



Title: Final Operational Report for the Removal of Introduced House Mice from Allen Cay, Exuma Islands, Bahamas

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EXECUTIVE SUMMARY

In May 2012, the Bahamas National Trust (BNT) together with Island Conservation (IC) undertook the removal of introduced House Mice (*Mus musculus*) from Allen Cay, Exuma Islands, Bahamas. The removal of mice was a necessary step in the restoration of the native environment of the cay, which is an important breeding and nesting site for Audubon's shearwater (*Puffinus lherminieri*) and the endemic Allen Cay Rock Iguana (*Cyclura cyclura inornata*).

Rodent bait containing brodifacoum was successfully applied to the 6 ha cay by hand broadcast. Monitoring efforts during the operation found no evidence of non-target mortality over 15 days following the initial application of bait. The removal of mice as a food source is expected to limit the presence of owls on Allen Cay, and subsequently reduce current levels of shearwater mortality attributed to owl predation. Observations of shearwater census plots and monitoring of banded individuals, indicating population changes and survivorship will provide a measure of these outcomes at Allen Cay. Allen Cay rock iguanas will be relocated to the cay after the operation has been confirmed successful and monitoring of the iguana population will continue.

BNT staff gained hands on exposure to eradication techniques and methodology during the project and this capacity will assist the organization to take on similar restoration projects within the Bahamas in the future. Several lessons were captured by BNT and Island Conservation during project planning and operational implementation. The following recommendations provided in this report draw on these lessons and suggest ways by which preparedness of field staff, organization of logistics, and institutional support for staff can be improved for future projects.

- Project staff should continue to partner with contracted experts until greater capacity is developed.
- Future eradication projects should include at least one day of orientation, briefing, and training prior to field deployment.
- Essential equipment should be budgeted for and purchased by future projects.
- Develop and enforce a biosecurity plan to protect Allen Cay and other restored islands in the Bahamas.

Ongoing monitoring will assess the benefits of the removal of mice at Allen Cay. A detection trip in May 2013 will determine the outcome of the operation. The development and implementation of biosecurity measures, both at Allen Cay and throughout the Bahamas, will reduce the threat of re-invasion by rodents and other invasive species.



1. INTRODUCTION

In May 2012, the Bahamas National Trust and Island Conservation undertook an operation to remove introduced House Mice on Allen Cay, Bahamas. The operation formed a key component of an ongoing restoration project aimed at recovering the endangered Allen Cay Rock Iguana (*Cyclura cyclura inornata*) and Audubon's shearwater (*Puffinus lherminieri*).

This report provides a brief overview of the site, the project and its objectives, and reports the results of monitoring efforts and progress towards realizing the project's anticipated outcomes. While monitoring to date has been able to verify the achievement of some of these outcomes, only preliminary conclusions are available about improvements to the environment and threatened species populations. Surveys will continue to monitor the progress of these outcomes. The report concludes with a discussion of the project, the outcomes and lessons learnt in undertaking an eradication operation in the Bahamas.

2. THE SITE

Allen Cay is located in the northern portion of the Exuma Islands, 60 km southeast of Nassau in the Bahamas. The cay is uninhabited but occasionally used by recreational boaters and academic researchers for wildlife observations and other unknown purposes. The Bahamas have a warm, humid, windy climate with little variation throughout the year, and are subject to tropical storms and hurricanes from June until November. The cay is home to a number of endemic species, one of which is the endangered Allen Cay Rock Iguana (*Cyclura cyclura inornata*). Only one invasive mammal was present on Allen Cay, the house mouse (*Mus musculus*). Mice attract barn owls (*Tyto alba*) to the cay, which in addition to hunting mice, prey upon Audubon's shearwaters as they return to nest at night.

Further details of the site can be found in the Feasibility Study Report (Alifano 2012b), and the Operational Plan (Alifano 2012a).

3. PROJECT OBJECTIVES

3.1. Goals

Two primary goals exist for the restoration of Allen Cay; increase the survival of Audubon’s shearwaters through the eradication of House mice and recover the Endangered (IUCN 2010) endemic Allen Cay’s iguana through the creation of breeding habitat on the cay. IC and BNT aimed to use the Allen Cay project to learn from conducting the operation and improve capacity within the Bahamas National Trust for future eradication projects.

3.2. Objectives, Outcomes and Indicators

The objectives of the project and its anticipated outcomes are:

Outcome	Indicator
Objective 1: Eradicate introduced House Mice (<i>Mus musculus</i>) from Allen Cay	
1.1 No population of mice on Allen Cay	Absence of mice
1.2 Increase population size and survivorship of Audubon’s Shearwater on Allen Cay	Past and future censuses of current shearwater population size
	Recapturing of banded shearwaters
	Non-breeding (juvenile) shearwaters return to the cay
	Decrease in the number of shearwater carcasses found
1.3 Decrease barn owl visitation to the cay	Decrease in the number of shearwater carcasses found
Objective 2: Make breeding habitat available for the endemic Allen Cay Rock Iguana	
2.1 Overall population of rock iguana on Allen Cay is increased.	New (untagged) iguanas are found
2.2 Breeding of rock iguana is observed	Juvenile iguanas are observed at Allen Cay
2.3 Survivorship of juvenile rock iguanas is improved.	Juvenile iguanas are observed at Allen Cay
Objective 3: Improve the capacity of BNT to undertake eradication projects	
3.1 BNT staff exposed to skills required to undertake further eradication projects.	BNT staff take a greater role in the planning and implementation of future projects.
3.2 BNT staff promotes and enforces biosecurity of restored sites.	Biosecurity plan developed and implemented for restored islands
	Development of a national biosecurity plan (long-term)
	Enforcement of national biosecurity plan (long-term)



Objectives 1 and 2 reflect the direct goal of improving the health of the native environment on Allen Cay by eradicating the mice population and preserving the critically endangered iguana species. The rationale for preserving the Allen Cay Rock Iguana reflects positively on Bahamian community values; it is an endangered species (IUCN 2010) protected by Bahamian law and in some places, an eco-tourism attraction that contributes to national revenue.

Objective 3 reflects Bahamas National Trust's long term strategy to continue to build in-house capacity to undertake restoration projects. Further information on the objectives of the project and monitoring details can be found in the Operational Plan (Alifano 2012a).

4. IMPLEMENTATION

The implementing agency was the Bahamas National Trust, whom also assumed responsibility for permitting, compliance, and biosecurity prevention measures. Dr Will Mackin assisted BNT with project planning and logistics and led shearwater monitoring efforts. Island Conservation provided technical expertise for the removal of mice and capacity building components of the operation.

4.1. Site Preparation

Food and human waste offer an alternative and potentially more palatable food source to rodent bait and this risk must be minimized during an eradication operation. To minimize this risk on Allen Cay all food stores in camp were secured in storage bins with locking lids. Personnel ensured that food scraps were properly disposed of in locked garbage containers rather than in the ocean where they might have washed ashore again. To eliminate the availability of human waste, it was secured in zip locked bags sealed inside five gallon buckets and regularly removed from the cay for disposal in a landfill.

Dense vegetation cover is prevalent across much of Allen Cay. To facilitate the hand spreading of bait and ensure that every mouse territory was targeted, transects were cut from east to west, spaced 10 m apart. Personnel used handheld Garmin™ GPS units to locate grid points every 10 m and navigate in a straight line across the cay. Working in four teams of two people, approximately 128 person hours were required to complete transects over the 6 ha island area. Within the two person teams, one team member cleared tracks using a machete and pruning saw, while the other navigated and marked each grid point with flagging tape. This work was accomplished within 2 days.



4.2. Eradication Components

Bait and rates

The bait application rate was selected based on the results of a feasibility study conducted at Allen Cay in December 2011 (Alifano 2012b). “Bait availability” is the time period within which mice have direct access to bait pellets broadcast on the ground. The feasibility study indicated that at an application rate of 20 kg/ha, bait would be available for at least 4 days. Bait consumption by non-target consumers such as land crabs is known to affect bait availability; however this risk was considered minimal because crab activity was extremely low in December.

Bait specifically manufactured for use in dry environments (Brodifacoum-25D Conservation) was packed in 25 lb buckets and shipped from Bell Labs in Madison, Wisconsin to the R/V Coral Reef II (Shedd Aquarium) in Miami, Florida. The active ingredient, brodifacoum, is represented at 25 ppm (0.0025%) in a 1.1 g pellet with an inert grain matrix.

Prior to implementation, the size of Allen Cay was estimated with satellite imagery and confirmed by walking the perimeter with a handheld GPS. We measured 6 ha of emergent land area, this value was used during the implementation and for reporting purposes.

Hand Broadcast

Seven personnel were trained in hand broadcast baiting techniques prior to the first application. The hand broadcast team applied bait at 20 kg/ha at each pre-determined baiting point for the first application. The time interval between the first and second bait application was 10 days. During the second application, bait was broadcast at a rate of 10 kg/ha in rocky habitats and 27 kg/ha in areas of vegetation.

The team took care to ensure that bait spread was uniform and there were no gaps between baited areas. To aid in the detection of gaps, each broadcast personnel carried a handheld GPS and created a waypoint at each distribution point. Upon the completion of an area, team members scrolled through the GPS for missing points. If any point were not entered on the GPS, personnel returned to that location and determined if bait had been spread. If untreated, bait was then applied to the area, and a waypoint created. The camp area was treated by hand broadcast as described above, however we intentionally avoided applying bait to the beach and footpaths to minimize the risk of personnel stepping on and crushing pellets. The first application was completed in approximately 8 hours with 7 personnel. The second application was completed in approximately 6 hours with 5 personnel.

Bait Availability

Bait availability over time was monitored by tracking the persistence of individual bait pellets. One person followed the hand broadcast team and installed 12 bait availability plots consisting of 1x10 m plots containing 18 pellets marked by pin flags. Extra pellets without flags were removed from the plot. Four plots were installed in each of three habitat types present on the island (Rocky, Short Vegetation, and Tall Vegetation), strategically dispersed across the cay. No significant difference in availability was found between vegetation types (thus hereafter is combined) however bait disappeared more quickly from areas with vegetation than rocky habitats (Table 1). Areas of vegetation comprised the majority of the cay (82%).

Table 1: Average kg/ha of bait remaining per day after the first bait broadcast, separated by habitat type. Habitat type depicts the percentage of Allen Cay’s area that each type comprised.

Habitat Type	Days After 1st Application				
	0	1	2	3	4
Vegetation (82%)	20	5.8	2	0.2	0.1
Rocky (17%)	20	10.8	8	5.5	3.6

Bait disappeared completely from one plot 24 hours after the initial broadcast. Three plots had no bait left two days after the first application. Bait uptake was higher than expected, thus the baiting strategy was adjusted for the second application. Two team members walked the entire cay and evaluated each 10x10 m bait plots for habitat type. When a plot consisted of at least ¼ rocky habitat, it was flagged with yellow tape indicating that it should be baited at 10 kg/ha. All other plots were baited at 27 kg/ha, allowing the team to increase the amount of bait distributed in areas where it disappeared fastest. Two days after the second application bait remained in all plots. The increased application rate successfully increased the amount of bait available in vegetated areas immediately after the second application (Table 2).

Table 2: Average kg/ha of bait remaining per day after each application of bait.

Application	Days After Application				
	0	1	2	3	4
First	20	7	4	2	1
Second	27	13	7	3	3



4.3. Non-Target Mitigation and Monitoring

Non-target Monitoring

To measure the impact to non-target species during the operation, directed and opportunistic carcass searches were conducted daily. To establish a baseline of carcasses present prior to the operation, personnel searched for carcasses while cutting transects across the cay, and found none (excluding shearwaters that were victims of owl predation). Twenty transects were randomly selected for directed carcass surveys and were monitored daily. Personnel also searched for carcasses opportunistically while traversing the cay for monitoring or hazing activities. On average, each person walked 2.6 km per day and spent 4 hours searching for carcasses. After 15 days of personnel working/living on the cay, a total of 336 person hours were spent monitoring across a distance of 273 km for carcasses. No mortality of non-target species was observed, suggesting the operation did not significantly impact the island's native species populations.

Gull Hazing

Laughing gulls were considered at risk of exposure from feeding directly on bait (primary) or feeding on contaminated prey (secondary) and mitigation efforts were planned. Efforts were made to harass the gulls and dissuade them from nesting and feeding on Allen Cay during the operation. Hazing efforts occurred before each application and between applications as required. Laughing Gulls nested in small scattered colonies across the cay making it hard to systematically disperse birds.

The most effective technique for discouraging the presence of gulls on the Cay appeared to be the destruction of nests and eggs. Approximately 15 breeding pairs were initially present on the cay, along with transient individuals. Fifteen gull nests containing 22 eggs were located and destroyed and the nesting material removed. Eggs were disposed of in the camp garbage to ensure they were not available to mice. The number of gulls seen on Allen Cay decreased to 4-5 individuals over a two week period and no new nests were observed to be constructed during this time.

Other methods were tested with varying degrees of success. Laughing Gulls, accustomed to daily tourist boats, were largely unaffected by human activity even in close proximity although gulls reacted aggressively when staff approached a nest site, which helped the team locate nests. Techniques such as air horn blasts, shearwater effigies, and lasers appeared ineffective at discouraging gulls from the area. A biosonic device (Foxpro) appeared to attract the gulls to the cay and its use was discontinued. Recorded animal distress calls attracted Laughing Gulls to the cay, with



up to 40 birds brought in at a time. The gulls habituated to the distress calls in approximately 5 minutes, and eventually lost interest. Efforts to catch or frighten gulls away with tall dip nets were also ineffective; the gulls returning to the area and settling down as soon as the team left.

Iguana Removal

John Iverson and a number of other individuals removed 18 of the 21 known iguanas on Allen Cay prior to implementation. Iguanas have been temporarily relocated to Flat Rock Reef Cay until the removal of mice is confirmed. The team spent 384 person hours searching the vegetation on Allen Cay, capturing iguanas, and implanting transmitters. The team also identified four large sinkholes at least 3 m in diameter with potential as iguana nesting sites. Three sinkholes were filled in with beach sand and vegetation was removed around a fourth to expose it to the sun. Other nesting sites will be constructed in the future. Following the return of the iguanas, these sites will be monitored for evidence of nesting (Iverson 2012).

5. LESSONS LEARNED and RECOMMENDATIONS

SKILLS AND CAPACITY BUILDING

Prior to this project BNT staff had limited experience in planning and executing a rodent eradication and some of the staff involved had not undertaken a multi-day expedition to a remote island. Consequently, coordination of logistics at times overwhelmed the capacity of the planners. BNT staff performed to a high level, demonstrated a strong desire to learn and participate, and the operation went well. However, dedication of more time and more staff to the planning phase would benefit future projects. The Lead Field Coordinator was at times hard-pressed because of other demands on her time. More staff trained and experienced in the planning aspects of eradication operations will enhance eradication operation planning and implementation capacity.

Recommendations:

- Project staff should continue to partner with contracted experts until greater capacity is developed.
- A BNT project manager with an appropriate amount of dedicated time available should be identified by BNT and assigned to manage future eradication projects.
- Key project documents produced by the implementing agency should continue to be reviewed by independent reviewers.



- As many as possible of the tasks that can be done ‘anytime’ should be carried out sooner rather than later, to avoid ‘bottlenecks’ at busy times of the project.

FIELD STAFF PREPARATION

In retrospect, Allen Cay was a considerable challenge, using hand broadcasting as a technique, across rugged terrain inundated with sharp rocks and sinkholes, and dense forest with coppice vegetation. Many of the staff involved had limited experience in this type of work and for some there was a learning curve throughout the first week as new techniques were introduced and practiced. Staff arrived to the field site with significantly different levels of understanding/knowledge of the project.

Recommendation:

- Staff should be fully informed of the scope of the project and the field conditions they will be exposed to prior to selection. Field team members should be selected carefully for various aspects such as fitness, willingness to work as part of a team, and demonstrated enthusiasm for the project. Less capable or enthusiastic team members create a risk of work not getting done properly with an associated increased risk of operational failure.
- Future eradication projects should include at least one day of orientation, briefing, and training prior to field deployment. This would allow project leads to communicate expectations and goals, and allow project staff to work with critical equipment in advance and develop an understanding of their role in the project.

MANAGING THE TEAM

Strong teamwork and professionalism occurred in the field, with team members operating as a group instead of individuals. Excellent camp management and supportive interactions among all personnel kept morale high despite environmental challenges. In hindsight, project leadership could have been better prepared for making project related decisions during implementation. Some team members were uncomfortable making decisions in the field without a directive from offsite points of contact who at times were unavailable. Continuous off island support by someone familiar with the project is critical for BNT to ensure that deviations from the project plan or field emergencies can be attended to.



Recommendation:

- Protocols for decision making should be discussed and agreed upon by the project partnership and field staff prior to implementation.
- Off-Island Point of Contacts must always be available while field staff are working in remote locations.

TRANSPORT AND LOGISTICS

Transport logistics to and from the cay were not as well defined as they could have been prior to the operation. This resulted in minor issues with arranging transport of staff and gear to the R/V Coral Reef II including getting advanced dock clearance for vehicles and finding vehicles capable of transporting equipment and supplies. It was sometimes unclear during the project how or when field staff were departing the cay. There was also a public holiday during the demobilization phase which complicated arrangements and could have been anticipated in advance. The responsibility for coordinating logistics may have been too great a workload for the staff involved who also had other responsibilities.

Replenishment of drinking water and removal of trash from the cay were at times unreliable, creating both safety and operational concerns. The field team accepted water donated from passing vessels, however it is risky for field teams to rely on these sources when working hard in hot humid climates. Some equipment proved inadequate for the conditions complicating components of the operation and posing a potential safety risk. Field camp conditions could be significantly enhanced by equipment that can withstand weather and the terrain.

Recommendation:

- Roles and responsibilities need to be clarified for all team members prior to project implementation.
- Project staff responsible for managing logistics should be allocated dedicated time to devote to these activities before the operation. Responsibility for coordinating project logistics can be delegated within a small team to ensure that plans and contracts are complete before operations begin.
- When relying on mission-critical supplies like drinking water, a paid contract may help to ensure consistency of delivery.
- Budgets for future eradication projects should include the costs of purchasing all essential equipment required for the operation and storage.



- Mission critical equipment must always be tested in the expected conditions prior to implementation.

BIOSECURITY

The development and implementation of biosecurity is essential to ensure that Allen Cay remains rodent-free. With the number of recreational boaters that visit the Exumas, reintroduction is a significant risk. Rodent prevention should be promoted to the general public. Development of biosecurity standards for future field operations should be put into practice to avoid transporting insects or seeds through the use of cardboard boxes or contaminated field/personal gear. Hands-on education is required to ensure the message of prevention is passed along to implementing agencies and applied to field projects.

Recommendations:

- Establish a sign at Allen Cay informing visitors of the pest free status of the island, the restoration work and its rationale.
- Develop and enforce a biosecurity plan to protect Allen Cay and other restored islands in the Bahamas.
- Implement internal and external biosecurity prevention awareness. Demonstrate the measures to be undertaken and develop protocols that implementing agencies can follow for future field projects.

6. CONCLUSION

Progress towards achieving the goal

The Allen Cay project was an enormously positive step towards the restoration of island ecosystems and endangered species in the Bahamas. With bait successfully applied twice to the entire cay, minimal (if any) non-target mortality, and a beneficial working relationship between BNT and Island Conservation, the foundation is laid to achieve the restoration of several Bahamian islands. The project team performed well on the current project. Planning and documentation was completed to a high quality and this process will be easier and improved for the next project now that the groundwork has been laid. The team made good use of the expertise within the partnership and the Bahamas National Trust have gained significant capacity in the planning and implementation of an eradication project.



Seasonality will continue to be an important element when planning eradications in the Bahamas. We found the rate of bait uptake to be different in May than in December, potentially due to increased crab activity, increased density of mice, or some other factor. Future eradications should aim to conduct field trials at the same time of year as implementation is planned to maximize the applicability of the information collected.

Steps toward project completion

Mice:

With the implementation of mouse eradication on Allen Cay now complete, an emphasis on monitoring and biosecurity is required to reduce the risk of re-invasion and document the beneficial impacts of the Allen Cay project. To determine the outcome of the eradication effort, BNT will coordinate a small team to return to Allen Cay in one year to confirm the absence of mice. Live traps, chewblocks, camera traps, and tracking tunnels are tools that will help indicate if mice are still present on the cay.

Shearwaters:

Dr. Will Mackin will continue to estimate and document the rate of shearwater mortality and assess the survival and recovery of the shearwater population on Allen Cay and other nearby cays.

Iguanas:

Dr. John Iverson will return to Allen Cay in May 2013. Assuming the successful removal of mice, his team will return the iguanas and continue long-term population monitoring on Leaf Cay, U Cay, and Flat Rock Reef Cay. Using samples collected over several years, he will collaborate with others to examine the genetic diversity on each of the various islands, genetic divergence distances among the various islands, and the relationship of the Allen Cays iguana (*C. c. inornata*) to the Exumas Iguana (*C. c. figginsi*).

7. ACKNOWLEDGMENTS

During all phases, the project received support from local businesses, friends, and NGOs without which the project could not have been completed. Among those who assisted were: the R/V Coral Reef II of the Shedd Aquarium, which helped by transporting large amounts of gear and workers to and from the island and altering their travel plans on multiple occasions to help us when we needed them; Powerboat Adventures, who provided essential support services including transportation to and from the island, storage of gear and equipment, replenishment of fresh water, and provision of



ice; Biodiversity Research Institute of Gorham, ME contributed the services of raptor specialist Rick Gray, who tirelessly worked on the December trip to assist with the project and lead owl trapping operations; Highbourne Cay Marina and Resort, who, in December 2011, allowed us to trap for owls on the northern reserve at Highbourne Cay, including the use of a golf cart; Stefan Paton of Norman's Cay Beach Club, who arranged a rescue for our broken down boat and provided a dry place to sleep when we had engine trouble on our way from Exuma Park to Allen Cay on May 12; The Pirate's Lady, a sailing vessel operated by Blackbeard's tours, who provided a ride to Nassau for 2 of us who needed to be off the island but had no other way of catching a flight, and Roscoe Burrows, who provided transport services in Nassau on multiple occasions.

8. REFERENCES

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Appendix 1: Post Implementation Efficacy Monitoring

Background:

In May of 2012, the Bahamas National Trust together with Island Conservation treated Allen Cay, Exuma Islands, Bahamas with rodenticide to remove introduced house mice (*Mus musculus*). The eradication involved a ground broadcast of bait containing the second generation anticoagulant brodifacoum at a concentration of 25 ppm (Brodifacoum 25W Conservation Bait manufactured by Bell Labs, Madison WI). During the operation the field team assessed efficacy by obtaining evidence that mice were consuming bait and succumbing to the effects of brodifacoum. One year after the eradication, a monitoring team will return to Allen Cay and establish mouse detection stations. During this monitoring effort 100 live traps, chew indicators, and tracking tunnels will comprise the detection stations, using the grid that was established during the eradication. Stations will be monitored every day for 12 days. It's likely that only one detection trip will be required.

Methods:

At least three personnel will return to Allen Cay to install and maintain the detection stations. Each station will include a corrugated plastic indicator block, a tracking tunnel, and a live mouse trap. Indicator blocks will be filled with peanut butter flavored attractant and nailed to a tree or staked into a rock fissure. Tracking tunnels are made from 30 cm sections of 3" PVC secured off the ground to avoid interference from land crabs. A strip of paper with a felt pad across the middle will be placed inside the PVC tube; ink will be mixed with peanut oil and worked into the felt while shredded coconut or dabs of peanut butter are placed on top. One Sherman mouse trap with peanut butter on a small piece of cracker for bait will be placed at each station. The monitoring team will search for rodent sign (droppings and chews) as well as live mice. Camera traps would add power to the detection efforts, if available.

Staff and Equipment:

The monitoring team should be comprised of at least two people with experience trapping and detecting rodents. Trap placement and sensitivity is important, and distinguishing mouse incisor marks from crab pinches on the plastic detection blocks could be difficult to the untrained eye. The expertise of one field team member from Island Conservation would be advantageous to the detection team and would support and supplement the training BNT staff has already undertaken. Supplies and equipment to support a small field camp, traps and detection supplies, field staff salary, and transportation to and from the cay are included in a preliminary budget provided to BNT.



Funding:

The monitoring effort is currently without funding, but is critical to determine the effectiveness of the eradication. The detection work could be paired with other academic efforts to monitor and evaluate the status of the island's Audubon's Shearwater (*Puffinus lherminieri*) population and assess whether or not mouse removal deters barn owls from frequenting the island.