National Park Service
San Juan National Historic Site
U.S. Department of the Interior

Cultural Resources Program

Inventory of Wildlife-Associated Nests, Burrows, Refuges, and Cavities – San Juan National Historic Site (SJNHS).

Pre-Implementation Monitoring Assessment 2026

Cultural Resources Program – Wildlife Program – SJNHS

ON THE COVER

The photograph was taken from the Garita del Diablo. In the morning hours.
Photograph by Miguel Angel Naveira (NPS-SJNHS)

Inventory of Wildlife-Associated Nests, Burrows, Refuges, and Cavities – San Juan National Historic Site (SJNHS).

2026

Cultural Resources Program – Wildlife Program – SJNHS

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This report documents the ongoing monitoring activities conducted across the management zones of the San Juan National Historic Site (SJNHS) as part of the implementation of the standardized protocol for the identification and inventory of nests, burrows, refuges, and natural or anthropogenic cavities used by wildlife—whether invasive, native, endemic, or migratory. The purpose of this document is to provide timely and accurate reporting on the presence, distribution, and observed patterns of habitat use within the surveyed areas of the park, in accordance with established National Park Service (NPS) resource-monitoring guidelines.

All efforts were made to ensure the accuracy and integrity of the raw data collected through direct field observation, photographic documentation, georeferenced mapping using Survey123, and systematic verification of the condition and characteristics of each structure. Field analysis and data interpretation remain ongoing; therefore, the findings presented in this report should be considered preliminary and subject to refinement as additional analyses and validations are completed. All reports produced under this monitoring initiative undergo the appropriate level of internal review to ensure scientific credibility, technical accuracy, and clarity for their intended audience. This document received informal peer review by a subject matter expert not directly involved in the field data collection, ensuring objectivity in the evaluation of its content and structure.

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ABSTRACT

This report documents the process of systematic monitoring, georeferencing, and descriptive analysis of physical nesting, shelter, and burrowing structures used by native, endemic, migratory, and introduced wildlife within the San Juan National Historic Site (SJNHS). In particular, it addresses the presence and use of microhabitats associated with the green iguana (Iguana iguana), an invasive exotic species widely distributed in Puerto Rico. The iguana's extensive use of cavities in historic structures poses significant risks to the ecological integrity and conservation of the park's cultural heritage. The establishment of a spatial and quantitative baseline allows for the identification of patterns of abundance, distribution, and active occupation, facilitating the early detection of threats, the prioritization of critical areas, and the design of adaptive management strategies.

The study incorporates a standardized field protocol based on systematic transects, the use of Survey123 (ArcGIS), GPS, photographic documentation, and qualitative verification of structures, followed by statistical analysis using descriptive methods and visualizations (tables, histograms, stacked bar charts, pie charts, and Pareto analysis). This approach allowed for the characterization of a total of 556 structures: 478 herbages, 66 caves, and 12 burrows, revealing a marked spatial concentration in specific areas of the park, such as Castillo San Felipe del Morro, Baluarte de Santa Elena, and Batería San Fernando. Likewise, the assessment of active occupancy (15.6% of the total) revealed a disconnect between the availability of structures and actual use, suggesting the influence of additional environmental and anthropogenic variables on habitat selection. The report's structure aligns with the format of previous National Park Service (NPS) management assessments, incorporating sections on introduction, theoretical framework, methodology, spatial and statistical analysis, results, discussion, conclusions, appendices, and references, consistent with NPS management guidelines, NEPA, and invasive species control policies applicable to the SJNHS. The baseline generated constitutes an essential input for planning control interventions, ecological restoration and the protection of historical heritage, and will serve as a reference for future monitoring, predictive risk models, and interdisciplinary initiatives aimed at the integrated conservation of the park's natural and cultural resources.

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ACKNOWLEDGMENTS

The Wildlife Team would like to express its sincere gratitude to the National Park Service – San Juan National Historic Site (SAJU) for the logistical support and authorization to conduct this nesting study within the park's protected areas. We acknowledge the collaboration of the staff from the Cultural Resources Division and the maintenance team, who facilitated access and the installation of monitoring equipment in the target zones, following protocols established in invasive species management plans.

Special thanks go to the technicians and volunteers from American Conservation Experience (ACE), whose commitment and dedication in the installation, data collection, and maintenance of cameras and tablets were fundamental to obtaining reliable and robust information. Their participation reflects the importance of inter-institutional and community collaboration in adaptive wildlife management, as promoted in the green iguana and free-ranging cat management plans. We also extend our recognition to all individuals and organizations supporting conservation efforts and the ethical management of invasive species at the San Juan National Historic Site. Their commitment contributes to the preservation of the natural, archaeological, cultural, and historical heritage of Puerto Rico and the United States of America, and strengthens the integration of ecological, social, and cultural criteria in biodiversity conservation decision-making.

Finally, we highlight the importance of community participation, transparency in reporting, and ongoing monitoring—key elements for the success of management programs and for preventing the recurrence of issues associated with invasive species, as documented in the green iguana and cat management reports for the Paseo del Morro area.

LIST OF ACRONYMS

ACE	American Conservation Experience
et al.	and others
°	degrees
°C	degrees Celsius
GIS	Geographical Information System
GPS	Global Positioning System
NEPA	National Environmental Protection Act
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
%	percent
SJBP	San Juan Bay Estuary Program
SJNHS	San Juan National Historic Site
SAJU	San Juan National Historic Site (park code)
U.S	United States
USFW	United States Fish and Wildlife Service
DOI	U.S. Department of the Interior
USGS	U.S. Geological Survey

INTRODUCTION

The green iguana (*Iguana iguana*) is an invasive exotic species whose spread into urban and coastal areas of Puerto Rico has created ecological and historical heritage conservation challenges. In the SJNHS, the presence of burrows and shelters on slopes, grasslands, and fortified structures can contribute to erosion, destabilize historic walls, and directly impact cultural and natural resources in a region characterized by eolianites and coral limestone, with coastal erosion pressures and a humid subtropical climate. (NPS, 2013; Gómez, 2014; Méndez-Lázaro et al., 2015). The development of a spatial and descriptive baseline of the habitats used by iguanas or other invasive species, as well as by native and endemic species, is critical for proactive management, enabling early detection, the prevention of impacts (both positive and negative), and mitigation based on primary data, particularly in areas of high heritage and ecological value (Bradley et al., 2019; Gallardo et al., 2016; Dueñas et al., 2021).

From a scientific perspective, the systematic inventory of nests, burrows, and shelters facilitates the identification of environmental variables that explain the presence and abundance of invasive, native, and endemic species. Furthermore, this inventory enables the creation of risk maps and habitat suitability models, essential tools for prioritizing vulnerable areas and optimizing control, management, or eradication strategies (Bueno et al., 2023; De Groot et al., 2024; Wang & Wan, 2021; Williams et al., 2024). Within the context of the SJNHS, where natural and cultural resources coexist along a historically sensitive coastal-urban corridor, detailed monitoring of these structures supports interdisciplinary decision-making that integrates ecology, geology, climate, and heritage (NPS, 2013; NPS, 2020; NOAA, 2022).

THEORETICAL FRAMEWORK AND JUSTIFICATION

Biological invasions can have significant impacts even at low abundances, especially when species occupy high trophic levels or act as habitat shapers. (Bradley et al., 2019; Dueñas et al., 2021). Due to their ecological plasticity and digging ability, green iguanas can transform microhabitats and disrupt local geomorphological processes in coastal and fortified areas of the SJNHS. A georeferenced inventory of burrows, shelters, and caves, with attributes of active occupation, allows us not only to gauge the magnitude of the problem but also to assess its spatial variability by area and its relationship with anthropogenic and environmental variables (Bueno et al., 2023; De Groot et al., 2024; Wang & Wan, 2021).

Several studies have shown that protected areas such as historic structures are used by endemic, migratory, and native species, although this is more commonly observed in natural areas. The golden-cheeked woodpecker (*Melanerpes chrysogenys*), a Mexican endemic, nests in large native trees within protected forests, but in nearby anthropogenic areas easily switches to nesting in utility poles and non-native palm trees, provided there is sufficient native vegetation and standing dead trees for foraging (Maya, et. al., 2025). However, in Guam, the Micronesian starling (Aplonis opaca) forages in the forest but now nests almost exclusively in developed areas of an air base, using a mix of natural and artificial structures that are relatively inaccessible to invasive brown tree snakes. Predator-resistant nest boxes in these built-up areas were quickly colonized (77% of boxes occupied) and supported sustained breeding (Sevidge, et. al., 2022). On a 17th-century door in India, insectivorous bats roost in architectural recesses, cracks, and shaded niches, finding shelter while helping to control insect populations; their droppings caused staining but did not immediately damage the structure (Ghosh, et. al., 2025). This illustrates how native species can utilize man-made structures if the key habitat structure is preserved or restored.

In the case of the green iguana (*Iguana iguana*), introduced to Puerto Rico in the 1970s through the pet trade, has become a highly invasive species due to its high reproductive capacity, its adaptation to the climate, and the absence of natural predators in the Puerto Rican archipelago. Its success is evidenced by exceptionally high population densities: up to 223 individuals per hectare, values higher than in any area of its native range, where it is controlled by predation and human exploitation. Studies have indicated that over two nesting seasons, more than 100 nests and 2,558 eggs were documented, with a viability rate of up to 91.4%, demonstrating a highly effective reproductive system in Puerto Rico. The synchronization with climatic patterns—courtship and nesting during the dry season; hatching during the rainy season—when food and camouflage further facilitate its ecological success in areas such as Las Cabezas de San Juan, characterized by loose soils and optimal thermal conditions for incubation.

The overpopulation resulting from these reproductive rates has significant effects. Ecologically, the species causes severe browsing on mangroves such as Laguncularia racemosa, competes with native wildlife, and occasionally preys on the nests of birds such as the common moorhen (Gallinula chloropus). In addition, its nests attract dogs, cats, and mongooses, increasing the risk to other species, including the leatherback turtle (*Dermochelys coriacea*), whose nesting season overlaps with that of the iguana. However, tools such as the identification of nests of all species in general or potential nesting sites, the use of artificial mounds, and targeted intervention during the breeding season (once the species has been identified) have been suggested as effective strategies for controlling populations of invasive species, such as the green iguana, especially in critical areas such as nature reserves, historic sites, and agricultural zones. (López, et. al.,2011). In addition, understanding the habitat preferences and geographic distribution of these structures informs suitability models and risk maps that predict future invasions or re-expansions, enabling early responses and adaptive management in heritage areas and adjacent ecosystems (Williams et al., 2024; De Groot et al., 2024). A systematic approach to monitoring and analysis, integrated with GIS and descriptive statistics, strengthens science-based proactive management, reduces uncertainty, and protects the park's historical, cultural, and socio-environmental value (NPS, 2013; NPS, 2025).

OBJECTIVES

This report aims to establish a georeferenced, descriptive baseline of structures where native, endemic, migratory, and introduced species reside or use the San Juan National Historic Site (SJNHS) as a habitat; This is achieved by documenting nests, burrows, and shelters by zone, estimating their magnitude and variability, and incorporating an indicator of active occupancy. Specifically, the aim is to identify and map these structures across the 20 official zones of the SJNHS, estimate their abundance and distribution by structure type, calculate the occupancy rate, and propose a prioritization scheme based on critical zones that concentrate the highest number of structures, in support of control, eradication, and restoration efforts. (NPS, 2025). Considering the direct threat posed by the green iguana (*Iguana iguana*) as the primary competitor displacing local species.

SCOPE

The nesting protocol outlined in this report applies to the entire SJNHS (75 acres, including 27 acres of land), incorporating data collection technologies, direct observation, ArcGIS Survey123, and manual field notebook records, using a multidisciplinary approach (NPS, 2013; NPS, 2020). The 20 areas under consideration include Castillo San Felipe del Morro, Castillo San Cristóbal, and the bastions, batteries, counterguards, ravelins, and gates listed in the park's historical inventory. Monitoring takes place in the mornings (8:00–10:30), two to three days a week, and concludes once all areas have been mapped. It began on August 21, 2025, and was completed on December 19, 2025. The report's narrative structure, sequence of sections, and emphasis on deliverables and appendices follow the organization of the preliminary assessment model used by the National Park Service, as outlined on the "I*nventory & Monitoring*" website (2025).

Natural and environmental description of the park

The SJNHS is located in the Old San Juan area, on a rocky peninsula bordered by the Atlantic Ocean to the north and San Juan Bay to the west and southwest. The geology of this site is dominated by eolianites and coral limestone, formations that, due to their porous nature and continuous exposure to coastal erosion and weathering processes, can compromise the stability of the area's historic fortifications (NPS, 2013). The park's climate can be described as humid subtropical, with average temperatures ranging from 24 to 32 °C and annual precipitation of 1,256 to 1,630 mm, influenced by trade winds, Caribbean weather patterns, and the documented presence of urban heat island events (González-Cruz, 2004; Méndez-Lázaro et al., 2015; Gómez, 2014; NOAA, 2022).

The area's vegetation includes grasses, shrubs, vines, monocots, and dicots, along with a few scattered trees, whose density is limited due to the long history of urbanization in the Old San Juan area (González-Cruz, 2004). This vegetation cover is found in grasslands, areas of sandy or rocky soil, and coastal transition zones—conditions that can facilitate the formation of burrows, shelters, or caves used by native, migratory, or invasive wildlife, potentially including the green iguana (NPS, 2020; NPS, 2013). The park seamlessly integrates coastal and urban habitats, allowing for the coexistence of a wide range of biodiversity. This diversity includes insects, reptiles, amphibians such as the coquí, more than 124 species of fish, as well as eight animal species and seventeen plant species classified as threatened or endangered, including the West Indian manatee (*Trichechus manatus*) (SJBP, 2025; Bassols et al., 2020). This combination of natural and cultural resources makes the SJNHS an ecologically dynamic and highly sensitive environment, where the presence and activity of wildlife—including the construction of nests, burrows, or shelters—have implications for both the environment and cultural heritage.

SAMPLING AND DATA RECORDING METHODOLOGY

The field methodology consisted of systematic walks through each area of the SJNHS (75 acres), with individual documentation of every nest, burrow, or shelter detected through direct observation, photographic documentation, and the collection of coordinates using the Global Positioning System (GPS). The Survey123 form records the technician's identity, date and time, type of structure (burrow, shelter, cave), active occupancy ("inhabited: yes/no"), zone, comments, and the corresponding georeferencing. When the app is unavailable, GPS, a camera, and a field notebook are used, with weekly data backups to OneDrive or the Wildlife Program's SharePoint. Sampling frequency is set at two to three days per week, with a daily morning session, following a coverage plan that distributes the days among the park's 20 zones and concludes once all have been recorded.

Figure 1: Map showing the location of San Juan (Puerto Rico), where the SJNHS is located.

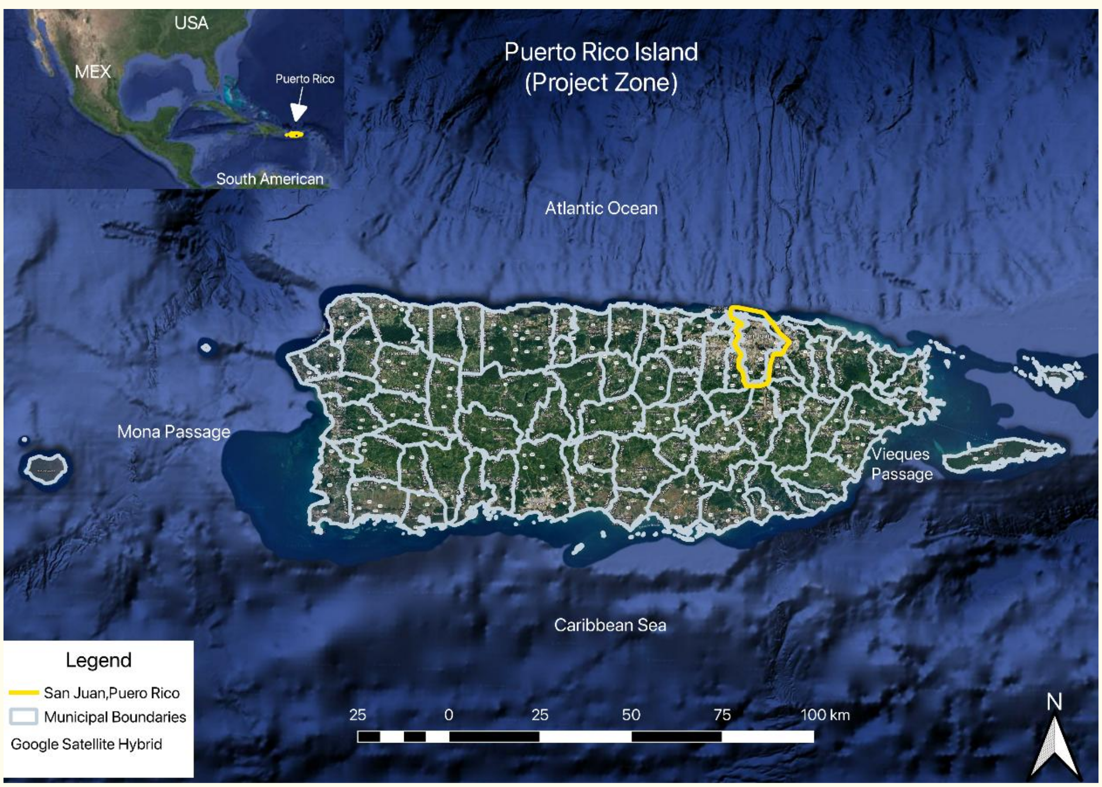


Figure 2: Map showing the extent of the impact based on nest counts and the study area (75 acres) in the SJNHS.

ANALYSIS METHOD

The spatial analysis will be conducted in ArcGIS – Survey123, generating point density maps and zoning by structure type, as well as maps of potential risks and impacts on cultural heritage. For the statistical component, descriptive statistics and basic visualizations will be applied to facilitate the interpretation of the magnitude and variability of the structures, based on best practices for data visualization and summarization in technical environments. (Cooksey, 2020; Saket et al., 2017; Schmuck, 2017).

In Minitab, the descriptive analysis of physical structures will be performed using the Basic Statistics module, selecting the variables "burrow," "den," and "cave" to estimate the mean, sum, minimum, maximum, and standard deviation, in order to characterize the magnitude and variability by structure type. Subsequently, a summary table by zone will be generated using the table procedure with the sum statistic applied to burrow, den, and cave, stratified by zone, to observe the distribution of structures by management area. The composition of structures by zone will be visualized using a stacked bar chart, configuring the bars by the sum of values and categorizing them by zones, with stacking by structure type; if greater flexibility is required, an auxiliary column will be prepared to stack the categories or Graph Builder will be used. To understand the distribution of each type, simple histograms will be created for burrows, dens, and caves, assessing whether the data is concentrated or dispersed and whether it shows asymmetry. (Saket et al., 2017; Xiong et al., 2021). Finally, in Excel, a long-form dynamic table was created with fields for zone, habitat type, count, and occupied nests, summarizing the totals by zone and habitat type. This would facilitate comparisons between zones in terms of absolute numbers and occupancy rates. A consolidated main table was generated that summarizes the entire quantitative analysis and serves as the basis for the graphs and discussion.

Expected Outputs

The process will generate a georeferenced database of structures and their occupancy status, density and distribution maps, summary tables by area, composition and distribution charts, a Pareto analysis for prioritization, and a consolidated table that combines habitat types, total structures, occupied nests, and occupancy rates. These outputs will be incorporated into the technical report and its appendices, with deliverables ready for internal management and monitoring of the Green Iguana Management Plan. (NPS, 2025).

LEGAL FRAMEWORK

The SJNHS-NPS's management of natural and cultural resources aims to ensure the protection of heritage and wildlife. At the federal level, the National Environmental Policy Act (NEPA) establishes guidelines for the assessment and mitigation of environmental impacts, promoting informed decision-making (NEPA, 1969/2025; NPS, 2015). The NPS Management Policies (2006) specify that invasive alien species shall be managed, including through eradication, when control is prudent and feasible; and when they affect resources, hinder management, or pose a risk to health and safety. At the territorial level, the Puerto Rico Animal Welfare and Protection Act (Act No. 154-2008 and amendments) establishes relevant responsibilities and safeguards. This framework, supplemented by manuals and operational guidelines, guides monitoring, control, and environmental education efforts within the SAJU. (NPS, 2015; Commonwealth of Puerto Rico, 2011).

Another important regulation in the management of invasive species is the protection of nests in historic areas or conservation areas for migratory, native, and endemic species. This is based on the U.S. Fish and Wildlife Service's Mitigation Policy (2023), which establishes the mitigation hierarchy of "avoid, minimize, and offset" as a guiding principle for reducing impacts on natural resources, including critical habitats and areas of high ecological value (USFWS, 2023). This policy requires prioritizing the avoidance of impacts on high-value habitats, particularly those essential for migratory or at-risk species, as well as for the integrity of ecosystems where the presence of invasive species can aggravate functional habitat loss—especially in our area, since migratory birds have been observed within our jurisdiction. In addition, under the NEPA and the

Endangered Species Act (ESA), it is required to assess and mitigate direct and indirect effects on protected species, including their nests, through measures based on the best available science and with a “no net loss” approach to the affected resources. (USFWS, 2023). In historic or conservation areas, these requirements are supplemented by the need to prevent cumulative impacts and ensure the long-term effectiveness of mitigation measures, including the control of invasive species that may affect native nests and the active protection of breeding habitat through temporary restrictions, adaptive management, and conservation practices consistent with the objectives of the SJNHS.

RESULTS AND DISCUSSION

Descriptive Statistics, Simple Bar Chart, Histogram of Frecuency, Stacked Bar Chart, Pie Chart, Test Run and Pareto Chart

The analysis was conducted using descriptive statistical methods, which served as essential tools for summarizing and interpreting the data collected on nesting sites. Measures of central tendency, dispersion, and data distribution were calculated to provide an overview of nest presence, variability, and spatial patterns across study areas and years. All analyses and graphical representations were performed using Minitab 22. Simple bar charts were used to compare the number of nests across different categories, such as study areas. These visualizations allowed for clear identification of differences in nest abundance and facilitated direct comparisons between datasets. In addition, stacked bar charts were used to represent subcategories within the nesting data, such as types of nesting structures (e.g., burrows, shelters, and cavities), allowing for a more detailed interpretation of how each category contributed to the total count. Pie charts were used to illustrate proportional relationships within the dataset, particularly the relative contribution of each nest category or study area to the total number of recorded nests. These charts provided a clear representation of the parts that make up the whole, allowing for a quick interpretation of the predominant categories in the study. (Hill, 2024; Albers et al., 2022; Tufte, 2001). Histograms are used to represent the distribution of quantitative data, allowing researchers to identify patterns, variability, and potential outliers within a dataset (Moore et al., 2017). This approach provided a better understanding of how nest observations were distributed across the sampling units. The Runs Test is a nonparametric statistical procedure used to assess whether a data sequence is generated randomly by analyzing the pattern and the number of consecutive runs within the sequence, which helps identify potential non-random patterns in the data (Bujang & Sapri, 2018). Pareto charts were used to identify the most significant categories contributing to the presence of nests. By combining bar charts with cumulative percentage lines, these visualizations highlighted the areas or types of nests with the greatest influence on the overall dataset, facilitating prioritization and management decisions. The Pareto chart is a tool used to identify and distinguish the few essential factors from the many secondary factors, allowing for better prioritization of problem-solving efforts (Kaoru Ishikawa, 1985).

Descriptive tables generated in Minitab 22 were used to validate the numerical values represented in the graphical results, ensuring the consistency and accuracy of the analysis. These calculations were based on point data and were used to compare variations in nest abundance and distribution over time. Overall, the integration of statistical summaries and graphical methods provided a comprehensive and accurate assessment of the nesting data. These approaches facilitated the identification of patterns, differences between study areas, and changes over time, supporting a data-driven interpretation of the dynamics of nesting sites within the study area.

Elements of the Analysis

Analysis of the data collected during monitoring was conducted with the aim of identifying, classifying, and evaluating all nesting and shelter structures observed in the SJNHS, regardless of the ecological origin of the associated species. This includes structures belonging to invasive, endemic, native, or migratory fauna, given that the goal of the process is to understand the presence, distribution, and habitat use within the park without limiting the analysis to a single taxonomic group. To ensure data quality, a thorough verification process was carried out to detect and correct potentially erroneous records related to location, structure type, and occupancy status. Once the database was validated (cleaned data), descriptive statistical methods were applied to characterize the magnitude and variability of the documented structures. This analysis included measures such as the total sum by structure type, the observed minimum and maximum values, and the dispersion reflected in the standard deviation, following methodological recommendations for exploratory data analysis in ecological studies (Jones, 2022; Mukhiya, 2020). These indicators allow us to visualize general patterns in the formation of nests, burrows, and shelters, providing an initial insight into the spatial dynamics of species that interact with the park's natural and cultural resources. To complement this approach, various graphical representation techniques were used to facilitate the interpretation of the results. Simple bar charts allow for the comparison of specific areas, while stacked bar charts make it easier to observe the relative composition of structure types within each sector. Histograms help identify distribution patterns or potential biases in the occurrence of structures, and pie charts help clearly communicate the total proportion of structures and the distribution of occupied nests or shelters throughout the park. In addition, the use of dynamic tables allowed for flexible summarization of the data, comparing areas, habitat types, occupancy rates, and levels of occupancy.

Together, these tools make it possible to detect spatial patterns, assess differences between areas, identify areas of potential ecological value, and pinpoint sectors where historical resources may be at risk due to the presence of active structures or excavations. Thus, the analysis serves a dual purpose: on the one hand, to document the current status of nests and roosts within the SJNHS, and on the other, to generate a body of evidence that can be integrated into future decision-making processes and adaptive management. The following section presents the results derived from this comprehensive analysis.

Results of the descriptive analysis of physical structures

A descriptive analysis of burrows, herborage, and caves provides an initial characterization of the presence of structures associated with all species—whether invasive, endemic, or native—summarized using means, sums, minimums, maximums, and standard deviations. The descriptive tables are shown below.

Table 1: *Descriptive Statistics of Iguana Structures (burrow, herborage, cave)*

Variable	N	N*	Mean	SE Mean	StDev	Sum	Minimum	Q1	Median	Q3	Maximum
Burrow	67	4	0.18	0.06	0.52	12	0	0	0	0	3
Herborage	67	4	7.13	1.05	8.563	478	0	2	4	9	54
Cave	67	4	0.98	0.39	3.19	66	0	0	0	0	21

Table 1 This table presents descriptive statistics for burrows, herborages, and caves, showing their mean, sum, minimum, maximum, and standard deviation. Herborages had the highest values, at 7.13, reflecting their greater abundance in areas with historic structures. Meanwhile, burrows and caves show lower frequencies and greater variability across areas, influenced by factors such as soil type, slope, and availability of cavities. This summary allows for a quick visualization of the magnitude and variation of each type of microhabitat and serves as a basis for interpreting habitat use patterns in the monitored areas. It is expected that shelters will have higher average values in areas with historic structures, while burrows and caves will show variability based on soil type, slope, and exposure to erosion.

Distribution by zone

In areas such as Castillo San Felipe del Morro and the Baluarte de Santa Elena, a greater number of structures were documented, reflecting structural complexity, visitor traffic, and coastal exposure. Table 2 provides a comparison that helps us prioritize and plan the sequence of conservation interventions.

Tabla 2: *Resumen de madrigueras, refugios y cuevas por zona (total)*

Zone	Burrow	Herborage	Cave	Total
Castillo San Cristóbal	2	31	5	38
Baluarte San Sebastián	0	7	0	7
Baluarte Santo Tomás	0	4	0	4
Baluarte Ánimas	0	4	0	4
Baluarte San Domingo	0	2	0	2
Baluarte Santa Rosa	0	4	0	4
Contraguardía la Trinidad	1	18	3	22
Puerta San Juan	0	15	0	15
Baluarte San Agustín	0	29	1	30

Baluarte Santa Elena	3	52	16	71
Batería San Fernando	2	5	31	38
Castillo San Felipe del Morro	2	194	10	206
Baluarte San Antonio	0	8	0	8
Revelin San Carlos	0	10	0	10
Batería Santa Teresa	0	48	0	48
Fuerte La Princesa	0	16	0	16
Fuerte el Abanico	1	26	0	27
Fortín San Juan de la Cruz (El Cañuelo)	1	5	0	6
Baluarte de San Justo	*	*	*	*
Baluarte de Las Palmas	*	*	*	*
Baluarte de Santa Catalina y Baluarte de La Concepción	*	*	*	*
Total:	12	478	66	556

NOTE: **= No data.*

Table 2 shows the total number of burrows, herborages, and caves in the monitored areas, as well as the total number of burrows, herborages, and caves. It can be seen that a total of twelve (12) burrows, four hundred seventy-eight (478) herborages, and sixty-six (66) caves were counted. It can be seen that the largest number of burrows is found at the Santa Elena Bastion, with a total of three (3) burrows. Meanwhile, the largest number of herborages is found at San Felipe del Morro Castle, with a total of 194 dens. The largest number of caves, however, is found at the San Fernando Battery, with a total of thirty-one (31) caves.

Figura 3: *Composition of Microhabitat Structures by Management Zone*

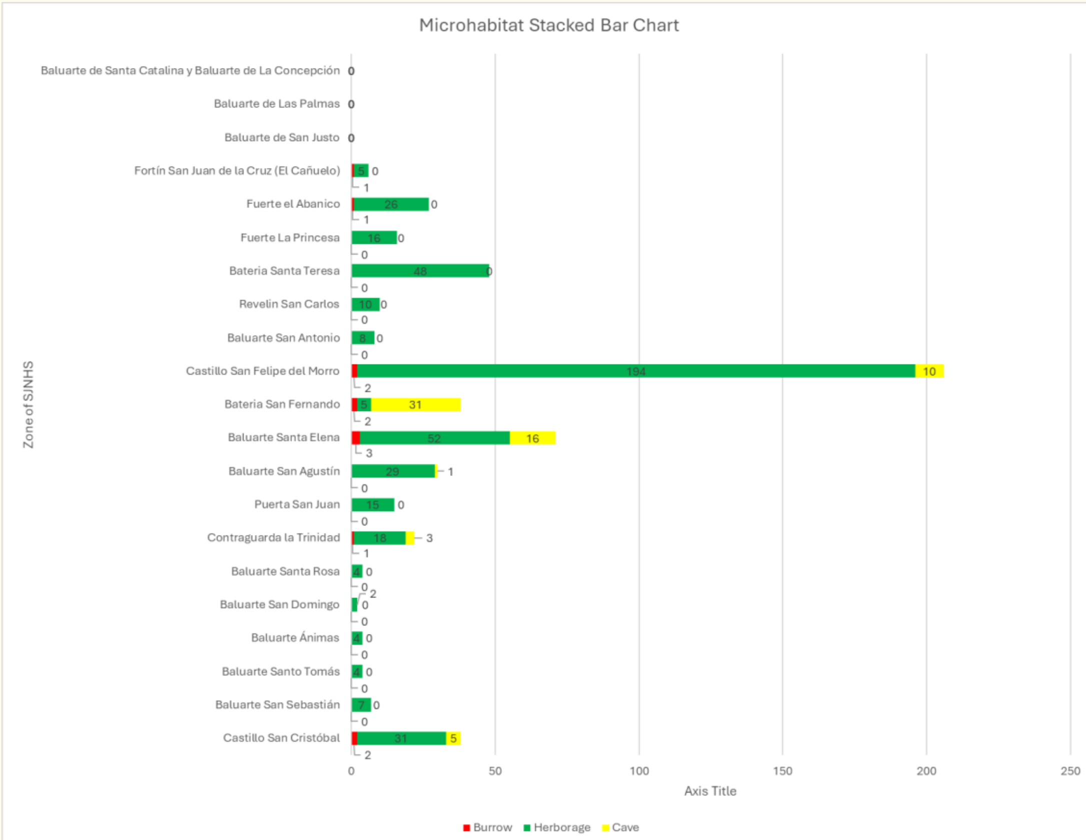


Figure 3 shows the composition of structures by area using a stacked bar chart, which allowed us to observe which type of structure prevails in each area, as well as the diversity of habitats available to iguanas. It can be seen that the number of herborages is the dominant factor in all monitored areas, with Castillo San Felipe del Morro having the highest number of herborages among the monitored areas, totaling one hundred ninety-four (194) herborages out of a total of four hundred seventy-eight (478) across all monitored areas. Meanwhile, caves are the second most common feature in the monitored areas, with a total of sixty-six (66). Caves were observed at the San Agustín Bastion with a total of one cave, at the Santa Elena Bastion with a total of sixteen (16) caves, at the San Fernando Battery with a total of thirty-one (31) caves, at Castillo San Cristóbal with a total of five (5) caves, at Castillo San Felipe del Morro with a total of ten (10) burrows, and at the Contraguardia la Trinidad with a total of three (3) burrows. Meanwhile, the number of burrows was low in the monitored areas. Burrows were observed at the Santa Elena Bastion, with a total of three (3) burrows, and a total of two (2) burrows at the San Fernando Battery, at San Cristóbal Castle, and at San Felipe del Morro Castle. Meanwhile, one burrow was observed at the Contraguardia de la Trinidad, at Fortín San Juan de la Cruz, and at Fuerte el Abanico.

Figure 4: *Histogram of Frecuency of Microhabitat (Structure nest)*

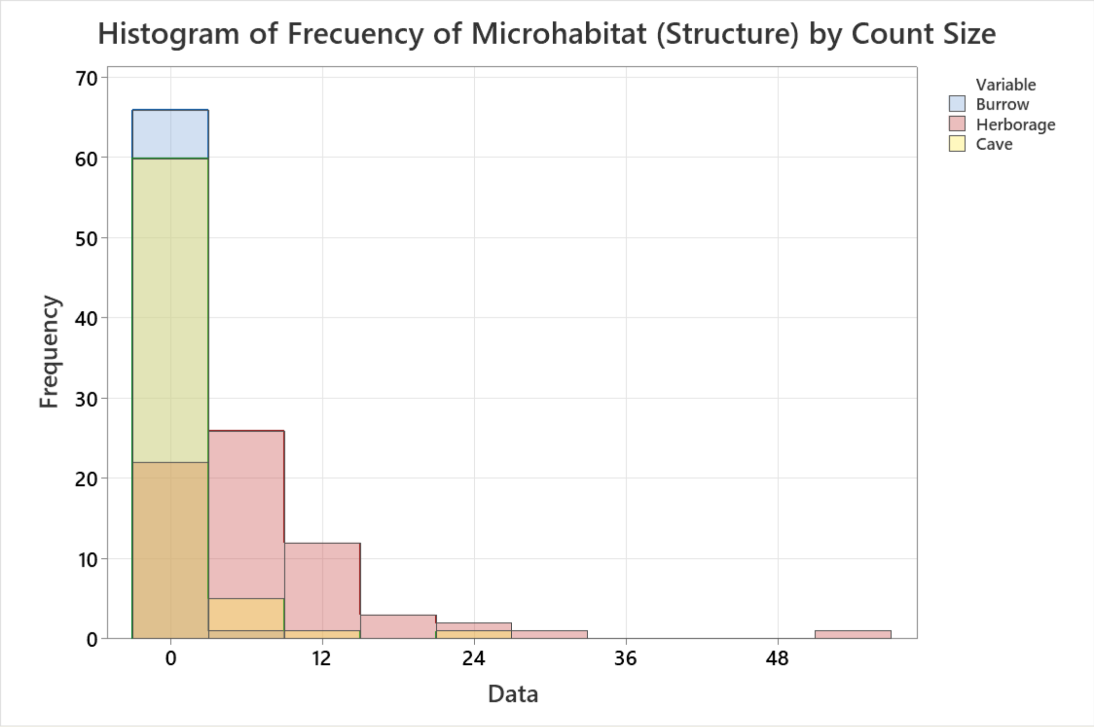


Figure 4 shows the frequency distribution of microhabitat counts (burrows, herborages, and caves) recorded in the monitored areas. This graph allowed us to observe the concentration, dispersion, and asymmetry associated with each structure. In general, most of the records cluster around values close to zero (0), indicating that most areas contain few documented microhabitats. However, the three variables show significant differences among themselves. Hides represent both the highest mean and the greatest dispersion, with a very long right tail due to a few extreme values reaching more than fifty (50) structures. This produces a pronounced positive skew to the left. In contrast, burrows show extremely low means and very little variability, concentrating almost entirely on values between zero (0) and one (1). Caves occupy an intermediate position: most values are low, although a few high cases generate a greater dispersion than that of burrows, but less than that of dens. Overall, the pattern reveals that only a few areas have high concentrations of herborages, or caves, while the vast majority have low counts, reflecting a strongly skewed and heterogeneous distribution across the park's zones.

Active Occupancy: Inhabited Nests and Occupancy Rate

The use of these structures can be analyzed by counting the number of occupied nests per area and their occupancy rate. Variations across areas reveal differences in the intensity of habitat use, showing that areas with fewer structures may have high occupancy rates, while areas with an abundance of structures do not always exhibit the highest occupancy rates; this suggests a decoupling between availability and use.

***Table 3:** Active Structures by Zone and Occupancy Rate*

Zones	Nest inhabited	Total Count	% habitantes
Fuerte el Abanico	13	27	48.14
Batería San Fernando	12	38	31.57
Castillo San Felipe del Morro	39	206	18.93
Baluarte Santa Elena	12	71	16.90
Fortín San Juan de la Cruz (El Cañuelo)	1	6	16.66
Castillo San Cristóbal	5	38	13.15
Baluarte San Agustín	3	30	10
Batería Santa Teresa	2	48	4.16
Baluarte San Sebastián	0	7	0
Baluarte Santo Tomás	0	4	0
Baluarte Ánimas	0	4	0
Baluarte San Domingo	0	2	0
Baluarte Santa Rosa	0	4	0
Contraguardía la Trinidad	0	22	0
Puerta San Juan	0	15	0
Baluarte San Antonio	0	8	0
Revelín San Carlos	0	10	0
Fuerte La Princesa	0	16	0
Baluarte de San Justo	*	*	*
Baluarte de Las Palmas	*	*	*
Baluarte de Santa Catalina y Baluarte de La Concepción	*	*	*
Total	87	556	

***NOTE:** *= No data.*

Table 3 shows the total number of occupied nests in the monitored areas. Nests were identified in the following areas: Fuerte el Abanico, with a total of thirteen (13) occupied nests, representing forty-eight point fifteen percent (48.15%) of the nests monitored in this area; and Batería San Fernando, with a total of twelve (12) inhabited nests, representing thirty-one point fifty-eight percent (31.58%) of the nests monitored in this area; Castillo San Felipe del Morro, with a total of thirty-nine (39) inhabited nests, representing eighteen point ninety-three percent (18.93%) of the nests monitored in this area; the Santa Elena Bastion with a total of twelve (12) occupied nests, representing sixteen point nine percent (16.90%) of the nests monitored in this area, Fort San Juan de la Cruz (El Cañuelo) with a single inhabited nest, representing 16.67% of the nests monitored in this area, Fort San Cristóbal with five (5) inhabited nests, representing 13.16% of the nests monitored in this area, the Baluarte de San Agustín with three (3) occupied nests, representing ten percent (10%) of the nests monitored in this area, and the Baluarte Santa Teresa with two (2) occupied nests, representing four point seventeen percent (4.17%) of the nests monitored in this area.

__Figure 5:__ Percentage Distribution of Iguana Structures by Management Zone

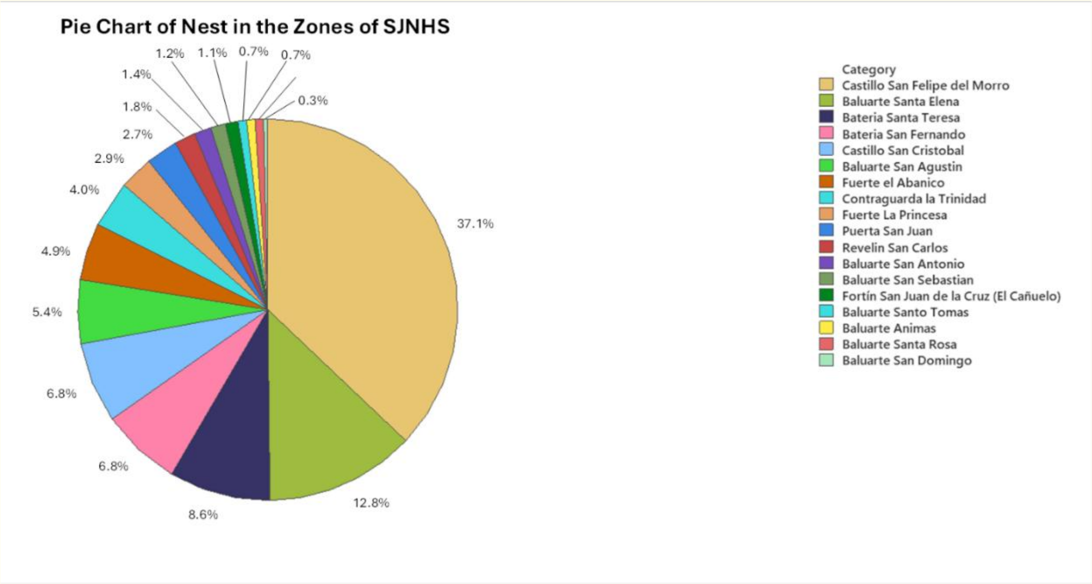
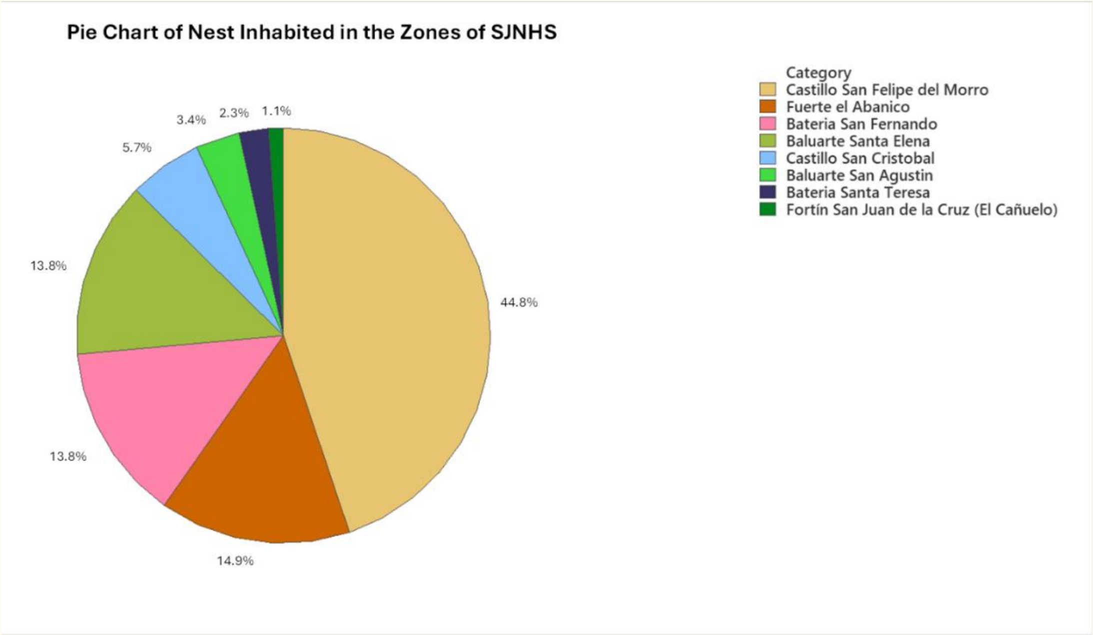


Figure 5 shows the relative proportion of burrows, herbortages, and caves recorded in each zone of the SJNHS. It can be seen that most nests are concentrated in a small number of areas, particularly at Castillo San Felipe del Morro and Baluarte de Santa Elena, where the Spanish architectural features contribute to the availability of microhabitats (nests). This graphical representation allowed us to project the relative weight of each area within the total number of documented structures and helped facilitate comparisons with other metrics, such as active occupancy and the risk associated with historical heritage, as shown in Figure 6 bellow.

Figure 6: *Distribution of Active Species Nests by Management Zone*



Figur6 6 shows the distribution of occupied nests in some of the areas that were monitored, highlighting the areas where the biological activity of invasive, native, and endemic species is most pronounced. Forty-four point eight percent (44.8%) of nests were found to be inhabited at Castillo San Felipe del Morro, fourteen point nine percent (14.9%) at Fuerte el Abanico, thirteen point eight percent (13.8%) at Batería de San Fernando and Baluarte de Santa Elena, 5.7% of inhabited nests at Castillo San Cristóbal, 2.3% of inhabited nests at Batería de Santa Teresa, and 1.1% of inhabited nests at Fortín San Juan de la Cruz (El Cañuelo). While some areas have a high number of potential structures, the proportion of occupied nests reveals a different pattern, in which the areas with the greatest abundance of burrows, herborages, and caves are not always the ones with the highest level of actual use. This contrast indicates and reflects a higher proportion of active occupancy, suggesting favorable conditions for the presence and activity of various species.

Figure 7: *Occupancy Rate by Zone (%)*

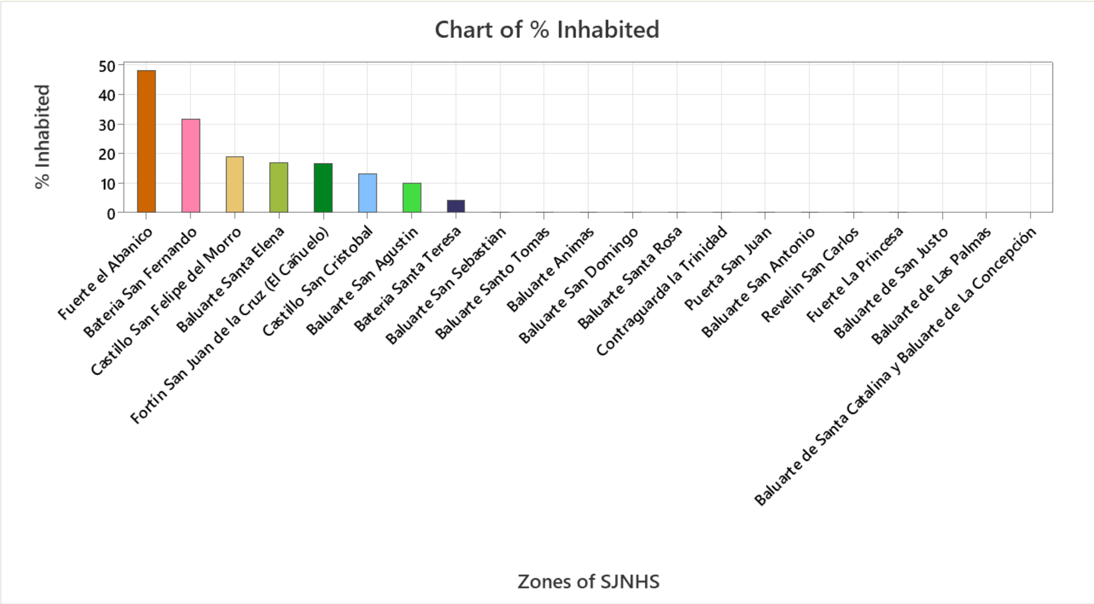


Figura 6 displays the variation in nest occupancy rates by monitored area. This shows which areas of the park exhibit more intensive use of available structures by invasive, native, and endemic species. Unlike distributions based on the total number of burrows, herborages, and caves, the occupancy rate reveals a more selective pattern, where some areas with structural abundance show low usage percentages, while other areas with fewer structures show proportionally higher occupancy. This figure allows for the identification of areas where biological activity is concentrated with greater intensity, providing key information to guide management, prioritization, and mitigation decisions regarding the presence and activity of various species.

Figure 8: *Zones with Highest Concentration of Iguana Structures*

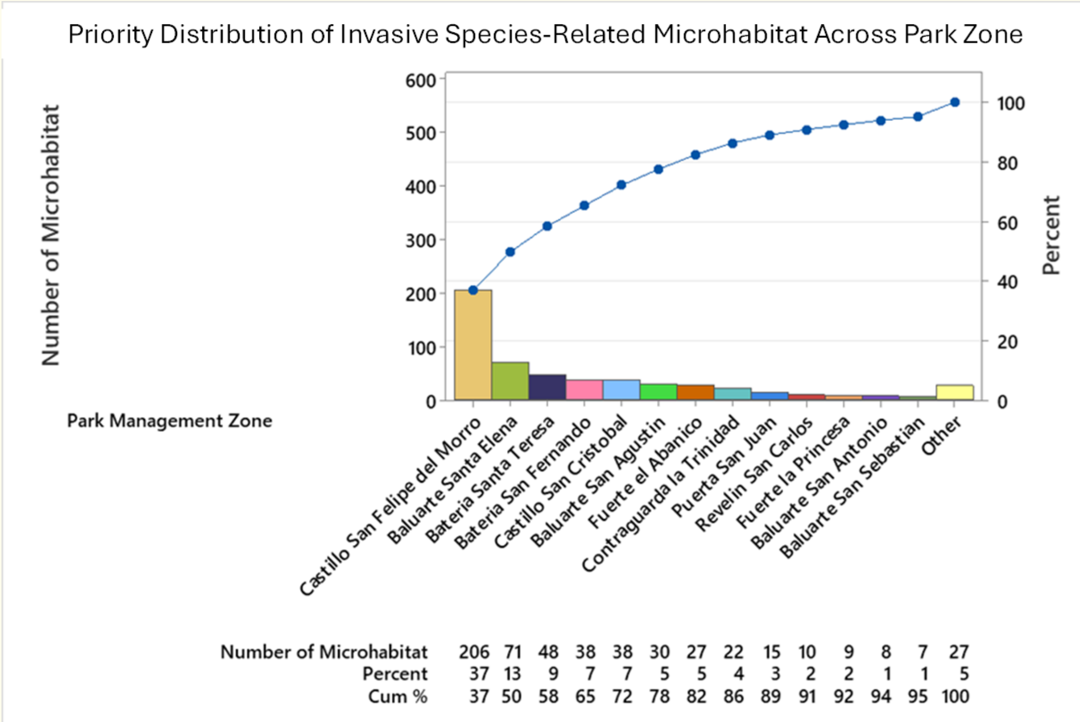


Figure 8 provides a Pareto analysis of the monitored areas, showing which ones contain the highest proportion of structures associated with invasive species, such as the green iguana, or areas that could be used by native and endemic species. This allowed us to identify the areas where the greatest number of burrows, herborages, and caves are concentrated. It can be observed that a small group is concentrated in: the Baluarte de Santo Tomás, the Baluarte de las Ánimas, the Baluarte de San Domingo, the Baluarte de Santa Rosa, the Baluarte de San Fernando, and the Fortín de San Juan de la Cruz (El Cañuelo). These areas account for the majority of the recorded structures, indicating an uneven distribution of the phenomenon within the park. Areas such as Castillo San Felipe del Morro, the Santa Elena Bastion, and the San Fernando Battery have the highest numbers of nests, especially herborages, which are the dominant type of structure. The cumulative curve shows that after reaching a significant percentage of the total within the first twenty to thirty percent (20–30%) of the areas, the remaining areas contribute only marginally to the total number of structures.

Table 4: *Summary of Iguana Structures and Occupancy by Management Zone*

Zone	Burrow	Herborage	Cave	Total Count	Nest Inhabited	Occupancy Rate (%)
Castillo San Cristóbal	2	31	5	38	5	13.15789
Baluarte San Sebastián	0	7	0	7	0	0
Baluarte Santo Tomás	0	4	0	4	0	0

Baluarte Ánimas	0	4	0	4	0	0
Baluarte San Domingo	0	2	0	2	0	0
Baluarte Santa Rosa	0	4	0	4	0	0
Contraguardía la Trinidad	1	18	3	22	0	0
Puerta San Juan	0	15	0	15	0	0
Baluarte San Agustín	0	29	1	30	3	10.00000
Baluarte Santa Elena	3	52	16	71	12	16.90141
Bateria San Fernando	2	5	31	38	12	31.57895
Castillo San Felipe del Morro	2	194	10	206	39	18.93204
Baluarte San Antonio	0	8	0	8	0	0
Revelin San Carlos	0	10	0	10	0	0
Bateria Santa Teresa	0	48	0	48	2	4.16667
Fuerte La Princesa	0	16	0	16	0	0
Fuerte el Abanico	1	26	0	27	13	48.14815
Fortín San Juan de la Cruz (El Cañuelo)	1	5	0	6	1	16.66667
Baluarte de San Justo	*	*	*	*	*	*
Baluarte de Las Palmas	*	*	*	*	*	*
Baluarte de Santa Catalina y Baluarte de La Concepción	*	*	*	*	*	*
Total:	12	478	66	556	87	

NOTE: **= No data.*

Table 4 provides a comparative overview of the total number of burrows, herborages, and caves documented across the monitored areas, along with the number of occupied nests and the occupancy rate. This helps us assess the availability of microhabitats and their effective use by Iguana iguana. It shows that some areas exhibit high structural abundance, particularly those with architectural complexity or favorable substrates. Occupancy intensity does not always correspond to availability, with some areas standing out where a moderate number of structures support a high proportion of active use.

Run Test

Descriptive Statistics

	Number of Observations		
N	**K**	**≤ K**	**> K**

Test

Null hypothesis	H_0: The order of the data is random

67	8.29851	46	21

K = sample mean

Alternative hypothesis	H_1: The order of the data is not random

Number of Runs

Observed	Expected	P-Value
24	29.84	0.094

The sequence of observations showed twenty-four (24) *runs*, while the expected number under the null hypothesis of randomness was twenty-nine point eighty-four (29.84). The p-value obtained was zero point zero ninety-four (0.094), indicating that the null hypothesis of randomness of the obtained data is not rejected ($\alpha = 0.05$). This implies that, statistically, the location of the monitored sites can be considered random; whether invasive, endemic, or native, the species are distributed randomly throughout the park, and there is no pattern in their nesting. Of the sixty-seven (67) recorded observations, forty-six (46) were below the median and twenty-one (21) above it, with eight (8) values equal to the median. The distribution shows a slight tendency toward more observations below the median, although this difference is not statistically significant, according to the test.

Figures by study zone

Figure 9: *"Structure density map by zone"*

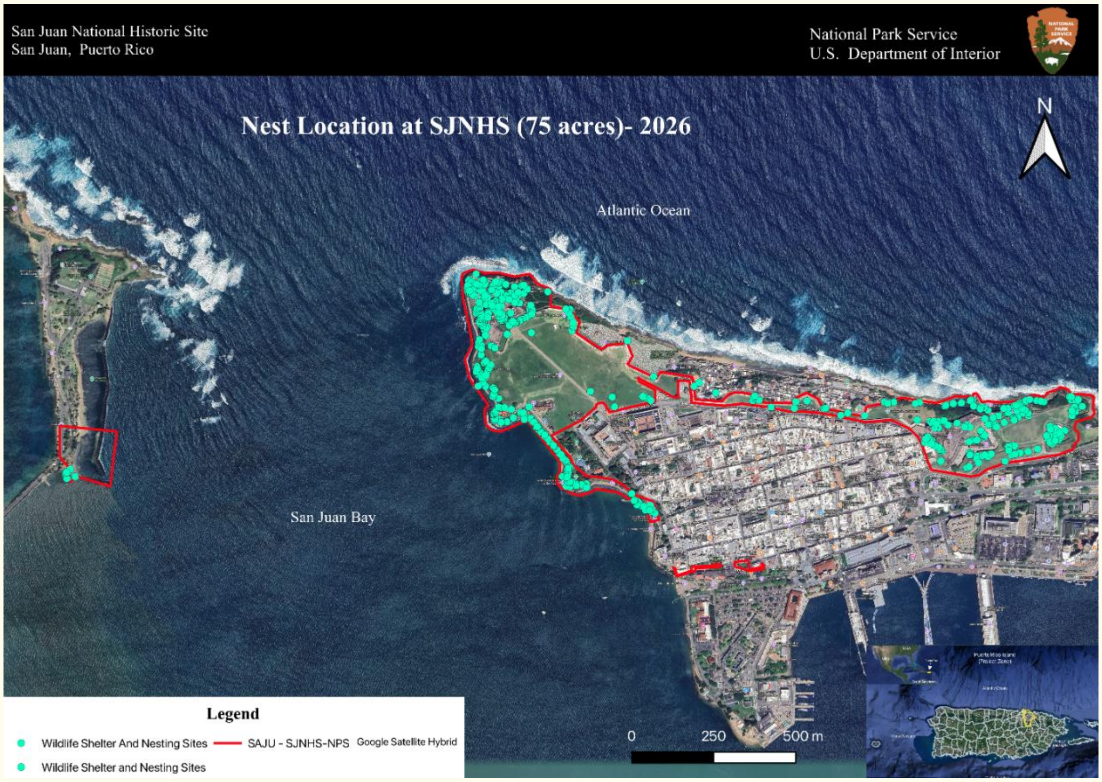


Figure 10: *"Structure density map by SJNHS boundaries"*

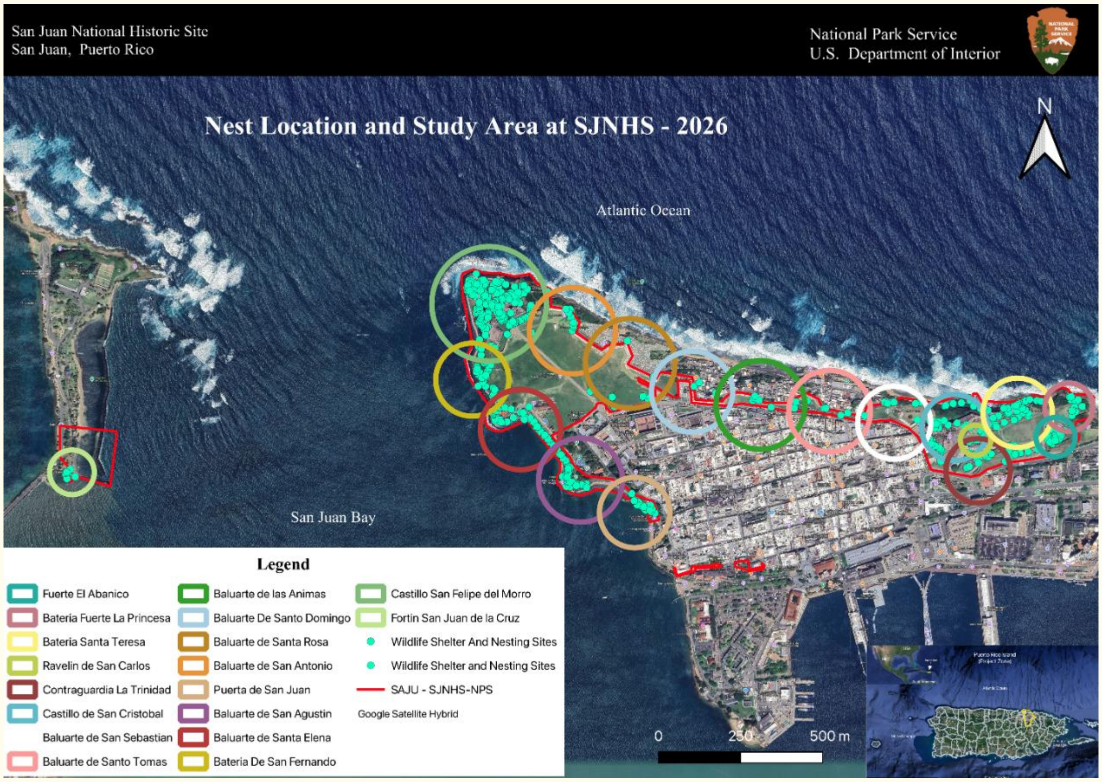


Figure 11: *Spatial heatmap of Susceptible Nesting Area in SJNHS*

Figure 12: *Spatial heatmap of Susceptible Nesting and Name Area of Zone in SJNHS*

Field Observations and Qualitative Notes

As part of the documentation process in Survey123, a substantial set of qualitative comments was generated for each georeferenced record of nests, burrows, cavities, and potential structures used by invasive, native, endemic, or migratory wildlife within the SJNHS. These observations were entered in real time by technical staff during monitoring and help contextualize the nature of each structure and the surrounding environmental or structural conditions. After reviewing the collected comments, thematic patterns were identified that highlight the site's ecological, architectural, and operational complexity. A considerable proportion of the notes relate to drainage systems, many of which exhibit features of ecological interest, such as functional inlets and outlets, internal connections to the park, the presence of active wildlife (particularly iguanas, land crabs, feral cats, pigeons, and bees), or conditions of blockage, sediment accumulation, or partial clogging by vegetation. Numerous drains mitigated through the use of wire mesh or bricks were also recorded, reflecting previous interventions or management efforts aimed at limiting access by invasive species, without considering native, endemic, or migratory life.

Another significant set of observations relates to structural voids and cavities located at the base or surface of the historic walls, as well as to cracks, active erosion, and microhabitats formed by the interaction between the coastal bedrock and the surrounding vegetation, particularly the roots of beach grape (*Coccoloba uvifera*) and accumulations of rocks exposed to wave action. In several cases, the direct presence of iguanas using cavities as daytime shelters was documented, as well as structures located in areas currently undergoing maintenance work, which underscores the need to integrate the ecological component into historical conservation processes. Observations regarding bird nests were also recorded, including uninhabited structures and cavities in walls where seasonal use by these species might occur, as well as the presence of bees in specific cavities, including drains, which represents a relevant factor for tourist safety planning and, in turn, for natural resource management. Some notes pertain to non-representative findings or those associated with structures having no apparent ecological function.

To conclude, these field notes supplement the quantitative information presented in the sections, providing environmental context, evidence of wildlife activity, indications of structural risk, and key elements for future decisions regarding mitigation, maintenance, monitoring, and spatial prioritization. Their full content is preserved in the project's digital archive as a technical appendix. A more in-depth analysis is recommended, given that drainage systems are essential for the management and distribution of surface water.

Discussion

A spatial and quantitative analysis of potential nesting and roosting sites at the San Juan National Historic Site (SJNHS) shows that the vast majority of the potential nests or roosts identified are located within historic structures, such as bastions, walls, fortifications, drainage systems, and artificial cavities, rather than in the surrounding natural environment, such as trails, grasslands, microhabitats, or other natural features. Of the five hundred fifty-six (556) structures documented in total, four hundred seventy-eight (478) correspond to "herborage" shelters, sixty-six (66) to "cave" shelters, and twelve (12) to "burrow" shelters. This means that shelters account for approximately eighty-six percent (86%) of the total structures, caves for twelve percent (12%), and burrows for only two percent (2%). Furthermore, according to field observations and documented notes, virtually all of these structures (including shelters, caves, and burrows) were located within historical architectural elements, and only a few burrows or natural caves were found outside the structures, representing less than five (5%) of the total. (National Park Service, 2013). This nest monitoring revealed data that, when compared with population estimates, will allow us to identify potential population-level effects on endangered or threatened populations, thereby providing targets for action (Massaro et al., 2013).

This situation is particularly relevant when considering the coexistence and competition between native, endemic, and introduced or invasive species, as the concentration of wildlife habitats within historic structures means that any management, control, or access restriction measures may have direct or indirect impacts on both local wildlife and the conservation of cultural heritage. From the perspective of management and institutional policy at the Department of the Interior–National Park Service, the presence and intensive use of historic structures by wildlife, especially by introduced species, poses a significant threat to the physical integrity of cultural resources. The founding document of the SJNHS (2013) stipulates that the park's fundamental mission is to preserve its natural and cultural resources without compromise for the benefit of present and future generations, and that the protection of the fortifications, walls, and associated heritage is a priority for management (NPS, 2013). NPS management policies emphasize that any use or activity that causes impairment or unacceptable impacts on the park's values and resources must be avoided or mitigated, and that conservation must take precedence over use when there is a conflict (NPS, 2006). The identification of burrows and natural caves is minimal, indicating that wildlife—including native, endemic, and introduced species—relies almost exclusively on historic structures for shelter and nesting. This is concerning, as excavation, intensive use, or alteration of these structures by wildlife can accelerate erosion, collapse, and structural deterioration, in direct contradiction to the management and conservation policies of the National Park Service. (NPS, 2013; NPS, 2006). The NPS regulatory framework is explicit regarding the management of exotic or invasive species. The policy states that exotic species shall not be allowed to displace native species if this can be prevented, and that all exotic species not necessary for an identified park purpose shall be managed—up to and including eradication—if they interfere with natural processes, the perpetuation of natural features, native species, or natural habitats, or damage cultural resources (NPS, 2006). In addition, the policy requires the implementation of integrated management plans for pests and non-native species, prioritizing those that may cause substantial damage to the park's resources. The current situation, where most potential shelters and nests are located in historic structures rather than in the natural environment, presents a management challenge that requires a balance between heritage protection, biodiversity conservation, and public engagement. Any intervention must be aligned with the principles of no harm, appropriate use, and prevention of unacceptable impacts, as established in the NPS's founding documents and management policies) (NPS, 2013; NPS, 2006). Programs focused on invasive, native, and endemic species, as well as natural resources, at the park level; and planning tools rely on distribution and abundance data to establish achievable management goals in protected areas. This approach contributes to data management and collection. (Ramírez-Cruz & Ortega-Álvarez, 2021).

It should be noted that the active occupancy rate was fifteen point six percent (15.6%), [eighty-seven out of five hundred fifty-six (87 out of 556)], but with significant variability between sites: at Fuerte el Abanico, forty-eight point one percent (48.1%) of the structures were occupied, whereas at Castillo San Felipe del Morro, which has the highest abundance of structures, occupancy was only eighteen point nine percent (18.9%). This discrepancy indicates that the intensity of use cannot be explained solely by the abundance of structures; other factors, such as proximity to vegetation, exposure to erosion, microclimate, and human traffic, should be explored in greater detail through multivariate and geospatial analyses (NPS, 2013). This information is also crucial for establishing species management strategies based on area priority. The Pareto analysis indicates that approximately thirty percent (30%) of the zones account for more than seventy percent (70%) of the structures, which supports the feasibility of a phased intervention, starting with critical areas, such as the Abanico zone, which has already been mitigated. The stacked bar chart confirms that the distribution of microhabitats within the SJNHS is highly uneven across the monitored areas. Overall, the results of the run test suggest that there are no evident systematic patterns in the arrangement of nests and shelters, which supports the need for observations to analyze the behavior of the invasive species of interest, such as green iguanas. Likewise, it was noted that the sequence of nest, shelter, and burrow locations does not exhibit a statistically significant pattern, with a p-value of 0.094. This suggests that the monitored sites are distributed essentially randomly within the study area; there are more observations below the median [forty-six versus twenty-one (46 vs 21)]. It should be added that no systematic pattern was generated that affects the randomness of the data.

Most structures are heavily concentrated in a few specific areas. This pattern suggests that this zone offers ideal conditions for the formation or use of shelters, whether by invasive species such as the green iguana or by native wildlife that might use similar cavities. By contrast, most other areas show very low or even zero counts, indicating that not all areas of the park provide the same opportunities or suitable characteristics for wildlife occupation.

This strategy optimizes resource use and reduces risks to historical heritage and local biodiversity (NPS, 2013). Scientific evidence emphasizes that early detection, rapid response, and adaptive management strategies, integrated with the community and multidisciplinary teams, improve the effectiveness of controlling introduced species in sensitive areas (Beaury et al., 2019; Richardson et al., 2020; Ditomaso et al., 2017). Aligning this plan with NEPA frameworks and NPS policies ensures compliance with legal and bioethical standards, establishing a transparent, evidence-based process (NPS, 2006; NPS, 2015). From an ecological perspective, the overlap of niches is critical: more than ninety-five percent (95%) of the structures documented in historic areas provide ideal conditions for both introduced species and native and endemic wildlife. This increases the risk of competition and displacement, especially in areas where pressure from introduced species is high and the resilience of local species is limited. Recent literature documents that introduced species can displace native species such as crabs and birds, altering the structure and function of communities (Burgos et al., 2016; De Jesús Villanueva et al., 2021). Inappropriate use or excessive restriction of access to microhabitats, such as the installation of physical barriers or the indiscriminate removal of shelters, can have negative consequences for local wildlife. Restricting access to cavities and drainage channels without considering the seasonality and life cycles of native and endemic species could reduce the availability of critical habitats and affect the ecological resilience of the system (NPS, 2013).

Adaptive, evidence-based management is essential to minimize negative impacts on biodiversity and historical heritage. Integrating quantitative data, such as occupancy and abundance rates, with qualitative risk assessments will enable informed and sustainable decisions for the conservation of the SJNHS (NPS, 2013; NPS, 2006). Systematic counts and spatial identification of nesting sites made it possible to locate and determine which types of nests pose the greatest risk to conservation, thereby allowing for the prioritization of management interventions for species protected under the ESA. Similarly, monitoring has revealed methods for analyzing losses, identifying causal factors, and linking threat patterns to habitat characteristics, mobility, and time periods.

CONCLUSION

Natural and cultural resources are directly or indirectly impacted by nesting invasive species, which can directly reduce the reproductive success of native and endemic species through predation, nest predation, and competition, and can generate novel biotic interactions that alter local communities. There are few studies or data on how our historical resources or infrastructure can serve as refuge and habitat for native and endemic species. However, studies indicate that there are invasive species that have directly targeted invasive predators such as rodents (rats) preying on the young of critically endangered seabirds, highlighting the clear vulnerability of nests to non-avian invaders. (Tapia-Jaramillo et al., 2025). In the same way, invasive nesters such as the green iguana can affect birds, as they may occupy cavities and force native species to inhabit suboptimal or lower-quality sites (Grarock et al., 2013; Mori et al., 2017). Some invasive nest builders (monk parakeets) create communal nests used by many occupying species, which can increase local biodiversity but also facilitate the presence of other non-native species and the transmission of diseases (Hernández-Brito et al., 2021).

This report from the Wildlife Program's Nest Inventory established a comprehensive georeferenced baseline of nesting structures, herborages, and burrows in the SJNHS, providing critical information on habitat use by native, endemic, migratory, and introduced species. The results show an uneven spatial distribution of the structures, with a total of five hundred fifty-six (556) microhabitats recorded, of which four hundred seventy-eight (478) are herborage [eighty-six percent (86%)], sixty-six (66) are caves [12%], and 12 to burrows [2%]. This distribution highlights the clear predominance of shelter-type structures (nests) within the study area, the 75-acre NPS site. A key finding of this research is the strong association between nesting structures and historic infrastructure. More than ninety-five percent (95%) of the documented structures were located within or directly associated with historical architectural elements such as walls, bastions, drainage systems, and fortifications. This indicates that the structural complexity of the built environment and geography at SJNHS plays a fundamental role in habitat availability. Consequently, both native and invasive species rely heavily on cultural resources for shelter, stopover sites (in the case of migratory species), and nesting, creating an ecological–cultural interface that requires careful management (NPS, 2013). However, the objectives set for this study were successfully met, resulting in the creation of a georeferenced and descriptive baseline of structures where native, endemic, migratory, and introduced species reside or use the SJNHS jurisdiction as a habitat. Similarly, it was possible to identify and map the structures across the twenty (20) official zones of the SJNHS within the 75-acre area. We were able to estimate abundance and distribution by structure type, calculate the occupancy rate, and propose a prioritization scheme by zone to support control, eradication, and restoration efforts. (NPS, 2025). The results of the Runs Test support the assumption that the location of nests, herborages, and burrows in the study area is not predetermined. This independence of the observations allows the data to be used in subsequent statistical analyses without bias due to spatial clustering. This contributes to the sampling protocol used, as it reliably reflects the actual distribution of sites of interest and provides a solid basis for management decisions and ongoing monitoring of the species in the SJNHS. Similarly, it is recommended that once the count of green iguanas or other species has been completed, graphs be used to compare any affinities that establish similarities in environmental or natural characteristics between coastal areas and higher-elevation areas or within the park (walls).

This analysis relates to vegetation density and the availability of cavities (herborages) and will contribute to the analysis of the nesting season for each invasive species; thus showing where and when invasive species are most likely to usurp nests, which allows for the creation of predictive risk maps. (Grarock et al., 2013; Mori et al., 2017). Another management issue would be vegetative restoration in the area or habitat modification. This should include increasing the density of trees and shrubs or the availability of cavities, thereby helping to reduce the suitability of the habitat for certain invasive species and minimize competitive interactions. (Grarock et al., 2013).

The analysis also revealed that the availability of structures may not directly determine their use. Although the overall occupancy rate was 15.6% [87 out of 556 structures], significant variation was observed across different areas. For example, El Abanico Fort had the highest occupancy rate [48.1%] despite having a smaller total number of structures and being smaller in size, while Castillo San Felipe del Morro, with the greatest structural abundance, showed lower occupancy [18.9%]. This decoupling between availability and use suggests that additional environmental and anthropogenic factors such as microclimatic conditions, proximity to vegetation, human disturbance (due to tourism), and substrate characteristics or texture significantly influence habitat selection (Beaury et al., 2019; Richardson et al., 2020). From a management perspective, the Pareto analysis showed that approximately thirty percent (30%) of the monitored areas account for more than seventy percent (70%) of the total structures. This finding supports the implementation of a prioritized and phased management strategy focused on high-density areas, such as Castillo San Felipe del Morro, Baluarte de Santa Elena, and Batería de San Fernando; the latter is being impacted by coastal erosion, runoff, and burrowing by green iguanas. Given this and the effects of climate change, this area is currently undergoing restoration under the "San Fernando Cliff Stabilization" project. In a way, this contributes to the elimination of areas susceptible to nesting, but the likelihood that nesting sites will shift is high due to the impact of the fortification's stabilization. Intervening in these critical areas allows for the optimization of resources, the reduction of impacts on historic infrastructure, and the enhancement of the effectiveness of control and mitigation measures. (DiTomaso et al., 2017). The presence of invasive species, particularly the green iguana (Iguana iguana), is a significant concern within this system. The use of structural cavities, burrows, and drainage systems contributes to erosion, structural weakening, and the long-term deterioration of historic resources. In accordance with NPS management policies, actions that result in impairment or unacceptable impacts must be avoided, and invasive species that threaten natural or cultural resources must be actively managed or eradicated whenever possible. (NPS, 2006; NPS, 2013). Therefore, the high concentration of managed structures within historic sites increases both ecological competition and the risk to cultural integrity.

However, this study highlights the importance of adopting a balanced and bioethical management approach. Given that these structures are also used by native and endemic species, the implementation of indiscriminate exclusion or removal measures could negatively affect the native and endemic biodiversity of the island of Puerto Rico. In this regard, effective management must integrate species-specific considerations, seasonal dynamics, and habitat requirements, avoiding unintended ecological consequences. Adaptive management approaches, supported by continuous monitoring and data-driven decision-making, are essential for addressing these complex interactions (Beaury et al., 2019; DiTomaso et al., 2017; Richardson et al., 2020).

Qualitative field observations supported the quantitative findings by documenting the ecological role of drainage systems, wall cavities, and microhabitats associated with vegetation. These structures serve not only as refuges but also as critical points of interaction between species and infrastructure. The presence of multiple taxa, including reptiles, birds, and invertebrates within these spaces underscores their multifunctional nature and the need for interdisciplinary management strategies that involve both academia and the broader community. I recommend that the breeding season and the characteristics of the cavities be included in the analysis and action plan once the necessary data are available, in order to predict the risk of encroachment and schedule interventions when invaders are most likely to acquire nests (Mori et al., 2017). This should be combined with zoonotic studies; when invasive species provide nesting opportunities for native species, the NPS should weigh the benefits against the risks before taking action (Hernández-Brito et al., 2021). There is no doubt that control methods informed by research specific to mammals, reptiles, and other taxonomic groups must be developed and implemented to ensure effective and ethical measures over the long term, given the threats at the island level (Palmer et al., 2007; Ramírez-Cruz & Ortega-Álvarez, 2021).

Together, this study provides a solid scientific foundation for future monitoring, management, and restoration efforts in the SJNHS and should be complemented by programs and various studies or monitoring initiatives focused on native, endemic, and invasive species. The integration of spatial analysis, through the Figures 1 and 2descriptive statistics and field observations provide a comprehensive understanding of nesting dynamics and habitat use. We suggest conducting a biological control study and studying the behavior in response to the use of decoy nests to deter the species from sensitive areas or those with limited access, specifically to better monitor the eggs and keep them away from cliffs, as it has been reported that the species takes refuge in areas such as Castillo San Cristóbal. This will help reduce pressure on nesting birds in threatened cavities and may be effective when the boxes are not used by invasive species; similarly, (Massaro et al., 2013; Grarock et al., 2013). Annual continuous monitoring protocols are recommended, subject to availability, in order to assess the effectiveness of control measures and ensure that management actions do not compromise the ecological integrity or functionality of habitats used by native and endemic species. Reforestation should be promoted, and logging or the reduction of grasses, herbaceous cover, or low vegetation in sensitive nesting areas, as well as the lack of vegetation, should be minimized. (see Appendix c) can promote nest viability. In addition, integrating vegetation surveys with those of other wildlife groups, such as birds, can enrich the ecological analysis and strengthen the interpretation of the observed patterns. Similarly, it is recommended that this report be considered in conjunction with the population count report for green iguanas (Iguana iguana), which will allow for a more robust and comprehensive assessment of population dynamics and their relationship to the availability and use of structures within the SJNHS. These actions will contribute to improving the effectiveness of invasive species management, while ensuring the protection of biodiversity and the historical integrity of the site (NPS, 2006; NPS, 2013).

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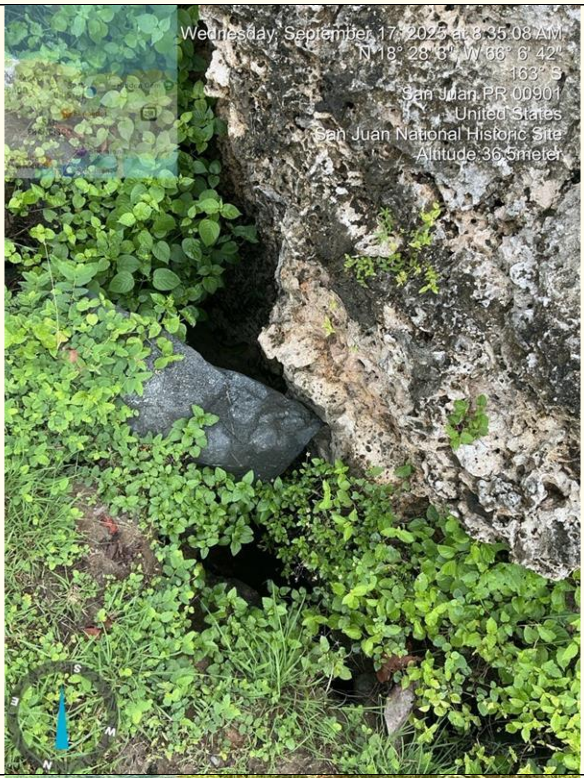
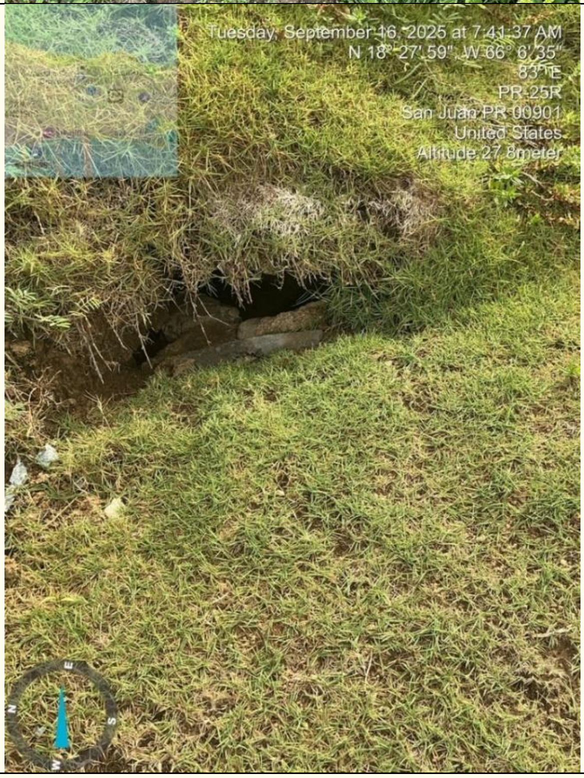
Note on using artificial intelligence: I used Microsoft Copilot, Consensus and Grammarly to help indicate purpose, such as brainstorming, reviewing grammar, translations, creating; charts, graphics and organizing content. I have taken the utmost care in revising, correcting, and expanding on the material 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.

APPENDIX

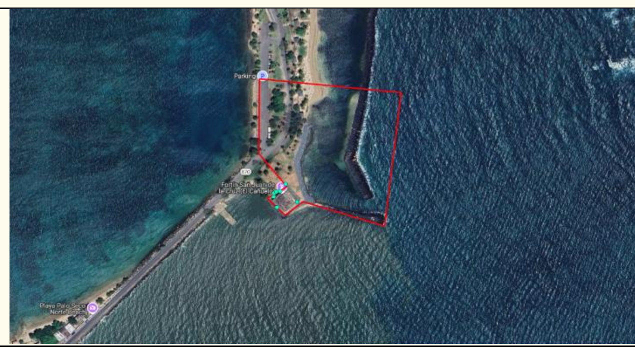
Appendix A: Photo Gallery

Description	Image
A domestic pigeon spotted near a drain on Paseo del Morro.	
Short eared owl (*Asio flammeus*) found in the outer defenses of Castillo San Cristóbal.	

A cave was spotted at the Santa Elena Fortress; this was caused by erosion.	
Cave spotted in Contraguardia la Trinidad.	

A cave spotted at La Batería de San Fernando; this was caused by erosion.	
A burrow was spotted at the San Fernando Battery; this one is made up of vegetation, and it is clear that it is used by a cat.	

Appendix B: *Photo gallery of structures by park zone*

Zone	Image
Nests found in the following areas: • Santo Tomás Bastion • San Sebastián Bastion • San Cristóbal Castle • La Trinidad Counterguard • San Carlos Ravelin • Santa Teresa Battery • La Princesa Fort • El Abanico Fort	
Nests found in the areas: • San Juan Gate • San Agustín Bastion • Santa Elena Bastion • San Fernando Battery • San Felipe del Morro Castle • San Antonio Bastion • Santa Rosa Bastion • Santo Domingo Bastion • Las Ánimas Bastion • Santo Tomás Bastion	
Nests found in the following areas: • San Juan de la Cruz Fort (El Cañuelo)	

Appendix C: *Area susceptible to nesting due to vegetation removal.*