray, Camouflage 10 cans	\$8.00	
Zip Ties/100 pack-	\$20.00	
Trail (Game)) Motion Cameras 10	\$50.00	
SD Card 64 MB-10	\$30.00	
Rope, Braided-100 Ft.-2	\$20.00	
Tool, Digging Garden Trowel-1	\$10.00	
Wire, safety, spool-1	\$10.00	
Tongs/Grapper-1	\$20.00	
Duct Tape-Industrial Strength-Black-10 Rolls	\$10.00	
Wagon, Hand with rails-	\$150.00	
Saw, Folding-	\$10.00	
Pruning Shears, gardening 1.	\$20.00	
Mechanic Gloves/6 Pair	\$6.00	
Trash Can-Large Rolling with Lid-2	\$40.00	
Cooler-50 Gallon-	\$50.00	
Machete-Short-2	\$15.00	
First Aid Kit-2	\$20.00	
Pack, field with hydration bladder-2	\$100.00	
Carrier, Cat, Large-2	\$40.00	
Locks, Trail Camera-10	\$20.00	
SD Card Reader-1	\$30.00	
Binoculars-Compact 2	\$50.00	
Shovel, Folding-	\$30.00	
File, sharpening, Rat 2	\$10.00	
Sharpening Stone-1	\$10.00	
Tool, Multifunctional, belt2.	\$50.00	
Bat, Tire-1 @	\$20.00	
Flashlight, 100 Lumen-2	\$100.00	
Headlamp-500 Lumen-2	\$50.00	
Tape Measurer-1-50 Yards	\$10.00	
Gloves, Leather, Work-2 pair.	\$20.00	
Safety Glasses, Clear-4 Pair	\$15.00	
Safety Glasses-Dark-4 Pair at	\$15.00	
Repellant, Insect, 100% DEET-6 cans	\$20.00	
Sunscreen-SPF 50-4 containers at	\$15.00	
Rake, Gardening-1	\$20.00	
Trash Bags, Large, Jobsite-5 boxes	\$20.00	
Tape, Clear, 4 Rolls	\$7.00	
Knife, Fillet-4	\$10.00	
Bait-Assorted Fruit and Vegetable Mix-	\$1,000.00	Every 3/4 weeks.
Anchor, Pte, Screw Type-6	\$12.00	
C-Clamp-12	\$2.00	
Snares-Coyote-12-	\$50.00	
Compass-Lensatic-2	\$50.00	



GPS, Field-1 @	\$150.00	
Camera, Digital-1	\$40.00	
2 Pack Stainless Steel Dog Bowls (11 cup)	\$20.00	
Thermometry	\$70.00	
Soga Nylon 1/16 in. x 500ft.	\$12.97	
Banderines 3.5 in. x 2.5 in. Flags (100-Pack)	\$10.97	
Benjamin Marauder Air Pistol	N/A	Check with distributors
Talon P Air Pisto	N/A	Check with distributors
Personal Protective Clothing (PPC):	Uniforms	
Protective glasses:	\$25.00	
Mask	\$30.00	
Safety boots:	\$200.00	
Helmets or cap	\$50.00	
XT Instrument – HTI Thermal Imaging Camera Model HT-19	\$500.00	
Tricaine Methanesulfonate (MS222)	\$241.33	
TOTAL (Estimated)	\$7,900.64	

At this time, the team will face several challenges to effectively implement conservation and invasive species control initiatives. We are convinced that investing in more trained personnel will translate into significant benefits for the program, environmental conservation, and historic infrastructure. This statement does not reduce execution but lengthens the period to obtain significant minimum results. There are programs such as Employee, Resource Assistants Program (RAP), Collaborations with USDA APHIS WS, American Conservation Experience (ACE) and other agencies could contribute to the management and handling of the resources of the San Juan National Historic Site (see [Table 4](#)).

Table 4: Representation of the Human Resources Required

Necessary Resources (Human)	
Increased workload	<i>Ongoing Projects: We are currently managing the possibility of expanding the projects or part of Plan and we could find deficiencies in the execution when handling simultaneous projects, which significantly increases the workload of the work team.</i> <i>Monitoring and Control: The need for constant monitoring and control of invasive species requires considerable and dedicated effort. If you cannot collaborate with USDA APHIS-WS, it</i>



	<i>will be necessary to monopolize all the locations that we want to impact.</i>
Efficiency and quality	• <i>Responsiveness: With a greater number of wildlife technicians and/or field personnel, we will be able to respond more quickly to emerging situations and cover a wider work area, such as the work scenario.</i> • <i>Improved Quality: More trained personnel will allow for more accurate and detailed execution of tasks, data collection, and improved overall quality of work.</i>
Sustainability and continuity	• <i>Reduced Work Stress: A larger team will help distribute tasks better, reducing work stress and avoiding burnout for current staff.</i> • <i>Medium/Long-Term Sustainability: Having more human resources guarantees the continuity and sustainability of the program in the long term.</i>
Innovation and collaboration	• <i>New Perspectives: Additional staff will bring with them new ideas and approaches that can result in innovative solutions to the challenges we will face.</i> • <i>Efficient Collaboration: A larger team facilitates better collaboration both internally and externally, improving relationships with other entities and organizations.</i>
Community and ecosystem Impact	• <i>Effective Conservation: A more robust team will allow conservation strategies to be implemented more effectively, directly benefiting the local and cultural ecosystem that the NPS represents.</i> • <i>Education and Awareness: With more human resources, we will be able to expand the environmental education and awareness program and provide training for interpreters/employees. In addition, this would positively impact the tourist community and population.</i>



9.6 Effectiveness of the method:

To ensure long-term effectiveness, a continuous monitoring system has been implemented, which includes the initial population count. This will allow for the aggregation of data on the population to be impacted. This analysis will be vital to establish the needs required to meet the initial goal of eliminating or reducing green iguanas. It allows for the evaluation of the impact of actions and the adjustment of strategies as necessary during the implementation process. Education and awareness campaigns have been and will be key to informing the community about the benefits of mitigation and the importance of ecosystem conservation. Collaboration with experts will ensure that practices are effective and ethical, while the use of advanced technologies will improve the accuracy and efficiency of control activities.

In summary, the green iguana mitigation protocol will prove effective through the reduction of the invasive population, the improvement of public/environmental health, and the conservation of the cultural landscape and native species, offering a comprehensive evaluation of the positive impact achieved. The annual report and technical visits (analysis) will indicate whether the Management Plan at San Juan National Historic Site has proven effective in its key aspects, both quantitative and qualitative.

9.7 Responsible:

- Kelly Altenhofen - NPS
 - Wildlife Biologist
 - kelly_altenhofen@nps.gov
 - (787) 729-6777 ext. 220
- Miguel Angel Naveira - NPS
 - Biological Science Technician
 - miguel_naveiraguzman@nps.gov
 - (787) 729-6777 ext. 220
- USDA - APHIS – Wildlife
- Other collaborations.

9.8 Evaluation methods:

Descriptive statistical methods will be established as an evaluation tool for the quantitative data of the resource management plan program. This will allow analyzing the averages or daily, weekly, or monthly data of the elimination/mitigation census and the population censuses or counts of species, whether introduced or native wildlife. Additionally, it will enable the analysis of any data to be studied or compared with other results, internal or external. These mechanisms will provide information on patterns and trends obtained from each variable, which will be vital for environmental evaluation ([Majeti et al., 2020](#)). The use of statistical software will be recommended for better data management. By using interval charts for each year (during the program time), it will contribute to statistical uncertainty, allowing us to focus on practical significance rather than statistical significance between samples and their relationship ([Hahn et al., 2019](#)). Descriptive statistical analysis, along with interval graphs, box plots, and histograms, will play a crucial role in the interpretation and visualization of any *green iguana* data. This will facilitate the identification of relationships and trends within the data sets ([Lailiyah et al., 2021](#)).



Interval charts will show the data over the years, making it easier to visualize and interpret trends over the study period (Peper et al., 2019). Histograms, on the other hand, will present the frequency distributions of the data, allowing for the identification of patterns and outliers in continuous data (Fayet, 2019). Box plots will help summarize the data in quartiles, highlight outliers, and showcase the median and variability. This will contribute to comparing distributions between the studied mitigation years and visualize whether they have surpassed or decreased the initial level and other quantitative aspects that could be added (Baru et al., 2019 and Hahn et al., 2019). The combination of these methods will enhance the robustness of the results and support the longevity of this program. Additionally, understanding data distribution, variability, and central trends will be essential for analyzing the program's effectiveness. These tools will provide valuable information on data distribution and contribute to identifying patterns, trends, and outliers (Cooksey, 2020).

The statistical results will allow determining, based on the qualitative complement established in NEPA and simplified in the "Management of damage caused by mammal and reptile species in Puerto Rico" by USDA APHIS, "National Park Service Management Policies 2006", "AVMA Guidelines for the euthanasia of animals: 2020", "Managing damage caused by mammal and reptile species in Puerto Rico" by USDA - APHIS - WS, the "Comprehensive action plan to control the population of the Green Iguana" by DRNA, and the Executive Orders on invasive species of the United States (E.O. 13112 and 13751), to identify and address the disproportionate impact of this invasive species on the facilities of the San Juan National Historic Site in Old San Juan under the NPS. This is in response to the various threats that may affect public health, ecology, and wildlife. During the process, other statistical analysis methods will be carried out with the purpose of comparing, observing patterns, analyzing frequencies, determining differences in means, and constants of emissions between the study years, based on the initial resource management plan (Jones, 2022 and Mukhiya, 2020).

9.9 Logistical aspects:

The park's ecosystem has been intensively manipulated for more than 400 years due to the construction of fortifications and currently does not resemble the native vegetation patterns of the region's coastal plains. Likewise, the entire park is considered a designed historic landscape, and the vegetation is maintained to preserve this historic character. Vegetation growing on or near historic structures can damage their stability and integrity, so it is regularly mitigated. Open gardens provide spaces for recreational activities, demonstrations, and special events. Trees and shrubs grow adjacent to the lawn, and on sea cliffs, and scrub vegetation can be quite dense. NPS has not completed a natural resource assessment, as the focus of San Juan National Historic Site is on cultural resources. The lack of a natural resource inventory has been sporadically pointed out as a data gap. In the absence of official surveys, the best available data comes from external scientists (NPS, 2023). For this reason, it is essential to have a clear understanding of the historical context of the site, and it is recommended that, during mitigation work, no excavations that disturb the soil substrate be carried out without first consulting archaeologists or historians. The required logistical aspects are structured below:

Table 5: Structure of Logistics



Logistics	
Location	<i>Specific areas where control and monitoring activities will be carried out:</i> • <i>External defenses of the San Cristóbal Castle.</i> • <i>San Felipe del Morro Castle.</i> • <i>Paseo del Morro.</i> • <i>Fortín San Juan de la Cruz (El Cañuelo).</i> • <i>The Bastions.</i> • <i>Gunpowder houses and three quarters of the wall that surrounds the city.</i> See Figure 5 for more details.
Storage	• <i>It is necessary to locate an area for the installation of a storage (18°28'04.2"N 66°06'36.4"W).</i>
Landscape and climate (of the field):	• <i>Covers 27 acres of land (NPS, 2020)</i> • <i>External walls 150 feet (45 m) north side (NPS, 2020)</i> • <i>Tropics – Subtropical North Atlantic (temperatures).</i> • <i>Temperature - Annual average: 81.0°F.</i> • <i>Northern two-thirds of Puerto Rico have a mostly humid climate, and the southern part has a drier, semi-arid climate.</i> • <i>There are almost no trees. In some areas you can see <i>Coccoloba uvifera</i> (Sci.)</i> • <i>There are areas with shrubs characteristic of the coast.</i> • <i>Northeasterly trade winds bring water vapor for precipitation along the north coast.</i> (NOAA, 2022)
Resources	• <i>Funds are a fundamental part, it is necessary for the implementation of the protocol, including funds for equipment, training, and other operational expenses.</i> • <i>Additional human staff may be required to carry out the work or the collaboration of other agencies.</i>
Tools and equipment needed	• <i>Protocol: This document will the ENTIRE process described in this work plan.</i> • <i>Capture equipment: Nets, traps, and cages designed specifically for the capture of iguanas.</i> • <i>Mechanical equipment: Refrigerator, bags, baskets, drawers, etc. This will be used for the management of dead iguanas.</i> • <i>Vehicles: Adequate transportation for equipment and personnel. Use for the field as well as for the transport of iguanas on public roads.</i> • <i>Monitoring equipment: Cameras, field cameras, GPS, field notebook (All weather) and data logging equipment (iPad, Tablet, etc.).</i>



	• <i>Personal protective equipment: Gloves, boots, disinfectants, cleaning liquids and protective clothing for field personnel.</i>
Data Management	• <i>Data collection: There will be three databases. (Field notebook, file-drive, external memory). It must be submitted to an "Excel sheet" and in iNaturalist/ArcGIS (collection system) and/or search for other data management resources.</i> • <i>Archiving and reference: All documents, studies and data will be stored in an organized manner. Accessible for future reference.</i> • <i>Continuous Evaluation: Continuously monitor and evaluate activities and results (for written reporting and/or auditing).</i> • <i>Review and adjustments: Make any necessary adjustments to the protocol, as needed, based on periodic evaluations.</i> • <i>Report Writing: Maintain detailed records and write periodic reports on the progress and results of the protocol. File in a folder in the two methods of "data collection" (avoid printing).</i>

9.10 Impact zones

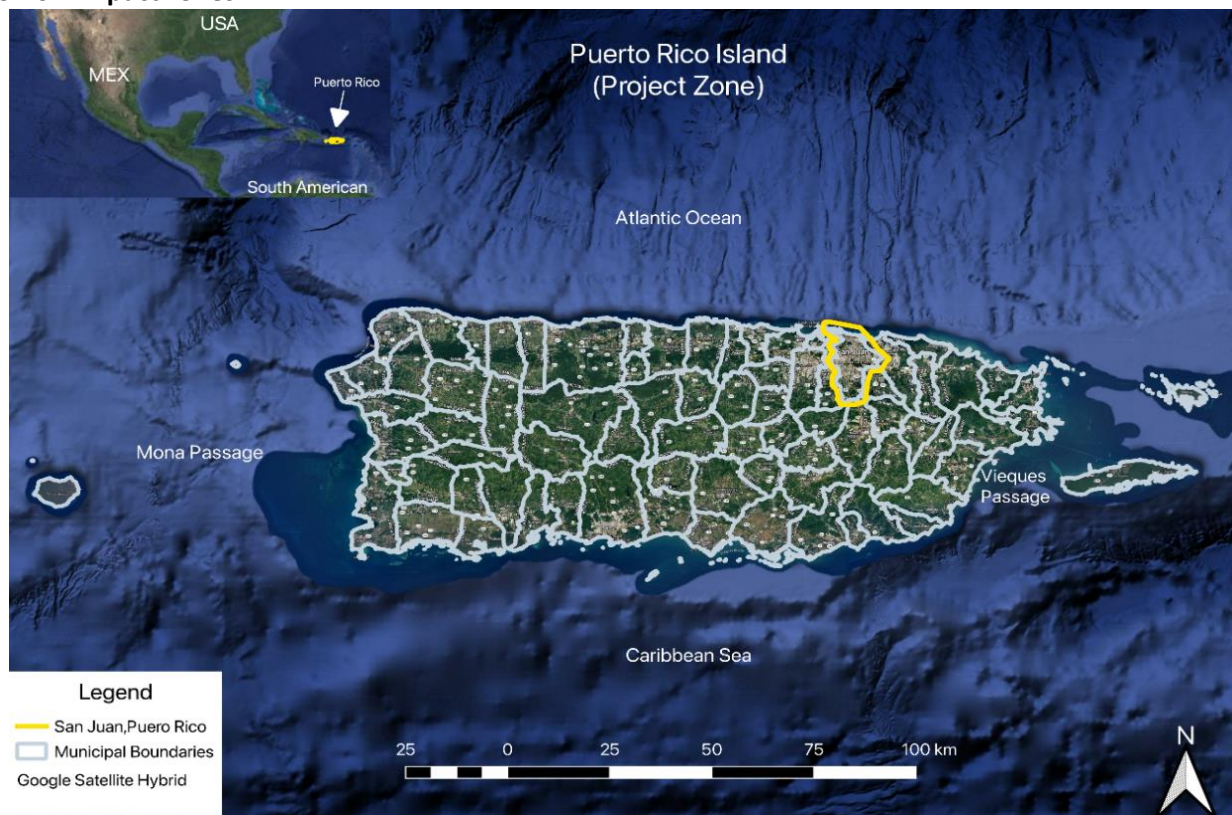


Fig. 4: Representation of the archipelago of Puerto Rico and the geographical area in which the Population Mitigation Project of the invasive species (green iguana) will be carried out.

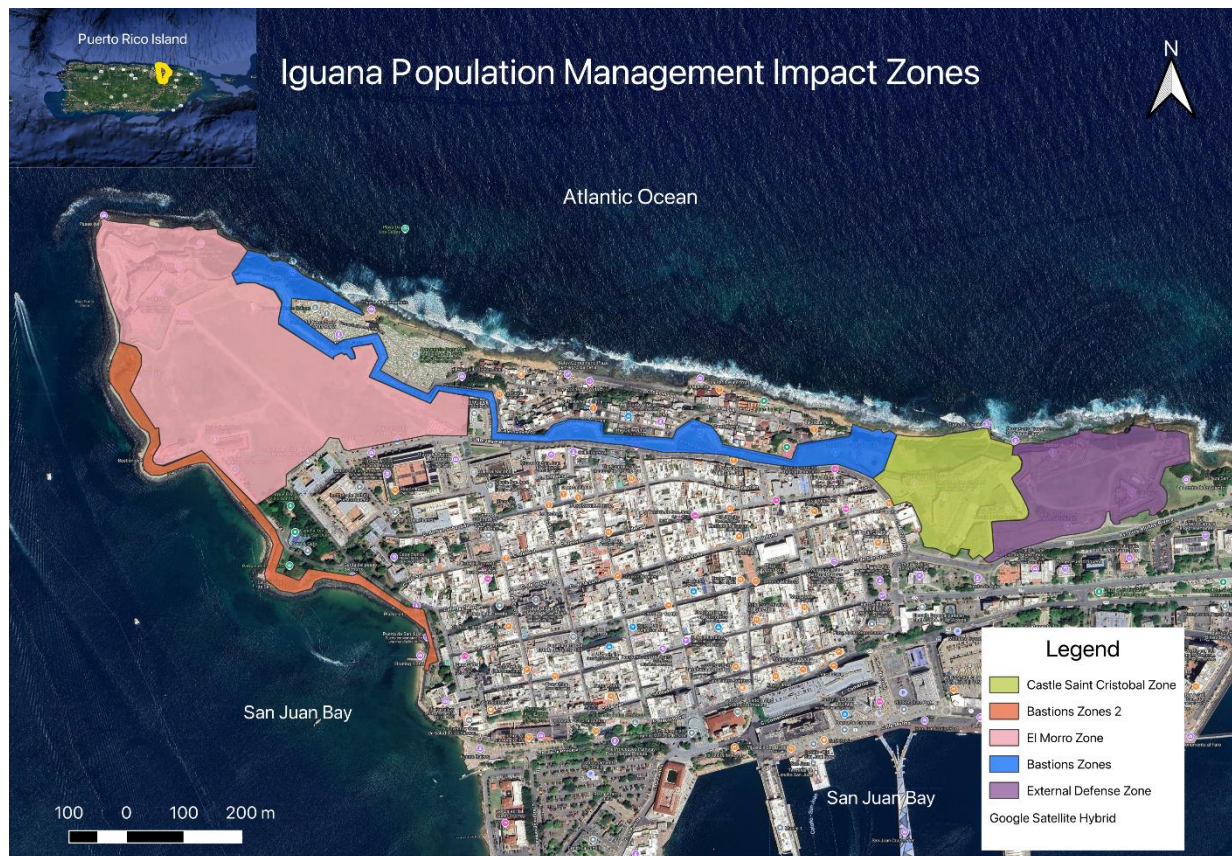


Fig. 5: Representation of the green iguana mitigation area in San Juan National Historic Site, Old San Juan, San Juan, Puerto Rico

10 RISK ANALYSIS:

During the execution of the iguana mitigation plan and mitigation protocol, several risks may arise that must be considered and properly managed in a professional manner, in addition to adapting methods of planning techniques and continuous evaluation. In quantitative terms, the high costs of materials, therefore, represent a significant risk, since the financial resources required to implement the plan can be considerable, including the hiring of personnel and the acquisition of equipment and materials. Another quantitative risk is the effectiveness of the control. There is a possibility that control measures may not be sufficiently effective and/or suitable, which could result in a persistent invasive population or require the search for new procedures for mitigation. Theft of cages may be another limiting factor in controlling iguanas. In terms of qualitative risks, public and environmental health is a major concern. Handling iguanas can expose staff and the community to reptile-borne diseases, and the biochemical integrity of soil, water, or air may be affected, although more research is required regarding these effects. Even so, it has been proven that green iguanas can present harmful health risks to humans, due to the possible transmission of *Salmonella* spp. green iguanas can also have varied effects on the environment, especially on seed dispersal and ecosystem dynamics. It is vital to take precautionary measures when managing iguanas and



consider their ecological impacts, especially in areas where they are invasive species and have no competition ([Burnham, 1998](#); [Burgos, 2016](#); [Mitchell, 2000](#)).

In addition, public perception is a risk to consider, as the community may have negative or dubious perceptions about the removal or procedures of iguanas, especially if they are considered as a "*tourist attraction*", normalized by the population itself and misinformation. Impact on the cultural landscape is another qualitative risk, as mitigation activities can negatively affect the cultural landscape and historic buildings if not properly managed or camouflaged correctly. Finally, animal welfare is crucial; ensuring that euthanasia practices are humane, as provided for in the AVMA and bioethics guidelines is essential to avoid unnecessary suffering of animals. Risk mitigation methods can be implemented and prevented through continuous monitoring. This will allow the impact of actions to be assessed, and strategies adjusted as necessary. Community education and awareness about the importance of mitigation and the long-term benefits to the ecosystem and public health are also essential. In addition, collaboration with experts, such as biologists and veterinarians, will ensure that practices are effective and ethical. The use of advanced technologies can improve the accuracy and efficiency of control activities.

Other risks include weather events that could halt work and decreased funding or cuts in the budget allocated for the program. For this reason, it is necessary to address this with diligence and planning, ensuring that the equipment and materials are not single-use and that their replacement is durable and sustainable. Changes and modifications to the schedule will be recurring due to the work environment. Therefore, thoroughly analyzing the financial resources, materials, equipment, and personnel required would be ideal for streamlining effectiveness in the face of the various risks we may face.

Studies have shown that abundance increased more than fivefold between August 2014 and 2018, from an average of 254,162 to 1,319,939 green iguanas in Grand Cayman. However, a major removal campaign led to the removal of more than 874,252 green iguanas in one year, demonstrating the potential scale of such efforts, the resource management that is required, and the commitment to reducing the species for the sake of cultural and historical heritage ([Rivera-Milán & Conley, 2020](#)). It has been studied that properly managed areas can have better yields compared to uncontrolled open areas ([De Jesus et al., 2024](#)). This has been seen in the agricultural sector, where uncontrolled areas have led to crop losses ([De Jesus et al., 2021](#)). The populations of iguanas in Puerto Rico have reached densities of up to 223 individuals per hectare, which is higher than in their area of origin. The reproduction success of these species is very high under these conditions; more than 100 egg clutches and 2,558 eggs have been documented, with a viability rate of 91.4% ([López-Torres, 2011](#)). For this reason, it is critical that green iguana management is continuous.



11 EXPECTED RESULTS:

The expected outcomes of the green iguana mitigation protocol could be diverse. As outlined in the three targets, the results will provide a comprehensive solution to the impact of mitigation, both in terms of reducing the invasive population, improving public safety, preserving historical heritage, and the well-being of native and endemic life. The following are the possible outcomes that are expected:

Table 6: Possible Outcomes of Resource Management on Iguanas

Expected Results	
Quantitative	Qualitative
<i>Reduction of Harborage, Eggs, Hatchlings and Invasive Alien Species:</i> - Percentage population decrease of green iguanas over a period of 2 years to 5 years. <i>Number of Harborage Eliminated:</i> - Data on the elimination of harborage and burrows. Reduction of harborage. <i>Number of Eggs and Hatchlings Removed:</i> - Accounting for the elimination of eggs (in groups) and iguana hatchlings. <i>Decrease in Reported Incidents:</i> - Reduced reported incidents of negative human-iguana interactions, analyze in percentage. <i>Number of Accidents:</i> - Record a decrease in iguana-related accidents. <i>Protection and Conservation of the Cultural Landscape and Native Species:</i> - Fewer protected native species. - Increase in the number of native species observed in the protected area. <i>Damage Reduction to Historic Infrastructures:</i> - Decrease in percentage of reported damage to historic buildings or sedimentation/erosion. <i>Increase in Biodiversity:</i> - Increase in the index or percentage of biodiversity of the area.	<i>Habitat Quality and Ecosystem Restoration:</i> - Increased recovery of native vegetation and improved soil and water quality. <i>Erosion Reduction:</i> - Qualitative evidence of a decrease in erosion caused by iguana burrows. <i>Community satisfaction and safety:</i> - Public perception: Surveys that show an improvement in public perception of safety and quality of life in managed areas. - Lower employee stress: Reports of lower stress and concern from interactions with iguanas in public areas. <i>Conservation and Protection of Cultural Heritage:</i> - Cultural landscape preservation: Qualitative observations on the improvement in the conservation of the cultural landscape and historic buildings. - Conservation Projects: Development of new conservation initiatives based on the protection of cultural heritage. <i>Ethics and Animal Welfare:</i> - Ethics in management: evaluation of adherence to ethical practices in the elimination and management of iguanas. - Humane Euthanasia: Evidence of humane methods in the management of iguanas, with an emphasis on the reduction of animal suffering.



12 EVALUATION AND MONITORING:

The San Juan National Historic Site - NPS does not have an iguana studies and management database. Due to the lack of existing information about the iguanas and the ecosystem of the park, it has been decided as part of the protocol to document and study all the necessary variables that must be added to this proposal.

12.1 Indicators:

The population count will estimate the population of green iguanas in the areas. This data in turn will be used for subsequent analyses, such as green iguana reduction data. The average/data of the daily euthanasia and/or mitigation observations will be analyzed. Once data collection has begun, we will be able to perform a more specific analysis of the area and the decrease or increase in hunting or elimination (euthanasia) of green iguana. This will be vital to compare the population estimate with the mitigation data.

Current findings do not present a decline in green iguana populations in Puerto Rico, rather, studies highlight their successful proliferation and significant negative impacts on agriculture and ecosystems. In addition, they outline the strategic needs for effective management to mitigate these impacts and control their spread. Annual data or estimates on the elimination of green iguanas in Puerto Rico are not highlighted in the documents analyzed. However, as a set of information, they mention the important impacts on agriculture, the management challenges of this invasive species, ecosystem impacts, and the threats to crop or seed production [De Jesus et al., 2024](#); [De Jesus et al., 2021](#); [Burgos, 2016](#)).

12.2 Monitoring:

Continuous and systematic monitoring is essential to make informed and effective decisions in the environmental management that is desired to be achieved through the **resource management plan on iguana management**. For this reason, it is important and imperative that the procedures carried out are monitored and that the processes are documented in a database. The document/Field Book and/or iNaturalist/ArcGIS must have, but be limited to, including:

- Name of the technician/specialist/scientist.
- Date and time of documentation/field. *
- Zone Name (**zone for which you should display the following**) *
- Temperature. *
- Coordinates of the Plot/hunted/caught (location of the "trap" or iguana). *
- Number of Individual(s) trapped/euthanized. *
- Name of the species (to apply).
- Physical description: ([] female [] male (at sexual maturity, presence of femoral pores) [] alive [] dead [] dying [] sick [] decomposing [] hatchlings/egg) [may be general]. *
- Weighing (weight of the animal): The weight of each animal caught must be available.
- Measurement (animal measurement): The measurement of each captured animal must be available.
- Detection Method: (Camera, direct or trap).
- Technique used (euthanasia): (chemical, biological, mechanical).



- Efficiency of the measure (euthanasia): (efficient, intermediate, deficient, to improve).
- Photo if [] / no [] (If digitized [in its absence there must be a folder]).
- Comments

12.2.1 Other Monitoring:

12.2.1.1 Harborage:

- Name of the technician/scientist.
- Count.
- Is the nest inhabited?
- What species of wildlife is it?
- Date and Hour.
- mitigation date.
- Location (Coordinates of the burrow, harborage or cave).
- Name of the zone (Based on the areas of the park).
- Photo.
- Comments.

12.2.1.2 General accounting of invasive/native species:

- *Date and time (start/end). **
- *Name of the technician/scientist.*
- *Plot coordinates (optional).*
- *Name of the parcel. **
- *Plot zone name **
- *Daily count. **
- *Count Number. (day and/or week). **
- *Characteristic of the area (environmental): disturbances/ Non-disturbances/ Human presence.*
- *Other species: interaction/ non-interaction/ presence/ non-presence.*
- *Behavior: Mating, burrowing, feeding, acclimatizing, etc.*
- *Disease sign: Observation, yes or no.*
- *Climate: LL/NBL/DRY/BRUM/CLA/OTHER.*
- *Temperature and/or average daily temperature. **
- *Animal Status: Alive, dead, dying, trapped).*
- *No. Sex of those observed (female [] or male []).*

12.2.1.3 Inventory of species in the area (plant/herbaceous/trees):

- *Scientific name and common name.*
- *Date and time.*
- *Name of the technician/scientist.*
- *Plot coordinates (optional).*
- *Name of the parcel.*
- *Plot Zone Name.*
- *Physical Characteristics: Cover (understory), soil, coast, rocks, etc. (Soil Classification: Prairies. Soil: Sandy and stony), DBH, Tree height.*



- *Remarks.*
- *Photos (north, south, east and west or plant).*
- *Comments.*

*Important **DO NOT** skip the data/process.

12.3 Results of the monitoring (Analysis):

The analysis of monitoring data can improve the effectiveness of the project by measuring the efficacy of management actions and identifying areas of improvement. The evaluation of the data obtained must be analyzed using a statistical procedure. It is recommended to carry it out on a semi-annual basis (every six months) and/or annually. A project status report must be written to the administration area (directly to the supervisor of the area). This ensures that decision-making is considered based on the proper management of the invasive species.

This analysis should include, but be limited to:

- Introduction (problem/justification/objectives/goal) [indicated above or observe proposed plan].
- Number of individuals captured/eliminated (euthanasia) during that day, week, month, semester, or year.
- Condition of the Individuals (alive, dead, in a state of decomposition, sick, etc.).
- Sex (female/male).
- Photographs/Videos.
- Results (tables, graphs, description).
- Evaluation/analysis of the results.
- Evaluation/analysis of previous results (if applicable).
- Conclusion (explain the facts).
- Sketch or Maps of the Location (**CREATE**) [That is only to place euthanasia numbers].
- Comment: Additional incidents and observations, problems encountered during monitoring, recommendations for future actions, additional observations, suggested adjustments to the monitoring plan.
- Unfinished Business: Monitoring and evaluation planned follow-up date.

12.4 REPORT (subject to change):

This report can be summarized, depending on the biannual or annual reports that are made on the study. It is up to the supervisor or scientist in charge to decide.

12.4.1 Cover:

- Report title.
- Date of preparation.
- Name of author(s).
- Responsible organization/agency.
- City.

12.4.2 Summary/Introduction (general/in your own words):

- Project objectives and goals.
- Project location (zones, coordinates, etc.).
- Problem or problem of the species in the area.
- Main activities carried out.
- Key achievements.
- Conclusions and recommendations.
- Description of the invasive species.
- Project justification.
- Background.
- Description of the study area.
- Relevance of the project to the community and the ecosystem.

12.4.3 Methodology:

- Monitoring methods used (observation/counting/data type, etc.)
- Control and management techniques.
- Evaluation procedures (if applicable).
- Team and personnel involved.
- Project development.
- Schedule of activities (how the work/work plan is distributed in the calendar):
 - Description of the tasks performed in the field.
 - Resources used (material, financial, human).

12.4.4 Results:

- Monitoring data.
- Observed impacts on the ecosystem.
- Effectiveness of control measures (data-based).
- Data tables.
- Charts and maps.
- Photographs and videos.
- Incidents and problems encountered.
- Data interpretation:
 - Analysis and discussion.
- Comparison with objectives, previous ones and goals.
- Impact on biodiversity and the ecosystem.
- Conclusions.

12.4.5 Summary of the main findings:

- Project effectiveness evaluation.
- Recommendations for future actions.
- Proposals for improvement.
- Recommendations.
- Suggested actions to improve the program.
- Proposals for new initiatives or projects.



12.4.6 Collaboration with Other entities/agencies [Fed./state].

12.4.7 References (APA style):

- List of sources and references used.
- Bibliographic citations.

12.4.8 Appendix (optional):

- Data tables.
- Charts and maps.
- Photographs and videos.
- Reference documents.
- Any other relevant information.

13 CONCLUSIONS AND RECOMMENDATIONS:

The implementation of the management protocol for the invasive green iguana species at the San Juan National Historic Site is crucial for the preservation of the ecosystem, public health, and cultural heritage of the historical area. The effective reduction of the green iguana population not only protects native and endemic species but also ensures the conservation of the cultural landscape and historical infrastructure. Adherence to the management plan guarantees the protection of native flora and fauna, improves public health by reducing the risks of accidents and diseases transmitted by iguanas, and primarily follows NEPA guidelines. Additionally, it ensures the preservation of the park's historical structures and cultural landscape.

To enhance the implementation of this work plan proposal, it is essential to provide regular training to personnel, implement a continuous monitoring system, and use advanced technology to improve the accuracy and efficiency of iguana detection and capture. Strengthening collaboration with experts and organizations and promoting community participation through environmental education programs is also crucial. Without this, the effectiveness of the measures will be challenging. For future phases of the project, it is suggested to consider working through implementation phases, conducting additional preliminary research as presented to develop new control methods. This includes periodic protocol reviews and securing long-term funding sources. In summary, the success in managing the invasive green iguana species depends on collaboration, strict adherence to the protocol, categorical compliance with NEPA, and the willingness to innovate and continuously adapt to new strategies. The information that will be documented and collected can strengthen programs such as historical interpretation and expand environmental programs. This could contribute to the development of new methods and the advancement of national science.

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Note on using artificial intelligence: I used Microsoft Copilot, Consensus, SciSpace, and Grammarly to help indicate purpose, such as brainstorming, reviewing grammar, translations, and organizing content. I have taken the utmost care in revising, correcting, and expanding on the material to accurately represent my own analysis, critical thinking, and understanding of the topic. I can confirm that this tool was used responsibly and in accordance with academic integrity standards.

15 APPENDIX:

Appendix 1:

Implementation timeline for the management of introduced alien species – Example of every six months

Execution Schedule for the Management of Introduced Alien Species - Semi-annual			
First Phase		Second Phase	
January		July	
Week 1-2	• Administrative management	Week 1-2	• Administrative management
	• Work plan review and planning		• Required Certifications and Training
	• Required Certifications and Training		• Purchasing and sourcing materials
	• Purchasing and sourcing materials		



Week 3-4	• <i>Daily and weekly monitoring</i> • <i>Fieldwork: Hunting days</i> • <i>Writing and reading preliminary reports</i>	Weeks 3-4	• <i>Daily and weekly monitoring</i> • <i>Fieldwork: Hunting Days and Disposition</i>
		Week 14	<i>The process is repeated.</i>
Febrero		Third phase	
Week 1	• <i>Analysis of data from the previous month</i> • <i>Writing the monthly report</i>	Week 15	• <i>Administrative management (last meeting).</i> • <i>Required certifications and training (renewal).</i> • <i>Purchase and supply of materials.</i> • <i>A new calendar is drafted.</i> • <i>Writing of Report and presentation.</i>
Week 2-3	• <i>Continuation of daily and weekly monitoring</i> • <i>Fieldwork: Hunting days and disposal of dead iguanas</i>		
Week 4	• <i>Team meeting for review and planning</i>		
March			
Weeks 1-2	• <i>Administrative management</i> • <i>Additional Certifications and Training</i> • <i>Monthly monitoring</i>		
Weeks 3-4	• <i>Fieldwork: Hunting days and disposal of dead iguanas</i> • <i>Writing and reading monthly reports</i>		
April			
Week 1	• <i>Analysis of data from the previous month</i> • <i>Writing the monthly report</i>		



Week 2-3	• <i>Daily and weekly monitoring</i> • <i>Fieldwork: Hunting days</i>	
Week 4	• <i>Team meeting for review and planning</i> • <i>Collaborative projects</i>	
May		
Week 1-2	• <i>Administrative management</i> • <i>Purchasing and sourcing materials</i> • <i>Additional Certifications and Training</i>	
Week 3-4	• <i>Monthly monitoring</i> • <i>Fieldwork: Hunting days and disposal of dead iguanas</i> • <i>Writing and reading monthly reports</i>	
June		
Week 1	• <i>Semester Data Analysis</i> • <i>Writing the monthly and semi-annual report</i>	
Week 2-3	• <i>Daily and weekly monitoring</i> • <i>Fieldwork: Hunting days</i>	
Week 4	• <i>Team meeting for review and planning</i> • <i>Collaborative projects</i>	



Appendix 2:
Air pistol/rifle model



- The Talon P Air Pistol is a highly accurate pistol with adjustable power levels. The Ring-Loc™ Valve delivers over 50ft. lbs. of energy with a .25 caliber hunting pellet. It represents state of the art technology in a compact, yet powerful hunting package.
- The Talon P is available in Original Black Finish. Air Force Inc. ([AIRFORCE, 2025](#))

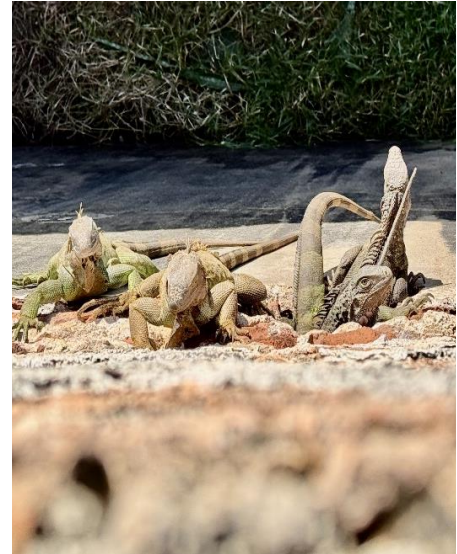
Benjamin Marauder Air Pistol



- Pre-charged pneumatic air gun has the power to take small game.
- Pistol grip can be swapped for synthetic, all-weather shoulder stock.
- Shrouded barrel delivers velocities up to 800 fps and superb precision.

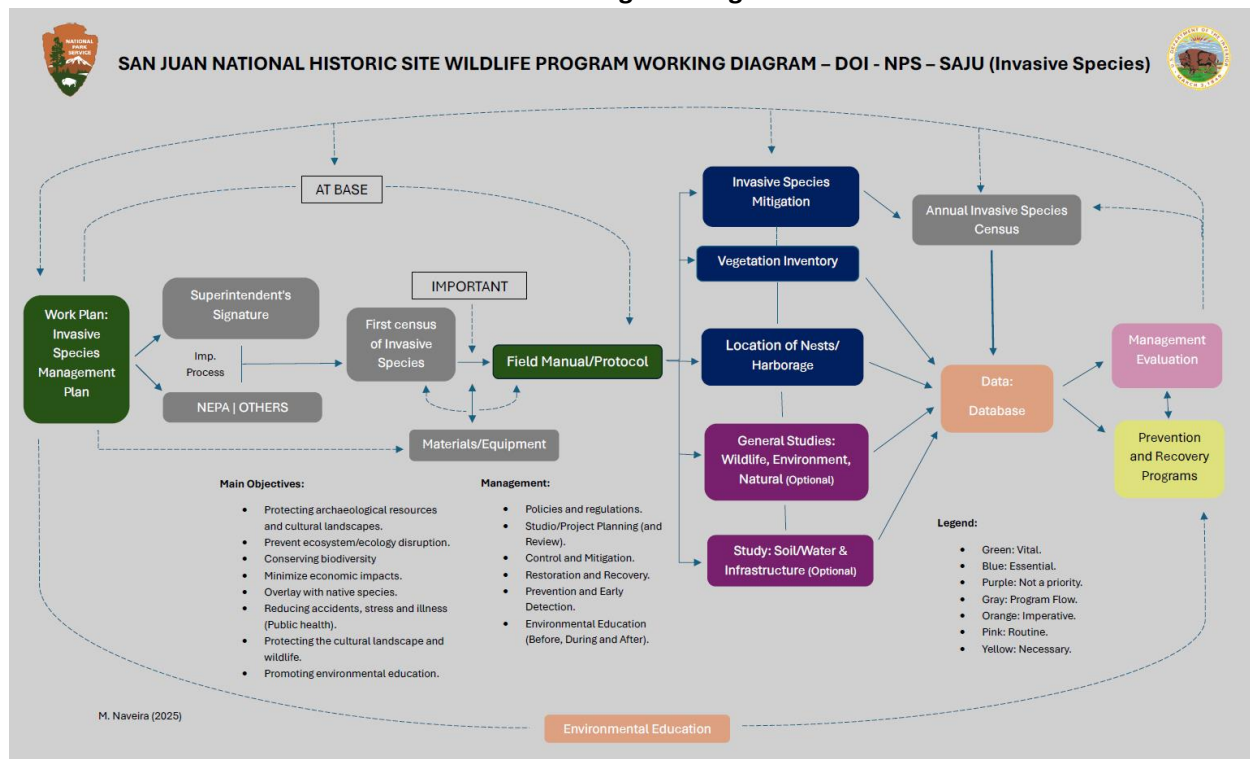
Appendix 4:

Photographs and Images of the Iguanas/Harborage at the San Juan National Historic Site



Appendix 5:

Wildlife Program Diagram



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**For more
information**

SAJU Superintendent
To the attention of: Green Iguana Management Plan
501 Norzagaray Street
San Juan, PR. 00901
Email: saju_superintendent@nps.gov

