Restoration of Allen Cay for Audubon's Shearwaters and Allen Cays Rock Iguanas

Final Report to the Bahamas National Trust, The Bahamas Environment, Science, and Technology Commission, and the National Fish and Wildlife Foundation

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Summary

Since the 1990s, naturalists have reported hundreds of dead Audubon's Shearwaters (*Puffinus lherminieri*) at Allen Cay, a 6.5 ha island at the northern end of the Exuma Cays. In 2003, it was discovered that House Mice (*Mus musculus*) were present on the island and that Barn Owls (*Tyto alba*), a species that eats primarily mice and rats, were responsible for the large numbers of dead shearwaters found each year. While it is common for shearwaters to be killed on their breeding colonies, the death rate at Allen Cay was twice that at other colonies and the population was in serious decline with many former breeding sites empty by 2007. In 2011, The Bahamas National Trust received a grant from the Recovered Oil Fund administered by the National Fish and Wildlife Foundation. The goal of this grant was to remove mice from Allen Cay and to disrupt nesting activities by Barn Owls near the island so that shearwaters would recover. In addition, endangered Allen Cays Rock Iguanas (*Cyclura cychlura inornata*) were removed to a safe location during the removal of mice and nesting areas for the iguanas were constructed by filling several sinkholes with sand. The measures of success for the project were to completely remove invasive mice from the ecosystem, to reduce the rate of death for shearwaters to levels similar to those on other colonies, and to create a reproducing population of Iguanas. The mice were removed in May 2012 by application of a rodenticide containing brodifcaoum, a coumerin-based second-generation anticoagulant. An owl roost on a nearby island was intentionally disrupted and one bird was captured and banded, but owls were abundant and seen on most nights during the 2012 fieldwork. In 2013, no evidence of mice was found after 8 days of searching, and the daily death rate of shearwaters from 2012-2013 was approximately 40% of that found in 2011-2012. A different owl was captured, banded, and released at Barn Owl Cay in the same roost as in 2013 and no owls were seen at Allen Cay during the 2013 study. Thus, our study indicates that mice were successfully removed and there

was an immediate and dramatic effect on shearwaters. We met or exceeded most of the metrics for the project, including removing the mice, creating breeding habitat for iguanas, and sharply dropping the death rate for shearwaters.

Introduction

Allen Cay is a small island near the northern tip of the Exuma Cays in the Bahamas. It supports a large colony of Audubon's Shearwaters that declined between the late 1990s and today. Each year, hundreds of shearwaters were found dead, frequently in groups of 6-8 birds. Investigations in 2003, 2005, and 2007 found Barn Owl feathers mixed in with the dead shearwaters and that mice *(Mus musculus)* had somehow been introduced to the island. In most parts of their range, Barn Owls consume rats and mice almost exclusively. In the present case, the owls were killing many birds but were not eating most if not all of the flesh. This phenomenon has occurred in other seabird colonies around the world including Reunion, Hawaii, and Farallon Islands, and it has been called 'hyperpredation' in that introduced species (here: rodents on Allen Cay and nearby islands) subsidize the predators during periods of low resources such that native species suffer much higher levels of predation than they would otherwise (Russell and Le Corre 2009). While shearwaters are killed by Barn Owls at other islands, studies in 2007 showed that the death rate of shearwaters at Allen Cay was twice that at a similarly dense colony of shearwaters 30 km to the south (Long Cay). The best explanation for the declines at Allen Cay was that mice were attracting owls and leading to the high death rate of shearwaters. Thus, removing the mice was a goal after 2007. When there was a call for proposals by the National Fish and Wildlife Foundation to mitigate the deaths of Audubon's Shearwaters from the 2010 *Deepwater Horizon* oil spill, the Bahamas National Trust proposed this project to restore Allen Cay by removing mice and enhancing habitat for endangered Iguanas. The primary activities of this project were (1) to eradicate invasive mice from Allen Cay without harming native iguanas or other wildlife, (2) to disrupt nesting and roosting sites for Barn Owls that kill hundreds of Audubon's Shearwaters (*Puffinus lherminieri*) every year, (3) to create appropriate nesting

habitat for iguanas when they are re-released on the cay, (4) to monitor the current and future status of the shearwaters with a system of circular plots installed across the island, and (5) to train staff of the Bahamas National Trust in techniques for eradicating invasive mammals to facilitate the restoration of other islands in the Archipelago.

Both shearwaters and iguanas are target species for conservation efforts within the bird and reptile conservation communities, respectively. Audubon's Shearwater has been extirpated from most of its former breeding range in the Caribbean region, and The Society for the Conservation and Study of Caribbean Birds (SCSCB) has worked since the early 1990s to halt this decline. About 10,000 breeding pairs are known to remain, with most of those in the remote, unsettled Cay Sal Bank of The Bahamas. The Iguana Specialists Group of IUCN has been working to create more breeding populations of *Cyclura cychlura inornata*, which is an endemic subspecies to the Allen Cays but is also endangered as a species.

The Bahamas National Trust received funding to conduct this project in 2011 and contracted with William Mackin, John Iverson, and Island Conservation of Santa Cruz, California for assistance. In December 2011, we conducted a pre-restoration visit to test out the procedures for removing the mice on the island and to train a team to perform the removal. In May of 2012, we removed the mice by spreading rodenticide, and we estimated the number of shearwaters breeding in the colony using circular plots. Here we describe the results of the project including our final visit in 2013 where we confirmed that mice are no longer on the cay, surveyed half of our survey plots, and again counted all dead birds on the island.

Eradicating invasive mice

Mice are smaller and less likely to directly prey on native wildlife than rats. However, mice can kill and eat even adult albatrosses, and they are a favorite prey item for Barn Owls. This owl has been implicated in extremely high levels of predation on seabirds at islands in California, Peru, the Seychelles, and, in this case, the Bahamas (see Mackin 2007). Mice are known to be more difficult to eradicate from

islands than are rats because they have much smaller home ranges and higher population densities, which increases the probability that a small number will survive eradication attempts. Techniques for eradicating mice have improved dramatically in the last decade, and Island Conservation is a leading group in this important field of conservation biology.

The removal of mice was conducted by two experts from Island Conservation, a seabird biologist who had studied Audubon's Shearwaters at Allen Cay, and a team of four staff-people from the Bahamas National Trust. The team applied rodenticide across the entire 6.5 ha cay by hand-broadcast on May 16 and May 27, 2013. A second broadcast increases the likelihood that all mice are exposed to and ingesta lethal amount of brodifcaoum. In 2011, trial applications with non-toxic bait demonstrated that two applications of 20 kg per ha Brodifacoum-25D Conservation (manufactured by Bell Labs Inc., Madison, Wisconsin) would provide sufficient bait to overcome consumption by crabs and expose all mice to a lethal dose. This toxicant is a delayed-action anticoagulant that rodents are known to consume. It is a vertebrate toxicant that acts by interfering with the blood's ability to form clots, causing sites of even minor tissue damage to bleed continuously. Brodifacoum is the primary rodenticide used in rodent eradications on islands. Soldier crabs (*Coenobita clypeatus*) have a different circulatory system, are not harmed by brodicafoum, and help to break down the toxicant by passing the bait through their digestive tracts. To effectively eradicate the population of mice from Allen Cay, sufficient rodenticide was applied to satiate land crabs and still expose every mouse.

We found that mice at Allen Cay were surprisingly difficult to trap. Only 7 were captured in 12 days of work in December 2011 and 3 were found in 2012. In 2013, we set out 30 baited tracking tunnels and 30 baited Sherman live traps spread across Allen Cay but detected no signs of mice after 8 days of fieldwork (see Table 1). If any mice survived the application of rodenticide from 2012, they

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should have repopulated the colony to detectable levels by a year later.[1] The ecological reasons for the detection difficulty are not clear, but it could be related to low density of mice from either restricted food or high predation levels by predators such as owls, snakes, andcrabs at the colony. Table 1. A comparison of trap-based and tracking tunnel based detection of mice at Allen Cay, from pre-eradication baseline results from 2011 and one year efficacy assessment after the eradication in 2013.

Events	Stations (n)	Detection devices	Detection nights	Mice detection (%)
2011 Field Trial	30	Live Traps	150	4.6
2013 Efficacy	30	Live Traps	150	0
Assessment	30	Tracking Tunnels	150	0

Protecting Iguanas and birds from ingesting toxic bait

The island was carefully prepared for the restoration by removing 17 of the 20 iguanas (all that could be caught) and discouraging the presence of Laughing Gulls that might be exposed to the rodenticide. The removal of iguanas from the cay was undertaken by John Iverson and volunteers from Earlham College to ensure that these endangered reptiles were not exposed to the toxicant. Three iguanas were so skittish that they could not be caught. However, our team decided to proceed with the removal of mice given that the iguanas were unlikely to eat the bait, the bulk of the population had been moved, and, if the worst case occurred, individuals from a nearby population with identical genetic structure (Leaf Cay) could be introduced to found a new population on an island free of invasive species and therefore more suitable for iguana reproduction and growth.

The 17 captured iguanas were moved to Flat Rock Reef Cay, a 4.9 ha island that is 1 km northeast of Allen Cay. Each adult iguana that was moved was implanted with a radio transmitter so that

[1] One female mouse produces 10-12 pups every 50 days. If one female survived the eradication and produced 10 pups every 50 days, the population would be 1*5^(365/50) = 126,613 female mice after one year. Thus, in theory, the population should be easily detectable after only one year if any survived.

it could be relocated. Flat Rock Reef Cay already had a small population of iguanas before 2012, so that any individuals that could not be relocated should have been able to establish themselves on that island.

A total of five iguanas from Allen Cay were found in 2013 on Flat Rock Reef Cay. Dr. Iverson and his team were only able to spend part of one day on the island because the weather in May 2013 was rough and prevented access. Of the five animals found by radio transmitter in 2013, two were showing signs of nutritional stress and three were deceased. The two iguanas were given intravenous saline solution by the team's veterinarian to rehydrate them and released in prime habitat near their sites of first capture at Allen Cay. The Iguanas that suffered mortality on Flat Rock Reef Cay were large individuals from Allen Cay. Such individuals have greater nutritional demands and may have had a challenge adjusting to the new island, despite its similar habitat. The iguanas that could not be relocated in 2013 included many smaller individuals (without transmitters) that are less susceptible to starvation and more able to hide deep within the rocks where their transmitters will not send a proper signal. We suspect that the mortality observed, though disappointing, was not indicative of the mortality rate in the population. Instead, it appears that we lost 3 larger individuals while the other 12 are presumed alive and evading detection. More searches and reintroductions will occur in 2014 and beyond whenever iguanas that were removed from Allen Cay are found at Flat Rock Reef Cay.

With regards to the iguanas that were not removed from Allen Cay before the removal of mice, iguana scat was found during May 2013 at multiple locations on Allen Cay from times prior to the reintroduction of animals from Flat Rock Reef Cay. The spacing of the scat in areas near the known hiding crevices of the three uncaught iguanas indicate that the animals were not harmed during the operation.

Of the birds that could have been subject to non-target mortality in the removal of mice, we focused on 4 species that inhabit the area and may come into contact with the bait: Clapper Rails (*Rallus longirostrus*), Yellow-crowned Night-Herons (*Nictanassa violocea*), American Oystercatchers (*Haematopus palliatus*), and Bahama Mockingbirds (*Mimus gundlachi*). During the preliminary testing of non-toxic bait in 2011, we examined the droppings of birds on the cay to assess whether they contained

the fluorescent dye. Searching was done by UV-flashlight moving through the baited areas at night. Feces of animals that consumed the bait fluoresce in the light. As we expected, the dye was very common in feces of soldier crabs. We found trace amounts of the dye in one fecal pellet from an unidentified small bird, and one Bahama Mockingbird was observed manipulating but not consuming one of the test bait pellets during the day. We found little evidence of consumption of the bait by non-target wildlife, and we were confident that there would be no negative, long-term effects on the animal community at Allen Cay from the operation.

During the removal, we destroyed 15 Laughing Gull nests encountered on Allen Cay by removing the eggs and nesting material, and we harassed roosting Laughing Gulls during the night with laser pointers and air horns. This activity scared the birds away, and they left the island before the application of rodenticide occurred.

We found no evidence for any non-target mortality among birds during our trial. In 2013, we removed 107 decayed or decaying carcasses of Audubon's Shearwaters along with a single Bahama Mockingbird and a single Yellow-crowned Night Heron skeleton which had accumulated over the preceding 12 months. This mortality was most likely natural, similar to levels expected on any island in the Exuma Cays, and well below rates found before the eradication (see below).

To summarize, we feel confident that we removed mice from the island while protecting non-target species from major mortality. We were disappointed that three iguanas did not survive the operation, but we knew in advance that it could be stressful to move them. We had decided it was worth the risk to individual iguanas for the gains in ecological health at the island. In future removals of invasive species, it might be better to hold iguanas in captivity during the eradication and then release them once the rodenticide has left the ecosystem. On the other hand, there is no guarantee that the iguanas would have survived the stress of captivity and we still feel that the population of iguanas is going to be better off as it expands with the new breeding habitat in an ecosystem free from invasive mice. The Allen

Cay population of iguanas is genetically identical to the Leaf Cay population.[2] If the individuals on Flat Rock Reef Cay cannot be recaptured in 2014, John Iverson and the Bahamas National Trust plan to restock Allen Cay with a carefully selected group of iguanas from Leaf Cay in the next few years to speed the development of a large, healthy breeding population at Allen Cay. In addition, the newly created nesting habitat will be monitored annually to gauge reproductive success of the population.

Disrupting nesting and roosting sites for Barn Owls

During the 2011 expedition, we were granted the services of raptor specialist Rick Gray from Biodiversity Research Institute in Gorham, Maine. Dr. Mackin and Rick Gray spent 6 nights (Dec. 5-10) on Allen Cay using mist nets and playbacks of owl and rodent vocalizations to attempt to capture owls. No Barn Owls were detected. On December 11, we asked for and were granted permission to trap Barn Owls at night on Highbourne Cay. This island has rats, mice, and humans and is two km south of Allen Cay. The staff at Highbourne Cay assisted our efforts by loaning us a golf cart to search the open, north end of the island where they reported seeing three different species of Owls – Barn Owls, Short-eared Owls (*Asio flammeus*), and Burrowing Owls (*Athene cunicularia*). We trapped 4 black rats (*Rattus rattus*) at the Island's repository for waste material. During the night of December 11-12, we used mist nets, bal-chatri traps baited with the rats, and playback of rodent and owl vocalizations to try to capture owls. We observed multiple Barn Owls including two that repeatedly swooped on our bal-chatri traps and a third that approached the mist net at the north end of the island, but we did not capture any and that was our final night in the Exumas. It seems clear that the owls spend a great deal of time near sources of rodents during the winter, as the inhabitants at Highbourne Cay reported seeing them regularly.

On December 8, 2011, we visited "Barn Owl Cay," an island 2 km north of Allen Cay that was named for nesting Barn Owls that were discovered in a crevice on the south end of the island by John

[2] It appears that the iguanas at Allen Cay were probably originally large, aggressive individuals at Leaf Cay. We suspect people moved them to Allen Cay because they were being aggressive towards people who were trying to feed the iguanas on the beach at Leaf Cay.

Iverson and his team of iguana biologists. We scoured Barn Owl Cay in the area where Dr. Iverson reported a nesting pair of owls years earlier, and we set 10 baited Sherman rodent traps for two days. We found no evidence of rats, mice, or Barn Owls on the southern 7/8 of the island and did not search the north end. In one particularly nice sinkhole near the middle of the island, we installed a motion-activated camera, but it did not detect any owls or other wildlife in the crevice between December 2011 and May 2012.

In May 2012, all effort in the early part of the trip focused on conducting the removal of mice. After the first application of bait, we set about our other objectives including work on owls and surveys for shearwaters (see below). In contrast to December 2011 where no owls were observed at Allen Cay, we heard or observed Barn Owls nightly in the colony during May 2012 and found 177 dead shearwaters in various stages of decay (see below). These birds were all newly dead between December 2011, when we removed all skeletons of dead birds from the island, and the May 2012 trip. Owls were actively hunting in the colony each night of our May 2012 trip and freshly dead birds were found on most days during our baiting operation.

No owls were found roosting at Allen Cay during the day in May 2012 despite visiting every square meter to apply bait, so we searched for them on other islands where good roosting spots might be found. Dr. Iverson's team did not observe owls at either of the islands next to Allen Cay (Leaf Cay and Southwest Allen Cay) where their iguana research is focused. On May 22, 2012, we visited Barn Owl Cay again during the day to look for owls. After searching the entire southern part of the island and estimating over 100 breeding pairs of Laughing gulls, we crossed a tidally exposed causeway to the northern 1/8 portion of the island. On this northern tip, the island has multiple large caves. Inside of the most impressive cave was a pair of Barn Owls. One escaped and flew north to Ship Channel Cay, a large island that is the home base for our partner in the project, Powerboat Adventures. We captured and banded the

other owl, a female.[3] We released the owl and filled the two potential nesting chambers in that cave with rocks so that owls would not be able to nest. The two other large caves on the north end of Barn Owl Cay did not have good nesting chambers and no other owls were found.

On May 26, 2013, we returned to Barn Owl Cay and searched for owls. In the same cave at the north end, a single female owl was captured, banded, and released. The owl moved to a second cave upon its release and later flushed from that site north towards Ship Channel Cay. This owl was the only one found despite searching all available caves with a team of 15 students and researchers from the R/V Coral Reef II. We will continue to revisit this area and caves on other islands in the area. Very little is known about the movements of owls in the Bahamas, and it would be exciting to use satellite tags or radio transmitters to follow their movements between seabird colonies and islands inhabited by people and commensal rodents.

Nesting habitat for Iguanas

Allen Cays Rock Iguanas dig nests in the sand or in old termite mounds and lay 1 to 10 eggs per attempt, a number which increases with the size and age of the female. The bulk of the population lives on Southwest Allen Cay and Leaf Cay, both of which have good sandy habitat with plenty of space for nesting. Allen Cay is separated from those cays by 100 to 200 m of water. Either by swimming or being moved by people, about 20 iguanas had made their way from these two breeding populations to Allen Cay. Allen Cay is much rockier than Southwest Allen Cay and Leaf Cay. It is long and thin in shape and has very few trees and no sandy areas above the high tide line where a female iguana could nest. By filling natural cavities on Allen Cay with sand, John Iverson and his volunteers created three ideal breeding sites at sites in the south, middle, and north ends of Allen Cay. Allen Cay is the fifth potential breeding cay for this subspecies with the potential of supporting as many as 1000 iguanas. Dr. Iverson

[3] These two owls were likely a pair although no chicks or eggs were discovered. Male Barn Owls are lighter in coloration. The owl that escaped was much lighter in coloration and the captured bird (see attached photo) was likely a female.

will maintain the breeding sites over the coming years and monitor the growth and reproduction of this population.

Monitoring the recovery of Audubon's Shearwaters

Audubon's Shearwaters are difficult to census because they are nocturnal and nest in crevices that are often not noticeable during diurnal searches. At Allen Cay, evidence for the population's decline included a decrease in the vocal activity at night and the fact that several nesting areas on the cay that were occupied in 2000 were empty by 2005 and had not recovered by 2012. Most nests that remained were on the windward (east) side of the cay near the water, whereas areas where large numbers of dead birds were found were on the leeward half of the island and had many nice nesting cavities nearby that were unfilled.

In this study we used three separate metrics to analyze the effects of removing mice on the shearwater populations. We have set up a series of 32 plots that can be monitored repeatedly to look for changes in the numbers of defended nests and numbers of chicks found in the plots. Second, we began a mark-recapture study of all birds within the area surrounding the landing beach that should provide an estimate of the survival and turnover within the population in this most accessible area of the colony. Finally, we counted all the dead birds found to measure the amount of predation.

It appears that owls kill shearwaters that are on the ground in windless areas. These shearwaters are helpless because they need strong winds or high places in order to achieve flight.[4] Shearwaters will frequently call on the surface on dark nights, but Barn Owls are capable of killing mice in absolute darkness only by honing in on their vocalizations. Shearwaters in wind gaps on the leeward side of the island would be very vulnerable because they cannot take off and there is little background noise to mask their position from the owls. In contrast, birds on the windward side of the cay almost always have a

[4] Shearwater wings are long and thin, an adaptation for long-distance flight at sea. They cannot create lift at low speed, however, a fact that likely leads to their nocturnal, crevice nesting habits. They are vulnerable to aerial predators whenever they are on land.

strong 10 to 15 knot air current that provides auditory cover that would disrupt an owl that was trying to hunt by sound. In addition, birds in windy areas have the ability to take off quickly and are not often funneled into low, dangerous areas. Whatever the explanation, it is clear that the largest numbers of dead birds were occurring on the leeward side of the island in pockets of particularly low wind. In such areas, we frequently found up to 10 dead birds with Barn Owl feathers molted near the dead shearwaters.

Because shearwater nests are very difficult to count and there is no monitoring program for them, we lacked good data on the population size. Our best estimate was 300 to 600 nests (a density of about 50-100 defended nests / ha). Our goal in this study was to allow the island to recover to its potential size of 600-1200 nests (~100 and 200 pairs / ha). In order to document the effects of the study, we established a grid of 32 circular census plots in which all nests were counted. This grid was established in May 2012 and partially censused again in 2013. Audubon's Shearwaters lay a single egg per year and begin breeding at 4-6 years of age. Thus, we expect a lag in the recovery of the population by about 4 years, but defense of nests by new breeders could increase more quickly in that these prospecting birds are the most vulnerable to owls and the most likely to benefit from reduced predation.

In 2012, the array of 32 plots was established by selecting random points on a grid and searched at night for birds. During searches, playbacks of shearwater calls (a looped tape including calls by a male, then a female, and then a duet) were used to elicit responses from birds within their nests. In 2013, 14 of the plots were relocated and searched again, and three of those plots were searched on two different nights. The marker for one of the plots could not be relocated in 2013 and a replacement plot was established at the plot center as specified by the GPS location. The plots were circular in shape with a radius of 7 meters and an area of 153.9 m^2. The plots provide an average density of defended nests for the island and, when multiplied by the area of the island and adjusted for pairs that were missed, they provide an estimate of the number of breeding pairs. The counts are distributed by the Poisson distribution with a conservative estimate of the confidence interval equal to the mean number of birds per plot ± 1.96 * √(mean/n) where n = the number of plots. In 2012, there were 86 defended nests in 32 plots with an average of 2.7 pairs per plot (95% CI = 2.1-3.3 pairs / plot). In 2013, there were 51 pairs in 15 plots with

an average of 3.4 pairs per plot (95% CI = 2.5-4.3 pairs / plot). These estimates of density can be applied to the whole island by adjusting for missed detections (dividing by the detection rate from previous studies of 0.8), multiplying by the island area (63,000 m^2) and dividing by the area of each plot (153.9 m^2). For 2012, the 95% confidence interval is 1084-1665 defended nests. For 2013, the 95% confidence interval is 1210-2128 defended nests. The two estimates overlap and both are much higher than previously was thought (300-600 pairs).

We also surveyed 6 shearwater plots at Barn Owl Cay, where we found habitat that was more exposed to the open ocean and contained fewer potential nesting cavities, but we detected some shearwater chicks during the day and knew the birds were nesting on the island. In those 6 plots, 5 defended nests were detected, indicating a density of 0.83 defended nests per plot (95% CI = 0.1 – 1.6) and a range of 193-1200 breeding pairs when adjusted for the 107,000 m^2 area of the island. Although the density of shearwaters is low at Barn Owl Cay compared to Allen Cay and other shearwater colonies, the large size of the island makes it the seventh-largest known populations of Audubon's Shearwaters in the Caribbean.

Counting quantities of dead shearwaters

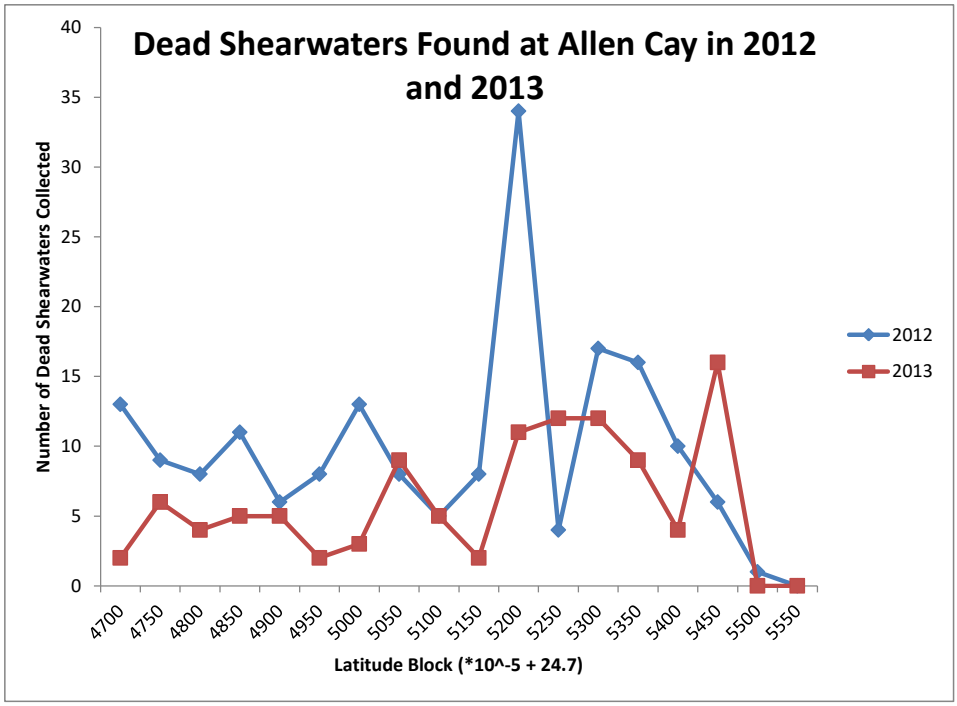
We collected and removed all dead shearwaters on Allen Cay during each visit. We also marked the location of each dead bird by GPS. The only natural predators of shearwaters at the site are Barn Owls and wintering Peregrine Falcons (*Falco peregrinus*), but we have not found high numbers of shearwaters killed by the diurnal falcons despite years of research, and they leave the Bahamas before the peak of shearwater breeding activity. The counts of dead shearwaters provide the simplest, most immediate measure of the success and usefulness of the project.

In May 2013, we found a dramatic decrease in the numbers of dead shearwaters and observed no owls at Allen Cay. Whereas we found 177 dead shearwaters between December 2011 and May 2012, we found only 107 dead shearwaters between May 2012 and May 2013. Even adjusting for times when no shearwaters are present in the colony (August-November), the daily death rate of shearwaters dropped

from 1.16 dead per day (177 in 152 days) to 0.45 dead per day (107 in 237 days). The numbers decreased across all areas of the island from north to south except for one location near the north end of Allen Cay where a large group of dead shearwaters was found, indicating that perhaps an individual owl was hunting regularly at that specific location (See Figure 1).

This decrease in dead birds exceeded our expectations, but it was only a single year of data. We hope this lower death rate will persist in the future, and we are unsure to what extent it resulted from our removal of mice, the disruption of owl roosts, or other factors outside our control. These results are promising, and it may be possible to use disruptive management techniques to dissuade owls from spending time around other seabird colonies.

Figure 1. ***Dead Shearwaters Collected at Allen Cay in 2012 and 2013. Note that all areas of island showed decreased dead except one location at the northern tip where it appears that a single owl may have been using a particular depressed area as a hunting location. Of the 18 latitudinal blocks, 14 showed a decrease, 1 stayed the same, and 3 showed an increase between 2012 and 2013. In addition, the dead from 2012 accrued between December and May while the dead for 2013 accrued between June and May.***



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Training of staff of the Bahamas National Trust to conduct eradications and monitor seabirds

There are thousands of islands in the Bahamas Archipelago, including many protected sites in national parks, where invasive mammals threaten native plants and animals. Eradications are one of the most cost-effective conservation tools available, and several have thus far been conducted in the Bahamas. In this project, six full-time employees of the Bahamas National Trust conducted the study

along with two experts from Island Conservation, an ornithologist, and a team of herpetologists. The BNT staff was trained in preparing, conducting, and assessing the success of the eradication and in censusing seabird populations. It was a primary goal to build the capacity of the Bahamas National Trust to take the lead in future eradications that can benefit seabirds, iguanas, and other wildlife around the Bahamas. We now have a number of experienced field researchers prepared to participate in eradications. Our organization is now planning to conduct more eradications in the Bahamas in partnership with Island Conservation, and we are well into the planning stages of our next operation at an iguana breeding island near Mayaguana.

Tracking Metrics: Indicate how the project will monitor/assess progress on the metrics selected previously in the application. Please note any challenges or limitations anticipated with tracking the metrics. Please provide an implementation timeline that includes primary activities and project milestones toward achievement of project outcomes.

Summary of Metrics of Success for the Allen Cay Restoration

In our original grant application, we were asked to specify progress measures and metrics. Above, we described the detailed results. Here, we list the outcomes thus far given one year of data post-operation. Our primary goal was to successfully remove mice from Allen Cay. Led by the expert work of Island Conservation, the team carefully applied rodenticide the island twice in May 2012 with Conservation 25-D pellets specifically formulated for rodents. On tropical islands, rodents can reproduce throughout the year and repopulate an island within a short time period compared to temperate islands. Rodent populations that experience year-round reproduction will reappear at detectable levels within 12 months of an unsuccessful eradication attempt; therefore, the project partnership was confident that the project outcome could be determined one year after the eradication attempt. To increase the probability of detecting house mice at Allen Cay, especially if at low density, best practices of island surveillance were used. In 2013, we monitored the island for 8 days using trap cameras baited with bread crumbs, tracking

tunnels baited with peanut butter, and Sherman traps baited with peanut butter crackers. With 150 trap nights and 150 tracking tunnel detection nights, mice were not observed and no other evidence of mice presence was found.

The successful removal of mice requires further effort from the project partnership to ensure that the cay remains restored. The threat of incursions by invasive species and anthropogenic habitat disruption is a constant risk but is especially risky at Allen Cay. The Allen Cays are uninhabited but visited frequently by tourism operators, researchers, and private vessels. The harbor formed between the Allen Cays is very important to the boating community, which has a huge impact on the culture and economy of The Bahamas. Careful consideration and inclusion of all stakeholders and constituents must be prioritized during strategy development to increase public awareness of the need for local and national biosecurity.

John Iverson and his team including a veterinarian and experienced iguana biologists from Earlham College moved 17 iguanas from Allen Cay to Flat Rock Reef Cay. Three iguanas were left on Allen Cay but survived the baiting for mice and remain on the island. Of the 17 iguanas moved, 2 have been returned, 3 did not survive the year at Flat Rock Reef Cay, and 12 have not been recaptured yet and will be moved back when they are caught. With respect to this metric, we were disappointed that any iguanas did not survive, but we are confident that the addition of breeding sites at Allen Cay will lead to a healthy, vibrant breeding population of iguanas, with breeding likely to begin in 2014 among the 5 individuals living on the cay right now and to increase as the others are reintroduced. Our original goal was to move 20 iguanas temporarily to another island and return them. At this point, we have successfully moved 17 initially and only 2 have been returned. The bulk of the individuals will hopefully be returned to Allen Cay in 2014. There is a possibility that several more individuals might not survive the relocation process, but the level of mortality has not been much greater than would be expected naturally had we not conducted the operation. Furthermore, now the animals can nest on Allen Cay and create a fifth breeding population of the subspecies. Thus, we feel that the population has benefitted from our intervention.

Our third metric was to precisely measure the number of shearwaters breeding on Allen Cay. Our surveys indicate that the population was much larger than we thought, despite the high predation levels.

Prior to this study, our best estimate was that 300-600 nests were defended on Allen Cay, but our 2012 data indicate that 1084-1665 nests were defended. We measure shearwater populations in terms of defended nests because it is very difficult in a nocturnal survey to identify the breeding status of a nest. We did not see a significant change from 2012 to 2013 (although the trend was higher), as you would expect for a seabird that takes 4 years to begin nesting. There could be a change in the number of chicks per detected nest if more birds survived to breed in 2013. In 2012, we identified 86 nests with 19 chicks in our 32 plots. In 2013, we identified 51 nests with 11 chicks in our 15 plots. Thus, we had a similar ratio of chicks to nests defended (0.22 chicks per defended nest in 2012 and 2013) with a slight uptick in the number of chicks detected per plot (0.59 chicks per plot in 2012; 0.73 chicks per plot in 2013). The 2013 season was the first season that the shearwaters were released from owls, so we might expect an increase in nesting activity in 2014. It would be unwise to make bold assertions based on one year of data. The important point is that now we have quantified the baseline nesting activity and we can monitor these metrics over the coming years to get a strong gauge of the effectiveness of our actions. Our original goal was to bring the population to 1200 pairs from 300 pairs. We should revise this goal to increase the population from 1084-1665 defended nests to a level of 1900 or more defended nests. In one year, the minimum population estimate increased by about 100 defended nests to 1200-2100. More importantly, we should focus on the number of chicks produced within the colony, which is a more direct estimate of how successful the breeding colony is. Our population monitoring data using mark and recapture techniques should indicate whether or not the population is increasing because we can use the Robust Design analysis technique to measure growth.

With respect to our fourth and fifth objectives, counting all the dead birds on the island and discouraging owls from hyperpredation, we found a huge drop in deaths between 2012 and 2013, moving from 1.16 dead per day in the months before the operation (177 in 152 days) to 0.45 dead per day in the year following the operation (107 in 237 days). In our application, we suggested the baseline level might be 200 dead birds per year while our long-term goal would be to have only 20 dead birds per year. In 2013, we found 107, but many of those were very decayed and probably died in the summer of 2012. We

did cut our death rate down significantly, but it will be interesting to see in 2014 whether or not the predation will reach as few as 20 birds per year. Such a level would represent dramatic success. Again, we should not make too much out of a single year of data, but the results were very promising. We have also identified a location – the north end of Barn Owl Cay – where owls apparently like to roost. It is possible that the location represents a fledging site and that with the mice gone, hopefully, the area will be abandoned for nesting and roosting by Barn Owls. We will continue to monitor the situation and discourage owls from using the area in the future.

Our sixth objective was to create iguana nesting habitat and a breeding population. We are well on our way with nesting habitat at 3 different sinkholes filled with sand across Allen Cay and 5 breeding size adults already on the island with 12 more to be returned in the future.

Finally, we have now trained 6 Bahamas National Trust staff to participate in eradications. In our original proposal, we hoped to have 3 trained. The Trust is actively engaging in an eradication effort as a partner with Island Conservation, and we believe such an arrangement will be wise until our organization gains more experience working with other mammals than mice. The details of the methodology will change and the greatest need is to conduct eradications of rats at this time. The staff was also trained in techniques to monitor seabirds. There is little time or money currently available to fund seabird monitoring, but these techniques – using a random array of plots, estimating detection error, and conducting censuses are very applicable to ecological work for other species. In short, our staff gained capacity to protect wild places in the Bahamas in terms of both using evidence-based, careful techniques to collect data and report their results. These same staff members are actively engaged in other monitoring programs and are applying their new knowledge on a daily basis in their work. They will be ready to assist as new projects commence for removals of invasive species.

References

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