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RESEARCH ARTICLE

A Study of Mona Rock Iguana (*Cyclura cornuta stejnegeri*)
Nesting Sites on Mona Island, Puerto Rico

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ABSTRACT.—The Mona Island rock iguana (*Cyclura cornuta stejnegeri*) is a threatened species. The iguana population is thought to be at an all time low due to predation and competition by feral animals. Furthermore, the population appears to be very aged, and there is a high mortality rate in hatchling iguanas due to feral cats. In October and November 1994, I studied the nesting areas of the iguana using a Geographic Information Systems (GIS) based Gap Analysis. This GIS was used to predict unknown nesting sites. Known and predicted nesting sites were subsequently visited and evaluated for their use by iguanas. From this research I was able to establish that nesting success is dependent upon location. Although successful nesting occurs on some beaches, in the interior of the island all of the nesting sites appeared to be completely destroyed by feral pigs. Continued research and direct intervention, for which I offer recommendations, are essential for the continued conservation and survival of the iguana on Mona Island.

Key Words: Mona Island, rock iguana, *Cyclura*, GIS, gap analysis, nesting sites, conservation

Yu-ana is a form of serpent with four feet, very ugly to the sight and very good to eat, of which... there are many in the isles and on the mainland... I have eaten these animals on the mainland on occasion, and many more times in this city (Santo Domingo, Hispaniola), and they still bring them to me by sea from Isla de la Mona, where they are plentiful, which is forty leagues from here, and is very good eating...

—Fernandez de Oviedo, Governor of Santo Domingo
1535 (Aquino, 1977)

Mona is located midway between Puerto Rico and the Dominican Republic. Encompassing 5,500 ha, Mona is the second largest of Puerto Rico's offshore islands. Over 90% of the island consists of a raised limestone plateau (mean elevation = 45 m). On this plateau are numerous sinkholes and depressions, many of which are filled with soil. Mona also has a large coastal terrace on the southwest coast and a smaller terrace on the southeast coast (3-4 m elevation). Despite high relative humidity, the minimal rainfall (810 mm/year; Calvesbert, 1973) and rapid evaporation contribute to an arid climate. This is reflected in Mona's vegetation: 86% of the plateau forests consist of short, scrubby trees (Cintrón and Rogers, 1991). Larger trees occur in the sinkholes on the plateau where the accumulated soil is moister than in surrounding areas.

The Mona rock iguana (*Cyclura cornuta stejnegeri*; Figure 1) is the largest native herbivore on the island. Because of Mona's limestone topography and paucity of areas with deep soils, only about 1% of the island has suitable nesting areas for the iguana. Because these areas are scattered in the interior and along the beaches of the island, female iguanas must migrate to the few areas that have soil. The iguana is fortunate that Mona has no permanent human inhabitants and no commercial development. However, feral pigs, goats, and cats have lead to a decline in the iguana population. Vegetation of the larger iguana nesting areas has been altered by humans and goats to the point that these areas may now be inhospitable to the iguana (Wiewandt, 1977).

Figure 1. Adult Mona Island rock iguana (*Cyclura cornuta stejnegeri*) on the northwest coast. *Photograph: Bernd Haneke*

Mona has had a long and interesting history. It was settled by Indians when Columbus first landed there in 1494. From 1874 until the 1920's, Mona's caves were exploited for phosphates (Wadsworth, unpublished manuscript), and hunters apparently provided the miners with food. Iguanas were probably shot for this purpose. Later, large areas of the southwestern terrace were lumbered for charcoal and stakes. Livestock were also imported. The remains of water troughs and feeding bins can still be found near Playa Sardinera. In the 1950's, the U.S. Air Force leased the island as a base for conducting strafing and bombing runs on Mona's sister island, Monito (Wadsworth, 1972). The island's administration was returned to the Puerto Rican government in 1962.

Large areas in the principal iguana nesting grounds around Playa Sardinera have been replanted with exotic vegetation. In the 1930-40's, mahogany (*Sweitenia mahagoni*) and casuarina (*Casuarina equisetifolia*) forests were planted along the southwestern terrace by the Civilian Conservation Corps. The casuarina forests have drastically altered plant communities in the area. Little understory vegetation now remains. Fallen needles from the casuarina trees have accumulated to build a one to two inch layer over the sandy ground. Wiewandt (personal communication) believes that the altered vegetation is leading to low survivorship of the hatchling iguanas due to reduced nutrition and because the missing understory makes it easier for predators to prey on hatchling iguanas.

Since the early 1970's, Mona has been administered by the Puerto Rican Department of Environmental and Natural Resources (PRDNER). The island has been classified as an insular Forest Reserve. In the late 1970's, due largely to Wiewandt's Ph.D. Dissertation (1977), *C. n. stejnegeri* was listed by the U.S. Fish and Wildlife Service (USFWS) as threatened on Mona Island. A Recovery Plan for the iguana was approved by USFWS in early 1984. The PRDNER prepares an

annual report on the results of the hunting season on Mona. In the 1993-1994 report (Fernández, 1994) to USFWS, the Department stated that it considers hunting to be an effective method of controlling feral animals on Mona. At the same time it acknowledged that there are no accurate data on populations of feral cats, pigs and goats. Estimates for pigs and goats range from the hundreds to the thousands, but there is no consensus on the actual numbers present.

Nevertheless, there have been some efforts by PRDNER to protect vital iguana nesting sites. The most noticeable are the wire mesh enclosures (with 10 cm^2 openings) around some of the larger and more accessible iguana nesting sites. These enclosures allow iguanas to enter areas that have enough soil or sand and direct sunlight for successful nesting. They also keep out feral pigs and goats but do not exclude feral cats. The Herpetological Society of Puerto Rico has also labored to protect iguana nesting sites. Near Playa Sardinera, the group recently cleared four 2,500 m^2 areas of casuarina (to increase sunlight and remove needles) and enclosed these areas with fencing. The Society has also enclosed turtle and iguana nesting sites at other locations on the island.

Because enclosures have generally been erected around the most accessible nesting areas, there are likely other areas more deserving of protection. Thus, the purpose of this study was to use a Geographic Information Systems (GIS) based model to predict and evaluate iguana nesting sites. As a basis for the GIS, I used a Gap Analysis approach, which is a recently developed method for evaluating areas with high biodiversity and areas in need of protection (Scott et al., 1993). In this particular study various nesting areas were modeled to determine which areas are in need of protection so that these areas can be emphasized in current and future iguana recovery programs.

Methods

Initially, an inventory was made of the available maps of Mona Island. Of the maps that were located, the most important were maps of iguana nesting sites by Wiewandt (1977), a geologic map by Briggs and Seiders (1972), a vegetation map by Cintrón and Rogers (1972), and soils maps by the U.S. Soil Conservation Service (1993).

The maps (also called layers) were all digitized using AutoCAD, a mapping software package. The digitized layers were then imported into IDRISI, a raster based GIS developed by Clark University. A raster based GIS divides a layer/map into a grid, each cell having a unique location and attribute. The raster based GIS was used because it efficiently performs mathematical calculations, but images may become distorted due to the size of the grid. Therefore, IDRISI maps used in the evaluation of nesting sites were subsequently remapped in AutoCAD for clarity and definition.

Areas under consideration were evaluated by aerial reconaissance for three purposes: to identify potential nesting sites predicted by the GIS (based on soil and vegetation features), to locate potential nesting sites not predicted by the GIS, and to find the best possible footpath to each nesting site. The latter was accomplished by taking compass bearings and by searching for distinct landmarks on the island. Once this information was acquired I then conducted field research from early October to early November 1994.

POTENTIAL NESTING SITES. All of the potential nesting sites identified by air or by the GIS were visited on foot. Each nesting site was evaluated for iguana nesting activity and for feral pig damage. The former was accomplished by counting both scratch sites and hatch holes visible at each nesting site.

A scratch site was a place where an iguana had attempted to, or had dug a nest, as evidenced by soil that had been dug up and moved. Scratch sites were tallied at each area and subsequently compared to the number of scratch sites at all other nesting areas. This resulted in a relative importance index for all of the known nesting areas on the island.

Hatch holes are the tunnels that juvenile iguanas have to dig to escape their nests. It was assumed that one hatch hole represented a single nest. The number of hatch holes was tallied to produce a relative importance index. This was accomplished by adding all hatch holes found on

Mona and dividing each nesting site total by the grand total (with results expressed as percentages. The tallying was performed at the end of the hatching period; thus, it was unlikely that iguanas hatched after the sites were visited.

PROTECTED NESTING SITES. All of the wire mesh enclosures were mapped in the field on a copy of Briggs and Seiders' (1972) geologic map of Mona. This information was then used to create a final layer of currently protected nesting sites on Mona. All of the known and newly discovered nesting sites were also displayed on the map to indicate potential candidate sites that should be protected. The criteria used in establishing which additional nesting sites should be included was based upon information obtained by the number of scratch sites and hatch holes.

HUMAN IMPACTS. Disturbances from human activities on Mona were evaluated qualitatively in the GIS. Areas affected by humans were mapped in the field and subsequently digitized in AutoCAD. The plant community map by Cintrón and Rogers (1991) was also used as an aid in identifying those places where the vegetation had been altered, i.e. where exotic vegetation had been planted or where roads, buildings and the airport had been constructed. The resulting map was to be used as a reference in identifying nesting sites impacted by humans.

Results

EVALUATION OF NESTING SITES. To determine whether nesting success varied with location, a G test for independence was run using a two by two matrix comparing evidence for nesting success (scratch sites and hatch holes) within the major nesting areas (interior and beach). Results of the Williams' corrected G (Sokal and Rohlf, 1995) were highly significant ($G=87.73$, $df=1$, $p < 0.001$), which indicates that nesting success was dependent upon location. As described below, nesting areas along the beaches produced numerous hatchlings while those at interior sites failed.

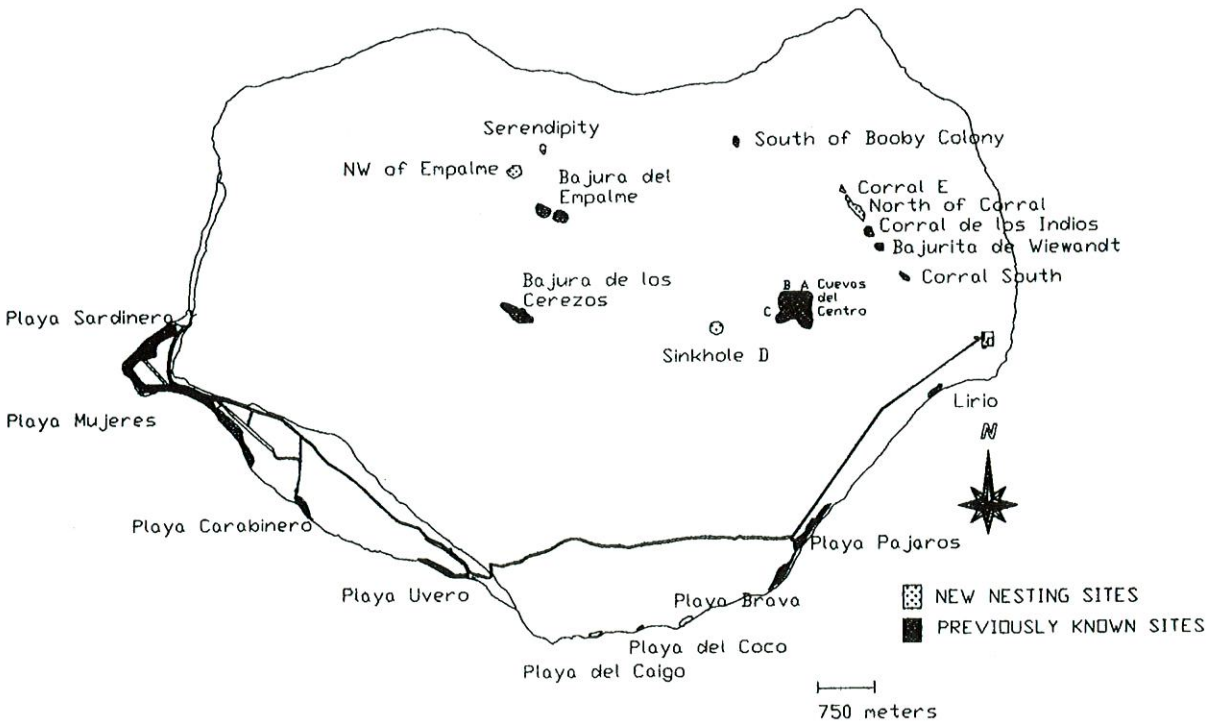

Figure 2. Names and locations of all currently known iguana nesting sites on Mona Island. The new nesting sites were those discovered during the present study.

INTERIOR NESTING AREAS. In the interior of Mona, five new nesting sites were located (Figure 2) by the GIS model and by aerial reconnaissance. The new nesting site that I named Corral E was the second most important interior nesting ground on the island. I also found two new nesting sites near Bajura del Empalme (Figure 3). These I called Serendipity and NW of Empalme. I found another new nesting site, Sinkhole Delta, to the west of the Cuevas del Centro. Two additional nesting sites were discovered just north of Corral de los Indios, and these were named Corral E and North of Corral.

By comparing all of the nesting sites on Mona, I found that the interior nesting sites comprised 25.7% of the total annual nesting on the island. However, not one successful iguana nest was located in any of the interior nesting sites that I surveyed. It appeared that all of the nests were destroyed by feral pigs. I based this conclusion on the fact that not one hatch hole was found in any of the sites, yet at each nesting site conclusive feral pig evidence was found. The feral pig damage manifested itself in the form of dug up and destroyed nests, pieces of iguana eggshells, and uprooted vegetation in and around the nesting sites.

As no successful nests were found in the interior, a regression analysis was run on the numbers of hatch holes and scratch sites to estimate how many nests were destroyed in these areas. The regression was significant at $F_{(1,6)}=183.6$, $p=0.007$. The equation for the regression is $Y=0.14x+5.22$. Using this technique it was established that at least 110 iguana nests were destroyed at all of the interior nesting sites. Assuming that each nest had an average of twelve

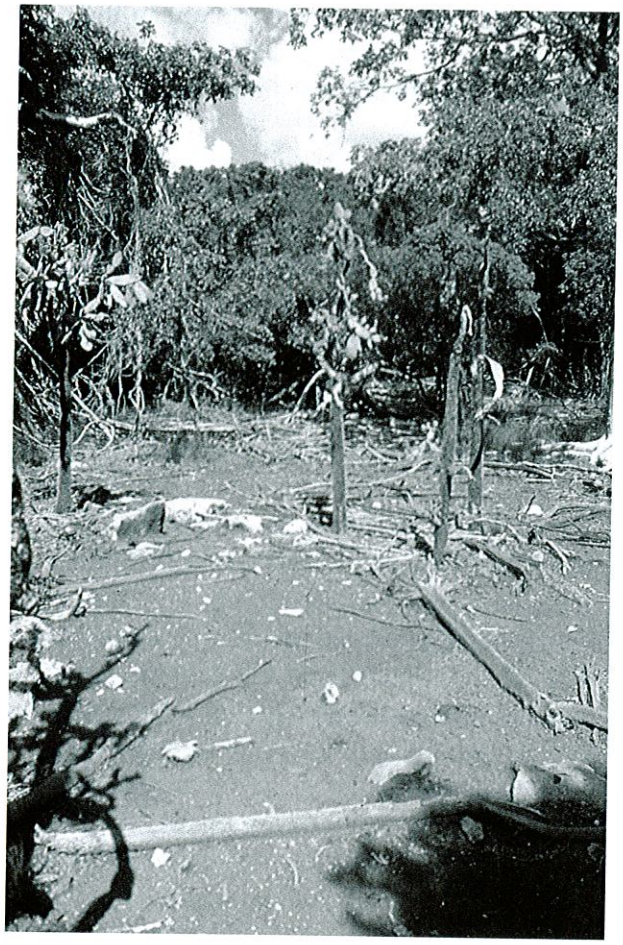

Figure 3. A large interior nesting site in the depression at Bajura del Empalme. *Photographs: Bernd Haneke*

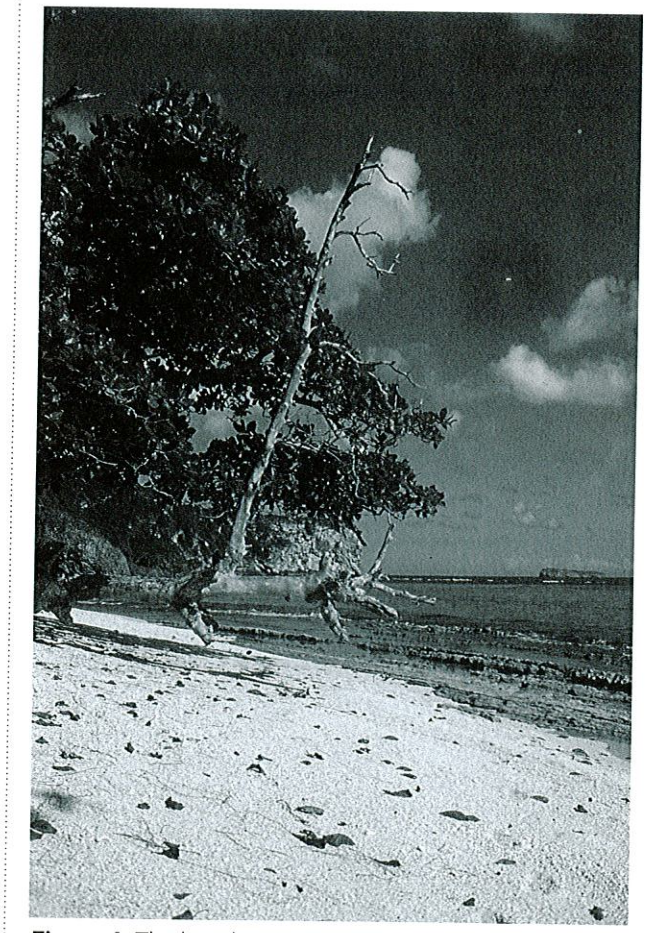

Figure 4. The beach at La Carmelita (not a nest site) to the northwest of Sardinera's nesting beaches. In the background is Monito, Mona's sister island.

viable eggs (Wiewandt, 1977), the number of destroyed viable eggs on an annual basis would be approximately 1,320.

Beach Nesting Areas. I found two new iguana nesting sites along the southeastern beaches at Playa Brava and Playa del Caigo (Figure 2). Five percent of the iguanas' nesting success (estimated by hatch holes) occurred at these two beaches. The vicinity of Playa Sardinera (Figure 4) hosts the greatest number of nesting sites, with 37.4% of all scratch sites on Mona and 41.5% of the iguanas' hatching success. In their entirety, the beach nesting grounds comprised 74.3% of the scratch sites on Mona. From numbers of hatch holes, it appeared that the beaches accounted for 100% of all the hatchling iguanas on the island. This is largely attributable to the fact that many of these sites were protected by fencing, protecting the nests from predation.

Protected Nesting Sites Map. Large iguana nesting sites have been protected around the southwestern terrace (Figure 5). The benefit of these wire mesh enclosures has been readily apparent and many hatchling iguanas were seen in these areas. I also observed two young iguanas that were substantially larger than the hatchlings, yet much smaller than the adult iguanas in the area.

Human Impacts Map. The most heavily disturbed areas were located on the southwest terrace (Figure 6). Houses, roads, utility buildings, an airport and camping facilities have been built in this area. The casuarina and mahogany plantations are also located in the major iguana nesting areas. Other impacted areas included Playa Carabinero, Playa Uvero and Playa Pájaros.

Feral Animals. During my field research I saw at least 70 goats on the north coast near the lighthouse, at least 10 near the booby colony and numerous others in the interior of the island. Feral pigs and cats are also abundant on the island. Usually entire families were observed in the early mornings as they searched for food in open grassy areas. At Playa Pájaros the feral cats have become

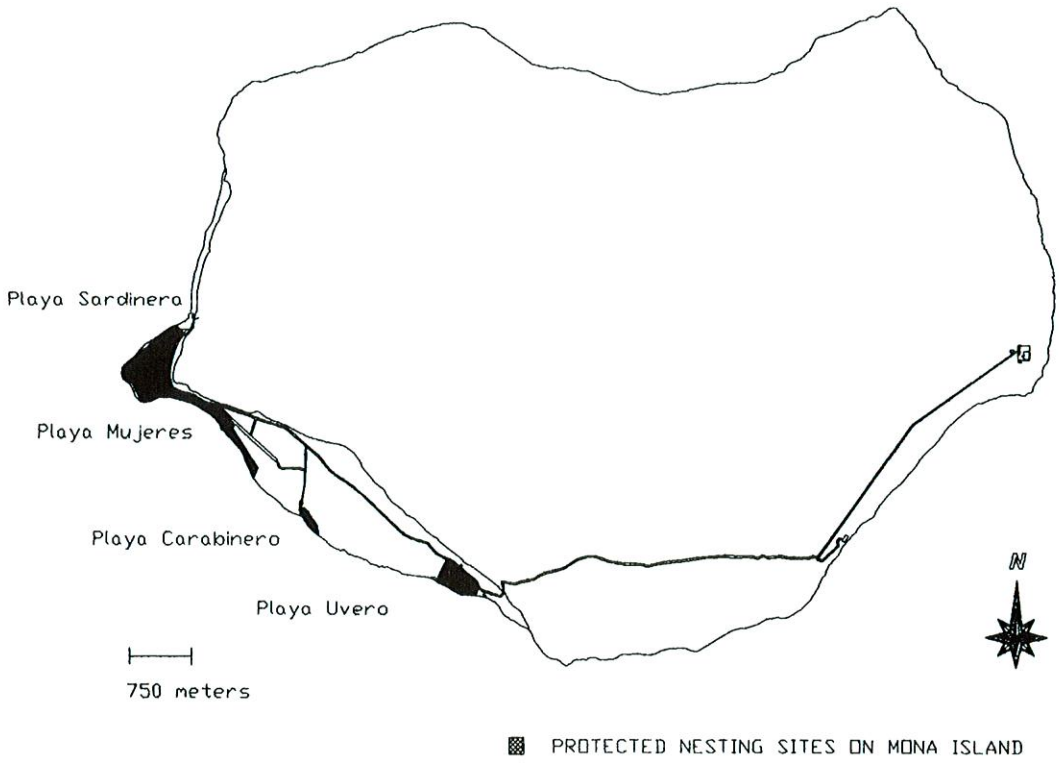

Figure 5. Areas (shown in cross-hatching) that are currently protected from feral goats and pigs by wire mesh fencing.

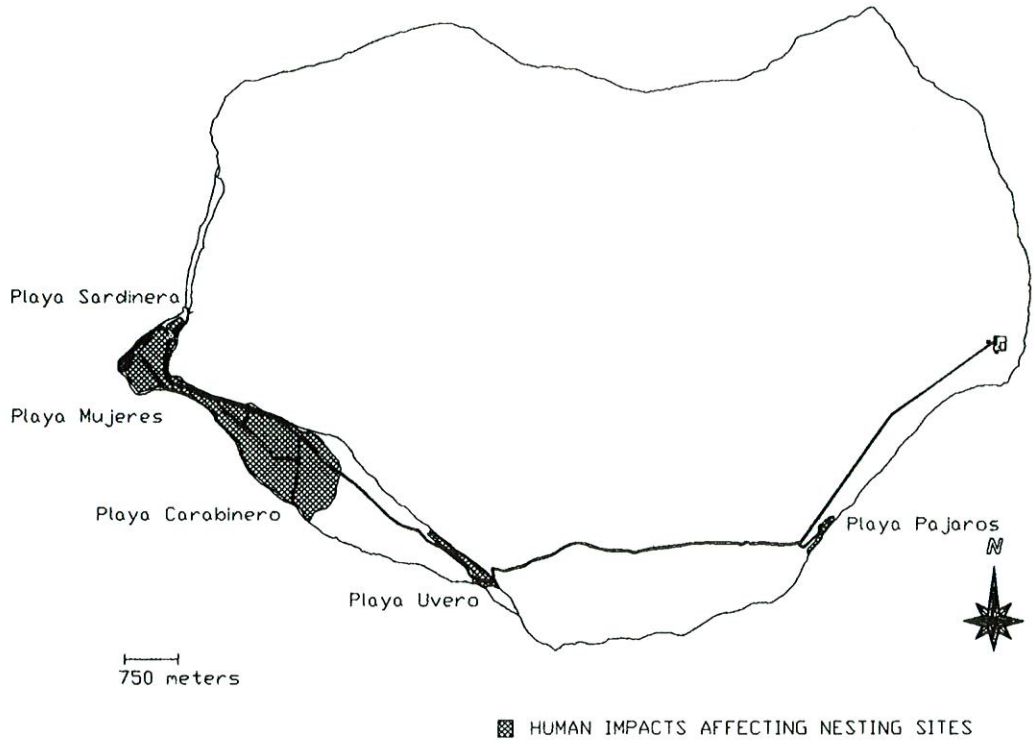

Figure 6. Areas (shown in cross-hatching) that have been impacted by humans in the recent past. Note that the largest nesting sites are in areas that have been impacted the heaviest.

so accustomed to humans that they were approachable, whereas cats observed along the major roads on Mona were always shy and aloof. In one instance, I observed a cat near Uvero that caught my attention becuase of its long hair and well-fed appearance. Well-fed cats were also observed near Playa Pájaros. Rats were commonly seen around Playa Sardinera and Playa Pájaros.

OBSERVATIONS OF HATCHLING IGUANAS. Compared to my previous visits to Mona during the past 15 years, numbers of hatchling iguanas have increased substantially. Nevertheless, adults were far more numerous than hatchling and juvenile iguanas. Most of the hatchling iguanas around Sardinera appeared to have full bellies. During the peak of the hatching season the young iguanas scurried through buildings (Figure 7) leaving reddish feces in all conceivable places. Upon examining some specimens I found that they had eaten the fruits from a shrub called *Eugenia axillaris*. This shrub has been described as being frequent or occasional on the coastal plain, at the base of the cliffs and on the plateau (Woodbury et al., 1977). The fruits of this shrub host insect larvae (Little et al., 1974) that may provide hatchling iguanas with a source of protein.

Figure 7. Hatchling iguana captured in a building at Playa Sardinera. *Photograph: Bernd Haneke*

I observed hatchling iguanas sitting on low shrubs near Sardinera. They appeared to be either resting or hiding there because upon my approach they would run away quickly. The hatchlings may climb into shrubs to escape or hide from native predators, such as hawks. One morning while hiking to the Bajura de los Cerezos I observed an iguana possibly drinking water on the dew-covered limb of a shrub. It too scurried away as I approached it.

Blindness in Mature Iguanas. I observed approximately 15 blind iguanas throughout the island. They had opaque blue eyes and appeared to be severely emaciated. They were also very passive: one could approach them to within a foot or so before they scurried away, often hitting rocks and shrubs. They preferred to remain stationary with their heads cocked up. Most appeared to be undernourished and generally in poor health.

Discussion

The GIS based Gap Analysis proved to be a useful tool for predicting and identifying nesting sites. While the Gap Analysis was capable of predicting many of the iguana nesting sites, it did not predict all of the nesting sites found because of missing information on the base maps. In numerous cases areas that had been marked as having soil were found to be devoid of it, while other areas were found to have soil. Using aerial reconnaissance to overcome the deficiencies of the maps proved to be of utmost value in creating the final layers of the Gap Analysis.

The final Gap Analysis, that is the identification of nesting sites that should be protected, was based upon the relative importance of each nesting area. Given the quantitative data, along with the visual display of location, this information should provide the PRDNER or the Herpetological Soceity of Puerto Rico with a useful guide for further efforts to protect iguana nesting sites.

While currently protected areas are yielding results, regular maintenance of the wire meshed enclosures should not be neglected. In many cases, especially around Carabinero, the fencing has rusted to the point that it easily falls apart. If the fencing is not maintained the mission and purpose of using enclosures to aid in iguana recovery will be completely invalidated. Future fencing should be accomplished using only galvanized mesh wire. As witnessed at several locations on Mona where galvanized wire was used, this type of fencing is much more resistant to environmental conditions than the ungalvanized fencing.

An important omission has been made in protecting iguana nesting sites at Playa Pájaros. This large beach accounts for 7.2% of the scratch sites and 13.8% of the hatch holes found on Mona. Its nesting sites have not been protected even though the beach is heavily used by tourists, campers and fishermen. To accommodate the latter, camping shelters have recently been built in the midst of iguana nesting sites despite the fact that the area has been declared critical habitat for the iguana under the Endangered Species Act of 1972. Because Playa Pájaros has its own docking facilities, it would be relatively simple to unload materials and erect enclosures around the larger nesting grounds at Pájaros.

I recommend that all of the interior nesting sites that have an excess of twenty scratch sites be enclosed. Moreover, the entire depression or sinkhole in which nest sites are located should be enclosed to protect the depression forest trees and shrubs that now are unable to reproduce because of goat browsing. Fencing off these areas may, on an annual basis, contribute close to 1,000 additional iguana hatchlings. Obviously, this would substantially increase the chances for recovery of the iguana population. Because adults greatly outnumber hatchlings and juveniles, the iguana population presently appears to be aged.

Visiting biologists on the island admit that there is currently no effort to control the pig population. They also claim that hunters no longer shoot the pigs because of their poor meat quality. The goat population is believed to be low because rangers and hunters do not see them any longer on the major roads. From my own observations over 15 years of visits to Mona, the pig population is high and the goat population has not decreased. Therefore, efforts to control the feral pigs and goats are still needed.

Table 1. Summary of scratch sites, hatch holes and relative importance values (RIV) for iguana nesting areas in the interior and along the beaches of Mona Island. Overall importance represents the rank of RIV values for both interior and beach nesting sites.

INTERIOR NESTING SITES

Nesting Site	Scratch Sites	RIV For Scratch Sites	Hatch Holes	RIV For Hatch Holes	Overall Importance
Bajura Cerezos	38	3.3	0	0	8
Bajura del Empalme	22	1.9	0	0	10
Serendipity	9	0.8	0	0	17
NW of Empalme	6	0.5	0	0	19
Bajurita de Wiewandt	20	1.7	0	0	11
Corral de los Indios	7	0.6	0	0	18
South of Bajurita	35	3.0	0	0	9
North of Corral	14	1.2	0	0	14
Corral E	49	4.2	0	0	7
Cueva del Centro A	58	5.0	0	0	6
Cueva del Centro B	18	1.6	0	0	12
Sinkhole Delta	13	1.1	0	0	14
South of Booby Colony	10	0.9	0	0	16
TOTALS	299	25.8	0	0	—

BEACH NESTING SITES

Nesting Site	Scratch Sites	RIV For Scratch Sites	Hatch Holes	RIV For Hatch Holes	Overall Importance
Sardinera-Mujeres	435	37.4	66	41.5	1
Mujeres-Carabinero	109	9.4	21	13.2	3
Playa Uvero	156	13.4	28	17.6	2
Lino	4	0.3	0	0	20
Playa Pájaros	84	7.2	22	13.8	4
Playa Brava	11	1.0	7	4.4	15
Playa del Coco	48	4.1	14	8.8	5
Playa del Caigo	17	1.5	1	0.6	13
TOTALS	864	74.3	159	100.0	—

Currently, there are no apparent efforts by rangers to the control the cat population. Because cats are known to prey on hatchling iguanas, increased numbers of cats will mean more iguanas lost in future hatching seasons. The cat population in and around Playa Pájaros could be reduced by a concerted effort, if only the necessary incentives and motivation were offered to the rangers.

After reviewing literature discussing the impact and management of introduced mammals on islands worldwide, Wiewandt (1977) concluded that even small populations of pigs, goats, and cats are not only extremely destructive but also exceedingly difficult and expensive to control. He also concluded that recreational hunters kill so few goats and pigs each year on Mona that no real progress toward feral mammal control has been possible under the government's management policies. These policies have practically remained unchanged since the 1970's and control practices are still needed.

As the Recovery Plan noted, if eradication of cats, pigs, and goats was not to become a prerequisite in the management plan, the recovery of the Mona Iguana population may never be achieved (USFWS, 1984). The feral animals either prey upon or compete with the iguanas for forage. Even though the eradication of feral animals was stressed, there have been few (and no successful) attempts at eradicating Mona's wild and prospering feral animal population. The reason may be that a strong hunting lobby influences the Puerto Rican government to continue the use of Mona as a hunting ground for feral pigs and goats. The annual hunting season is popular among Puerto Rican hunters. Therefore, there are conflicting interests that make eradication an issue of controversy.

There have been no studies on the effects of feral rats on hatchling iguanas. Wiewandt (1977, personal communication) stated that although rats were abundant he had not observed any adverse effects while doing research on Mona in the seventies. Rats are still abundant, and indirect evidence from the Galápagos (de Roy, 1987), and from the Bahamas (Hayes et al., 1995) suggest that rats can adversely affect iguanas. Perhaps further research should be conducted to evaluate whether feral rats are impacting Mona's iguanas. However, until rats are demonstrated to be detrimental, control of other feral mammals should receive higher priority.

Blindness is now a fairly common occurrence in mature iguanas on Mona Island, and I take this disturbing observation very seriously. The malady is evidently a new development (Wiewandt, personal communication), one possibly due to a virus or an environmental problem. An afflicted animal should be captured and examined by a qualified veterinarian.

Much has been done to protect the iguana on Mona, but more is needed—especially to protect the interior nesting sites and those of Playa Pájaros. It is encouraging that private groups such as the Herpetological Society of Puerto Rico have taken the initiative to restore and protect nesting sites. Recently I learned that the group has enclosed two 10 m2 nesting sites in the Bajura de los Cerezos and in the Cuevas del Centro. Clearly, there is concern among Puerto Ricans for the welfare of Mona and its endemic iguana, which offers hope for eventual restoration of the population.

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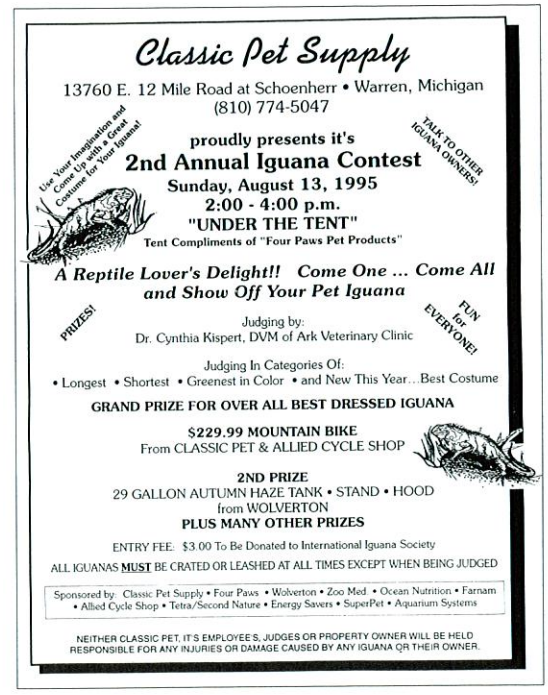
THANK YOU AGAIN

Classic Pet Supply of Warren, Michigan recently made a $105.00 donation to The International Iguana Society. They raised the donation from entry fees for their **2nd Annual Iguana Contest.** This year, winners in the new category, "Best Dressed Iguana," were an "iguana sub" and a Santa Claus. In addition to prizes of various iguana care supplies, 2nd Prize was a 29 gallon aquarium setup and the Grand Prize was a $300 mountain bike.

The International Iguana Society would like to thank Classic Pet Supply for their generous donation...we look forward to news of the 3nd Annual Iguana Contest!



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Adult Mona Island rock iguana, *Cyclura cornuta stejnegeri*, at entrance to burrow. *Photograph: Thomas A. Wiewandt*