Iguana Times

THE JOURNAL OF THE INTERNATIONAL IGUANA SOCIETY
$6.00

VOLUME 4, NUMBER 2
JUNE 1995

Male San Salvador rock iguana, *Cyclura rileyi rileyi*, Bahamas. The reddish coloration is typical of individuals on Goulding Cay. *Photograph: William Hayes*

Journal of the International Iguana Society, Vol. 4, No. 2, pp. 21-30, 1995

RESEARCH ARTICLE

POPULATION STATUS AND CONSERVATION OF THE ENDANGERED SAN SALVADOR ROCK IGUANA, *CYCLURA R. RILEYI*

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ABSTRACT.—The San Salvador rock iguana, *Cyclura r. rileyi,* is a subspecies of one of three Bahamian iguana species, all of which are endangered. In May and July, 1994, we sampled six of the seven known populations confined to tiny offshore/inshore cays (sightings of iguanas on the San Salvador mainland are very rare). Lincoln-Peterson population estimates on two cays (based on resightings of marked iguanas) and censuses on other cays suggest a total population of 500-600 iguanas; however, numbers of juveniles are possibly underestimated. These data provide important baseline information by which future assessment of management needs can be made. We also identified threats to the long-term survival of several populations. The larvae of an introduced moth are infesting the prickly-pear cacti that are a major food source for iguanas on Green Cay; feral rats seen on Low Cay may prey upon iguana eggs and juveniles; and an unknown cause of mortality recently decimated the Guana Cay population. Continued research and direct intervention, for which we offer specific recommendations, are essential to preserve both the native habitat and genetic diversity of these imperiled populations.

Key Words: Bahamas, Reptilia, *Cyclura,* rock iguana, population size, conservation

Among the largest but least studied lizards in the world, Caribbean rock iguanas of the genus *Cyclura* are represented today by only eight species. On the islands where they occur, they are the largest native terrestrial herbivores. They are important grazers and seed dispersers (Auffenberg, 1982a; Iverson, 1985), assuming an integral role in maintaining the ecosystems in which they live. However, these draconian creatures are disappearing rapidly; up to six taxa are already extinct (Wiewandt, 1977). All eight surviving species are designated as endangered and afforded international protection by CITES (Convention on the International Trade of Endangered Species) Appendix I status. Their demise can be attributed directly to human activities. They are hunted for their meat in certain countries, smuggled illegally for the pet trade, and increasingly threatened by introduced plant and insect pests, feral animals, and rapid loss of habitat. As an alarming example of their vulnerability, feral dogs and cats brought by hotel construction workers led to nearly complete extirpation of a thriving iguana population (ca. 15,000) on Pine Cay, Caicos Islands, in less than five years (Iverson, 1978).

One of the most vulnerable of the three Bahamian species is *Cyclura rileyi,* considered the smallest of all rock iguanas. The three recognized subspecies are scattered on some of the most remote Bahamian islands. *Cyclura r. rileyi* (Figure 1) is confined to seven tiny offshore/inshore cays (islets) of San Salvador island; *C. r. nuchalis* exists on just two cays in the Acklins Bight; and *C. r. cristata* is restricted to a single cay in the southern Exumas (Blair, 1994).

For *C. r. rileyi,* a handful of population estimates have been published in recent decades. Auffenberg (1976) believed that populations were on the decline, none remained on the mainland of San Salvador itself, and that fewer than 200 individuals persisted on the satellite cays; in a later report (Auffenberg, 1982b), he considered the iguanas to be present on five cays and extirpated on five others. Based on transect surveys conducted on three cays (Manhead, Green, Low) in

Figure 1. San Salvador rock iguana, *Cyclura rileyi rileyi*, on Green Cay. *Photograph: Richard Moyroud*

1974, Gicca (1980) considered these populations to be near maximum densities and estimated a combined maximum of 93 animals. Assuming that iguana density on High Cay (where he saw only seven animals during his brief visit) was similar to other cays, he suggested another 113 iguanas were possible on High Cay and surmised that fewer than 500 animals remained on the mainland. Ostrander (1982) reported the discovery of a new population on Guana Cay in Hermitage Lake (Northeast Arm of Great Lake), where he saw or heard a minimum of 45 individuals and "conservatively" estimated the population to be at least 80. More recently, Blair (1991) visited several cays in 1990 and summarized their relative abundance on six cays, their very rare but continued presence on the mainland, and their presumed extirpation on at least seven cays. Blair believed that roughly 500 individuals remained. Although these reports reflected well the precarious nature of the iguana's status, none were based on rigorous sampling.

The purpose of this study was to evaluate the population status of *C. r. rileyi* on San Salvador Island, Bahamas, more precisely. In addition to our population estimates, we also report on several human-related factors that threaten the future survival of the subspecies.

Materials and Methods

STUDY SITE. San Salvador (Figure 2) is a relatively small island (156 km^2) situated east of the Grand Bahama Bank. Because it is not a part of any bank system, it has presumably been isolated from the rest of the Bahamian archipelago throughout its history (Olson et al., 1990). It is composed of limestone, with many karst features including caves, sinkholes and an abundance of fissures that serve as retreats for iguanas. The greatest elevation is 43 m (Smith, 1993). An extensive system of mostly hypersaline lakes comprises much of the surface area of the island. Temperatures average 31 °C during summer and 17 °C during the coolest month, December (Smith, 1993). Annual precipitation varies considerably, generally ranging from 100-180 cm, with a definite rainy (hurricane) season from August to November, and a lesser rainy season in May and June (Smith, 1993).

Centuries ago, the island was occupied by Lucayan Indians, whose impact on the native flora and fauna is poorly understood. In the pre-

vious century, however, the habitat of San Salvador was significantly altered when most of the island was under cultivation (Olson et al., 1990). Feral animals, in addition to habitat loss and probable hunting by humans, may have contributed to the iguanas' demise (cf. Iverson, 1978). Surviving colonies of iguanas, it would appear, are now largely confined to a handful of small cays just offshore and within the inland lakes (Blair, 1991; see Figure 2). During the last glacial period (which ended ca. 10,000 years ago according to Plummer, 1979), these cays would have been connected to the mainland (since water depths of only ca. 3-10 m now separate them) and were therefore probably populated by iguanas. But as sea levels increased, iguanas inhabiting the newly-formed cays became isolated. Some cays may have become populated or supplemented by iguanas that swam or "rafted" to them on floating vegetation from the mainland or other cays. Presumably, iguanas originally arrived at San Salvador via rafting (Schwartz and Carey, 1977).

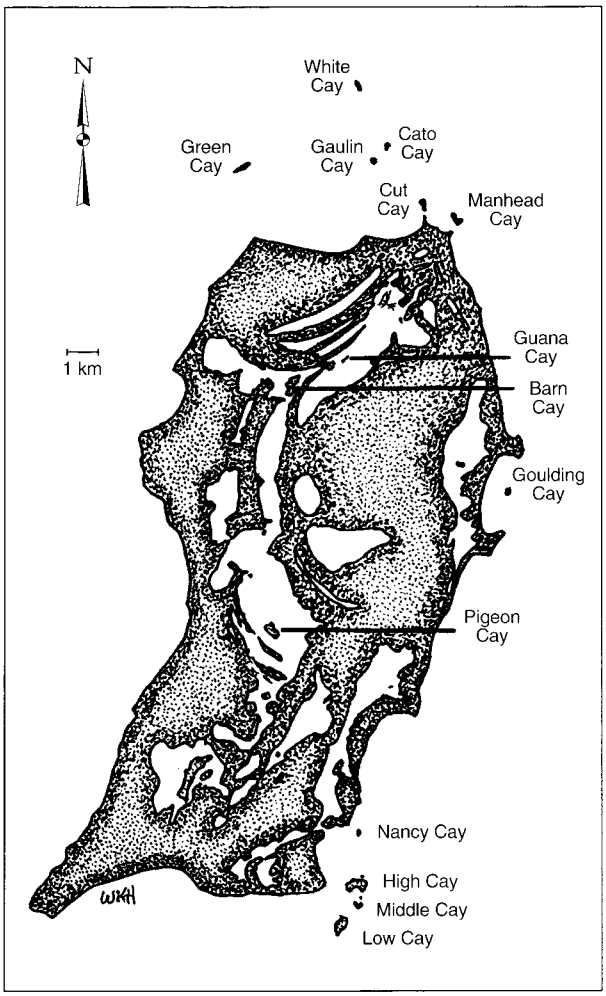

Figure 2. Map of San Salvador Island, Bahamas.

The vegetation of these cays is highly varied, particularly in plant diversity, which ranges from a mere 10 species on Green Cay to more than 40 species on Guana and High Cays (Moyroud and Ehrig, 1994). The vegetation on the offshore cays is similar in varying degrees to the coastal rock, the sand strand and sea oat, and the coastal coppice plant communities on the mainland (Smith, 1993). However, for cays within the inland lakes, the vegetation of Guana Cay resembles the blacklands (coppice) community on the mainland (Smith, 1993), while that of Pigeon Cay represents the mangrove community (Blair, 1991; Smith, 1993).

POPULATION SURVEYS. We began our studies in May 1993 by capturing and marking iguanas on three cays: Guana (n = 5), Manhead (n = 11), and Green (n = 12). In May 1994, we marked additional iguanas on Manhead (5 more) and Green Cays (35 more), as well as on Low Cay (n = 9); we visited but did not attempt to capture more lizards on Guana Cay. We also explored several cays lacking iguanas. Our marking technique was that of Rodda et al. (1988), consisting of two colored plastic (and later, glass) beads sutured to the nuchal crest by monofilament line.

We returned to San Salvador in July 1994 to conduct population surveys on five of the seven cays inhabited by iguanas. All censuses conducted in July were made during the heat of the day, between 1000-1500 hrs, in typically clear, dry weather. On some days, light showers occurred in the afternoons (stimulating iguana activity), but always after we had completed our surveys. During these censuses, iguanas on all cays were largely inactive due to the high midday temperatures. Most were located by two investigators carefully searching vegetation clumps in a coordinated manner so as not to double-count iguanas. While many were found at rest, numerous iguanas were detected only when flushed. Gentle probing of the denser brush with 2.7 m fishing rods was especially effective at flushing concealed, otherwise immobile animals.

We performed Lincoln-Peterson estimates of iguanas on Manhead and Green Cays, where there were sufficient marked animals (n = 16 and 47, respectively). This technique is used mostly for mark/recapture studies (Nichols, 1992), but the highly visible colored beads we used made resighting of marked and unmarked iguanas a better alternative to recapture. For the Lincoln-Peterson estimates, we recorded all iguanas seen or heard during a careful, deliberate search covering the entire cay. With the aid of binoculars, we categorized well-seen iguanas as either marked or unmarked. Poorly-seen iguanas were categorized as "uncertain" because we could not determine whether they were marked or not.

Accordingly, we had two estimators for iguana abundance: the numbers of well-seen and poorly-seen iguanas, respectively, observed during our cencuses. In both cases, because many iguanas were underground in burrows or were not flushed during the census, the numbers of iguanas counted represented only a portion of the iguanas on the cay. For well-seen iguanas, we calculated the total number of iguanas they represented (N_1) by use of the Lincoln-Peterson equation. In essence, the ratio of the numbers of marked ($N_{resighted}$) to total animals seen (N_{seen}) during a given census on a cay should be equal to the ratio of marked animals (N_{marked}, a known entity) to the total population represented by well-seen iguanas (N_1, an unknown number that is extrapolated). Hence, N_1 was estimated by the equation: $N_{marked}/N_1 = N_{resighted}/N_{seen}$.

The number of iguanas represented by poorly-seen individuals (N_2) had to be estimated in another way. To calculate these, the number of "uncertain" iguanas seen ($N_{uncertain}$) was multiplied by the ratio of marked animals (N_{marked}) on the cay to the number of marked animals resighted ($N_{resighted}$). The latter ratio represents the proportion of iguanas known to be present that were resighted during the census. Thus, $N_2 = (N_{uncertain})\ (N_{marked}/N_{resighted})$. Accordingly, the total population estimate (N_{total}) for a given cay was the sum of the estimate based on well-seen iguanas (N_1) and the estimate derived from poorly-seen, or "uncertain" iguanas (N_2).

Because of significant variation in body size among the populations (Goodge et al., 1995) and resultant confusion in clearly separating juveniles from adults on the different cays, and because several juveniles were marked in the Manhead and Green populations, we did not distinguish between size classes in our counts. Though widely employed by population biologists, the Lincoln-Peterson method has implicit assumptions that should always be specified. In our case, we assumed that: 1) the colored beads remained on all animals (we saw no evidence to the contrary, although several iguanas had lost the beads on one side of their neck); (2) mortality of marked animals was negligible [generally true of adult *Cyclura* (95-99% annual survival; Iverson, pers. comm.), and nearly all animals were marked adults]; (3) marked iguanas were as likely to be seen during the census as those never captured before [Iverson (1989) indicated that capture rates for *C. cychlura inornata* were similar for marked and unmarked iguanas]; and (4) the ratio of marked to unmarked animals was similar for animals seen poorly and those seen well enough to determine whether they were marked. Because juveniles were seldom seen, perhaps being less active at midday or occupying microhabitats that were not examined closely, we have possibly underestimated total population sizes.

On other cays without (or having too few) marked iguanas, we followed a similar, deliberate search that usually covered the entire cay, and simply counted the number of individuals encountered. On Low Cay, we concentrated our survey in the vicinity of sea grape (*Coccoloba uvifera*) stands (the favored habitat of iguanas on this cay) along the western and northern portions of the island. The large stand on the west side of the cay was so extensive, however, that we chose not to tramp through it in search of additional iguanas. Similarly, our census was limited on Goulding Cay (to about two-thirds of the habitat) by the nearly impenetrable density of much of the vegetation.

Simply counting iguanas on these cays, however, is not enough to establish the population size. The Lincoln-Peterson surveys indicated that approximately one-third of the marked iguanas on Manhead (6/16; 37.5%) and Green (15/47; 31.9%)

cays were resighted (21/63 for both cays combined; 33.3%). This ratio suggests that, on any given cay (under similar survey conditions), only one-third of the population present is likely to be encountered during a census. Hence, for the other cays visited, we simply multiplied the number of iguanas seen by three to derive a reasonable estimate of population size (our "observed × 3" method). Obviously, this multiplication factor might vary for season, weather conditions, and time of day. Therefore, one cannot directly apply our method to surveys at other times of the year, or to other populations. The investigator must have some means of first estimating the percentage of animals that can be counted during the brief time when a census is taken. In our case, the two Lincoln-Peterson estimates provided a statistically justifiable basis for the method.

Figure 3. The extensive prickly-pear cacti (*Opuntia stricta*) on Green Cay (left) are being decimated by the larvae (inset; a video image) of an introduced moth from South America (*Cactoblastis cactorum*). *Photographs: William Hayes*

Results

The absolute numbers of iguanas found on each cay, and their corresponding population estimates, are summarized in Table 1. Prior status of the iguanas, based on reports by previous investigators, is also summarized.

On Manhead Cay, twenty animals were seen well enough to determine whether they were marked; of these, six were previously marked. The Lincoln-Peterson index suggested a total of 53 for well-seen iguanas. Six (37.5%) of the 16 marked animals were resighted. An additional eight iguanas were poorly seen, and these "uncertain" sightings were estimated to account for another 21 animals. By summing these two estimates, we calculated a total of 74 iguanas on Manhead Cay, with an absolute minimum (actual number of iguanas counted) of 28 (see Table 1).

Similarly, on Green Cay we sighted 61 iguanas well enough to determine if they were marked, and 15 had been marked previously. The Lincoln-Peterson index suggested a total of 191 iguanas based on the well-seen sightings. Fifteen (31.9%) of the 47 marked animals were relocated. Another 19 animals were poorly seen, and these were estimated to account for an additional 60 iguanas. Summing the two estimates, we calculated a total of 251 iguanas on this cay, with an absolute minimum of 79 animals (Table 1).

The absolute minimum number of San Salvador iguanas is 174, while the estimated population size (excluding the unknown numbers on Pigeon Cay) is 527 (Table 1). Green Cay probably hosts the largest population, while two cays (Gaulin and Guana) may have fewer than 25 individuals.

Several potential threats to iguana well-being were documented. On Green Cay, we discovered that many stands of prickly-pear cacti *(Opuntia stricta*) were infested with the larvae of *Cactoblastis cactorum* moths (Figure 3). On Manhead Cay, we observed many iguanas having a tar-like substance adhering to their snouts. In 1993, eight of the nine iguanas photographed (89%) were thus affected, whereas two of eight (25%) had the condition in May and August 1994. However, this

Table 1. Summary of previously published status and our recent (1994) population estimates of iguana (*Cyclura r. rileyi*) populations on San Salvador Island, Bahamas.

Known/Potential Populations (area)	Prior Status	Absolute Minimum	Estimated Pop'n Size	Census Method
Barn Cay (14 ha)	Extirpated[a]	0	0	Observed × 3
Cato Cay (3 ha)	Extirpated[b,c]	—	—	Not visited
Cut Cay (3 ha)	Extirpated[b,c]	0	0	Observed × 3
Gaulin Cay (2 ha)	Extirpated[b,c,d]	3	9	Observed × 3
Goulding Cay (3 ha)	Small pop'n[a]	30	90	Observed × 3
Green Cay (5 ha)	Small pop'n[a,c,d]	79	252	Lincoln-Peterson
Guana Cay (1 ha)	Abundant[e]	8	24	Observed × 3
High Cay (15 ha)	Extirpated[a,b,d]	0	0	Observed × 3
Low Cay (12 ha)	Abundant[a,c,d]	25	75	Observed × 3
Mainland (15,000 ha)	Small pop'n[b,c]	1	3	Observed × 3
Manhead Cay (3 ha)	Small pop'n[a,d]	28	74	Lincoln-Peterson
Middle Cay (2 ha)	Extirpated[a]	0	0	Observed × 3
Nancy Cay (1 ha)	Unreported	0	0	Observed × 3
Pigeon Cay (10 ha)	Small pop'n[c]	—	unknown	Not visited
White Cay (3 ha)	Extirpated[a,b,d]	—	—	Not visited
Estimated Totals		**174**	**527**	

Population surveys conducted in May (Barn, Guana, Middle Cays) or July (all other keys we visited) of 1994; for comparative purposes only, sizes of cays (area in ha) are crude estimates, based on a map lacking accurate surface detail, and are rounded to nearest hectare; absolute minimum = number of animals seen; see text for explanation of census techniques.

[a] Auffenberg (1982b), based on relative numbers observed and interviews with local residents; he estimated the Low Cay population in excess of 100.

[b] Don Gerace (pers. comm.) reported that although iguanas have long been absent from Cato, Cut and White Cays, they were still present on Gaulin (up to 18) and High Cays in the early 1980's; further, a small mainland population (2+ iguanas) still persists near Fortune Hill. The mainland iguana we observed was a juvenile several hundred meters west of Sandy Hook.

[c] Blair (1991) updated Auffenberg's (1982b) summary based on relative numbers observed; he saw only 5 iguanas on Pigeon Cay and none on Gaulin Cay in 1991; however, Sandra Buckner (pers. comm.) saw one individual on Gaulin Cay in 1993.

[d] Gicca (1980) saw 27 iguanas on Green, 15 on Manhead, 10 on Low, and 7 on High Cay in December, 1974; by transect methods, he estimated 35, 28, and 30 iguanas on Green, Manhead and Low cays, respectively. He saw no iguanas on White and Gaulin cays.

[e] Ostrander (1982) saw and heard approximately 45 iguanas, and estimated at least 80 present on Guana Cay.

condition may reflect natural foods that they had eaten (e.g., fruits or insect larvae; T. A. Wiewandt and J. B. Iverson, pers. comm.). On Guana Cay, we sighted 15 iguanas in May 1993, while in May 1994 we sighted only eight or nine (including two juveniles). Six adult carcasses (including an individual marked in 1993), all in a similar state of decay, were discovered on Guana Cay in March 1994, and two others in a much greater state of decay were found in May 1994 (Jones et al., 1995; see Figure 4). Lastly, on Low Cay, three adult rats (of unknown species but non-native to San Salvador; Olson et al., 1990) were seen during midday on 20 July 1994, all within or at the periphery of dense *Coccoloba* patches. Local residents described an abundance of rats on the mainland.

Figure 4. Mummified iguana from Green Cay. Decaying iguana carcasses found on Guana Cay in 1994 were indicative of a die-off of unknown cause. *Photograph: William Hayes*

Discussion

Presently, *C. r. rileyi* appears to be limited to seven small populations on offshore/inshore cays and one or more small populations on the mainland. However, further exploration, particularly on the mainland and on the southernmost hypersaline lakes, may reveal additional colonies.

It is interesting to compare our data with the conclusions ("prior status" in Table 1) arrived at by other investigators. For example, the "small population" on Green Cay is much healthier than previously believed; indeed, it may host nearly half of all San Salvador iguanas. Likewise, the "small" populations on Manhead and Goulding Cays appear to be comparable in size to the "abundant" population on Low Cay. The population on Goulding Cay, which appears to be flourishing, evidently had not been visited in at least 14 years (Auffenberg, 1982b). Compared to Auffenberg's (1982) dismal estimate of 200 remaining iguanas and Gicca's (1980) low estimates for the three cays he sampled, our estimation of 500-600 iguanas is closer to that predicted by Blair (1991). If we underestimated the comparatively secretive juvenile population (which we suspect), total numbers may be even higher. Nevertheless, these numbers still rank the subspecies among the rarest lizards in the world, and the remaining populations are critically threatened (see below). Our results serve as important baseline data for future assessment of *C. r. rileyi.*

Consistent with previous reports, we failed to locate iguanas on Barn, Cut, High, and Middle Cays. To these we can add that iguanas are not present (and likely never were, considering the minimal vegetation) on tiny Nancy Cay, directly north of High Cay. More importantly, we discovered three adult iguanas on Gaulin Cay, where they were suspected of being extirpated (Blair, 1991). Evidently, a small population still coexists with the several hundred pairs of brown noddies (*Anous stolidus*) and sooty terns (*Sterna fuscata*) that nest there. The Gaulin population probably never has been sizeable, and therefore genetic sampling of the iguanas should be a high priority.

Extirpation of iguanas on several of the cays has apparently been quite recent. Auffenberg (1982b) spoke with local residents who indicated that iguanas were present on Barn Cay in the early 1970's, but neither he nor our group could find iguanas or any sign of their presence. Gicca (1980) encountered iguanas on High Cay as recent as 1974, but they were evidently gone by 1980 (Auffenberg, 1982b). High Cay, however, is large and vegetationally diverse enough to con-

ceal a small remnant of iguanas, but searches in March 1994 by Jones et al. (pers. comm.) and by us in May and July found none.

Unfortunately, most of the surviving populations are presently vulnerable to human-related causes. The prickly-pear cacti on Green Cay, a major food source and one of only 10 plant species on the island (thus providing a very low diversity diet; cf. Auffenberg, 1982a), are under severe attack by the larvae of a moth *(Cactoblastis cactorum)* introduced to the Caribbean from South America several decades ago (Ehrig, pers. comm.). To date, no effective means of controlling the moth are known, and as a result the cacti population may decline dramatically. The relationship between cactus destruction and iguana abundance and condition should be closely monitored, and cacti on other cays should be inspected periodically for infestation.

Iguanas on Guana Cay experienced a mysterious die-off in the spring of 1994, as evidenced by the discovery of eight adult carcasses that appeared to be several weeks or more in decay (Jones et al., 1995). Because the carcasses all appeared to be in similar states of decay, they may have died within a narrow time frame of a similar, but unknown, cause. Ostrander's (1982) observation of 45 individuals contrasts sharply with the maximum of 15 individuals seen by us in May 1993, and of 8-9 individuals seen by Jones et al. (1995) in March and in May 1994. This population is parasitized by ticks, which have not been detected on other cays visited (Goodge et al., 1995). Perhaps the added stress of parasitism (e.g., reduced blood cell volume, especially in the case of adult lizards; Dunlop and Mathies, 1993) made the iguanas more susceptible to the agent that caused their deaths. However, the live iguanas seen in March (C. Jones, pers. comm.) and in May appeared to be perfectly healthy, with no obvious weight loss. Several juveniles were among the sightings; hence, some successful reproduction is occurring. Occasional blood screening (cf. Auffenberg, 1982b) could help identify causes of mortality.

With continued downsizing of the Guana Cay and other populations, inbreeding depression and random extinction events become increasingly likely. Moreover, a minimum level of social interactions may also be necessary to stimulate maximal reproductive output. Although introduced populations of *Cyclura* have become established with as few as three founders (Ehrig, pers. comm.), such success may be an exception more so than the rule.

On Low Cay, juvenile and subadult iguanas appear to be virtually absent. In contrast, in March of 1982, Auffenberg (1982b) reported seeing numerous juvenile iguanas on the cay. Because we saw numerous juveniles on both Manhead and Green Cays, we doubt that the different seasons of sampling (March vs. May and July, respectively) were responsible for the discrepancy between 1982 and 1994. The presence of rats and conspicuous lack of small iguanas (only one juvenile seen during the May 1994 expedition) suggests that the introduced rats are harming the population, most likely by preying upon juveniles and/or eggs. Most iguanas that we saw appeared to be old adults (Figure 5) holding territories along the periphery of the enormous *Coccoloba* stand on the west side of Low Cay, but it is possible that the smaller iguanas were more concentrated in the center of the stand (where we did not search) or in another microhabitat we overlooked. Iguanas have already become extirpated on nearby High Cay, where evidence of rats led Auffenberg (1982b) to suggest them as the cause of the iguanas' demise. The potential predation by rats upon iguanas should be evaluated both by direct observation (if possible) and by experimentation. Further, the cay is small enough that the rats could probably be extirpated by live-trapping at night, when iguanas are inactive.

Some of the cays presently inhabited by iguanas, Green Cay in particular, are probably close to their carrying capacity. With the exception of Low Cay (and possibly High Cay), feral animals do not appear to threaten populations. This is in contrast to the mainland, where feral animals would negate reintroduction into any but the most remote localities. Other cays, however, clearly are not at their carrying capacity—most notably Guana Cay and the cays where populations have been extirpated. The latter cays need to be carefully examined for possible reasons why iguanas

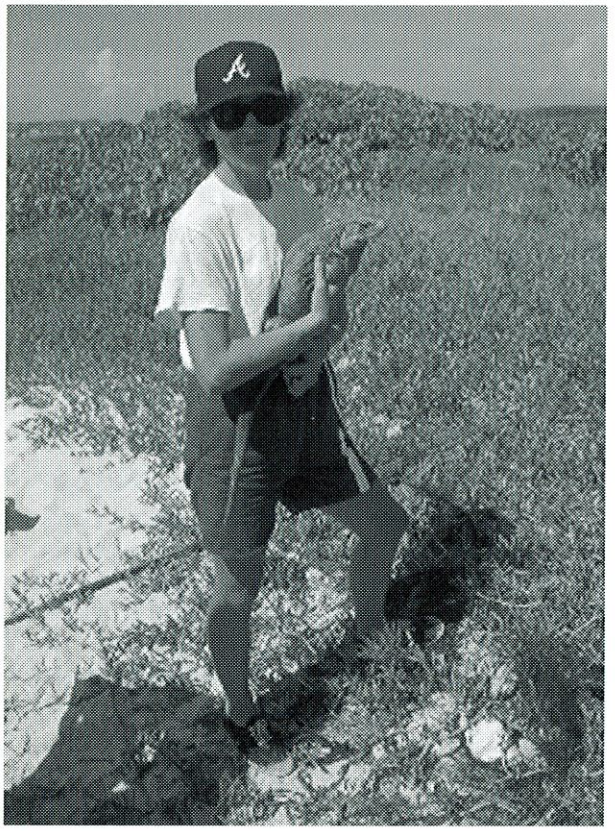

Figure 5. The iguanas on Low Cay appear to be mostly old adults. Although regarded as the smallest *Cyclura* species, *C. r. rileyi* on Low Cay attain a maximum body size equivalent to or larger than several other taxa. *Photograph: William Hayes*

disappeared. Because local extinction events can occur (e.g., by natural course of disease), we need not assume that empty cays are incompatible with iguanas. If these cays can be deemed or rendered satisfactory, iguanas from healthy populations or from a head-start/release program (e.g., Alberts, 1995) could be reintroduced.

However, reintroductions of iguanas cannot be done haphazardly. It is important that we first ascertain the genetic composition of each and every population so that we can work to maintain genetic diversity—and if necessary the genetic identity—of the populations. Because of their isolation, presumably with reduced gene flow, individual populations may have diverged genetically. Accordingly, management decisions should be based on genetic information. For example, populations low in number could be most rapidly replenished by translocation of individuals from other populations—but only if the iguanas are deemed genetically compatible. Currently, we are comparing DNA samples from each population to make better-informed management decisions in the future.

In addition to the factors discussed already, we must consider direct human effects. Although the local residents occasionally collect bird eggs from the cays (K. Gerace, pers. comm.), they evidently do not feed on iguanas, and most islanders express respect and concern for their well-being. Smuggling, however, has been a problem (D. Gerace, pers. comm.). Increased visitation of the cays spawned by the growing tourism industry represents another threat. These problems could be at least partially alleviated by a public relations campaign that should include posting information signs on each cay (as done recently in the Allan's Cays; see Iguana Times 1(5):13) and distributing pamphlets that alert residents to report smugglers. Fortunately, San Salvadoran officials have expressed a commitment to safeguarding their endemic iguanas, and (like many residents) are alert to any boaters that visit cays harboring iguanas.

Clearly, the San Salvador rock iguana and other endangered *Cyclura* species will continue to decline without direct intervention. As primary agents of their demise, we must take seriously our responsibility for the stewardship of these unique relics of West Indian natural history.

Acknowledgements

We are indebted to numerous individuals for their generous and enthusiastic assistance with this project. The following participated in the capture and processing of iguanas: S. and S. DeLay; R. W. Ehrig; A. and F. Ferko; B., D. and J. Francis; N. Gonzalez; T. Haack; E. Harris; M. Hills; R. Moyroud; D. Sammer; T. Simoes; and Dr. Jerry Carpenter with his students from Northern Kentucky University. C. Jones, C. and M. Keith and G. Livingston visited Guana and Barn Cays during the May expedition. R. Armentrout helped conduct the survey on Green Cay, and J. Garbisch assisted with the census on Goulding Cay. R. W. Ehrig not only discovered and identified the *Cactoblastis* larvae, he freely offered suggestions and advice based on his extensive knowledge of *Cyclura* biology. S. Buckner and D. Gerace kind-

ly supplied valuable information and heartfelt encouragement. J. Iverson, T. Wiewandt and two anonymous reviewers offered suggestions that improved the manuscript. Research was supported by the Bahamian Field Station and by grants to WKH from Southern College and from the Geoscience Research Institute (Loma Linda University, California).

Literature Cited

Alberts, A. 1995. A reintroduction program for the iguanas of Guantanamo. Iguana Times 3(4):10-12.

Auffenberg, W. 1976. Bahama Rock Iguanas, Part Two. Bahamas Nat., Summer 1976:9-16.

Auffenberg, W. 1982a. Feeding strategy of the Caicos ground iguana, *Cyclura carinata*. Pp. 84-116 in: Burghardt, G. M. and A. S. Rand (Eds.), Iguanas of the World: Their Behavior, Ecology and Conservation. Noyes Publ., Park Ridge, New Jersey.

Auffenberg, W. 1982b. Conservation of Bahamian Rock Iguanas (*Cyclura* sp.). Unpublished Project Report, U. S. Fish & Wildlife Service.

Blair, D. 1991. Update on the status of the San Salvador rock iguana, *Cyclura rileyi rileyi*. Iguana Times 1(2):1-3.

Blair, D. 1994. Rock iguanas. Reptiles 1(4):40-63.

Dunlap, K. D. and T. Mathies. 1993. Effects of nymphal ticks and their interaction with malaria on the physiology of male fence lizards. Copeia 1993:1045-1048.

Gicca, D. 1980. The status and distribution of *Cyclura r. rileyi* (Reptilia:Iguanidae): A Bahamian rock iguana. Carib. J. Sci. 16:9-12.

Goodge, B., D. Brouhard, W. K. Hayes, D. M. Hayes and R. L. Carter. 1995. Population estimates, morphological variation, and conservation of the San Salvador Island rock iguana, *Cyclura r. rileyi*. J. Tenn. Acad. Sci. (abstract in press).

Iverson, J. B. 1978. The impact of feral cats and dogs on a population of the West Indian rock iguana, *Cyclura carinata*. Biol. Conserv. 24:3-73.

Iverson, J. B. 1985. Lizards as seed dispersers? J. Herpetol. 19:292-293.

Iverson, J. B. 1989. Natural growth in the Bahamian iguana *Cyclura cychlura*. Copeia 1989:502-505.

Jones, C., G. Livingston and C. Keith. 1995. Mortality and ecological observations on rock iguanas (*Cyclura r. rileyi*) of Guana Key, San Salvador Island, Bahamas. J. Tenn. Acad. Sci. (abstract in press).

Moyroud, R. and R. W. Ehrig. 1994. I.I.S. vegetation studies. Iguana Times 3(2):13-16.

Nichols, J. D. 1992. Capture-recapture models. BioScience 42:94-102.

Olson, S. L., G. K. Pregill and W. B. Hilgartner. 1990. Studies on Fossil and Extant Vertebrates from San Salvador (Watling's) Island, Bahamas. Smithson. Contrib. Zool. 508:1-15. Smithsonian Inst. Press., Washington, D. C.

Ostrander, G. K. 1982. Discovery of an isolated colony of rock iguanas. Bahamas Nat. 6(2):22-24.

Plummer, C. C. 1979. Physical Geology. Wm. C. Brown Co. Publ., Dubuque, Iowa.

Rodda, G. H., B. C. Bock, G. M. Burghardt and A. S. Rand. 1988. Techniques for identifying individual lizards at a distance reveal influences of handling. Copeia 1988:905-913.

Schwartz, A. and W. M. Carey. 1977. Systematics and evolution in the West Indian iguanid genus *Cyclura*. Stud. Fauna Curacao and Carib. Is. 53(173):15-97.

Smith, R. R. 1993. Field Guide to the Vegetation of San Salvador Island, the Bahamas. 2nd Edition. Bahamian Field Station, San Salvador, Bahamas.

Wiewandt, T. A. 1977. Ecology, behavior, and management of the Mona Island ground iguana, *Cyclura stejnegeri*. Unpubl. Ph.D. dissertation, Cornell University, Ithaca, New York.

Acting Editor: John B. Iverson
Received: 3 February 1995
Accepted: 2 March 1995

NOTE ADDED IN PRESS: We visited Pigeon Cay in March 1995 and saw or heard 15 iguanas—all at the periphery of the cay. We assume iguanas also inhabit the virtually impenetrable mangrove interior, in which case a healthy population would be present. Regarding the rats on Low Cay, a recent article (by A. Cree, C. H. Daugherty and J. M. Hay, 1995, Conservation Biology 9:373-383) provides evidence that island populations of the tuatara *(Sphenodon punctatus)*, an iguana-sized reptile in New Zealand, have been significantly impacted by introduced rats. Thus, we are further convinced that rats pose a serious risk to the future of the Low Cay iguanas.

This marked female on Guana Cay appeared to be copulated by a male within one hour of being processed and released on 26 May, 1993.
Photograph: William Hayes