Cat eradication and the restoration of endangered iguanas (*Cyclura carinata)* on Long Cay, Caicos Bank, Turks and Caicos Islands, British West Indies

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Abstract Endangered Turks and Caicos rock iguanas (*Cyclura carinata*) are being displaced on Big Ambergris Cay by an expansive development project. We chose Long Cay, Caicos Bank, as a relocation site for some iguanas because it: (1) is a large (111 ha), uninhabited, protected reserve, (2) previously supported iguanas but did not have a current population, (3) could support thousands of iguanas, and (4) had no native mammals, few scavenging birds, and no nesting colonies of scavengers. There was a small population of feral cats, well-known iguana predators. To restore the island, we conducted an intensive cat poisoning campaign using sodium monofluoroacetate (1080), in July 1999. In November 1999, a test-group of 25 iguanas was taken from Big Ambergris Cay to Long Cay. Since their successful establishment we have relocated more than 400. The first hatchlings were confirmed in January 2001. Occasional trapping may be necessary to maintain Long Cay free of cats. We have begun patrols and courtesy visits to vessels cruising the area, installed informative and cautionary signs, and produced public service announcements for TV to reinforce the importance of keeping domestic animals away from uninhabited islands.

Keywords Feral cats, *Felis catus*; eradication; iguanas, *Cyclura carinata.*

INTRODUCTION

"When you have hope… that's what you've got."
Tom Sinclair

Biologists who work with rare species and their sustaining resources quickly realise that there is rarely good news to report. Ecological milestones typically range from "Good News - We Found One," to "Good News - They'll Only Be Destroying 90% of the Place!" We measure success on a relative scale, somewhat like a bug being rinsed down a sink drain who manages to hook his foot on the lip of the pipe and pulls himself out of the vortex… temporarily.

Considering all this, it is delightful to have any opportunity to report an ecological improvement: "Good News - We Have Successfully Restored an Island and Have Repopulated It With Endangered Turks and Caicos Rock Iguanas (*Cyclura carinata*)". In order to repopulate, we eradicated a population of predatory feral cats that was responsible for extirpating the native iguanas there. The habitat was then suitable and available for iguana re-colonisation. As of November 2000 we had restored a population of 400 iguanas to the island. They have been thriving and now have offspring. Perhaps this case history can serve as a template for those who are still hopeful.

Background

Human expansion, development, and the biotic baggage that arrives with them have adversely affected most Caribbean iguanas. Impacted taxa include the Lesser Antillean iguana (*Iguana delicatissima*) and all eight species in the genus *Cyclura*. Human predation, habitat reduction through clearing, burning, farming, and building, introduction of exotic competitors for food (feral ungulates), as well as exotic predators (dogs *Canis familiaris*, cats *Felis catus*, and mongooses *Herpestes auropunctatus*) have, on many islands, completely extirpated populations of endemic iguanas.

For example, in the British Virgin Islands where three of us have worked, no one remembers normal populations of the Anegada rock iguana (*Cyclura pinguis*). This species, once widespread on the Puerto Rico Bank, has slowly been reduced, by a number of human-related factors, to one naturally occurring population of fewer than 200 individuals (Mitchell 1999a, 1999b). The most critical problem for adult Anegada iguanas is livestock, which out-compete them for food. Adults are large and, although dogs can and do kill them, they are too big to be taken by cats. Cats kill and eat smaller hatchlings and subadults. Cat predation is the newest threat on the island, because of a town dump, established in the 1990s, that subsidised rapid growth of a feral cat population (Veitch 1998). Anegada needs habitat preservation and restoration, and radical management of exotics if iguanas are to persist there (Veitch 1998, Mitchell 1999a, 1999b, 2000). As of the year 2000, there has been no movement to conserve or restore the island, consequently the relocation of Anegada iguanas to two other islands with exotic species control, Guana and Necker, has proved prudent, successful, and may have temporarily saved *C. pinguis* from extinction (Goodyear and Lazell 1994; Mitchell 2000).

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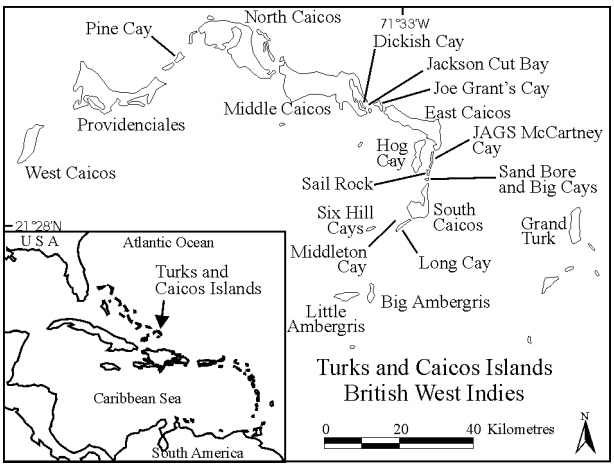

Fig. 1 The Turks and Caicos Islands.

A similar problem is becoming critical in the Turks and Caicos Islands (Fig. 1). Unlike Anegada iguanas, Turks and Caicos rock iguanas (*Cyclura carinata*) are still numerous on some islands. Gerber and Iverson (1999) estimated the total Turks and Caicos population at about 30,000 individuals. Normal densities in undisturbed populations approach 30 adults per hectare (Iverson 1979). As impressive as these numbers may sound, entire island populations are proving to be extremely vulnerable. Iguanas have completely disappeared from 13 Turks and Caicos islands over the past 20 years. Since most of the islands are relatively large, the range of the species was reduced from 500 km^2 to 28 km^2 (or 6% of its former extent) during this period (Gerber and Iverson 1999). In the 1970s John Iverson determined the principal reason for the decline. Between 1974 and 1976 he studied a population of 5000 adult *C. carinata* on Pine Cay, Caicos Bank, and documented its decline as a hotel was constructed there. By 1978 he could find no evidence of iguanas on Pine Cay although they were not completely extirpated (Smith 1992). Iverson linked the drop in numbers to free-ranging pets (cats and dogs) owned by the new hotel staff and residents (Iverson 1978). Adult *C. carinata* are much smaller than adult *C. pinguis*; consequently, cats prey on all age groups. In the Turks and Caicos Islands cat predation has proved the most serious problem for iguanas.

Currently, the two largest remaining populations of *C. carinata* occur on two remote islands on the Caicos Bank: Big and Little Ambergris Cay. Both are more than 30 km from the nearest inhabited cay. As of 1998 each island was thought to support populations of 15,000 adults (Gerber 1998). Commendably, the National Trust of the Turks and Caicos Islands has entered into a 99-year lease to protect Little Ambergris. Big Ambergris, however, will probably be developed. The developer's planned build-out leaves only small areas of the cay undeveloped and most of the iguanas there will be displaced.

As a mitigative measure, the Government is requiring the relocation of some of these endangered iguanas. In 1998 three agencies (The Department of Environment and Coastal Resources of the Turks and Caicos Islands (DECR), British West Indies; The Conservation Agency; and The Denver Zoological Foundation, the latter two non-governmental organisations from the United States) joined in a collaborative effort and began to discuss strategies for moving some of the animals. The problem was where to put them.

Based on prior experience we were confident that a relocation effort would be successful if we identified a suitable site (Goodyear and Lazell 1994; Knapp 2000). During our visit to the Turks and Caicos we examined potential targets for iguana translocation. Initially we searched for cays with the following characteristics: (1) no current population of iguanas, (2) no feral mammals (cats, dogs, donkeys, cattle, goats) that either prey on iguanas, compete with them for food (Mitchell 1999), or trample their burrows, and (3) suitable habitat (a diversity of food plants, loose sand for nesting, rocky retreats). To avoid mixing what might represent different genetic stocks we tried to locate translocation sites on the eastern Caicos Bank as near as possible to Big Ambergris Cay. Large islands were also considered desirable because they would accept a larger population of displaced Big Ambergris animals. A larger translocated population also would be less vulnerable to stochastic or catastrophic events that might cause local extinction.

We decided it was not prudent to introduce Big Ambergris iguanas to an island with a pre-existing iguana population. Because the iguana is fecund, we assumed that all islands currently supporting iguana populations would be at carrying capacity under the existing environmental conditions on each. New immigrants would cause stress to both groups of animals and presumably the population density would return (through mortality) to the original level and there would have been no net benefit from the relocation. We therefore opted to select among islands without iguanas.

METHODS

Relocation site selection

Potential targets for iguana translocation were examined in January 1999. Working from a 1995 report to the National Trust by Glenn Gerber (1998), as well as recommendations from islanders familiar with the uninhabited cays, we identified a number of islands to survey. Using a boat supplied by the DECR, we examined 15 islands. Six of these cays were known to support iguana populations; from these we developed a baseline for habitat quality and relative population status.

We verified iguana presence using one or several of the following indicators: tail drags in soft substrates such as sand or mud; dung; burrows with tail drags; or actual iguana sightings. Qualitative judgments of relative abundance were made from the number of sightings or signs. Small islands were surveyed completely by walking transects; on large islands we attempted to sample as much potential

habitat as possible. We searched for areas with sand or soft soil that might accommodate iguana burrows or nests. On each island we noted the composition of the plant community, particularly noting food plants available to, or utilised by, the iguanas. The presence of feral cats, dogs or ungulates (burros, goats, cows), or rodents, was also determined using sightings, tracks, or presence of dung. We noted the occurrence of other species of native vertebrates on each cay as well. Through the use of these techniques, we selected Long Cay, Caicos Bank, an island that was large, previously supported iguanas, and had a population of feral cats. The island had no native mammals and no resident iguanas.

Feral cat eradication

To restore Long Cay we conducted a single intensive cat poisoning campaign on the island before any iguanas were relocated. We planned to augment the programme using leg-hold trapping if necessary. During this phase Dick Veitch, who had years of experience with cat control, joined the collaborative effort. 1080 (sodium monofluoroacetate) was chosen for the toxin because he had used it, along with leg-hold trapping, to successfully eradicate cats on islands in New Zealand (Veitch 1985). If cat problems recurred after iguanas were relocated to Long Cay, we planned to follow-up with live trapping as needed. Our group consulted with Charles Wigley, 1080 manufacturer (Tull Chemical Company, Oxford Alabama), who gave us additional guidance on dosage and handling.

Loose sand is a common substrate on Long Cay ridges, flatlands, and beaches. Cat tracks were evident in sandy regions when cats were present on the island. We used tracks as an index to cat abundance and to identify the areas they used. The poisoning campaign was conducted in July 1999. Although the cats seemed localised in certain parts of Long Cay, we set up bait stations that allowed us to systematically distribute the poison baits uniformly over the 3.5 km long island. Bait stations were marked with bright pink surveyor's tape or bright red plastic cups, numbered, and spaced 25 m apart in roughly-parallel lines 50-100 m apart. The north-east section of the island is less than 100m in width and therefore had only one line of bait stations; wider mid-sections of the island had four parallel lines of bait stations, and so on, depending on the width of the cay (Fig 2).

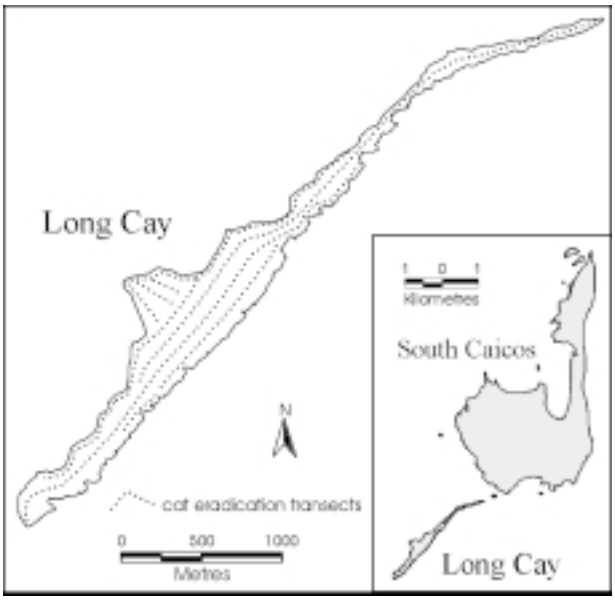

Fig. 2 Long Cay, Turks and Caicos Islands, showing transects along which 1080 bait stations were placed at 25 metre intervals to kill cats.

We used fresh whole minnows or fish chunks injected with 0.009 ml of a 22% 1080 solution for cat bait. The minnows (*Allanetta harringtonensis*, Atherinidae) or sprat (*Harangula* sp., Clupeidae) were seined daily in the morning. Larger fish were cut into 2 cm^3 sections. 1080 was injected into the peritoneal cavity of minnows and into the musculature of cut fish. Most of the bait was placed or skewered on branches overhanging clearings or trails at a height of about 15 cm. This suspended the bait at cat nose-height and out of the reach of land crabs. On the beach, or in areas without vegetation, bait was placed on inverted red plastic cups (15 cm high) that were filled with sand to prevent them from being displaced by wind. The cups also kept baits clean and away from crabs. Thorough and even coverage of Long Cay required 460 bait stations. We would, however, set up to 500 because we added stations along beaches, the areas most frequented by cats. Bait was laid at the stations between 1600-1900 hrs to minimise exposure to heat and scavenging birds. Old baits were collected when fresh bait was deposited daily for 5-6 days. At the end of the week, leftover toxin and contaminated items were diluted to non-toxic levels and disposed of or burned, respectively.

Iguana relocation and monitoring plan

Once cats appeared to be gone from Long Cay we began translocating iguanas from areas of Big Ambergris that were undergoing incipient development. We endeavoured to collect all that we encountered, with a body mass greater than 250 g. Iguanas were captured using two principal methods: (1) a 200 lb (90 kg). test monofilament noose tied at the end of a 1.5-2 m fishing pole, and (2) pulling animals by hand from rocky retreats.

After capture, iguanas were immobilised with loops of surgical tape around their fore and hind legs. An additional tape loop was placed over the mouths of all animals to prevent them from biting each other. Animals were placed in groups of five in cloth bags. These were placed in shaded locations while we captured our quota which varied between 20-100 animals/day. The bags were then loaded onto a padded section of flooring in the DECR boat in which they travelled to South Caicos. There, at the DECR Fisheries Laboratory iguanas were subcutaneously marked with PIT tags in the dorsal surface of the left thigh (allowing individual identification using a Trovan reader). The sex of all iguanas was confirmed by probe, animals were

weighed, snout-vent length was measured, and distinguishing features were noted (e.g., regenerated tails, pigmentation, dorsal spine anomalies).

Iguana translocations from Big Ambergris to Long Cay usually occurred every 2-3 months. Generally, 10 individuals in each group relocated were fitted with 5 g radio collars (151 MHz) and were directly approached weekly and monitored until the next translocation.

During weekly checks of radio-tagged iguanas we recorded animal location using a differential global positioning system (DGPS), as well as habitat and behaviour variables. Most animals allowed us to approach them closely. Plant species within a 0.5 m radius of each animal were recorded. Most iguanas were seen basking on rocks, climbing in shrubs, or were hidden in burrows. At the end of 2-3 months, during the next relocation session, we would remove the collars and remeasure and reweigh the individuals before releasing them. We noted the condition of all radio-collared animals. As the numbers of animals on the island increased we caught and reported the condition and location of un-collared animals opportunistically. All information was transferred to a GIS database. The majority of the data collected will be detailed in a future report.

RESULTS

Relocation-site selection

We visited six cays that were previously known to support iguanas (Gerber 1995): Big Ambergris, West Six Hill, Middleton, Joe Grant's, Dickish, and one unnamed islet in the centre of Jackson Cut Bay (Fig. 1). Iguanas and their signs were usually spotted immediately. We saw no iguanas on Joe Grant's Cay when we visited parts of the eastern and western ends, but they were reported by Gerber (1995) to be rare there (approximately 50 individuals), perhaps patchily distributed, and we did not explore the entire cay. The numbers of iguanas on Middleton Cay seemed lower than the 150 Gerber (1995) reported in 1995; in two midday visits to the island a total of two iguanas and one tail drag were seen.

We re-evaluated nine other islands that were reported to have no iguanas present (Gerber 1995): Long Cay, East Six Hill Cay, J.A.G.S. McCartney Cay, East Caicos (Hog Cay, the south-eastern point, and Jacksonville areas), Sail Rock Island, one unnamed cay adjacent to Hog Cay, and three unnamed cays north of Joe Grant's Cay and west of Joe Grant's Point (Fig. 1). We attempted to visit Sand Bore and Big cays but could not reach them due to extremely low tides. We saw no iguanas on eight visited islands but found a previously-unreported dense population likely to consist of several thousand iguanas on the ninth, J.A.G.S. McCartney Cay (Mitchell *et al.* 2000).

In general, the small islands we examined that had suitable iguana habitat and no feral mammals already had existing iguana populations. We found that most islands without iguanas were either extremely small (<0.1 ha; iguana populations there would be small and vulnerable to extinction) or that they supported populations of feral cats or grazing ungulates (goats, cattle, donkeys, etc.) which suppress or eradicate iguanas. The latter would need restoration and management before they became suitable.

Therefore we concluded that we should focus our efforts on the largest cay with suitable habitat and on which feral mammals might successfully be controlled. Long Cay, Caicos Bank, was selected because of its size (approximately 3.5 km long, 111 ha), suitable habitat, and proximity to Big Ambergris Cay. Our visit confirmed the presence of cats previously reported by Iverson (1978) and Gerber (1995). Rats and mice (*Rattus rattus* and *Mus musculus*) also were in evidence on the cay but we did not consider them a threat to the iguanas as they occur on most islands in the Turks and Caicos, including those with healthy *C. carinata* populations. There were no other feral mammals on Long Cay, though goats and pigs had ranged there in the recent past.

Another important factor was that Long Cay was part of the former range of *C. carinata* (Schwartz and Thomas 1975). Iguanas had been seen there by John Iverson in visits between 1974 and 1977 (pers. com.), but had been since extirpated, presumably by resident cats.

We decided that the best alternative was to eradicate the feral cats on Long Cay, and focus the initial relocation effort from Ambergris Cay there.

Cat eradication

We found most of the evidence of cat foot traffic on Long Cay's beaches. Though large areas of the island contain sandy regions where tracks are easily seen, cat tracks were only noted twice away from the beach. The number of tracks we saw could be attributed to the wanderings of several individuals or small family groups. We did not attempt a population estimate but suspected there were fewer than 10 cats on the cay. The low number of cats present would facilitate cat removal. We conducted our baiting programme each evening from 8 through 12 July 1999. During the first three nights cat tracks were seen approaching three of our bait stations; two up on the limestone ridge, one on the beach. In those areas in which we did see cat tracks regularly, we did not see them during the last days of the study (11 and 12 July). No cat corpses were seen. We did not find any evidence of mortality in non-target species.

Weekly spot checks were made for cats on Long Cay during radio-tracking sessions in the following months. In early November 1999, we again surveyed the island thoroughly for tracks or signs of cats. In three days of walking surveys no evidence of cats was seen anywhere on the cay. No follow-up trapping appeared necessary. This result allowed us to proceed with the next step: iguana relocation.

Iguana relocation and monitoring plan

Until January 2000, during our field sessions and weekly radio tracking, no cat tracks were seen on Long Cay and survivorship of radio-tagged iguanas was 100%. During January and February 2000, radio-collared iguanas in the test group of 25 animals were recaptured and radio-collars were removed. Animals were weighed and measured. All recovered animals appeared healthy and each had established one or more burrow sites. Survivorship of this small group provided a second test for presence/absence of cats.

Later in January, we found tracks from a cat that one of us (Clerveaux) confirmed had been recently released on Long Cay by its owner from South Caicos. We succeeded in trapping and removing the cat from Long Cay within two weeks.

Since our first translocation in November 1999 we have relocated a total of 404 iguanas. We continue to collect data on habitat use, burrow location, home range dynamics, and will soon be collecting information on reproduction and recruitment of young. Since all Long Cay founders are PIT tagged, and dispersal to the cay is unlikely, we can be reasonably sure that untagged iguanas were born there. In January 2001, Mitchell confirmed the presence of two Long Cay hatchlings.

Condition

Repeat measurement of a random sample of 10 translocated animals (Fig. 3) shows that the average body weight increased by 252.5 g in the 3-12 months following translocation and that these animals were often larger than a random sample of 20 animals on Big Ambergris Cay at the same time of year (Fig. 3). The translocated sample includes four radio-collared individuals, two of which lost weight while the other two gained less than the average of the 10. If these radio-collared individuals are excluded from the sample, the average weight gain is 412.5 g. These weight observations on radio-collared animals suggest that either the collar or frequent human disturbance during radio tracking inhibits optimal growth.

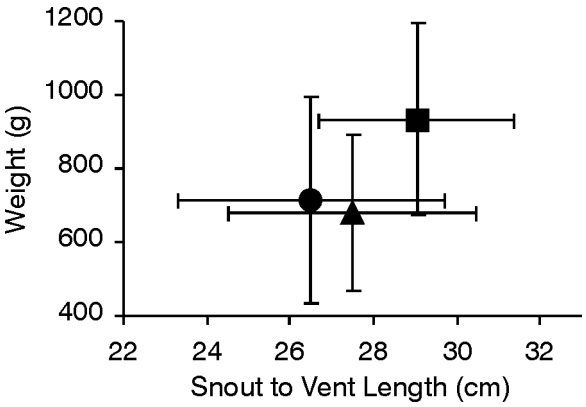

Fig. 3 Average weights and snout-vent length (cm) of a random sample of iguanas. Circle = 20 Big Ambergris Cay animals in January. Triangle = 10 Long Cay animals at the time of their release. Square = the same 10 Long Cay animals in January, 3-12 months after release. The error bars are ± one standard deviation.

DISCUSSION

Iguanas have disappeared from almost all of the larger Turks and Caicos Islands though some (e.g., Salt, Joe Grants, and Pine cays) still have relict populations (Gerber 1995). Most of these larger islands are overrun by feral hoofed livestock (donkeys, cattle, goats) or feral predators (cats or dogs). In his report to the National Trust, Gerber (1995) thoroughly described the negative impact feral mammals have on *C. carinata*. In particular, our survey reinforced the conclusion that, because cats are such efficient predators, cat populations cannot coexist with *C. carinata* (see also Iverson 1978).

For example, we surveyed three islands adjacent to East Caicos (50-100 m offshore) on which we found reasonably-dense populations of iguanas. We then conducted walking transects on the East Caicos shoreline opposite the iguana-populated cays. Though the habitat was vegetatively similar there was not a single iguana present. The most significant differences noted between East Caicos and the smaller satellite cays were the presence of cat and donkey populations on the larger cay.

Many of the smaller cays may be favourable for iguanas because they cannot support cats, the primary threat to iguanas. We suspect that every young iguana that disperses over water to colonise islands with an established population of cats will eventually be discovered and eaten. This is due primarily to the iguanas' small home range size, predictable behaviour, and sluggish movements in the colder early morning hours.

We suspect cats may not survive on small cays because of the general unavailability of fresh water. On large islands rainwater accumulates in the porous limestone rock. During periods of low rainfall, cats can reach this fresh water supply through solution holes and cavities in the rock. Smaller islands do not have fresh water reservoirs and thus do not provide long-term support for cats. In the absence of management, small cays and remote cays have been the salvation of the iguanas to date.

Populations on small islands, however, are more likely to fluctuate to zero (e.g., East Six-Hills Cay, Middleton Cay) and frequently they have impossibly-large dispersal distances between them. Satellite cays alone will not provide a long-range solution to maintaining the viability of *C. carinata*. Wherever it is logistically possible, it will be crucial to control or exclude exotic predators or competitors on large islands, and develop large, protected, island reserves. The larger, more stable, iguana populations supported will serve as genetic reservoirs and a source of dispersers (e.g., Long Cay, J.A.G.S. McCartney, Little Ambergris). We need to purposefully preserve and manage clusters of large and small satellite cays that together

possess the qualities to ensure the survival of the endemic iguana.

The technique(s) required for managing invasive species on islands will probably be different in every case. Long Cay seemed well suited to the use of 1080. We carefully considered possible effects of the poison before conducting the cat removal work. Long Cay was unusual in that it had no iguanas, no native mammals, few scavenging birds, and no nesting colonies of scavengers. We judged that it was possible, but unlikely, that incidental bird deaths would occur.

Cats are extremely susceptible to minute quantities of 1080, 20 times more susceptible than humans, 10–30 times more susceptible than birds. Sub-lethal doses are metabolised and excreted. This chemical is broken down into non-toxic by-products by bacteria in soil or water. In freshwater the compound is 70% degraded after 24 hours (Veitch 1998). We also planned and equipped ourselves for supplemental cat trapping if it was necessary after the poisoning effort was concluded.

One of the things we found extremely encouraging at the outset was that, although much of the island has sandy exposed areas in which cat prints would be highly visible, in most areas no cat tracks were seen. Since we thoroughly explored all regions of the island before and during this baiting campaign, based on the few sets of tracks we saw, we feel that there were very few cats on Long Cay to start with (maybe 10 or fewer). It would have been difficult for these few cats to have avoided encountering a bait after we began the poisoning programme.

The equally-spaced, highly-visible, and numbered bait stations were useful for two reasons: (1) to assure good dispersion and thorough coverage of the island with bait, and (2) to allow us to find and recover uneaten baits. The first was important because it was vital that each cat on the island encountered a toxic bait during our programme. We therefore chose to have a small interval between bait stations: 8-12 baits per ha. The second reason that recognisable stations were important was that the toxicity of the baits rapidly degraded, as mentioned above. If uneaten baits were left available we risked saturating the island with non-toxic food sources for cats, which would decrease the likelihood of them eating fresh toxic baits. If baits were not placed at a bait station, uneaten baits would be very difficult to retrieve the following day because they were hard to see.

To keep Long Cay free of cats it is of the utmost importance to increasingly involve the community of South Caicos, reaching everyone with the message that unwanted animals should not be dropped off on uninhabited cays. DECR patrols and courtesy visits to vessels cruising the area are underway, and informative signs for Long Cay have been erected.

We have also begun production of a series of informative public announcements for local cable TV. In this regard we were lucky to have the services of a professional film maker, Vladimir Bibic. He donated time, equipment, and materials and completed two public service announcements that were aired in May 2000.

We will continue to monitor the establishment of *C. carinata* on Long Cay. Preliminary indications are that the Big Ambergris population is food limited, and that at this point Long Cay animals are not. The condition of recolonisers suggests that Long Cay iguanas are thriving and that the population has not reached carrying capacity. While the development on Big Ambergris advances we can therefore continue to relocate displaced animals until we have evidence that Long Cay is nearing population saturation. Based on observed *C. carinata* population densities elsewhere in the Turks and Caicos archipelago, and Long Cay's size, we expect that the island has the potential to support thousands of animals. We hope to use our experience on Long Cay to restore iguanas to other large islands in the Turks and Caicos where populations are currently dwindling or extirpated.

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