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Male *Cyclura pinguis* (no. 9) one year after the initial release. This iguana traveled only about 13 m from the original release site on Middle Cay.

Conservation of the Anegada Iguana (*Cyclura pinguis*)

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Abstract.—The long-term survival of the Anegada Iguana (*Cyclura pinguis*) is uncertain. The species is in danger of becoming extinct due to habitat destruction, competition with feral livestock, and the introduction of non-native mammalian predators. In an effort to save the Anegada Iguana, the IUCN Iguana Specialist Group and the British Virgin Islands National Parks Trust began a concerted conservation effort in 1997. They initiated a headstart program in order to bolster the wild population until many of the problems facing the iguanas can be minimized or removed. Headstarted iguanas were released back into the wild in October of 2003 and 2004. This paper briefly reviews the natural history of *C. pinguis* and presents some preliminary results from the ongoing long-term monitoring of the subadult iguanas reintroduced to the wild.

Key Words: Anegada Iguana, *Cyclura pinguis*, British Virgin Islands, Conservation, Headstarting, Reintroduction, Radiotelemetry

Natural History

Herbivorous Rock Iguanas (Iguanidae: *Cyclura*) occur only in the West Indies. The critically endangered Anegada Iguana (*Cyclura pinguis*) is one of the largest species in the genus. Adults can grow to 550 mm in snout-vent length (SVL) and weigh up to 7 kg (Carey 1975). Genetic studies have shown this species to be the most basal of extant lineages (Malone et al. 2000). The extent of the historical range is uncertain. The species is known to have occurred on Puerto Rico, where cave fossils date from 15,000–20,000 years ago, before the arrival of humans (Pregill 1981). Fossil evidence also has been found on St. Thomas (U.S. Virgin Islands). These remains, however, are associated with Native American middens (Miller 1918). Whether these remains were imported or collected locally is unknown. Regardless, presumably before Europeans arrived in the Americas, the Anegada Iguana became restricted to the island of Anegada in what is now the British Virgin Islands (BVI).

Since 1984, the species' range has been expanded through the introduction of iguanas from Anegada to Guana, Necker, and, most recently, Norman Island, all three of which are also in the BVI (Goodyear and Lazell 1994, Lazell 1995). These islands are privately owned and afford these established populations some protection from threats facing the population on Anegada. These satellite populations appear to be thriving, and serve as a hedge against extinction for the species as a whole.

On Anegada, iguanas typically are found in two habitat types, sandy scrub or rocky woodland. Sandy scrub is charac-

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A hatchling *Cyclura pinguis* emerges from a nest that was excavated in July by a female in the Bones Bight area of Anegada.


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Fort Worth Zoo veterinarians surgically place transmitters into the coelomic cavity of each iguana.

terized by small to medium-sized woody shrubs, grasses, and some larger trees. Vegetation can be very dense and can limit access in some areas. In this habitat, iguanas dig burrows for retreats. Rocky woodland has a limestone substrate with many holes and crevices that iguanas use as retreats. Vegetation is composed of some smaller shrubs, tall mature trees, and cacti. Vegetation at both sites supplies iguanas with food (leaves and fruit), shade, and retreats.

Reproductive activity is tied to seasonal changes that promote a high hatch rate (Alberts 2000, Harris 1982, Rand and Green 1982, Wiewandt 1982). The mating season falls in May and June. Females dig nests from late June through July, shortly after the spring rains, when the ground is soft. Temperatures are high during the summer 90-day incubation period. Hatchlings emerge during the wet fall, when food resources are most abundant (Gerber 2000).

Females can lay up to 20 eggs, although the average is 13. The reproductive strategy of producing fewer but larger offspring is the result of evolving in a predator-poor environment. This strategy, however, renders the species very vulnerable to introduced predators that target juveniles. In contrast, the Green Iguana (*Iguana iguana*), which evolved in the predator-rich environments of Central and South America, can produce clutches of fifty eggs. Consequently, introduced Green Iguanas can become established even on islands with effective predators such as cats and mongooses.

Conservation Status and Major Threats

The Red List of the International Union for the Conservation of Nature and Natural Resources currently lists *C. pinguis* as "Critically Endangered" (IUCN 2004) and the species is listed in Appendix I by the Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES 2004). Recent population estimates suggest that the Anegada Iguana has suffered an 80% decline in numbers since the late 1960s (Mitchell 1999). Accurately estimating population size is difficult because of the species' secretive nature and fragmented population. The most recent estimates are 200 wild adults and 44 repatriated iguanas on Anegada (Gerber 2004) plus 80 individuals currently in the headstart facility (Walker, pers. comm.), 130 on Guana, and 30 on Necker (Perry and Mitchell 2003). These low numbers suggest that *C. pinguis* is one of the most endangered lizards in the world.

Cyclura pinguis faces many threats. Human encroachment is destroying the remaining habitat. An ongoing controversy over land ownership on Anegada has resulted in many of the long-term residents being unable to acquire clear title to land on which they have lived for generations, and many locals have negative feelings toward establishing a large national park that incorporates most of the core iguana area. A portion of the core iguana area on Anegada is within a Ramsar site (Ramsar Convention on Wetlands), which is internationally protected wetland. However, the most productive nesting area for the remaining population is currently unprotected.

A second major threat to the survival of *C. pinguis* is the large feral livestock population. Large herds of cattle, donkeys, goats, and sheep range freely. Simply by stepping on them, live-


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The staff of the British Virgin Islands National Trust (Nevil Vanterpoole, Raymond Walker, and Rondel Smith) and Sylvia Faulkner, a local resident who participated in the release of headstarted iguanas back into the wild.

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A rare hatchling *Cyclura pinguis* was captured along the road near Pomato Point on Anegada. This individual was transferred to the headstart facility after being weighed and measured and having a blood sample taken for genetic studies.

stock can collapse burrows and nest chambers, which can result in the death of an animal or an entire clutch of eggs. Secondly, livestock is a significant competitor for food. Vegetation is severely overbrowsed, and the plants not consumed by livestock come to dominate large sections of habitat, where the flora has been completely degraded. The result is vegetation that is used by neither mammals nor iguanas.

The most immediate threat to the survival of C. *pinguis* is the feral cat (*Felis catus*), a very effective predator of iguanas (Iverson 1978). Each fall, when hatchling iguanas emerge from their nests, feral cats prey on the naïve iguanas, resulting in high juvenile mortality. As a result, the wild population on Anegada is made up almost entirely of older adults, with other age classes virtually absent.

In the late 1990s, the British Virgin Islands National Parks Trust (BVINPT) contacted the IUCN Iguana Specialist Group regarding the creation of a conservation plan modeled after the Jamaican Iguana headstart program. The *C. pinguis* headstart program was established in 1997, when Rondel Smith of the BVINPT found three hatchlings floating in Manhead Pond. In cooperation with the ISG, a captive facility was constructed on Anegada to serve as a safe place for hatchling iguanas to be raised. This headstart facility has expanded over the years and currently houses over 80 iguanas. Each July, nesting females are located and their nests are marked. The BVINPT then places protective barriers around each nest. Hatchlings are collected in October and transferred to the headstart facility, where the iguanas are raised in a protective environment by the BVINPT until they are large enough to survive in the wild at relatively little risk from feral cats.

The first release of Anegada Iguanas back into the wild was designed to answer several questions: (1) What is the smallest body size at which an iguana can survive cat predation? (2) What habitat type correlates with the highest survival rates? (3) Can compromised habitat with feral livestock support additional iguanas? (4) Can iguanas adapt to living in the wild after spending the first four to six years in captivity?

Methods

Study Animals.—Forty-eight iguanas were selected from the headstart facility on Anegada during a pre-release health screening. These animals had been in the facility from four to six years. The health screenings consisted of physical exams, blood chemistry analyses, and fecal analyses. These were performed by the Fort Worth Zoo veterinary staff as part of a five-year, multispecies, health-screening project funded by a Morris Animal

Foundation grant to Bonnie Raphael and Rick Hudson. All health screenings followed the guidelines for pre-release screening adopted by the ISG.

After passing the health screening, animals underwent surgery to implant radio-transmitters. A transmitter was surgically placed in the coelomic cavity of each animal prior to release by veterinary staff of the Fort Worth and Bronx zoos. Two radio-transmitter models manufactured by Holohil Systems, Ltd. (Ontario, Canada) were used. Twelve animals were implanted with model SI-2, which weighed 9.3 g and had a projected battery life of 12–14 months. Thirty-six animals were implanted with model AI-2T, which weighed 16 g and had a projected battery life of 24–26 months. Each transmitter type provided both directional and temperature data. All transmitters were less than 1% of the average subject mass. The smaller transmitters were used in the smaller iguanas (<1200 g).

Morphometric data (SVL, tail length, mass, head width, head length, and largest crest scale length) were recorded for each animal prior to release. Animals were uniquely marked by using colored glass beads attached to nuchal crest scales. Additionally, each animal also had an identification number painted on each side of its body using T-shirt bubble paint. After a recovery period of 5–10 days, the iguanas were released into the wild.

To experimentally determine the optimal body size of headstarted iguanas for release back into the wild, we released a variety of sizes (Table). In 2003, we released 24 animals ranging in mass from 750–2050 g. In 2004, we released another 24 iguanas ranging in mass from 597–1590 g. We released equal numbers of male and female iguanas at each site in both years.

Release Sites.—Each year, we released iguanas at two sites where wild iguanas were present prior to the release. Iguanas were transported from the headstart facility and released in the early morning. Each year, half of the iguanas were released on Middle Cay, one of the large peninsulas located in the western salt ponds. The substrate on Middle Cay is eroded limestone filled with solution holes and crevices. Iguanas typically use the rock crevices and sink holes for retreats. Vegetation is mostly xerophytic thorn forest, with the principle plants being "Pokemeboy" (*Acacia anegadensis*), Loblolly (*Pisonia subcordata*), and cactus (*Melocactus intortus*) (Carey 1975, Mitchell 1999).

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Kelly Bradley manually tracking iguanas at the Faulkner study site.

The second release site is the Faulkner site, located in the Bones Bight area. The Faulkner site, part of the dune system on the northwestern shore, is a coastal scrub habitat with a sand substrate. Iguanas typically dig burrows in the sand to use as retreats. Vegetation is fairly dense, and principal plants are Torchwood (*Dodonaea viscose*), Sea Grape (*Coccoloba uvifera*), and Black Candlewood (*Erithalis fruiticosa*) (Carey 1972, Mitchell 1999).

Both sites are within the remaining core iguana area and are encompassed within the Ramsar site, affording the iguanas some degree of protection. All of the animals were released in the same location at each study site on approximately the same day in

Table. Initial mass of headstarted *Cyclura pinguis* at time of release for the 2003 and 2004 study groups. Mass in g.

2003 Release				2004 Release			
Middle Cay		Faulkner Site		Middle Cay		Faulkner Site	
Sex	Mass	Sex	Mass	Sex	Mass	Sex	Mass
M	2050	M	1900	M	1540	M	1590
M	1300	M	1590	M	1340	M	1150
M	1200	M	1170	M	1040	M	950
F	1420	F	1360	F	1160	F	1160
F	1400	F	1360	F	1040	F	1060
F	1250	F	1290	F	950	F	980
M	1150	M	1250	M	760	M	930
M	1000	M	910	M	750	M	710
M	860	M	890	M	605	M	680
F	1200	F	1285	F	860	F	870
F	890	F	880	F	665	F	685
F	800	F	750	F	665	F	597

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Kelly Bradley and Glenn Gerber measure and weigh each iguana prior to release.

early October, during the peak of the wet season, corresponding to natural hatching periods when food resources are presumably most abundant.

Post-release Monitoring.—Animals were manually tracked for the first 30 days after initial release in October. Post-release monitoring trips lasting two to three weeks were made at 60 days, 120 days, 180 days, 270 days, and 360 days post-release during the first year for a total of 125 days of monitoring. Animals that have a two-year battery transmitter will also be tracked at 420 days, 510 days, 570 days, 630 days, and 720 days for a total of 204 days of monitoring.

Animals were located daily, using a YAGI antenna and a TX1001 receiver. Each time an animal was sighted, its location was recorded using a Trimble GEO XT GPS unit. In addition to manual tracking, a telemetry station was installed at the Faulkner site. The telemetry station consists of a Televit RX-900 scanner/receiver/data logger attached to four directional antennae on a 20-foot metal pole. During fieldtrips, the unit continuously records data, spending one minute on each iguana's frequency. Each time a frequency is detected, the unit records which antenna(e) responded, the strength of the signal, the pulse period relating to internal body temperature, and the time and date.

We conducted focal animal observations on one individual each day. Iguanas were observed for 45 minutes. Observation periods occurred throughout the day to determine temporal patterns. Data were collected on diet, habitat use, activity periods, and interactions with wild adults.

Virtually all animals were recaptured 60 days post-release. For each captured animal, we recorded morphometric data, body temperature, presence and location of ectoparasites, body condition, and surgical incision-site condition. Identification numbers on the animals were reapplied and glass beads reattached, if necessary. We also attempted to recapture iguanas during subsequent monitoring trips, however, iguanas quickly learned the capture techniques, and new techniques had to be used. As a result, recaptures were not always successful. At various time, we used noose poles, large fishnets, and live traps. All animals were released at the point of capture.

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Kelly Bradley and Glenn Gerber paint an identification number on a male iguana before he is released back into the wild at the Faulkner study site.

We collected all fecal deposits found in the field to document the diet and seasonal changes in diet of the headstarted iguanas as compared to the diet of wild adults. A size difference in fecal boluses from wild adults and the much smaller headstarted animals made the distinction obvious.

Results

This is an ongoing project and information presented here is only an overview of results to date. Data will continue to be taken through October 2006 or until transmitter batteries die.

2003 Release.—Sixteen months after initial release in October 2003, 83% of individuals survived. Of the four animals lost, two from each site, three were males, and all were of medium size (890–1170 g). One female was found dead on Middle Cay two days after the initial release, and the death was attributable to complications from surgery. A second mortality occurred after 60 days for reasons unknown; only the transmitter was recovered. A thorough search of the area was made, but the carcass was not recovered. This animal was the smallest male released at the Faulkner site, and also had traveled the farthest from the original release site. The last time this animal was observed alive, at the end of October 2003, it was approximately 322 m south of the point of release. Rondel Smith of the National Trust saw the animal for another two weeks, but was unable to locate it after that time.

Two mortalities were discovered during the March monitoring trip. After 195 days, the transmitter of a medium-sized

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Iguana no. 4, three months after release on Middle Cay of Anegada.

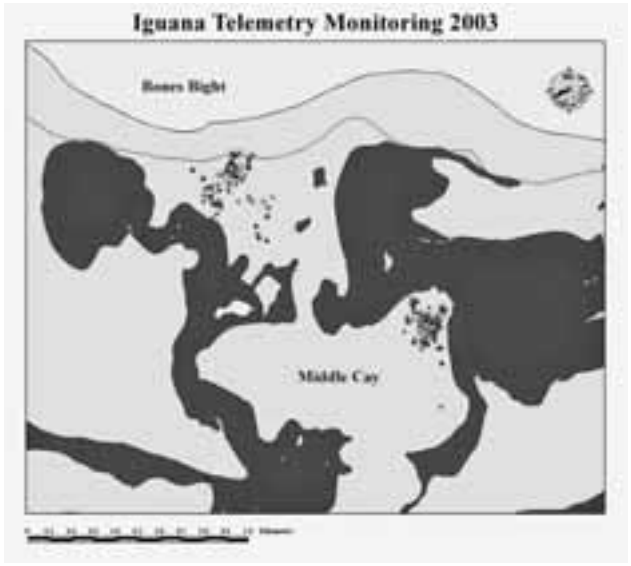
male was found at the Faulkner site. The transmitter appeared to be damaged by rats. We assumed that rats or large land crabs scavenged the carcass. The second mortality was another medium-sized male found in a rock crevice on Middle Cay. The animal was found alive, but in very poor shape. The animal was captured, but died on its way to the local veterinarian. This death occurred 202 days after initial release. A subsequent necropsy conducted by Shannon Ferrell, D.V.M., of the Fort Worth Zoo, showed that this animal had ample fat reserves, but significant muscle atrophy, especially along the dorsal ridge and rear legs. The necropsy clearly showed no signs of granuloma formation or inflammation associated with the transmitter. The iguana had begun to wall off the transmitter with an almost transparent membrane. No clear cause of death was established.

Animals at the two sites moved similar distances from the release point. The shortest and longest distances moved by animals on Middle Cay were 13 m and 391 m. The respective distances for the Faulkner site were 22 m and 322 m. The farthest distance one animal moved in a single 24-hour period was 286 m. Approximately 26 GPS points were recorded for each of the surviving 2003 animals, indicating that the iguanas had spread out evenly in their respective field sites.

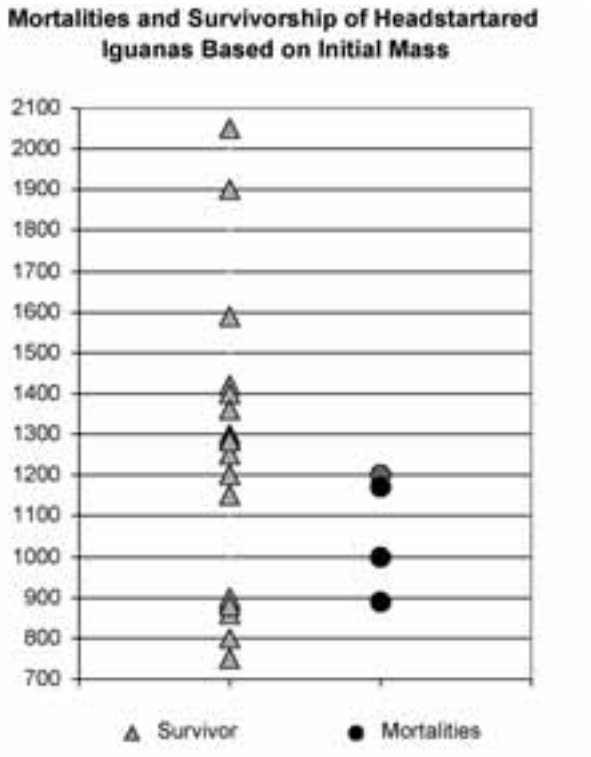
2004 Release.—The second group released in 2004 has been tracked for five months with 92% surviving. One animal from Middle Cay died at 60 days. The animal was a male with a mass at release of 760 g. No carcass was found; only the transmitter was recovered. A second dead iguana was discovered on Middle Cay five months after release. This female had an original mass of 860 g. The carcass was recovered, but it had been severely scavenged. The animal was deposited at the BVINPT and will undergo necropsy at a later date.

Future Plans

We hope to release a third group of iguanas from the headstart facility during October 2005. We plan to release eight animals of a smaller size class. Because the five smallest iguanas released in 2003 are still alive 16 months after release, we believe that we have not yet determined the smallest size at which an iguana can survive in the wild while exposed to potential predation by feral cats. The minimum size of the 2003 release iguanas was 750 g; the minimum size for the 2004 release was 597g. We propose to release animals with a mass as low as 450 g in 2005. By incrementally decreasing the size of released iguanas, we should be able to determine the optimum size for release. This would



Points on the map represent locations where headstarted iguanas have been sighted during the first 10 months after initial release in October 2003.



Our initial prediction was that the smallest individuals would suffer the highest mortality. Instead, iguanas of medium size died. The gray dot represents an animal that died due to complications from surgery.

enable the BVINPT to minimize an individual's time in the headstart facility, and maximize the number of iguanas being brought through the headstart facility. The information gained from this study will optimize the efficiency of the headstart program and thus bolster the remaining wild population at a maximum rate in future years.

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