West Indian Iguanas: An Update[1]

Anegada Island Iguana (*Cyclura pinguis*)

In order to determine the genetic suitability of the San Diego Zoo's six adult (3.3) Anegada Iguanas for a captive breeding program, relatedness within the captive population was examined by comparing their microsatellite variation to that observed for two groups of wild Anegada Iguanas, one known to be closely related (clutchmates from marked nests) and one presumed to be randomly related (haphazardly captured adults and juveniles).

A *Cyclura pinguis* DNA microsatellite library was constructed using 23 of 48 candidate loci screened for polymorphism and found to be useful for analysis. DNA was extracted from a total of 178 Anegada Iguanas: 12 captives at the San Diego Zoo (the six adult founders and their six offspring) and 166 wild individuals (68 haphazardly captured animals assumed to be randomly related, and 98 hatchlings from eight nests assumed to represent eight sibling groups). Genotypes were obtained for all individuals and the average number of alleles observed across the 23 loci in the captive and wild populations was 2.8 and 4.3 respectively, with observed heterozygosity determined to be 0.61 in the captive group and 0.53 in the wild population.

A maximum likelihood statistical approach, using the six captive founders and most of the wild individuals sampled, was used to infer relatedness among the captive adults. Results of this analysis suggest the six captive adults contain three related pairs (one pair of males, one pair of females, and one male and female pair) and that each related pair is unrelated to the other pairs. The statistical approach used requires more markers to estimate specific relationships, such as determining whether two iguanas are likely to be siblings, half-siblings, parent-offspring, etc. For this reason, we can only generally state whether each pair is likely to be related or not.

The molecular data compiled to infer relatedness of the six adult founders was also used to correctly assign parents to a captive offspring with a questionable pedigree. The adults that were believed to be the parents of the offspring were excluded at 7 out of 23 loci. Of the four other possible adult candidates, microsatellite allele data revealed that only one male and female qualified as parents of the offspring at all 23 loci.

The microsatellite data have also provided important information about the genetic diversity of the wild population on Anegada. Although population estimates suggest that the wild population contains fewer than 300 individuals, the microsatel-

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To determine the genetic suitability of the San Diego Zoo's adult Anegada Iguanas (*Cyclura pinguis*) for a captive breeding program, relatedness in the captive population was compared to that observed for two groups of wild iguanas.

lite data suggest that the population is genetically healthy (observed heterozygosity is 0.53) and that subpopulations are not significantly subdivided (FST is 0.153).

The genetic data also support the presence of partial sibling relationships across multiple field seasons for hatchlings captured on the tiny islet of Windberg Cay (0.26 ha) in Red Pond, suggesting that females return to this cay year after year to lay their eggs.

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Allen Cays Iguana (*Cyclura cychlura inornata*)

Two separate research trips were made to the Allen Cays area in the northern Exumas, Bahamas, one from 18–26 March 2006 and one from 16–21 July 2006. The March trip consisted of an alumni team that surveyed cays in and around the Allens Harbour for potential migrant iguanas and for the collection of blood samples. This expedition replaced the normal May trip for current Earlham College students that involves intensive mark-recapture work on Leaf and U cays. The July trip focused on nesting activity on Flat Rock Reef Cay (FRRC) just northeast of Leaf Cay. We hoped to compare nesting parameters in this rapidly growing population with those observed in 2001 and 2002 on Leaf and U cays, where populations are presumed to be at or near carrying capacity.

March Survey Trip.—As early as 1995, JBI (author) began hearing reports that iguanas were seen on islands around Leaf and U cays, where they had not been previously observed. By 2001, populations had been confirmed on Allen Cay and FRRC (ca. 1 km NE of Leaf Cay), both of which contained individuals previously marked on Leaf or U cays. Our assumption was that people were relocating iguanas. In 2005, two iguanas and a carcass, none of which were marked, were discovered on a tiny islet just north of Leaf Cay that had yielded no sign of iguanas when surveyed in 2001. In order to better understand the issue, 13 Earlham alumni and associates spent six days in March 2006 in the Allen Cays area to survey islands and to collect blood samples for future DNA work.

A total of 12 cays were visited during this trip. U Cay and Leaf Cay were visited long enough to collect blood samples, but no other work was conducted on either cay. Allen Cay and FRRC were extensively sampled and blood was collected at each location. Total population estimates for each now stand at 20 (total marked) and 100 (based on 38 captures this trip that included five recaptures and a total of 45 marked for the island), respectively. To date, neither juveniles nor adequate nesting sites have been observed on Allen Cay.

FRRC, which had no evidence of iguanas in 1994, now has a thriving, growing population and the estimate of 100 iguanas includes a subjective count of 30 elusive juveniles. Eight other cays between the Allen Cays and Robert's Cay just south of Ship Channel Cay, most of which had never been surveyed before, were also visited during this trip. A total of seven iguanas was seen on three of these islands and a fourth island had iguana scat and tail drags. Of the observed iguanas, two were captured and blood was collected from each. One of these iguanas was unmarked and the other was a female originally from U Cay that had clearly been relocated sometime after 2001, when it had been included in our nesting study on U Cay.

July Nesting Study.—JBI and KNH returned to FRRC for five days after the presumed nesting season (mid-June to mid-July on Leaf and U cays). A total of ten potential nest sites were identified based on mound presence, soil and vegetation disturbance patterns, and female attendance. All ten sites were excavated and egg clutches were uncovered at seven of the sites. Unlike on Leaf

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An adult female Allen Cays Iguana (*Cyclura cychlura inornata*) in the northern Exumas, Bahamas.

and U cays, female nest defense was minimal and it took some time to determine which nests had associated females. Nonetheless, seven nesting females were identified and six were matched with precise clutches. One female was associated with a potential nest site, but the eggs were never uncovered. At one nest where eggs were found, no female was observed. Two of the identified sites yielded no eggs nor associated females, indicating that our initial nest identification may have been incorrect for those sites.

In addition to a lack of strong nest defense, the most important differences between the young population on FRRC and the older populations on Leaf and U cays tentatively appear to be a higher clutch frequency (40–50% on FRRC; ~33% on Leaf and U cays) and more rapid growth rate (32 cm SVL = 10 years on FRRC; 32 cm SVL = 18–23 years on Leaf and U cays) on FRRC. The latter apparently results in female sexual maturity being attained in less than a decade on FRRC rather than the 12 or more years necessary on the other cays. Other nesting parameters, including clutch size, egg size, and distance between closest nests, do not appear to differ significantly between FRRC and Leaf and U cays.

As a follow-up to the March survey, JBI and KNH revisited one of the cays where four iguanas had been observed and the previously unmarked individual had been captured. We observed a total of five individuals and captured two. As with the March capture, these were unmarked, adult females. The captured females demonstrated site fidelity suggestive of nesting, and digging was observed, but soil appeared to be too sparse for actual nest construction. No juveniles were observed, reinforcing the notion that these individuals may be unable to nest on this island.

Conclusions.—Our research this year leads us to wonder whether this might be an optimal time for the Bahamian government to formally protect the Allen Cays Iguana area. The discovery of a U Cay female as far away as Robert's Cay (6 km to the north) verifies that unauthorized persons are relocating iguanas from Leaf and U cays. The presence of unmarked adult iguanas on at least two new cays also suggests a wider natural distribution than previously known. For example, at least three of the five iguanas on the newly surveyed cay appear to be long-term natural inhabitants. Aside from Leaf, U, and FRR Cays, however, the other cays appear to lack nesting habitat, potentially rendering the iguana populations there biologically dead.

Results of DNA analyses from collected blood and future survey work should help clarify relationships among these island-separated populations. In the meantime, preliminary nesting results from FRRC verify that populations can establish quickly given appropriate nesting habitat. In addition, the island with five iguanas offers a potential experimental site to study the demographic effects of adding nesting soils to an island.

Launching an educational campaign that includes informational kiosks on Leaf and U cays is essential to the long-term well-being of the Allen Cays Iguana. Leaf Cay and its iguanas support a booming tourist industry, but the latter depends on a vulnerable species that is made even more so by increased

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John Iverson exhumes an Allen Cays Iguana (*Cyclura cychlura inornata*) nest in the northern Exumas, Bahamas.

human involvement. Well-meaning tourists may be creating some of these biologically dead populations. Too many islands support only single sex individuals or may not have sufficient nesting soil. Furthermore, preliminary observations suggest that tourist feeding has dramatic effects on a subset of the populations. We have yet to understand the implications this may have on the health of individuals and the population as a whole. Education, combined with a cooperative agreement among the owners of Leaf and U cays and the Bahamian government, could go far in ensuring the long-term existence of the Allen Cays Iguana, the indigenous endangered Audubon's Shearwater, and other flora and fauna in that area of the Exumas.

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Exuma Island Iguana (*Cyclura cychlura figginsi*)

Surveys in the Exuma Island chain were conducted from 6–11 April 2006. The surveys were part of the John G. Shedd Aquarium's citizen-scientist iguana research program and included the islands of Leaf (northeast of Normans Pond), White Bay, North Adderly, Noddy, and Pasture cays. Objectives for 2006 were to: (1) survey iguana populations in the south-central Exuma chain because they have not been visited since 1998, (2) translocate iguanas from Leaf Cay (northeast of Normans Pond) to Pasture Cay in the Exuma Cays Land and Sea Park to augment the initial colony that was translocated in 2002, and (3) collect preliminary diet and body condition data for comparative studies of iguana populations inhabiting Exuma cays visited by tourists versus un-visited cays.

In addition to the April surveys, Gaulin, Bitter Guana, and Pasture cays were visited by CK (author) between 26 May and 4 June 2006. The surveys were part of a Bahamas Ecology course that included undergraduate students to help collect data from each cay (Gaulin: 27, 28 May and 4 June; Bitter Guana: 27 May; Pasture: 26 May and 2, 3 June). Research on Gaulin and Bitter Guana cays is part of an annual monitoring project initiated in 1998. Approximately 2.5 days were spent on Gaulin Cay, one day on Pasture Cay, and three hours on Bitter Guana Cay.

General Surveys and Morphometrics.—During the April surveys, we captured and processed 123 iguanas from five cays (Leaf, n = 19; North Adderly, n = 33; Noddy, n = 14; White Bay, n = 51, Pasture, n = 6). This was the first year that iguanas were all marked with PIT tags on these cays (except Pasture Cay) for long-term identification. During the May/June surveys, we captured an additional two founder iguanas from Pasture Cay, one iguana from Bitter Guana, and 51 iguanas from Gaulin Cay. Of the 51 Gaulin captures, 27 were recaptures dating back as long ago as 1998. No differences existed in body mass, snout-vent length, or ectoparasite load between the North Adderly, White

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Exuma Island Iguanas (*Cyclura cychlura figginsi*) populations in the south-central Exumas were surveyed for the first time since 1998.

Bay, and Gaulin cay iguana populations (all P > 0.05). Leaf and Pasture cays were excluded from statistical analyses because they represent translocated populations with low densities and thus exceptional large body sizes. Noddy and Bitter Guana cays also were excluded from analyses because of small sample sizes. The southern end of Bitter Guana Cay was surveyed by CK and L. Roth on 27 May. Twelve iguanas representing multiple age classes were observed, but only one large male was captured because of the extreme wariness of the iguanas and our short time on the island. Additionally, while at anchor on 26 May off of Bitter Guana Cay, four iguanas were observed foraging on the north beach. These observations represent an increase in recorded iguanas over the past nine years. Although speculative, annual increases in observations coincide with the informative/protective signs posted on the island in 1998.

On 10 April, we set Sherman live rat traps on White Bay (n = 28 traps) and Leaf Cays (n = 30 traps). We trapped six rats from White Bay and none from Leaf Cay. To date, rats have been confirmed from White Bay, Gaulin, Bitter Guana, and Pasture cays. North Adderly, Noddy, and Guana cays (not visited in 2006) still need to be surveyed for rats.

Translocation.—The original translocation from Leaf Cay [northeast of Normans Pond] to Pasture Cay in the Exuma Cays Land and Sea Park was conducted as a necessity because of a land sale dispute that required the removal of as many lizards as possible in two days. The translocated colony was heavily male-biased (11.5) resulting in an initial loss of large males. Since December 2002, three male iguana carcasses have been recovered, while the fate of four (2.2) iguanas remains uncertain. One of the male carcasses was discovered in December 2002 washed up on Compass Cay located approximately 5 km south of Pasture Cay. Interestingly, two large iguanas have been spotted this year on the north beach of a private cay (Little Halls Pond) located 1.5 km north of Pasture Cay (Tom Barbernitz, personal communication). We were not granted permission to land on the island, so we were unable to determine if those iguanas came from Pasture Cay. However, no iguana-inhabited islands are in the area, so, if the iguanas did not originate from Pasture Cay, they were purposely put on the island from a distant iguana-inhabited cay.

Seven (5.2) of the founder iguanas remaining were recaptured on Pasture Cay and all appeared healthy and had gained body mass since last capture. Two additional founder iguanas (1.1) were observed but not captured. One subadult that hatched on the island was recaptured and increased its body mass by 302 g and SVL by 5.9 cm (BM = 420 g; SVL = 19.6 cm) since it was last captured in 2004. Two other subadults were observed but not captured.

Evidence of exploratory dig activity was observed on the north beach, and two iguanas appeared to have nested. One female was aggressive toward male and female conspecifics in her nesting area and chased iguanas away from the area if they approached too closely. A snake (*Alsophis vudii*) was captured on the island in April. High predation rates of iguana hatchings by these snakes on Andros Island warrant future investigations concerning predation effects on Pasture Cay.

Dietary Comparisons.—Visitor traffic in the Exuma Cays has been increasing significantly over the past decade. Many of these tourists land on cays inhabited by iguanas. For example, the Allen Cays in the northern Exumas experience up to 600 people each week from one-day Nassau excursions. The islands in the southern Exumas also receive high-impact visitors from Great Exuma aboard one-day excursion tourist trips. Previously undisturbed populations in the more remote central Exumas also are becoming subjected to more frequent visits by tourists due to increased traffic from the Staniel Cay Yacht Club. Consequently, few iguana populations remaining in the Exumas are free from visitor impact. Visitors purposely feed the iguanas, thus altering their natural behavior and potentially their health. In order to assess the impact of tourist feeding on populations of Rock Iguanas in the Exumas, general dietary data were collected for comparative analyses between disturbed and undisturbed islands. We collected 131 scat samples from six cays in the central and southern Exumas (White Bay, North Adderly, Pasture, Noddy, Leaf [northeast of Normans Pond] and Guana). In March 2006, KH (with John Iverson) collected 84 scat samples of *C. c. inornata* from seven cays in northern Exumas (Leaf [east of Allens], Southwest Allens, Flat Rock Reef, Roberts, and three unnamed cays just north of Allens). Scat samples were collected in different habitats and areas that included wooded interior, rocky areas, and beach habitat. Preliminary results indicate that prolonged, high rates of feeding do alter iguana diets. Of the islands sampled, Leaf Cay (Allens) has by far the longest history and greatest rate of food provisioning by tourists. Scat samples from the main tourist beach on Leaf Cay contained high levels of ooid sand grains (six of 19 samples), remnants of grapes (seven of 19), and fresh samples with more of a loose/liquid consistency than fresh samples found on other parts of the island (sand in two of 17 samples; grapes in one of 17; no loose/liquid samples). To a much lesser extent, other sampled iguana populations experience food provisioning by tourists (e.g., White Bay Cay, Southwest Allens Cay), but no distinct differences were evident between samples from these islands and samples from populations with minimal or no food provisioning by tourists. More data are needed to make meaningful conclusions, but we now have a working hypothesis for future studies. Future work will also focus on blood chemistry and behavioral comparisons.

Further reinforcing the timeliness of this work, we documented an increase this year in tourists visiting Gaulin and Pasture cays, thereby stressing the need for signs advertising the protected status of the iguanas. Additionally, dialogue needs to be initiated to prohibit the feeding of iguanas on selected cays to prevent potential perturbations or preserve selected "natural" populations.

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