

Status Survey and Conservation Action Plan

West Indian Iguanas

Compiled and edited by Allison Alberts



IUCN/SSC West Indian Iguana Specialist Group

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Foreword

The idea for this Action Plan was originally conceived at an international workshop on the biology of West Indian iguanas carried out in conjunction with the IUCN/CBSG Population and Habitat Viability Analysis for the Jamaican Iguana. Held in Kingston in 1993, the workshop was attended by field biologists, academic researchers, zoo managers, and government policy makers from throughout the West Indies and abroad. This represented the first time that so many professionals with a strong interest in the survival of West Indian iguanas had gathered to share their expertise and concerns. As such, it proved to be a valuable forum for beginning to identify and prioritize the conservation needs of this unique group of lizards.

Much of the background information for this first edition of the Action Plan was initially compiled for

use in the IUCN/CBSG Conservation Assessment and Management Plan for Iguanid and Varanid lizards (Hudson et al. 1994). Since the CAMP results were published five years ago, this material has been substantially expanded and updated. Regional development and related habitat disturbance are progressing so rapidly that status estimations for some of the taxa involved are constantly changing. In light of this, the present edition of the Action Plan should be considered a starting point for an evolving process of reassessment and continuing evaluation. As new information becomes available, interested parties are strongly encouraged to contact the Co-Chairs of the IUCN/SSC West Indian Iguana Specialist Group to ensure that subsequent drafts remain as accurate and comprehensive as possible.

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Although many people have generously contributed their time, energy, and valuable expertise toward making this Action Plan as complete and accurate as possible, special recognition is due to two individuals. Rick Hudson has worked closely with me on this project since its inception. Not only was the initial idea

for undertaking the Action Plan his, but since then he has continued to provide invaluable guidance and critical support for all aspects of the project. Mark Day has been an inspiration in terms of his unflagging enthusiasm, and was responsible for compiling and editing all the maps and photographs contained in the Action Plan. Many heartfelt thanks to all who made the Action Plan possible.

*Allison Alberts, July, 1999
Center for Reproduction of Endangered Species
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Executive Summary

The West Indian iguanas form a unique group of species inhabiting tropical dry forests throughout the Bahamas and the Greater and Lesser Antilles. They are among the most endangered of the world's lizards, primarily because much of their fragile island habitat has been eliminated by human development or severely degraded by exotic species (Case et al. 1992; Taboada 1992). Mongooses, dogs, and feral cats prey heavily on juvenile iguanas, and in many areas introduced livestock have denuded the native vegetation on which iguanas depend (Iverson 1978; Carey 1966, 1975). The Jamaican iguana, considered by some to be the rarest lizard in the world, may number no more than 100 adults, and several other subspecies of West Indian iguanas have declined to below 1,500 individuals (Blair 1991 a; Alberts 1993). Until recently, these lizards were the largest land animals in the West Indies, and a dominant ecological force. Because they are likely to be important seed dispersers for many endemic plants (Iverson, 1985), the loss of West Indian iguanas has serious consequences for the ecosystems in which they live.

The purpose of this Action Plan is to summarize the current status of wild populations of all West Indian iguanas, including the rock iguanas (genus *Cyclura*) as well as the Lesser Antillean iguana (*Iguana delicatissima*). Each taxon has been ranked as Critically Endangered, Endangered, or Vulnerable according to IUCN Red List Criteria (Mace and Lande 1991; Mace et al. 1992; IUCN 1994). The primary threats impacting each taxon are identified, and specific actions for mitigating those threats are recommended. On the basis of this information, the Action Plan prioritizes the conservation projects most urgently needed to help insure the survival of each taxon.

The Action Plan is organized into six major sections. Introductory essays on the systematic relationships of West Indian iguanas to other iguanid lizards, the biogeography of the West Indies, socioeconomic

history and current issues, the ecology of dry tropical forest ecosystems, and West Indian iguana habitat are presented in order to provide a broad context for the material that follows. Next, the status of each taxon is reviewed, including current population estimates and a ranking of relative endangerment. This is followed by an overview of major threats and existing conservation measures. Individual species/subspecies accounts follow, providing more detailed information on distribution, status of wild populations, ecology and natural history, condition of critical habitat, threats to survival, current conservation programs, critical regional conservation initiatives, and specific priority conservation projects. Recommendations for reintroduction, translocation to unoccupied habitat, population monitoring, control of introduced species, genetic research, captive management, and education follow. Finally, a list of national agencies, research institutions, and conservation organizations in the countries of origin for the taxa covered by the Action Plan is included.

The West Indian Iguana Action Plan was drafted by 27 contributors from nine different countries, with the common goal of designing viable conservation strategies for the iguanas we have come to care deeply about but only begun to understand. It is our collective hope that the plan will not only inspire those in the scientific community to further study the intriguing biology of these magnificent lizards, but also serve as a strong impetus to government officials, conservation planners, and community leaders to implement immediate and effective conservation measures on their behalf. Iguanas represent a unique and irreplaceable component of West Indian natural heritage that must be preserved for future generations. To the extent that this Action Plan can help foster an increased sense of pride and stewardship for iguanas in the people with whom they share the islands, we will have begun to achieve our mission.

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Chapter 1. Conservation Strategy

Introduction

Only 60 of the 3,000 species of lizards living today attain an adult body mass greater than one kilogram. Although large lizards represent only 2% of all lizard species, they account for 60% of lizard species considered threatened or endangered. Indigenous large lizards are often the predominant vertebrates with respect to biomass in undisturbed environments (Case 1982; Iverson 1979; Dugan 1980; Pianka 1986; Phillips 1995). However, in degraded habitats, populations of these lizards may be severely depleted relative to expected carrying capacity. Biomass estimates of healthy iguana populations often exceed 20kg/ha, an order of magnitude greater than reported for mammalian herbivores. The absence or reduction of these lizards unquestionably alters the ecosystems of which they are a part.

The islands of the West Indies form the principal archipelago of the neotropics. As a result of prolonged geographical isolation, native mammal species on these islands are few, consisting mainly of bats and rodents. Birds, reptiles, and amphibians, however, have undergone significant radiations and comprise the majority of the vertebrate biodiversity of the West Indies. Most of the large islands are densely populated by people and suffer from environmental degradation and the ill effects of introduced species (Case and Bolger 1991). As a result, a significant number of taxa, including many endemics, have disappeared or are on the brink of extinction.

The iguanas of the West Indies (*Cyclura* and *Iguana delicatissima*) are among the largest and most impressive members of the family Iguanidae, yet they are also the rarest. All taxa are currently protected under the Convention on International Trade in Endangered Species (CITES), with five of 17 forms considered to be Endangered, and eight Critically Endangered, by the World Conservation Union (IUCN 1996). Although exploitation of West Indian iguanas began long ago by native peoples, it was probably not until the arrival of Europeans that iguana populations began their most precipitous decline. In addition to the habitat loss and degradation inevitably resulting from large scale human settlement, the commensal species that accompanied immigrants to the islands have had a devastating impact on iguanas and the ecosystems they inhabit. Dogs, cats, pigs, and rats prey on iguanas and their eggs, while goats, sheep, cattle, and other livestock have contributed to the

deterioration of the unique plant communities on which iguanas and other native species depend. The introduction of the Indian mongoose (*Herpestes javanicus* [= *aurouunctatus*]), ostensibly to control rats, has instead resulted in predation of untold numbers of native species, including juvenile iguanas.



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Typical dry tropical forest habitat for iguanas at Guantanamo Bay, Cuba.

West Indian iguanas inhabit dry subtropical thorn forest regions in the Bahamas, the Virgin Islands, and the Greater and Lesser Antilles. While *Cyclura* are terrestrial, depending heavily on the presence of rocky crevices to serve as retreats, *Iguana delicatissima* is primarily arboreal. Both require sandy areas with appropriate soil conditions in which to lay their eggs. Most species live for multiple decades and may take several years to reach sexual maturity. Social organization ranges from systems in which adult males are highly aggressive and territorial to large groups which appear to coexist peacefully. Mating is seasonal, with a single clutch per year, usually laid in May or June. Raptors, cuckoos, herons, and colubrid and boid snakes are the only natural predators of West Indian iguanas, and then usually only of juveniles.

West Indian iguanas are almost exclusively herbivorous, consuming an unappreciated diversity of vegetation types. The Turks and Caicos iguana is known to feed on at least 58 plant species (Iverson 1979; Auffenberg, 1982), the Cuban iguana on 25 species (Perera 1985a), the Grand Cayman iguana on 45 species (Burton and Gould, in preparation), the Lesser Caymans iguana on over 40 species (G. Gerber, unpublished data), and the Mona Island iguana on 71 species (Wiewandt 1977). Because these lizards do not chew appreciably (Throckmorton 1976), and

digestion of plant foods is incomplete, seeds passing through the digestive tract are probably still capable of germinating (Iverson 1985; F. Burton and S. Gould, unpublished data). For this reason, West Indian iguanas are likely to be important seed dispersers for many endemic plants.

The sections that follow are designed to provide a broad historical context for the specific conservation activities recommended later in the Action Plan. Taxonomic issues relevant to West Indian iguanas are discussed, including the need for further phylogenetic studies to help establish conservation priorities. Effects of climate change, ecosystem-level processes, and past and modern human disturbance are covered as well. Finally, an overview of the current status of West Indian iguanas is provided, together with a summary of existing threats and conservation measures for each taxon.

Taxonomic Considerations

By Jack W. Sites, Jr.

Several recent hypotheses have been presented regarding relationships among the living genera of large herbivorous lizards collectively known as iguanas (de Queiroz 1987; Frost and Etheridge 1989; Norell and de Queiroz 1991; but see Lazell 1989, 1992). As a working hypothesis, the family Iguanidae is here considered to be restricted to this radiation, which contains seven genera (*Amblyrhynchus*, *Conolophus*, *Ctenosaura*, *Cyclura*, *Iguana*, *Dipsosaurus*, *Sauromalus*; eight if *Enyaliosaurus* is considered distinct from *Ctenosaura*) indigenous to North and South America (de Queiroz 1987; Frost and Etheridge 1989), as well as the South Pacific genus *Brachylophus*. Much attention has been given to the behavioral and ecological aspects of iguana biology (Burghardt and Rand 1982), but until recently modern systematic studies have lagged behind (Etheridge 1982). Consequently, the biogeographic history and evolutionary relationships among these genera remain poorly understood and controversial. In addition to morphological and chromosomal data collected thus far, different classes of molecular data hold great promise for further resolving iguanid relationships. These approaches might also address some of the objections raised by Lazell (1989) regarding species and generic boundaries within the radiation. Research is needed to test independently the current definitions of species and genera recognized on the basis of morphological and skeletal characteristics, and to develop a well-corroborated phylogenetic hypothesis for the

entire group.

About 30 species of iguanas are currently recognized (Burghardt and Rand 1982; de Queiroz 1987). Many are not well defined, especially within the genera *Ctenosaura* and *Cyclura*, and ideally all should be verified by several genetic markers. The radiation of rock iguanas throughout the Greater Antilles and the Bahamas is among the most diverse within the Iguanidae with respect to species numbers recognized on the basis of morphological criteria. Sampling with molecular markers to verify species boundaries is especially important in the West Indies because of the island distributions of rock iguanas and the extremely complex patterns of diversification and geological history in this region (Rosen 1985; Hedges et al. 1992).

The literature on species and their recognition continues to increase, with little apparent consensus on how to diagnose independently-evolving lineages (Wiley 1978; reviewed by Frost and Kluge 1995). However, a number of operational proposals have been offered which avoid the pitfalls of tree-based character methods (Doyle 1995), with specific guidelines for their implementation (Avice and Ball 1990; Davis and Nixon 1992; Templeton 1994; Templeton and Sing 1993; Mallet 1995). Under these methods, evaluations of species boundaries become testable hypotheses subject to verification or falsification, a practice that should become standard in future genetic studies of iguanas whenever species boundaries are an issue. A concern arises with regard to the use of mitochondrial DNA markers to address questions regarding species boundaries (Moritz 1994). Although mtDNAs are known to show substructuring in some geographically widespread iguanid lizards (Lamb et al. 1992), small inbreeding effective population size may render this approach inadequate for delimiting species boundaries.

Equally important to the identification of species for determining the taxonomic composition and diversity of the Iguanidae is the development of a well-corroborated phylogenetic hypothesis for all species and genera. This will provide not only an evolutionary and biogeographic context within which specialized ecological and behavioral adaptations can be evaluated, but also a measure of the genealogical distinctness of each species. The latter can contribute to the establishment of conservation priorities on the basis of overall measures of taxonomic diversity and evolutionary importance (Vane-Wright et al. 1991; Avice 1992; Brooks et al. 1992; Stiasny 1992). Sites et al. (1996) recently reconstructed the phylogenetic relationships among living Iguanidae on the basis of mtDNA sequence and morphological characters, and showed strong support for monophyly of all genera named above except *Enyaliosaurus*.

Biogeographic Considerations

By James Lazell

Despite, or perhaps because of, the enormous amount of factual information developed since 1492, the West Indies remain a region of extreme controversy (Williams 1989). Probably no other tropical realm has been so extensively studied, but fundamental disagreements over the origin of the islands and their biota remain. A critical but neglected factor in West Indian biogeography has been the enormous change in land areas and potential dispersal distances wrought by sea level fluctuations dependent on glacial and interglacial climatic cycles. Dramatic sea level changes in the region have greatly modified total land area and in many cases altered dispersal distances by orders of magnitude (Lazell 1996).

As a rough generalization, the West Indian islands today surmount banks of rather shallow water which fall off abruptly at their edges. Not surprisingly, the biogeographic significance of the banks is largely reflected in the degree of difference in biotas: islands on the same bank have rather similar, slightly differentiated faunas, while islands on separate banks show high degrees of endemism (Williams 1969). The West Indian iguanas form a suite of obviously very closely allied forms. Hispaniola, the Great Bahama bank, the Greater Puerto Rico bank (Virgin Islands), and the Guadeloupeen archipelago have two forms each, but otherwise there is only one form on any island bank. In general, West Indian iguanas present an overall picture of weak differentiation in which geographically intermediate forms are apt to be morphologically intermediate (Lazell, 1989). Hybridization between forms is known to occur.

Climate change has combined with human disturbances over the last 4,000 years to alter the West Indian fauna dramatically. Many mammals, large birds, and reptiles once occupied a broad array of islands but are now extinct. It seems that iguanas, however, tolerated these changes well until European invasion. However, in the last century, and especially in the last three decades, changes in iguana populations and ranges have been catastrophic. Teeming populations have simply disappeared and animals once abundant are now critically endangered.

Iguanas tend to be most common in coastal lowlands, and these areas tend to be covered with oceanic limestone formed during times of high sea levels dating back at least to the Miocene. Limestone, being porous and often cavernous, drains quickly and provides poor soil compared to volcanic terrain. Iguanas may be associated with limestone terrains because they find security from exotic predators like dogs and

cats in the limestone cavities, and as a result of their ability to survive on soils of very low agricultural potential. In the Lesser Antilles, however, *Iguana delicatissima* was once abundant on volcanic strata directly adjacent to the sea. It is possible that limestone habitats are suboptimal for iguanas, and iguana presence there today represents fortuitous survival rather than adaptation.

Socioeconomic Perspective

By Jose Ottenwalder

The Wider Caribbean encompasses a vast marine area, bordered by island nations, dependent territories, and continental countries. With 36 nations represented, it comprises the largest number of national jurisdictions of any similarly sized region in the world. Within the region, the West Indies consists of 23 island States featuring a variety of people, cultures and political systems characterized by different types and stages of economic development (Table 1). Although part of the Americas, the islands of the West Indies are a unique entity whose history, societies, environment, and general ambiance differ in many significant aspects from those of any found on the Latin American, North American, or European mainland.

The West Indies were the first to encounter the initial thrust of European expansion across the Atlantic. The consequences of the ensuing traffic of plant and animal species, peoples, diseases, and raw materials are well known, and include the eventual loss of all aboriginal human populations inhabiting these islands. In addition, the islands bore the brunt of the European movement towards tropical plantation development. The region entered a new stage of environmental change characterized by increased resource use, a shift in human-environment relationships, and greater exposure to outside technologies, a process that continues to the present. The cumulative effect of this history is reflected in widespread ecological transformations. Like most small tropical islands, West Indian ecosystems are environmentally fragile and vulnerable to deforestation, erosion, and conversion for development. Reduced area, exposure to hurricanes, and the presence of active volcanoes on some islands further compound their social, economic, and environmental vulnerability.

Historical perspective of development

The historical impact of aboriginal peoples on West Indian ecosystems is still uncertain. A key question is whether the native inhabitants of the islands ever

achieved high population densities. Proposed figures for Hispaniola, the standard demographic reference for the region, range from 100,000 to 6-8 million (Watts 1987, Keagan 1992). According to Keagan (1992), it is not inconceivable that the Taino population of Hispaniola reached 1-2 million. Although a matter of continued debate, the total native population of the West Indies in 1492 could have been more than 5.8 million (Watts 1987). Despite this, it is generally believed that aboriginal inhabitants did not have a significant impact on the natural environment, leaving most mature forests largely untouched. Taino social and political complexity was based in part on a system of intensive agriculture, with manioc as a staple, supplemented with abundant wild estuarine and marine resources (Wing 1989, Deagan 1995). Following European contact, disease, falling birthrates, hard labor, and even anomie from culture shock decimated aboriginal populations. By 1576, native peoples had been extirpated on Hispaniola, which was then occupied by Spanish, black, and racially mixed populations.

Following early colonization, the region became a source of tropical agricultural commodities. Markets in Europe and North America were relatively accessible and the slave trade had enormous demographic, social, and environmental consequences. Rapid population growth, widespread use of plantation agricultural systems after the 17th century, large-scale land clearing for sugar cane, and timber harvesting produced widespread deforestation, erosion, loss of water resources, and a decline in fertility and productivity (McElroy et al. 1990). As a result, many West Indian islands were deforested early. The forest cover of Puerto Rico was reduced to 10% of its former range by the end of the 19th century, and what remained was disturbed and often mixed with coffee understory (Harcourt and Sayer 1996). For the West Indies as a whole, total forest cover remaining in 1920 was only 50% (Zon and Sparhawk 1923). Further deforestation for sugar cane plantations and cattle ranching up until the 1970s reduced overall West Indian forest cover to 18% (Lugo et al. 1981). While a few island countries still presently maintain about 50% of their forest cover, others have lost almost all of it.

The spread of exotic species was another emerging threat, including both deliberate and unintentional introductions of domestic, commensal and, eventually, wild stocks. Prominent among intentional Spanish imports were hogs, cattle, sheep, and goats for food, with horses, donkeys, dogs, and cats also brought in to satisfy other needs. In the absence of competitors and predators, feral populations flourished. Free-range cattle ranching was widespread, developing first in the lowlands, and trade in cattle hides was extensive, with

as many as 200,000 hides exported from Hispaniola annually prior to the 1580s (Deagan 1995).

In the 200 years following colonization, coastal lowland forests were extensively reduced through conversion to plantations and cattle ranching. Degradation of lowland habitats led to the spread of sugar cultivation and livestock production to higher elevations. Pressure upon montane forests for subsistence agriculture increased between 1880 and 1940 following the abolition of slavery. After emancipation (circa 1840), the economic return from sugar cultivation and export plummeted as a result of higher labor costs and competition from larger producers (McElroy et al. 1990). The consequences of these economic losses spawned a continuous migratory trend, a demographic shift from the steady population growth maintained since colonial times, the appearance of marginal, small-scale farm systems, and a tendency for local populations to turn to artisanal fisheries as a subsistence and largely unregulated commercial enterprise (McElroy et al. 1990).

During the early 20th century, the cumulative effect of these environmental changes, as well as the clearing of primary and secondary forests, over-browsing by livestock, and continued erosion, habitat destruction, and soil degradation had a strong impact on West Indian island ecosystems. Widespread depletion of resources resulted in diminishing productivity for farming and fishing and a decline in rural employment and traditional cash crops. These changes resulted in large scale and continuing emigration, reduced availability of food and energy at accessible costs, severe sectoral imbalances in insular economies, and drastic changes in land use. A few very large tracts of land became consolidated into large-scale export crop and livestock farms, while a large number of small tracts of land appeared as fragmented and largely non-productive family farm plots. A shift from production to service-based economies was stimulated by low-cost food imports and the need to support increasing urban populations and tourists.

Present and future challenges

At present, all West Indian islands have population densities that are among the highest in the world, excluding southwest Asia (FAO, 1997) (Table 1). About 72.6% of the total population in the region are concentrated in Cuba, the Dominican Republic and Haiti, with Hispaniola supporting the highest numbers. The average annual rate of population increase for the region is 1.3%, although a few countries are approaching or below the replacement level. Characterized by high rates of urbanization (World Resources Institute 1996), the region's population is projected to increase to about 40 million by the year

2000, and to nearly 60 million by 2025. The cosmopolitan array of peoples representing a variety of races, ethnic mixes, languages, and cultures has hampered regional integration and implementation of environmentally and socially sustainable development.

The tourist industry in the West Indies has developed rapidly over the last 40 years, and since the 1960s has become the leading economic sector in many island states. According to the World Council on Travel and Tourism, the impact of this industry on West Indian economies is significant, representing about 30% of the regional Gross Domestic Product (GDP). Its current estimated annual growth is 35%, contributing strongly to the generation of local employment. Furthermore, the industry is the leading provider of foreign currency income, accounting for 76.2% of total capital investment in the region. The rapid expansion of tourism has resulted in escalating land values, with concomitant increases in population growth and per capita income. With modernization, the traditional rural sector has been reduced and farming and fishing have become marginal activities. Extensive coastal development due to urbanization, industrialization, and tourism has impacted estuaries, mangrove forests, and coral reef ecosystems. Unregulated exploitation has caused widespread depletion of formerly abundant traditional subsistence fisheries in the region (FAO 1993). Simultaneously, local populations of highly threatened marine species such as sea turtles and manatees have been drastically reduced.

West Indian countries face special challenges because of their small size and extreme economic and environmental vulnerability. As a result of mountainous topography and high population densities, the cost of economic and social infrastructure is high. Internal markets are small and open to world trade, with exports and imports of goods and services averaging 75% of GDP. Most of the islands have traditionally been monocrop economies, relying on preferential trade arrangements for their main exports. Commercial barriers for West Indian exports to the US have increased, and the region's export markets are now threatened by larger trade arrangements (e.g. General Agreement on Trade & Tariffs [GATT], integration of European Common Market, North American Free Trade Association [NAFTA]).

Regional economic growth remains constrained by a number of factors, including underdeveloped domestic financial sectors and infrastructure, low domestic saving rate, and associated scarcity of capital for investment. As aid to the region has declined, economic prospects have depended increasingly on private sector development to generate growth to com-

pete in the global economy, create jobs, and increase per capita income. As a result, West Indian economies continue to be vulnerable to external changes, particularly trade and financial flows influencing regional markets. Major economic challenges include improving social development, strengthening public finances, reforming financial markets, improving legal and regulatory environments to promote private sector activity, and reforming the public sector to improve governance.

Following the economic stagnation of the 1980s, productivity and exports are currently rising, per capita income is growing, private sector performance is improving, and inflation continues to decrease. Against this encouraging economic picture, overcrowded and polluted cities, persistent poverty, and threatened biodiversity stand in stark contrast. In light of these problems, the region's challenge is to align economic growth with social equity, sustainably manage biologically diverse areas, and control urban environmental problems. Achieving these tasks will require integration of environmental concerns into investment programs and policy frameworks to ensure sustainability, and building the institutional capacities to implement priority programs and monitor compliance.

Implications for iguana conservation

West Indian iguanas occur primarily in dry forest habitats in coastal lowlands, where they are vulnerable to impacts from human land use and associated degradation of coastal ecosystems. West Indian nations largely depend on the health and beauty of coastal habitats to generate income, particularly from nature-based tourism. As a result, economic activities and human populations are heavily concentrated along coastal areas. The conservation of coastal biodiversity in the region is therefore linked not only to social, cultural, and political conditions, but also to economic realities and prevailing financial constraints.

Environmental problems and priorities affecting coastal biodiversity in the region are complex and diverse. Causes of destruction, fragmentation, and degradation of coastal ecosystems include: urbanization; uncontrolled development of tourism and industrial infrastructure; coastal modification through construction, mining, filling and dredging; deforestation; fuelwood and hardwood extraction; soil erosion and watershed degradation; demand for food and raw materials; retention of freshwater flow and withdrawal of water for irrigation; sewage, industrial, and solid waste disposal; agrochemical runoff; operational and accidental spills. In addition, introduced mammalian herbivores and carnivores in coastal areas have proven highly detrimental to native plant and animal biodi-

versity, including iguanas and their habitats.

A number of authors (in Harcourt and Sayer 1996) recently concluded that most of the natural lowland forests of West Indies have already been devastated. Total forest cover for the West Indies in 1995 was estimated at 19.4% of total land area, with an average annual deforestation rate of 1.7% for the period 1990-95 (Table 1). Major causes of forest degradation include habitat destruction and clearing of land for agriculture, extraction of forest products for timber, fuelwood and charcoal, and forest fires, often originating from subsistence agriculture.

Although moist forests have suffered extensively, some relatively large tracts of mangrove and coastal xeric communities remain less impacted. However, little information exists about the total remaining extent and present status of West Indian dry forest communities (World Wildlife Fund 1996). According to the World Conservation Monitoring Centre 1997 Forest Database, 14,802 km² of dry forest remains, including deciduous/semideciduous broadleaf forest (7,734 km²), thorn forest (1,206 km²), sclerophyllous dry forest (5,822 km²), and sparse trees/parkland (40 km²). A recent regional analysis of geographic priorities for biodiversity conservation in Latin America and the Caribbean ranked Caribbean ecoregion as endangered and its xeric communities as regionally significant for their biological value (Biodiversity Support Program et al. 1995).

According to the recent IUCN/SSC Status Survey and Conservation Action Plan for Cactus and Succulent Plants (Oldfield 1997), 75% of cactus and succulent plant species surveyed are endemic to the West Indies (actual percentage likely even higher as Burseraceae, Begoniaceae, Piperaceae, Rubiaceae, Urticaceae, aroids, and orchids are not covered). While the taxonomic status of West Indian succulents remains poorly known, new species continue to be discovered (Areces-Mallea 1997). In general, the largest number and highest density of endemics occur in arid coastal areas and other dry habitats, which also support West Indian iguanas. Vegetation categories listed in Oldfield (1997) for West Indian succulents (sandy beaches; strand littoral scrub and low forest; saline flats; rock pavement vegetation; dry limestone shrubwoods; semi-desert cactus scrub; dry serpentine shrubwoods) generally also support West Indian iguanas. Not unexpectedly, many threats identified for these plant communities are similar to those affecting iguanas (clearing for agriculture, urbanization and tourism, mining and quarrying, collecting, introduced species, and natural disasters).

Sustainable forest management in the West Indies is complicated due to the great diversity of forest types, making it difficult to develop successful man-

agement techniques that can be applied over large areas (Lugo 1990). Furthermore, competition for flat land is intense and the price of coastal land has soared during the last two decades. Conservation of West Indian iguanas is clearly linked to future preservation of dry coastal habitats. For some countries like Haiti, it may already be too late to save remaining forests (Table 1). However, many countries have passed new laws and regulations pertaining to natural forest management and use that reflect the key social, environmental, and economic roles forests play.

Conclusions

Regional success in managing coastal ecosystems is ultimately rooted in the ability of individual West Indian states to build their internal capacities and commit wholeheartedly to a regional approach. In the past, mostly because of the lack of political support, integration efforts have failed. Notwithstanding these and other obstacles, it is heartening to see a great deal of functional cooperation being practiced daily, a process which is expanding. Over the ensuing decades, it may well be economic issues, especially those of tourism, commercial trade markets and fisheries, rather than political issues that will effectively integrate the region. In addition, promotion of basic and essential linkages at the physical, cultural, and institutional levels will be critical to integrating philosophies and activities among countries. Parallel implementation of a comprehensive coastal management policy to preserve and protect the remarkable biodiversity resources of the West Indies will be essential. Participatory management experiments, which allow local stakeholders to play a leading role in identifying priorities, problems, and management strategies, are vital to national planning efforts and capacity building. Successful implementation of these actions can then effectively complement the establishment of a regional consensus on conservation priorities, standards, and strategies (Ottenwalder 1996).

Below is a set of general recommendations from a socioeconomic perspective for achieving the conservation goals and activities outlined herein.

- Apply ecosystem management principles to conservation efforts.
- A range of actors including local communities, government institutions, and private organizations, including non-governmental organizations and the tourist sector, should be involved in the planning and implementation of conservation and management activities, as appropriate.
- Develop and promote sustainable management

of dry forest habitats in cooperation with local communities.

- Maximize overall biodiversity conservation by integrating efforts at the species, community, and ecosystem levels.
- Enhance impact and effectiveness of efforts by cooperating with other IUCN Commissions and SSC Specialist Groups active in the region, in order to pursue an integrated, multi-disciplinary approach.
- Prioritize and incorporate coastal habitat protection in tourism development planning, making use of tools such as environmental impact assessments, and strengthening relevant legislation.
- Emphasize capacity building and strengthening local conservation institutions, for both government agencies and non-governmental organizations.
- Promote regional cooperation and integrative approaches among and between West Indian states.

Tropical Dry Forest Ecosystems

By Ariel Lugo

Tropical and subtropical dry forest ecosystems occur in frost-free climates from lowlands to lower montane regions where potential evapotranspiration exceeds precipitation on an annual basis (Holdridge 1967). Generally, they occur in environments with mean annual rainfall ranging from 1000 to 2000mm and mean annual biotemperatures of 12°C and above. Forest stature, primary productivity, and tree species richness increase with increasing rainfall (Murphy and Lugo 1986a; 1995). Dry forests are seasonal forests, experiencing wet and dry periods. Air temperatures are usually high and relative humidities low. The result is that dry forest plants have multiple adaptations to dry conditions, including drought avoidance and resistance through a variety of morphological and behavioral characteristics (Lugo et al. 1978; Medina and Cuevas 1990).

Tropical dry forests occur on substrates ranging from nutrient-rich alluvial soils to nutrient-poor rock outcrops. They can occur on volcanic, limestone, or ultramorphic rocks, with soil textures ranging from sandy to clay, rocky, or organic. Substrate type can greatly exacerbate the water limitations of dry tropical forest climates. If soils are droughty and have low water holding capacity, vegetation may acquire a

greater xeromorphic aspect than expected. Conversely, in locations where soils store water well or where water is channelized (as in valleys or canyons), vegetation may acquire great stature and biomass (Murphy and Lugo 1990; 1995). Tropical dry forest vegetation is generally water rather than nutrient limited (Lugo and Murphy 1986).

West Indian dry forests are characterized by smaller stature and biomass, lower biodiversity and productivity, and more seasonal tree growth, reproductive cycles, and organic matter turnover than forests in areas of higher and less seasonal rainfall (Murphy and Lugo 1995). Leaf and litterfall is seasonal (Lugo et al. 1978; Lugo and Murphy 1986; Cintron and Lugo 1990). Soils can have high organic matter, high pH, and low bulk density (Brown and Lugo 1990). Soil nutrient content is relatively high but with low phosphorus availability to plants (Lugo and Murphy 1986). Animal activity can be highly seasonal as well. Termites are important in the decomposition and turnover of dead wood. Ants and other soil organisms turnover inorganic soil, transport seeds for great distances, and participate in a complex biotic web that processes large quantities of organic matter.

Tropical dry forests support a large fraction of the human population in the tropics, and as a result, are under intense pressure (Murphy and Lugo 1986a). Because dry climates are preferred over very wet climates in the tropics, large population concentrations occur in dry forest life zones. The result is that tropical dry forests not only provide space for the expanding human population, but are also used intensively as a source of fuelwood and charcoal. Grazing animals are also often allowed to roam free through dry forests.

The net result of human activity in this life zone is the serious degradation or disappearance of dry forests in most tropical regions. Because succession is usually slow in these forests, chronic human use results in deforestation and modification of vegetation cover. Usually, degraded stands lose their understory to grazing animals, trees are repeatedly harvested and resprout as multiple small stems, the canopy is opened, and soils are exposed to erosion (Murphy et al. 1995). In cases of extreme use, fire is introduced. Despite these problems, the current condition of dry forests opens the opportunity for restoration and management. Tropical dry forests are resilient in terms of their ability to root and stem sprout, a characteristic that can be used to rehabilitate forests and restore biomass (Murphy and Lugo 1986b; Murphy et al. 1995; Murphy and Lugo 1995). Experience with tree plantations shows promise provided they are managed carefully (Lugo et al. 1990; Wang et al. 1991).

Table 1. Basic socioeconomic and environmental indicators for the insular Caribbean.

Country	Area	Population				GNP per capita		Total Forest (1995)			Change in Forest Cover 1990-95			
	Total (000's of km ²)	Total Pop. 1995 millions	Pop. Density 1995 #/km ²	Annual rate of change 1990-95 (%)	Rural Pop. 1995 (%)	Total 1995 (US\$)	Real annual growth rate 1985-95 (%)	(000's of ha)	% of land area	ha/cap	Natural forests 1995 (000's of ha)	Total change 1990-95 (000's of ha)	Annual change (000's of ha)	Annual rate of change (%)
Antigua and Barbuda	0.44	0.1	150.0	0.6	63.6	a	2.4	9	20.5	0.1	9	0	0	0.0
Bahamas	10.01	0.3	27.6	1.5	13.4	11,940	-0.8	158	15.8	0.6	158	-22	-4	-2.6
Barbados	0.43	0.3	609.3	0.4	52.7	6,560	-0.8	0	0.0	0.0	0	0	0	0.0
Bermuda	0.05	0.1	1260.0	0.7	0.0	b	n.a.	0	0.0	0.0	0	0	0	0.0
(British Virgin Islands)	0.15	0.0	126.7	2.9	36.8	n.a.	n.a.	4	26.7	0.2	4	-1	0	-4.4
(Cayman Islands)	0.26	0.0	126.9	3.5	0.0	b	n.a.	0	0.0	0.0	0	0	0	0.0
Cuba	109.82	11.0	100.5	0.8	24.0	c	n.a.	1,842	16.8	0.2	1,597	-118	-24	-1.2
Dominica	0.75	0.1	94.7	-0.1	38.0	2,990	4.1	46	61.3	0.6	46	0	0	0.0
Dominican Republic	48.38	7.8	161.7	1.9	35.4	1,460	2.1	1,582	32.7	0.2	1,575	-132	-26	-1.16
Grenada	0.34	0.1	270.6	0.3	38.0	2,980	4.1	4	11.8	n.s.	4	0	0	0.0
Guadeloupe	1.69	0.4	253.3	1.8	0.5	a	n.a.	80	47.3	0.2	80	-7	-1	-1.7
Haiti	27.56	7.2	260.5	2.0	68.4	250*	-5.2	21	0.8	n.s.	13	-4	-1	-3.4
Jamaica	10.83	2.4	225.9	0.7	46.3	1,510	3.6	175	16.2	0.1	160	-79	-16	-7.2
Martinique	1.06	0.4	357.5	1.0	6.6	b	n.a.	38	35.8	0.1	38	-2	n.s.	-1.0
(Montserrat)	0.10	0.0	110.0	-0.3	81.8	n.a.	n.a.	3	30.0	0.3	3	0	0	0.0
Netherlands Antilles	0.80	0.2	248.8	0.9	30.7	b	n.a.	0	0.0	0.0	0	0	0	0.0
Puerto Rico [Mor Is]	8.86	3.7	414.7	0.8	26.6	a	1.8	275	31.0	0.1	272	-12	-2	-0.9
St. Kitts and Nevis	0.36	0.04	136.1	-0.3	55.1	5,170	4.8	11	30.6	0.3	11	0	0	0.0
St. Lucia	0.61	0.1	232.8	1.4	52.1	3,370	3.9	5	8.2	n.s.	5	-1	0	-3.6
(St Pierre & Miquelon)	n.a.	0.0	n.a.	0.7	16.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
St. Vincent & Grenadines	0.39	0.1	287.2	0.9	52.7	2,280	3.8	11	28.2	0.1	11	0	0	0.0
Trinidad and Tobago	5.13	1.3	254.6	1.1	28.2	3,730	-2.7	161	31.4	0.1	148	-13	-3	-1.5
US Virgin Islands	0.34	0.1	308.8	0.6	54.3	b	n.a.	0	0.0	0.0	0	0	0	0.0
Insular Caribbean	228.36	35.8	156.7	1.3	37.5	3,086	0.9	4,425	19.4	0.1	4,134	-391	-7.8	-1.7

Notes and Codes. *Country* - island-countries and/or territories with West Indian iguana populations; () indicates countries with a total population below 100,000 (expressed as 0.0 in corresponding column). *Area* - given figure is equivalent to total land area, excluding inland water bodies. *GNP per capita* - data from World Bank Atlas method, subtotals based on available data: (a), estimated to be upper-middle-income, \$3,036 to \$9,385; (b) estimated to be high income, \$9,386 or more; (c), estimated to be lower-middle-income, \$766 to \$3,035; (*) figure for lower-income countries is \$765 or less. *Forest Cover* - 'Total forest' is the sum of natural forest and plantations. *Change in Forest Cover* - method for data collection based on deforestation model (adjustment function) developed for correlation of forest cover change over time, incorporating ancillary variables (population change and density, initial forest cover and ecoregion). *All columns* - numbers may not tally due to rounding; (n.a.) no available data; (n.s.) no significant change or data indicating a very small value.

Sources of data. Socioeconomic indicators: *World Development Report 1997. The State in a Changing World: Selected World Development Indicators*, The World Bank, 1997; *The World Bank Atlas 1995*, The World Bank, 1996; *World Population Prospects*, United Nations, 1995; *World Urbanization Prospects*, United Nations, 1995; *FAO Production Yearbook, 1996*. Environmental indicators: *State of the World's Forests 1997*, FAO 1997; *World Development Report 1997. The State in a Changing World: Selected World Development Indicators* The World Bank, 1997; *UN World Population Prospects, 1994*; *Proceed. XI World Forestry Congress*, FAO 1997.

West Indian Iguana Habitat

By Robert Ehrig

West Indian xerophytic forests inhabited by iguanas have survived drastic climatic variation, geological activity, and rising and falling sea levels throughout their existence. Although they are often less tolerant of unnatural disturbance than other vegetation communities, dry forests survive hurricanes and tropical storms and recover quickly if they are in good condition. These xerophytic plant communities contain some of the world's hardest woods, harbor many spectacular bird species, and support the earth's largest saurian herbivores.

Although the Lucayan, Caloosa, Taino, and Arawak Indians probably all utilized iguanas as food, it was the arrival of Europeans that precipitated dramatic declines in iguana populations and the destruction of native habitats. In modern times, West Indian dry forests have continued to suffer steady degradation. On larger islands and in populated areas, these forests are mostly gone, although some excellent examples survive in remote or sparsely populated areas, primarily in Cuba and the Bahamas. Fragments in good condition still remain in a number of other areas, but most are under intense pressure and in danger of being lost in the near future.

West Indian dry forests have been historically referred to as thorn forests, due to the presence of cactus, agave, epiphytes, thorny or spiny trees and shrubs, and their typically low canopy. Stem densities are high, helping to reduce water loss. The substrate may be sandy, but often consists of sharp, pitted limestone containing numerous holes and crevices. Solution and sink holes in which organic soils accumulate are common, providing places for trees and shrubs to grow. Larger holes may be maintained in an open state by the annual nesting activities of iguanas.



©Glen Gerber

Good quality iguana habitat on Great Sand Cay, Turks and Caicos Islands.

The rough and inhospitable nature of West Indian iguana habitats, along with heat and rocky terrain, have made few people lament their destruction. In many areas, the absence of permanent fresh water has been the most important factor preventing forest degradation. On larger islands, the availability of water for irrigation has enabled agricultural development of forested areas. Limestone mining has destroyed large forest tracts on Cuba, Puerto Rico, and Jamaica. In many countries, woodcutting for charcoal, an inexpensive cooking fuel, has decimated vast areas.

Goats, burros, sheep, cattle, and other free-ranging and feral mammalian browsers contribute to destruction of iguana habitats by preventing natural regeneration of vegetation. Non-native trees such as Australian pine (*Casuarina equisetifolia*), non-native naturalized weeds such as jumbie bean (*Leucaena leucocephala*), and early successional natives such as *Acacia macracantha* have become dominant in many degraded xeric forests. These species have very little value for native wildlife. Lower plant diversity translates into reduced food resources for wildlife, which in turn leads to loss of more specialized organisms.

Conservation of West Indian iguanas will be difficult in the face of growing, economically depressed human populations. Because the continued existence of dry forest vegetation communities is imperative for iguana survival, protection of habitat should be the first priority of conservation efforts. Free-ranging livestock and woodcutting for charcoal production are probably the most common negative impacts on dry forest habitats in rural areas. Because xerophytic forests are slow growing and grazing by mammalian herbivores precludes regeneration, mammals must be removed if vegetation is to recover. Reduction plans will need to involve compensation for livestock owners and may be facilitated by establishing a warden from the local community. Fences may be required to exclude browsers kept for dairy purposes from iguana areas. Elimination of woodcutting will undoubtedly require a longer time frame. Several wardens will be needed to enforce restrictions in larger areas. However, local employment opportunities could be generated by establishing plant nurseries for native species that include seed gathering and restoration planting. Reforestation with native hardwoods such as mahogany (*Swietenia mahagoni*) and black ironwood (*Krugiodendron ferreum*) in clearly defined buffer zones or close to settlements would be feasible, and plantings of a variety of indigenous species could provide firewood, medicinal plants, and wildlife habitat. Such programs could allow recovery of degraded habitats and provide strong incentives for conservation and wise management of forest resources.

Overview of West Indian Iguana Populations

As a group, West Indian iguanas are among the most endangered lizards in the world, probably due in large part to their exclusively insular distribution. As a result of their low metabolic rates and naturally high population densities, lizards in many mainland habitats are relatively resistant to extinction. However, the restricted ranges and small population sizes of lizards on islands render them highly susceptible to a variety of human-caused threats. Pressure to exploit undisturbed natural areas is particularly strong in the West Indies, where unutilized land is often perceived as economically undesirable (Barzetti 1993). Recolonization following local extinction on islands may be quite rare because West Indian iguanas, like most other terrestrial reptiles, are probably poor over-water dispersers.

According to IUCN Red List Categories (IUCN 1994), four West Indian iguanids are considered Vulnerable, five Endangered, and eight Critically Endangered. Two taxa, the Turks and Caicos iguana (*C. carinata carinata*) and the Cuban iguana (*C. nubi-la nubila*), are still fairly numerous in the wild. However, both have been nearly extirpated on the larger, more populous islands within their ranges, and today are restricted primarily to smaller, uninhabited islets or cays. Although both still exist over a wide area, they are subject to a variety of human disturbances, with the Turks and Caicos iguana reduced to 10% of its former range. The rhinoceros iguana (*C. cornuta cornuta*) and the Andros Island iguana (*C. cychlura cychlura*), both ranked as Vulnerable, inhabit increasingly fragmented ranges and are threatened by invasive exotic species. Although it still occurs on many islands, the Lesser Antillean iguana (*I. delicatissima*) is undergoing very rapid decline as a result of habitat loss, competition with introduced goats, predation by exotics, and hybridization with common iguanas (*I. iguana*).

Of the West Indian iguanas ranked as Endangered, the majority occur in the Bahamas (the Exuma Island iguana, *C. cychlura figginsi*; the Allen's Cay iguana, *C. cychlura inornata*; the San Salvador iguana, *C. rileyi rileyi*; and the Acklins iguana, *C. rileyi nuchalis*). All of these taxa are restricted to a limited number of small islands or cays, often no more than a few hectares in area. While populations are generally stable, many of these islands are heavily visited by tourists and some taxa have been subject to illegal smuggling in recent years. The Mona Island iguana (*C. cornuta stejnegeri*) occurs only on the remote island of Mona, where it is scarce due to predation by

feral pigs and cats, browsing by feral goats, and destruction of nest sites.

While very small, the single population of Bartsch's iguana (*C. carinata bartschi*) in the Bahamas appears to be healthy and stable, supporting all age classes. However, this subspecies is restricted to one tiny cay with a high point of 6.2m and most of its area below 3m. Because environmental catastrophe, particularly in the form of a heavy hurricane, is a very real threat, this species has been ranked as Critically Endangered. Another Bahamian form, the White Cay iguana (*C. rileyi cristata*), has only one small population remaining from which illegal smuggling has been confirmed. The Jamaican iguana (*C. collei*), the Lesser Caymans iguana (*C. nubi-la caymanensis*), the Grand Cayman iguana (*C. nubi-la lewisi*), the Anegada Island iguana (*C. pinguis*), and Ricord's iguana (*C. ricordi*), are probably currently far below natural carrying capacity on the islands where they



Active iguana nesting site in the Hellshire Hills, Jamaica.

occur. The Jamaican iguana was believed extinct until the 1990 rediscovery of a tiny remnant population in the remote Hellshire Hills. Since that time, a highly successful captive rearing program involving over 100 juveniles has helped provide a hedge against extinction, but the wild population is still very much in peril. For the Lesser Caymans iguana, the only remaining viable subpopulation is that on Little Cayman, and it is subject to a variety of threats, particularly habitat loss and introduced predators. Based on recent genetic data, the Grand Cayman iguana has probably existed at an extremely small population size for an even longer period than the Jamaican iguana. Genetic variation among the remaining individuals examined thus far appears to be very low, posing serious concerns regarding conservation efforts for this taxon. The Anegada Island iguana has undergone precipitous



declines in recent years, primarily due to competition with feral livestock for food and predation by feral cats. The population of Ricord's iguana, historically small and disjunct, is declining as a result of habitat degradation and introduced species.

Remains of a charcoal kiln in the Hellshire Hills, Jamaica.

Table 2. Current Status of West Indian iguana populations according to the 1996 IUCN Red List. See Appendix 1 for explanation of listing criteria.

Taxon	Estimated Population	Vulnerable	Endangered	Critically Endangered	Listing Criteria
Turks and Caicos iguanaf	30,000			•	B1+2a,b,c,d,e
Bartsch's iguana	200-300			•	B1+2b,c,e; C2b
Jamaican iguana	100			•	B1; 2c
Rhinoceros iguana	10,000-17,000	•			Ala,c,d,e
Mona Island iguana	1,500-2,000		•		Alc,d,e+2c,e
Andros Island iguana	2,500-5,000	•			Ala,c,e; B1+2b; C1
Exuma Island iguana	1,000-1,200		•		C1
Allen's Cay iguana	400-500		•		B1+2c
Cuban iguana	40,000-60,000	•			Ala,c,d,e+2c,e
Lesser Caymans iguana	1,000			•	B1+2a,b,c,d,e
Grand Cayman iguana	100-175			•	B1+2b,c,e; C2b
Anegada Island iguana	200			•	Ala,b,c,d,e; B1+2a,b,c,e; C1+2b
Ricord's iguana	2,000-4,000			•	Alc,e+2c,d,e; B1+2c,e
San Salvador iguana	500-1,000		•		C2
White Cay iguana	150-200			•	B1+2e; C2
Acklins iguana	13,000		•		B1+2c; C2
Lesser Antillean iguana	15,000	•			Ala,c,d,e+2c,d,e; B1+2a,b,c,d,e

† Although the population estimate for this taxon is relatively large, its range has contracted significantly in recent years.

Overview of Current Threats

The major threat to survival of West Indian iguana populations is habitat loss, a problem affecting virtually all taxa. This process takes a variety of forms, including conversion of dry forests for mining (Dominican Republic, Jamaica), agriculture (Dominican Republic, Grand Cayman, Lesser Antilles), charcoal production (Dominican Republic, Jamaica), timber extraction (Dominican Republic, Lesser Antilles), tourist resorts, housing developments, and other real estate ventures (Bahamas, Turks and Caicos, Cayman Islands, Cuba).

An inevitable consequence of this disturbance is the arrival of human-commensal species which can act as unnatural predators or competitors for native species. While feral cats and mongooses primarily threaten juvenile iguanas, dogs are capable of preying on adults. For some taxa, particularly the Jamaican, Lesser Caymans, and Anegada Island iguanas, predation by introduced species appears severe enough that population recruitment is very low, with few juveniles present in the wild. Among smaller species of iguanas, predation by introduced rats on juveniles and feral cats on all age classes can similarly lead to depressed population growth. Egg predation by feral pigs is a significant problem on Mona, Andros, parts of Cuba, and possibly Jamaica. Because they trample nesting sites and decimate the native vegetation on which iguanas depend, feral livestock also pose a seri-

ous threat, particularly on Anegada, Mona, Booby Cay in the Bahamas, in parts of the Turks and Caicos and the Dominican Republic, and throughout the Lesser Antilles. On some of these islands, over-browsing has stunted vegetation and produced radical changes in species composition.

Hunting is also a threat for several taxa, although the reasons for this exploitation are varied. In Haiti, the Dominican Republic, and the Lesser Antilles, iguanas are hunted primarily for food, whereas in the Bahamas and the Turks and Caicos, illegal poaching for international trade is becoming an increasing concern. Finally, on islands undergoing very rapid urbanization, particularly the Caymans and some of the Lesser Antilles, road casualties are a significant cause of death for both adults and juveniles.

Overview of Existing Conservation Measures

All species of West Indian iguanas are protected internationally under the Convention on International Trade in Endangered Species (All rock iguanas on CITES Appendix I; the Lesser Antillean iguana on CITES Appendix II). Although many species also receive some degree of national legislative protection in the countries where they occur, local enforcement of regulations is sporadic. Protected habitat, in the

Table 3. Current Threats to West Indian iguana populations.

Taxon	Habitat Loss	Hunting/Trade	Predation by Feral Animals				Introduced Rats	Road Casualties
			Dogs	Cats	Mongoose	Pigs		
Turks and Caicos iguana		•	•	•			•	
Bartsch's iguana	•						•	
Jamaican iguana	•		•	•	•	•		
Rhinoceros iguana	•	•	•	•	•	•	•	
Mona Island iguana	•			•		•	•	
Andros Island iguana	•	•	•			•		
Exuma Island iguana		•	•			•		
Allen's Cay iguana	•	•						
Cuban iguana	•		•	•		•		
Lesser Caymans iguana	•		•	•		•	•	
Grand Cayman iguana	•		•	•			•	
Anegada Island iguana	•		•	•			•	
Ricord's iguana	•	•	•	•	•		•	
San Salvador iguana	•		•	•		•		
White Cay iguana	•	•				•		
Acklins iguana	•	•						
Lesser Antillean iguana	•	•	•	•	•		•	



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Natural area supporting iguanas on the east end of Grand Cayman.

Table 4. Existing conservation measures for West Indian iguanas.

Taxon	Protected Areas	National Legislation	Exotics Control	Research	Education	Satellite Populations	Habitat Enhancement	Captive Breeding
Turks and Caicos iguana	•	•	•	•	•			
Bartsch's iguana		•	•					
Jamaican iguana		•	•	•	•			•
Rhinoceros iguana	•	•						•
Mona Island iguana	•	•	•	•			•	
Andros Island iguana		•						
Exuma Island iguana	•	•		•	•			
Allen's Cay iguana		•		•	•			
Cuban iguana		•		•				•
Lesser Caymans iguana	•	•		•				
Grand Cayman iguana	•	•		•	•		•	•
Anegada Island iguana		•	•	•		•		
Ricord's iguana	•	•						•
San Salvador iguana		•	•	•				
White Cay iguana		•	•	•				
Acklins iguana		•		•		•		
Lesser Antillean iguana	•	•		•	•			•

form of national parks, nature reserves, or sanctuaries, exists for approximately half of all West Indian iguanas. However, in many cases, these areas are very small (e.g., Cayman Islands) or represent only a tiny fraction of the species' total range (e.g., Lesser Antilles). Even in countries with fairly extensive reserve systems (Turks and Caicos Islands, Cuba, Dominican Republic), limited resources for protected area maintenance remain a concern.

While at least some form of exotics control is underway for six taxa of West Indian iguanas, these pilot programs are aimed at single species on one or two islands (feral cats on Pine and Water Cays, Turks and Caicos; goats on Booby Cay, Bahamas; sheep on Guana Island, British Virgin Islands; mongooses in the Hellshire Hills, Jamaica; feral cats on Mona Island, Puerto Rico; rats on Low and White Cays, Bahamas). Although complete eradication is the goal for feral cats and rats, other species such as mongooses will require continuous trapping to keep population numbers low in core iguana habitat. Fencing has successfully excluded feral goats and pigs from iguana nest sites, particularly on Mona Island. Because of the variety of threats posed by exotic mammals to most species of West Indian iguanas, control programs will need to be expanded in the future, and implemented on islands where they do not yet exist.

Field research is making a significant contribution to the conservation of many species of West Indian iguanas. Studies ranging from population surveys to ecological and systematic investigations are taking place which should provide the scientific data necessary to begin to develop species conservation plans for many taxa. For others, particularly Bartsch's iguana and the Andros island iguana, such studies are still urgently needed as little is known of their biology.

The only West Indian iguanas for which full-scale public education programs currently exist are the

Turks and Caicos and Grand Cayman iguanas. Each year, the National Trust for the Cayman Islands holds a fair at which several thousand children have the opportunity to learn about iguanas and their habitat requirements. The National Trust for the Turks and Caicos Islands has produced an iguana poster and regularly provides information about iguanas to local schools. The Jamaican iguana conservation program involves education of local forest habitat users, particularly charcoal burners and pig hunters. In the Bahamas, signs informing tourists of the protected status and vulnerability of iguanas have been helpful, particularly on small cays visited by private yachts. The IUCN/SSC West Indian Iguana Specialist Group recently sponsored production of a color poster urging protection of West Indian iguanas for distribution in as many range countries as possible.

Secondary populations have been established for three taxa, the Allen's Cay iguana, the Anegada iguana, and the Acklins iguana. These satellite populations have the potential to serve as reservoirs should primary populations become extinct in the future. Similar programs are planned for the Jamaican iguana, the Exuma Island iguana, and the White Cay iguana, but have yet to be implemented.

Habitat enhancement, although it has the potential to contribute to conservation efforts for all species of West Indian iguanas, has to date only been carried out for two taxa. Clearing of patches of exotic forest has provided new nesting area on Mona Island, and removal of exotic vegetation to prepare a release site for headstarted hatchlings is taking place on Grand Cayman.

Captive breeding programs currently exist for six taxa of West Indian iguanas. *In situ* programs, such as those on Jamaican and Grand Cayman, are having immediate effects on population viability through the successful repatriation of headstarted juveniles.

Chapter 2. Taxonomic Accounts

Turks and Caicos iguana

Cyclura carinata carinata

By Glenn Gerber and John Iverson

Description

The Turks and Caicos iguana is a small (up to 770mm total length) rock iguana, characterized by a lack of enlarged scales on the upper surface of the head, rostral scale in contact with the nasal scales, 80 to 110 dorsal crest scales, enlarged, spiny whorls of scales on the tail, and 9 to 10 dark vertical stripes on the dorso-lateral wall that fade with age (Schwartz and Carey 1977; Iverson 1979). Body color varies among island populations, from gray or brown to dull green. In some populations, the head and neck have a vermiculated pattern, and the dorsal crest scales and the tail of adult males are pale blue and reddish-brown, respectively. Body size is sexually dimorphic and varies among islands, with the smallest animals occurring on Long Cay on the Turks Bank, where adult males and females average 221mm snout-vent length (SVL) (0.40kg) and 185mm SVL (0.24kg), respectively. Iguanas are largest on Plandon Cay on the east side of the Caicos Bank, where adult males and females average 325mm SVL (1.41kg) and 268mm SVL (0.64kg), respectively (G. Gerber and M. Welch, unpublished data). The largest recorded male and female are from Pine Cay on the west side of the Caicos Bank, measuring 360mm SVL (1.86kg) and 290mm SVL (1.14kg), respectively.

Distribution

This subspecies is native to the Turks and Caicos Islands, located southeast of the Bahamas and approximately 150km north of Hispaniola. The islands lie on two shallow oceanic banks, the Turks Bank and the Caicos Bank, separated by a deep water channel. Although politically separate from the Bahamas, the Turks and Caicos are geologically part of the Bahama Archipelago. There are 10 islands in the Turks Bank and over 100 islands in the Caicos Bank, with a combined surface area of approximately 500km². Maximum elevation is about 85m and the climate and vegetation are similar to that of the Bahamas. Historically, this subspecies occurred throughout the Turks and Caicos, but has been extirpated from many areas, including most of the larger islands.

Status of populations in the wild

A comprehensive survey of iguana populations in the

Turks and Caicos was conducted in 1995 (G. Gerber and M. Welch, unpublished data; Fig. 1). Based on preliminary analyses, about 30,000 adults remain in the wild. Iguanas were found on 56 of 120 cays visited. However, most cays with iguanas are very small (area \leq 1 ha) and the combined area of all cays with iguanas is only about 28km². Over half of the area occupied by iguanas consists of five cays (Salt, Joe Grant's, Major Hill, Dellis, and Pine) where iguanas are extremely rare (Fig. 1), probably due to the presence of introduced mammals (Fig. 2; see also Iverson, 1978, and Smith, 1992). The combined area of cays where iguanas are still common (densities can exceed 30 adults per ha; Iverson, 1979) is only 13km², most of which is accounted for by three cays (Big Ambergris, Little Ambergris, and East Bay), the largest of which (Big Ambergris, 4.3km²) is privately owned and under development. A comparison of the 1995 survey with a less extensive survey conducted in the mid-1970s (Iverson, 1978) suggests that at least 13 iguana populations, most on relatively large islands, have been extirpated over the last 20 years.

Ecology and natural history

Iverson (1979) studied the natural history of this subspecies in the Caicos Islands from 1973 to 1976. This iguana is most abundant in rocky coppice and sandy strand vegetation habitats, and sandy habitat is required for nesting. The Turks and Caicos iguana is diurnal and spends the night in burrows it has dug or in natural retreats in or under rocks. It is primarily herbivorous throughout its life, feeding arboreally or terrestrially on the fruits, flowers, and leaves of at least 58 plant species, as well as occasional insects, mollusks, crustaceans, arachnids, lizards, and carrion (see also Auffenberg, 1982). In captivity, it readily takes both animal and plant food.

Adult males are territorial throughout the year, apparently to guarantee access to food and females. Courtship and mating occur in May, with a single annual clutch of two to nine eggs laid in June. Females defend the nest burrow for several days to several weeks after nesting, but are not territorial during the rest of the year. Hatching occurs in September, after about 90 days incubation, and hatchlings average 80mm SVL and 14.6g.

Growth rates in juveniles average slightly less than 20mm per year until maturity, which in males occurs at about 7 years (220mm SVL, 0.33-0.48kg), and in females at 6 to 7 years (185-200mm SVL, 0.20-0.30kg). Adults grow much more slowly (0.2 to

1.7cm/yr) and show strong sexual dimorphism.

Annual survivorship ranges from about 55% for the first three years of life, to about 67% during years four through six, to 90-95% in adults. Life table analysis suggests that mean cohort generation time is 14 years. Preliminary data suggest that some individuals live at least 20 years.

Habitat

The current human population of the Turks and Caicos is about 8,000, inhabiting eight of the larger islands (Fig. 1). On these islands, considerable habitat has been lost to human activities, particularly tourist-related, and the rate of development is increasing. An even more significant cause of habitat destruction has been the mammalian predators and livestock accompanying modern settlement (Fig. 2). Iguanas are still common only on uninhabited islands that have no introduced mammals. However, many uninhabited islands exist which could support dense populations of iguanas if rid of feral mammals.

Threats

The primary threat to Turks and Caicos iguanas is introduced mammals, particularly cats and dogs. Iverson (1978, 1979) documented the near-extirpation of a population of over 5,000 adult iguanas from Pine Cay (3.9km²) in just three years as a result of predation by feral cats and dogs. Feral livestock (goats, cows, donkeys, and horses) pose a serious threat also, presumably because they compete for food plants, alter the vegetational composition of habitats, and trample soft substrates where iguanas burrow and nest. In 1995, iguanas were found on only five of 26 islands with cats or livestock (G. Gerber and M. Welch, unpublished data). Furthermore, iguanas on these five islands were rare, whereas iguanas on islands without introduced mammals were common. Iguanas are still occasionally eaten by local fishermen, and although illegal exportation for international trade is undocumented, it probably occurs.

Current conservation programs

The Turks and Caicos has a fairly extensive system of national parks, nature reserves, and sanctuaries, a number of which encompass areas supporting iguanas (Fig. 1). Unfortunately, reserves are not immune to the effects of introduced mammals (Fig. 2), and few governmental resources are presently allocated to maintain or enforce protection of non-marine parks. However, with the establishment of the National Trust for the Turks and Caicos Islands in 1994, a significant increase in conservation of terrestrial wildlife and habitats has begun. Largely due to the urging of the National Trust, legislation to protect iguanas within

the Turks and Caicos Islands has recently been drafted. In addition, the government has granted the National Trust stewardship of Little Water Cay, which supports a large population of iguanas but needs management due to its popularity with tourists and the threat of invasion by feral cats over a recently formed isthmus to Water Cay. A similar transfer is currently pending for Little Ambergris and East Bay Cays. The National Trust recently initiated a trapping program to remove feral cats from Pine, Water, and (if needed) Little Water Cays. If successful, this program will remove the threat of cats from Little Water Cay and allow iguanas to repopulate Pine and Water Cays. On Little Water Cay, boardwalks and observation towers have been constructed at two popular landing sites to reduce the negative impacts of tourism, and a visitation fee has been instituted with the proceeds supporting conservation activities. In addition, the National Trust has initiated a public education program that includes distribution of an informative poster about iguanas and a tour of all schools to discuss iguanas and other conservation issues.

A preliminary study of genetic variation in the Turks and Caicos iguana using blood samples collected from 29 island populations in 1995 found significant differences among islands and revealed a pattern of strong regional differentiation (M. Welch, unpublished data). This preliminary study utilized microsatellite markers developed for *C. nubila*, of which only two were informative; further description of inter-island genetic variation awaits the development of markers specific to *C. carinata*. No captive programs currently exist for this taxon.

Critical conservation initiatives

- Legislation prohibiting the introduction of mammals to uninhabited islands in the Turks and Caicos.
- Incorporation of all uninhabited islands supporting iguanas into the current reserve system.
- Increased governmental commitment to terrestrial conservation, including the provision of resources necessary to enforce compliance with environmental regulations.

Priority projects

- 1) Eradicate or control introduced mammals on islands uninhabited by humans. Free-ranging domestic livestock should also be captured and relocated to inhabited islands.
- 2) Complete study of genetic differentiation among island populations.
- 3) Establish a long-term monitoring program and

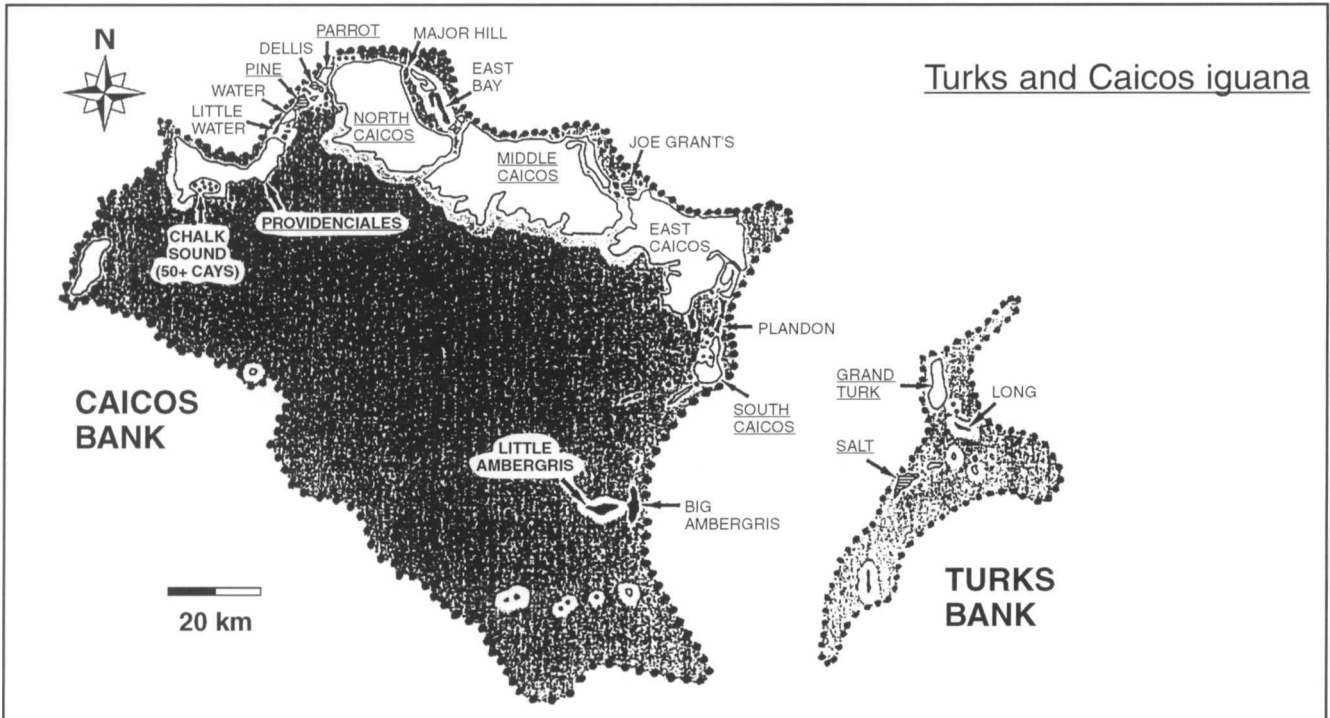


Fig. 1. Map of the Turks and Caicos Islands showing ocean banks (gray surrounded by dotted lines), terrestrial reserves (lighter shading around islands), and abundance of iguanas on islands in 1995 (white = not found, hatched = rare, black = common to abundant). Iguanas were found on 24 of 31 cays visited in Chalk Sound. Names of islands inhabited by humans are underlined.

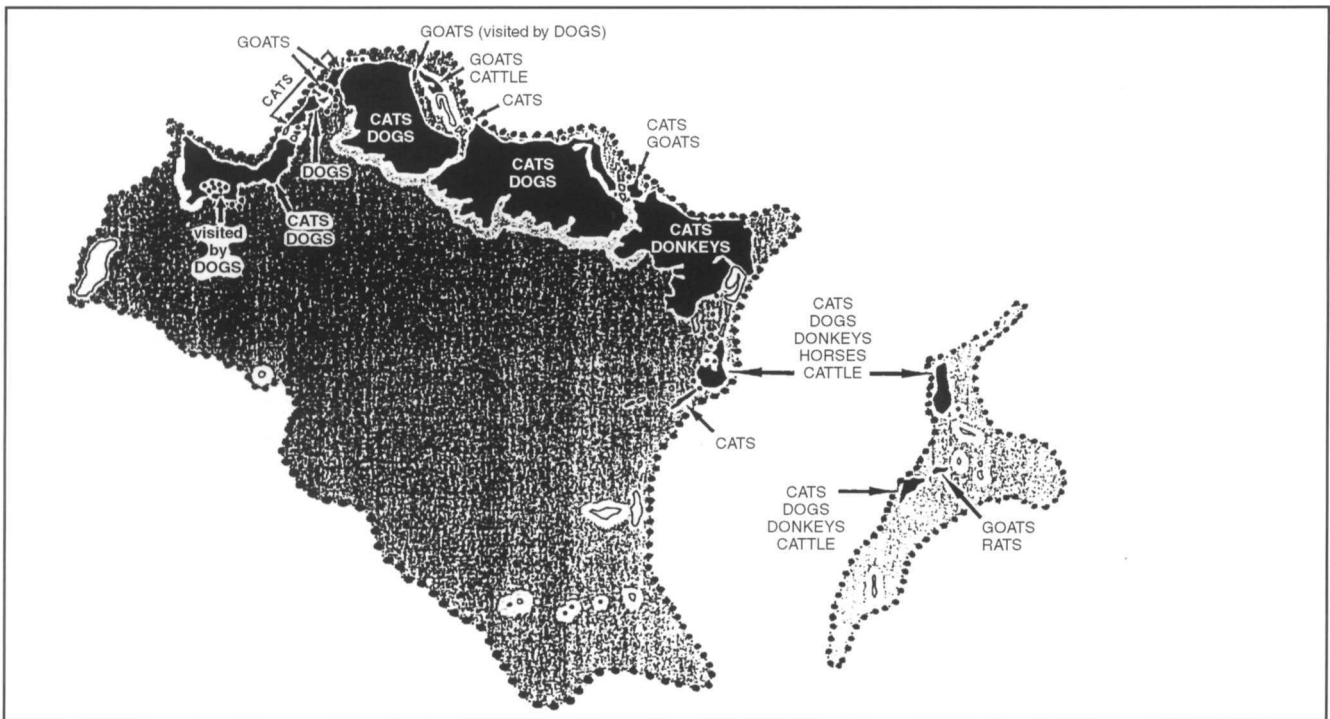


Fig. 2. Map of the Turks and Caicos Islands showing where feral or free-ranging domestic mammals were (black) and were not (white) found in 1995. Labels indicate the types of mammals identified by sight, tracks, or droppings. The label "visited by dogs" indicates islands frequented by dogs residing on nearby islands. Other features labelled as in Fig. 1.

Geographical Information Systems database of iguana populations.

4) Conduct field studies to determine the conditions necessary to re-establish healthy, self-sustaining populations of the Turks and Caicos iguana on islands uninhabited by humans, supporting suitable habitat, and lacking feral mammals. Results could serve as a valuable model for other West Indian rock iguanas, some which may depend on reintroduction programs for their survival.

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Bartsch's iguana

Cyclura carinata bartschi

By Sandra Buckner and David Blair

Description

Bartsch's iguana is greenish to brownish-gray, with a yellow dorsal crest, faint yellow-brown reticulations on the bodies of the adults, and a golden iris (Auffenberg 1976). Large specimens are approximately 770mm total length. Schwartz and Carey (1977), who examined nine specimens (seven in life), recorded an SVL of 335mm in the largest male and 285mm in the largest female. They state, "in general their body colors seem to be somewhat paler (tending

towards creams to pale grays) than those of nominate *carinata* (gray to dull tan)." As this subspecies has not been studied in the field, the paler body color may be accounted for by temperature or time of year when specimens were observed.

Distribution

This subspecies is restricted to Booby Cay, located 0.5km off the eastern end of the island of Mayaguana in the southern Bahamas. The cay is 2km in length, approximately 750m wide at its northeastern end, narrowing to less than 100m, and again widening to approximately 250m at its southwestern end. Approximately 30% of the cay is taken up by two ponds. Iguanas probably originally ranged over the entire cay but were likely concentrated on the eastern half where the vegetation was more dense. There are historical anecdotal references to the presence of iguanas on Mayaguana. However, there have been no recent sightings on the island, which has an area of 285km² and a human population of approximately 500 concentrated on the western half. There are no roads extending to the eastern end of the island and it is conceivable that iguanas still exist in this area.

Status of population in the wild

Surveys indicate that iguanas were fairly numerous in 1988 and 1997 with all age classes present, indicating a healthy reproducing population. However, this subspecies is restricted to one population on a single small cay with a high point of 6.2m and most of its area below 3m. Although no census has been conducted, it is unlikely that the population exceeds 500 animals, and is estimated to be between 200 and 300 (Blair 1991a; Bendon 1997).

Ecology and natural history

No research has been conducted on this subspecies. Like the Turks and Caicos iguana, this subspecies is primarily herbivorous throughout life, although insects, mollusks, crustaceans, arachnids, lizards, and carrion are occasionally consumed. Burrows or crevices in or under rocks are used for retreat.

Habitat

Like the Turks and Caicos iguana, Bartsch's iguana probably inhabits rocky coppice and sandy strand vegetation habitats (Iverson 1979). D. Blair reported that he saw one group of about ten goats on the eastern portion of the island in 1988. The vegetation was heavily grazed and stunted, and the area was littered with goat droppings. J. Bendon reported the presence of goats in 1997, but indicated that they did not appear to be impacting the habitat severely.

Threats

The immediate threat to the single population of Bartsch's iguana is the presence of goats, introduced to Booby Cay by the individual who holds the land under Crown lease. The cay is not readily accessible from the settlements on Mayaguana which could be the reason this population has survived so far. However, the cay is visited on an irregular basis by local conch fisherman, who sometimes overnight there. Catastrophe, particularly in the form of a hurricane or hurricane surge, is a very real threat.

Current conservation programs

All Bahamian rock iguanas are protected under the Wild Animals Protection Act of 1968. There have been no reports of poaching of iguanas on Booby Cay and it is not known if any are taken by local fishermen for consumption. The Bahamas National Trust has proposed to the Bahamas Government that Booby Cay, which is also of significant value for nesting seabirds, be named a protected area under the national parks system.

Representatives of the Wildlife Committee of the Bahamas National Trust and the Department of Agriculture began to survey the status of the iguanas on Booby Cay in early 1995 and to initiate removal of feral goats. There are no other research programs in progress or currently proposed for this subspecies, and no captive programs currently exist.

Critical conservation initiatives

- Removal of feral goats from Booby Cay. Prior to such action, the status of the Crown Lease will need to be reviewed and ownership of goats determined.
- Establishment of protected area status for Booby Cay.
- Institutional strengthening of responsible agencies to develop enforcement capabilities.
- Initiation of a national education program for tourists and residents.

Priority projects

- 1) Assess the present status of the population on Booby Cay, identify plant species cay wide, and monitor vegetation changes after removal of goats.
- 2) Determine whether any subpopulations exist at the eastern end of Mayaguana and establish captive breeding programs with the potential goal of restocking on Mayaguana.

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Jamaican iguana

Cyclura collei

By Peter Vogel

Description

The Jamaican iguana is a moderate-sized rock iguana, with SVL reaching 428mm in males and 378mm in females. Schwartz and Henderson (1991) describe coloration as green, grading into slaty blue with oblique lines of dark olive-green on the shoulder. Three broad triangular patches extend from dorsal crest scales to venter, with dark olive-brown zigzag spots. The dorsal crest scales are somewhat brighter bluish-green than the body. The top of the head is washed green and the dorsal and lateral body surfaces are blotched with straw, with the blotches breaking up into small groups of spots. Wild individuals, particularly nesting females, often appear deep reddish-brown in color after digging in the coarse ferrallic soils of the Hellshire Hills region.

Distribution

According to Sloane (1725) who visited the island in 1688, iguanas were once common in Jamaica although their distribution seems to have been restricted to the drier sections of the south coast, at least in historic times. The Jamaican iguana declined dramatically during the second half of the 19th century, probably due to the introduction of the Indian mongoose (*Herpestes javanicus* [=auro-punctatus]), changing land use patterns, and human population growth. Today, the iguana survives only in the Hellshire Hills, a rugged limestone area of 114km² with fringing wetlands and beaches located 20km west of Kingston. Despite their closeness to

Jamaica's densely populated capital, the Hellshire Hills persist as a wilderness area because of their ruggedness and lack of surface water, making them unsuitable for agriculture and large-scale settlement.

Status of population in the wild

At the beginning of the century, the Jamaican iguana was thought to have survived only on the Goat Islands, two small islets off the Hellshire Hills. The species was believed extinct after this population disappeared in the 1940s. However, the continued survival of the Jamaican iguana in the Hellshire Hills was confirmed in 1970, and again in 1990. A preliminary survey in 1990 revealed a small surviving population of perhaps a hundred or so animals in the least disturbed central and western sections of the Hellshire Hills, and two active nesting sites. Iguanas have disappeared from northern and eastern sections of the Hellshire Hills because of extensive charcoal production, use of dogs for pig hunting, and human settlements. There may be no more than a hundred adults remaining in the wild, and juvenile recruitment appears to be minimal.

Ecology and natural history

Rugged limestone outcroppings make up much of the Hellshire Hills, although coarse red ferrallic soil has accumulated in crevices and depressions. Soil suitable for nesting is comparatively rare. The vegetation of the Hellshire Hills consists of varying formations of tropical dry forest. The area supports about 300 species of higher plants, including 53 endemics. Jamaican iguanas are found only in the remotest sections of the Hellshire Hills where the forest remains in good condition. Jamaican iguanas feed on leaves, fruits, and flowers of a wide variety of plant species, supplemented occasionally by animal matter, including snails. Diet composition changes seasonally according to the flowering and fruiting cycles of local plant species.

Following the rediscovery of the Jamaican iguana in 1990, the two known communal nest sites have been observed intensively (Vogel 1994). Nesting occurs in underground tunnel systems of nest burrows filled with loose soil. Gravid female iguanas begin digging trial holes long before egg laying. Females deposit their eggs in mid-June, and hatchlings emerge approximately 85-87 days later. After oviposition, nest guarding by females lasts up to two weeks, and involves aggressive interactions, including threat displays, biting, and chasing. Clutch size averages 17 eggs (range 16-20). Hatching success varies from 0 to 100% and appears to be related to maternal body size.

Habitat

The northeastern portion of the Hellshire Hills has been totally degraded, and much of the land in this section is now virtually barren. Along the north-central border, the charcoal burners have moved 2-3km into the forest, and are approximately 1.5km from the two known nesting sites. Along the south coast, charcoal burners have cut some of the coastal forest, although they have not yet expanded their activities northwards into the limestone karstland. The central and most of the western sections of the Hellshire Hills are still covered with little disturbed, primary tropical forest. However, even in intact forest, iguanas are vulnerable to pressure from exotic predators, especially dogs. In moderately exploited sections of the forest, many trees survive, and there is a rapid regrowth of shrubs and small trees. Such areas might still provide habitat for the iguanas if pressure from exotic predators could be controlled (Vogel et al. 1995).

The most promising site for the establishment of a new subpopulation in the wild appears to be Great Goat Island, where a population of iguanas had survived until at least the late 1940s. However, the numerous goats on the island would have to be removed, and the ground vegetation given an opportunity to recover before any release could take place. At the same time, the island could be rendered mongoose free. The removal of goats would have to be carefully negotiated with the goat owners who live in a nearby fishing village. Other potential release sites include Little Goat Island and the Portland Ridge area, which like the Hellshire Hills retains extensive areas of relatively undisturbed dry forest.

Threats

One of the most significant pressures on the remaining population in areas of intact forest is exotic predators, including mongooses, cats, stray dogs, and possibly feral pigs. Mongooses are very common throughout the Hellshire Hills and several observations suggest that they at least occasionally prey on iguana eggs. During the nesting season, they show vivid interest in iguana trial diggings. Mongooses probably prey heavily on hatchlings and young juveniles as well, but few data exist. Cats, which also prey on juveniles, have been observed at various locations in the Hellshire Hills, including nesting areas. The dogs used to hunt feral pigs are of particular concern, as they are able to take even adult iguanas (Woodley 1980). Although feral pigs have not been observed disturbing iguana nests in the Hellshire Hills, evidence from Mona Island suggests that they are potentially important egg predators (Wiewandt 1977).

Another significant problem is the burning of the forest for charcoal production, a local industry that

provides income to some 10,000 Jamaicans. Approximately a third of the Hellshire Hills is badly degraded as a result of this enterprise. Short-term management policies have involved establishing good personal relationships with the burners and trying to convince them to move east or west, away from iguana populations and sensitive areas in the center of the Hellshire Hills. Longer term solutions aim at establishing specified buffer zones with low-scale, sustainable charcoal production. Development projects proposing large scale limestone mining and human settlements also threaten the eastern half of the Hellshire Hills. Although a few localized limestone quarries might have only limited impact on the iguanas and their habitat, the new roads that would be constructed to facilitate the mining process would undoubtedly allow charcoal burners, pig hunters, and other forest users to migrate further into the forest.

Current conservation programs

Although most of Jamaica's remaining ecologically important forests, including the Hellshire Hills, are owned by the government and protected by law under the Forestry Act of 1937, the act has received little enforcement. Burning of wood to produce charcoal, slash and burn agriculture, and other destructive uses of the forest still progress. The Hellshire Hills is currently under evaluation as a potential site for a new national park (Jamaica Conservation and Development Trust 1992). To provide interim protection to the area until national park status can be achieved, the Natural Resources Conservation Authority has been petitioned requesting that the Hellshire Hills be declared a protected area under the NRCA Act of 1991. Designation of a protected area would represent a promising legal instrument to prevent the expansion of large-scale development projects in the Hellshire Hills.

Following the rediscovery of the species in 1990, a local Jamaican Iguana Research and Conservation Group comprising representatives from the University of the West Indies, the Natural Resources Conservation Authority, Hope Zoological Gardens, and the Institute of Jamaica was formed. The group carried out an initial field survey during which 23 sightings representing at least 15 different individuals were made (Vogel and Kerr, in press). In addition, a number of signs were found including fecal pellets, tail impressions, and pieces of shed skin. Since then, the group has continuously monitored the two known nesting sites and witnessed each nesting season (Vogel 1994). Each year, about eight females are known to have deposited eggs. A detailed study of the natural history of the species is currently being carried out by Richard Nelson, a postgraduate student in the

Department of Zoology, University of the West Indies. His work includes a systematic assessment of the Hellshire Hills habitat, as well as fieldwork on feeding habits, home range use, migration patterns, and reproductive biology.

To devise a comprehensive plan for the recovery of the Jamaican iguana in the wild and to draw international attention to their conservation needs, an IUCN-sponsored workshop was held in Kingston in 1993 (CBSG 1993). The goals of the workshop were to use computer modelling techniques to systematically evaluate the threats to iguana populations and how they might be mitigated through various management strategies, and to heighten awareness about the importance of conserving the biodiversity of the Hellshire Hills. After several computer simulations were run under a variety of scenarios, it became clear that the current level of mortality of juvenile iguanas in the wild was too high to permit survival of the population. This led to recommendations for a headstarting program, in which 50% of the young from wild nests were brought into captivity for up to four years. Once these individuals have attained large enough body size to avoid mongoose predation, they will be acclimated to natural foods and local conditions and released into managed areas within the Hellshire Hills. Initial pilot releases in 1997-1999 have involved subadults outfitted with radiotransmitters so that their movements patterns and survivorship rates can be carefully monitored.

A program to rear a group of approximately 100 captive juveniles for headstarting is underway at Hope Zoological Gardens in Kingston under the direction of curators Rhema Kerr and Nadin Thompson. In addition to providing a safe environment for juveniles to grow, the zoo is sponsoring studies of juvenile nutrition, social interactions, thermoregulation, and daily activity patterns (Gibson, 1993). The zoo also has plans to develop an exhibit on dry tropical forest ecosystems which highlights the native plant and animal species of the Hellshire Hills.

In 1994, an *ex situ* captive population was initiated with the importation of 12 individuals to three U.S. institutions (Indianapolis Zoo, Fort Worth Zoo, Gladys Porter Zoo). In 1996, this group was supplemented by a second importation of 12 individuals to the San Diego Zoo (Center for Reproduction of Endangered Species), the Central Florida Zoo, and the Sedgwick County Zoo. Genetic studies carried out by S. Davis have insured that the captive breeding nucleus represents as many founders as possible, thus sampling a diverse cross-section of the wild gene pool. With successful propagation in the U.S., the program will expand to other facilities. Once a target population of 200 is achieved, individuals will be returned to Jamaica for headstarting to assist recruitment into the

wild population. As a further safeguard against extinction, captive-reared iguanas may also ultimately be used to establish satellite populations on the Goat Islands provided they can be rendered free of predators.

Critical conservation initiatives

- Designation of the Hellshire Hills as a protected area, and ultimately as a national park.
- Prevention of further population decline through access restrictions, regular patrolling, removal of dogs, and protection of nest sites and hatching young.
- Establishment of sustainable forest use programs in specific buffer zones with low-scale, sustainable charcoal production
- Exploration of other traditional non-invasive uses of the forest, including collection of medicinal plants, and fishing and crab hunting in coastal areas.

Priority projects

- 1) Promote recovery of the iguana population through predator control.
- 2) Continue Hope Zoo headstarting program and tracking of released radiocollared individuals in the Hellshire Hills.
- 3) Conduct field research, including habitat assessment, feeding ecology, home range use, migration patterns, reproduction, and survivorship.
- 4) Develop an education program in which schools are visited and the importance of iguana conservation is communicated to local people. Programs could initially be concentrated in the Hellshire Hills but should eventually include Kingston and surrounding communities.
- 5) Establish an iguana sanctuary on Great Goat Island following mongoose eradication, removal of goats, and restoration of vegetation.

Note: A portion of the material presented in this species account was adapted from a previously published work (Vogel et al. 1996).

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Rhinoceros iguana

Cyclura cornuta cornuta

By Jose Ottenwalder

Description

The rhinoceros iguana attains a large adult size, with SVL up to 560mm in males and 510mm in females. Large males weigh between 6 and 10kg. Adults are grayish brown, dark brown, dark gray, or even black, without pattern, and with the venter less heavily pigmented than the dorsum. Bright colors are entirely absent. Juveniles are similar in appearance to adults, but with approximately nine paler crossbars which disappear relatively soon after hatching. Minimum recorded SVL for juveniles is 80mm.

According to Schwartz and Carey (1977), rhinoceros iguanas can be distinguished from the other two recognized subspecies, the Mona Island iguana (*C. cornuta stejnegeri*) and the extinct Navassa Island iguana (*C. cornuta onchiopsis*; Schwartz and Henderson 1991), by a combination of scale counts and femoral pore number. In the Dominican Republic, the only West Indian country where two distinct species of rock iguanas are found, the rhinoceros iguana and Ricord's iguana can be easily differentiated. In contrast to the diagonally barred back and sides of Ricord's iguana, rhinoceros iguanas are uniformly

dark on their back and sides (Schwartz and Carey 1977).

Distribution

Rhinoceros iguanas are still widely distributed throughout Hispaniola, including most of its offshore islands (Fig. 3). Their current geographic range is fragmented relative to their more continuous historical distribution, and is strongly associated with xeric regions of lower human population density. Islandwide, 20 or more subpopulations may exist, assuming that at least half of the Haitian populations known 20 years ago still survive (Ottenwalder and Meylan, unpublished manuscript). Most iguana concentrations are found along the southern side of Hispaniola, with the highest numbers in south-southwestern Dominican Republic.

In the Dominican Republic, a minimum of ten subpopulations, many of which contain further subdivided populations, are known from the north-northwest (f 2, Valle del Cibao Oriental, Llanura Costera del Atlantico north of Cordillera Septentrional), the northeast (1, eastern end of Samana Peninsula), the southeast (g 2, La Altagracia coastal region south of the line between Bayahibe-Boca de Yuma-Macao, including Isla Saona), and the south-southwest (g 5, from Bani Province west to the Neiba Valley and south to the Peninsula de Barahona, including Isla Beata). In Haiti, ten or fewer increasingly threatened subpopulations may still exist. Surveys conducted by P. Meylan in 1975 and information gathered by J. Ottenwalder and others during the 1980s indicates that rhinoceros iguana populations, while under heavy hunting and habitat pressure, were until recently known from Tortue Island, Massif du Nord, Gonaives region, southeastern tip of Gonave Island, Petit Gonave Island, Cul-de Sac Valley around Lake Etang Saumatre, and several areas of the Tiburon Peninsula, including Belle Anse, Marigot, Jacmel, Aquin, Les Anglais, Jeremie, Ile Grande Cayemite, Ile Petit Cayemite, and other small offshore islands and cays between Coral and Petit Trou de Nippes (Ottenwalder and Meylan, unpublished manuscript).

Status of populations in the wild

Rhinoceros iguanas were common and widespread until the early 1950s, but accurate information concerning current population estimates on Hispaniola is lacking. Unpublished data based on opportunistic surveys are available for a few localities, but are inadequate for extrapolation to other areas facing different levels of disturbance, particularly in Haiti. Observations on population and habitat trends recorded since the 1970s provide a fair but rough approximation of 10,000 to f 17,000. The highest densities

are found on the Barahona Peninsula, Isla Beata, and the Valle de Neiba-Cul de Sac region. Moderate populations densities may still exist in localized, isolated areas of the Bani-Azua region in the Dominican Republic, and Petit Gonave Island, the Cayemite island-complex, and the Lake Etang Saumatre basin in Haiti.

Rhinoceros iguana densities are low in the majority of the areas where they presently occur and appear to be declining due to increasing human pressure and the impact of feral mammals. Local extirpations are known from both Dominican Republic and Haiti. Populations are seemingly stable only on Isla Beata and the extreme of the Barahona Peninsula inside Parque Nacional Jaragua, although predation by introduced carnivores has been documented.

Ecology and natural history

Rhinoceros iguanas are most abundant in, although not restricted to, dry forests characterized by xeric, rocky habitats of eroded limestone in coastal terraces and lowlands of the mainland and several offshore islands and small cays. In areas supporting iguanas, mean annual rainfall ranges from 470 to 1000mm, and mean annual temperature is 25°C. With some exceptions, the species ranges in elevation from -35m (Isla Cabritos, Lake Enriquillo) up to 400m. It is found in a variety of subtropical life zones and habitat types, including thorn scrub woodland, dry forest, and transitional semideciduous to subtropical moist forests.

In addition to the habitat conditions described for areas of sympatry with Ricord's iguana, the variety of plant communities occupied by the rhinoceros iguana elsewhere in Hispaniola clearly indicates the ecological generalism and adaptability of this species. While most areas now exhibit a xeric mosaic of habitats as a result of human disturbance, variation in dry forest composition and structure of remaining undisturbed areas is generally influenced by edaphic and climatic factors. Habitat profiles of areas supporting rhinoceros iguanas are given below (vegetation data from Garcia and Alba 1989; DVS/SEA 1990; Hager and Zanoni 1993; DNP/AECI 1993; Mejía and García 1993; Ottenwalder and Meylan, unpublished manuscript; J. Ottenwalder, unpublished data).

Disturbed dry forest. Characterized by declining iguana populations, these areas exist in various stages of succession and are impacted by charcoal production, livestock grazing, fires, hardwood extraction, and other activities. *Prosopis juliflora* forest, a widespread invasive community occupying areas of former natural dry forest, represents one such habitat. This 6-8m forest is dominated by *Prosopis juliflora*-*Acacia macracantha* association, with reduced presence of

Bursera simaruba, *Phyllostylon rhamnoides*, *Senna atomaria*, *Lemaireocereus hystrix*, *Pilosocereus polygonus*, *Opuntia moniliformes*, *Neoabbottia paniculata*, and *Caesalpinia coriaria*. A second type of disturbed dry forest is found in iguana localities around Montecristi in the northwest, at the southeastern end of Altagracia Province including areas in Parque Nacional del Este, and from Las Tablas and Galeon de Bani to Llanura de Azua to Cabral, continuing into the Neiba Valley. The forest canopy is 5-6m, and is dominated by cacti. Trees include *Prosopis juliflora*, *Pilocereus polygonus*, *Lemaireocereus hystrix*, *Opuntia moniliformes*, *Neoabbottia paniculata*, and *Capparis ferruginea*. A very few *Guaiacum officinale* and *G. sanctum* are now left as a result of selective logging. Shrubs include *Cylindropuntia caribea*, *Harrisia nashii*, *Tournefortia stenophylla*, *Caesalpinia sp.*, *Cordia globosa*, *Boerhavia scandens*, *Turnera diffusa*, and *Pictetia spinifolia*. With the exception of *C. caribea*, most of these species are expected to eventually disappear with continued habitat alteration.

Natural dry forest on slopes. This community occurs on the north lake of Lake Enriquillo on foothills 100-400m in areas of stony soil with little organic material. The vegetation is characterized by trees, 30% of which are deciduous, approximately 30 species of shrubs, half which are thorny, a few herbs, and prolific vines. The 6-11m canopy includes *Bursera simaruba*, *Guaiacum sanctum*, *Phyllostylon rhamnoides*, *Colubrina elliptica*, *Senna atomaria*, *Guaiacum officinale*, *Exostema caribeum*, *Capparis flexuosa*, and *C. ferruginea*.

Natural dry forest on rocky substrate. This low elevation, primarily cactus community occurs in the lowlands bordering the south Lake Enriquillo basin. The site is characterized by sandy soil and rocks on shorelines, becoming more rocky on slopes with little fine soil. Rainfall is erratic (470-600mm), and vegetation consists of a slow growing shrubby, open tree canopy up to 3-4m. Trees include *Acacia scleroxyla*, *Cameraria linearis*, *Capparis ferruginea*, *Guapira brevipedunculata*, *Bursera simaruba*, *Plumeria subsessilis*, *Opuntia moniliformes*, *Lemaireocereus hystrix*, *Pilosocereus polygonus*, and a few *Prosopis juliflora*. Shrubs include *Caesalpinia sp.*, *Cordia spp.*, *Isidorea leonardii*, *Bursera brunei*, *Comocladia dodonaea*, *Harrisia nashii*, *Cylindropuntia caribaea*, *Guaiacum sanctum*, *G. officinale*, and *Tournefortia stenophylla*.

Natural dry forest of the Barahona Peninsula. This habitat, occurring south of the Oviedo-Pedernales road, and on Isla Beata, Parque Nacional Jaragua,

consists of a mixture of coastal lowland and typical dry forest with high endemism. Soils are dominated by dogtooth limestone formations with little accumulation of alluvial deposits except for low lying zones, depressions, and rock cavities. Annual rainfall ranges from 630-800mm. On the western boundary, vegetation is open and low (5-8m) on limestone rocks, while in the more humid eastern areas, the same vegetation grows more densely and reaches 6-12m. Common plants include *Metopium brownei*, *M. toxiferum*, *Acacia scleroxyla*, *Guaiacum sanctum*, *Bursera simaruba*, *Plumeria obtusa*, *Senna atomaria*, *Capparis cynophallophora*, *Haitiella ekmanii*, *Thouinidium inaequilaterum*, *Coccoloba pubescens*, *Cameraria linearifolia*, *Catalpa punctata*, *Opuntia moniliformis*, *Tabebuia ostenfeldi*, *Phyllostylon rhamnoides*, *Comocladia dodonaea*, and *Lonchocarpus pycnophyllus*.

Semideciduous to transitional semihumid broadleaved forests. These forests occur along the east and west coasts of Parque Nacional del Este, and the western portion of Isla Saona. Low coastal forests typically occur on reef limestone, with annual rainfall up to 1,300mm, and 25-60% vegetation cover. Plant species include *Jaquinia arborea*, *Coccoloba diversifolia*, *Conocarpus erectus*, *Guapira brevipedunculata*, *Coccoloba uvifera*, *Borrchia arborescens*, *Bursera simaruba*, *Plumeria obtusa*, *Pilocereus polygonus*, *Erythroxylum arcolatum*, *Widelia calicina*, *Capparis flexuosa*, *C. cynophallophora*, *Guaiacum sanctum*, and *Metopium brownei*. Tall semihumid broadleaved limestone forest is characterized by a mosaic of forest patches with varying canopy heights, depending on soil conditions and depth of the water table. Vegetation cover ranges from 25% to 60%, with a canopy dominated by *Clusia rosea*, *Bucida buceras*, *Coccoloba diversifolia*, *Bursera simaruba*, *Krugiodendrum ferreum*, *Celtis trinervia*, *Metopium brownei*, *Sideroxylon foetidissimum*, *Swietenia mahogany*, *Ottoschulzia rhodoxylon*, *Guaiacum sanctum*, and *Bumelia salicifolia*. The forest floor is dominated by *Zamia debilis*, with *Peperomia* epiphytes and vines. Leaf litter and a layer of humus covers rocks. Iguana localities with more mesic conditions are known but these are the exception.

Like other rock iguanas, rhinoceros iguanas are diurnal, spending the night in retreats. Rock crevices, caves, burrows dug in soil or sand, and hollow trunks are also used during the day for resting, cooling, or sheltering. Males defend territories containing retreats attractive to females. High trees and exposed rocks are used by males for basking and overseeing defended areas. Mating takes place at the beginning of or just prior to the first rainy season of the year.

Females lay from 2 to 34 eggs, with an average clutch size of 17 (J. Ottenwalder, unpublished data). Females guard nests for several days after laying, and incubation lasts approximately 85 days. Hatchlings weigh about 51g, with a mean SVL of 104mm and total length of 288mm. Females probably become sexually mature at 2-3 years of age. Rhinoceros iguanas feed on fruits, leaves, and flowers of a variety of plants, depending on availability. Additional information on their ecology and natural history is summarized by Schwartz and Henderson (1991).

Habitat

In the Dominican Republic, roughly 35% of rhinoceros iguana habitat has been lost, and approximately 75% of what remains is disturbed. Both figures are much higher for Haiti. Only the natural communities of Isla Beata have been spared noticeable impacts, and extensive dry forest stills remain in Parque Nacional Jaragua. Most of the currently occupied habitat is characterized by fragmented forest patches, including Montecristi, Samana Peninsula, Peninsula de la Altagracia, including Parque del Este and Isla Saona, Llanura de Azua-Bani, Valley de Neiba, and Peninsula de Barahona.

In Haiti, conditions are more critical, and extensive areas of previously diverse plant associations are now dominated by disturbed *Prosopis juliflora*-*Acacia macracantha* communities. Large areas of original forest have been extirpated and desertification is progressing rapidly. Among the localities containing habitats supporting iguana populations until the late 1970s are Tortue Island, Riviere Saline, Plaisance, Mole St. Nicolas, Anse Rouge, Gonaives to St. Marc, Gonave Island, Ile Petite Gonave, Mirebalais, Miragoanne to Jeremie, Les Anglais, Cap St. George, Jacmel to Marigot, Belle Anse, Marigot to Anse-a Pitres, and Lake Etang Saumatre in the Cul-de-Sac region (Ottenwalder and Meylan, unpublished manuscript).

Threats

Habitat destruction, due to extraction of hardwoods and fuelwood, charcoal production, agriculture, livestock grazing, and limestone mining, represents the major threat to rhinoceros iguanas in both the Dominican Republic and Haiti. In the Dominican Republic, about 13% of the human population (\pm 1 million) occupy dry forest regions. These areas are also the most economically depressed, and exploitation of forest habitats for charcoal and fuelwood represent important sources of income. About 75-80% of the total national demand for these products originates from dry forest habitats.

Other important threats are predation by feral dogs,

cats, mongoose, and pigs on adults, juveniles, and eggs, and illegal hunting of subadults and adults for food and local trade. The use of iguanas for food in Haiti is extreme in rural areas where iguanas are conspicuous enough that local people are familiar with them. International trade of wild animals from Hispaniola, a conservation problem until the mid 1980s, has been controlled in the Dominican Republic under CITES since 1987, but no such control exists in Haiti.

Current conservation programs

In the Dominican Republic, most rhinoceros iguana populations are either fully or partially protected inside existing national parks and reserves. Protected areas supporting iguana populations include Montecristi National Park, Parque Nacional del Este including Isla Saona, Parque Nacional Jaragua including Isla Beata, Las Caobas Strict Natural Reserve, El Acetillar scenic area, Sierra Martin Garcia National Park, and Lago Enriquillo National Park, including Isla Cabritos. However, the foothill regions in the latter two areas remain only partially protected. Management in most protected areas is not intensive, and in some cases is restricted to legislation.

A number of fragmented populations are found outside protected areas, primarily in the Cibao Occidental Valley, Samana Peninsula (part of the proposed Samana Bay Biosphere Reserve), the dry coastal portion of the Altagracia peninsula, Las Tablas of Bani, Peravia Province, west to Llanura de Azua, the eastern half of the Neiba Valley, including the northeastern slopes of Sierra de Bahoruco above Cabral Lagoon, the lowlands of Puerto Alejandro, and the southern slopes of Sierra Martin Garcia near Bahia de Neiba, the drier slopes of the eastern half of Sierra de Bahoruco, and the dry forest region north of the Pedernales-Cabo Rojo-Oviedo road.

Compliance with international trade regulations is effective, aside from occasional smuggling of animals across the border with Haiti. Rhinoceros iguanas are protected nationally by Dominican wildlife regulations. Enforcement has improved during the past few years, but clearing of the natural habitat for development is not being prevented, and illegal hunting and poaching for food and for the local pet market continues. No formal protected areas are known within the present distribution of iguanas in Haiti. The status of protective legislation is also uncertain, although the rhinoceros iguana was included on a list of protected wildlife by the Ministry of Agriculture during the 1980s. Enforcement of any potentially existing wildlife regulations seems unlikely at present.

Rhinoceros iguanas are the most common rock iguana in captivity. A successful breeding program

existed at the Parque Zoológico Nacional of the Dominican Republic (ZooDom) from 1974 to 1994, with an average of 100 young hatching annually. These efforts included experimental reintroductions of captive-bred young to several protected areas in the southwest Dominican Republic. Although a captive colony of almost 300 iguanas representing all age classes was maintained at ZooDom until December 1994, the program was adversely affected by administrative changes. In recent years, the captive breeding and conservation program has been gradually and successfully reactivated.

As of November, 1995, rhinoceros iguanas elsewhere in captivity included 39,323 individuals at about 20 zoological institutions, with an additional 533 animals of unassigned subspecies, reported by seven American Zoo and Aquarium Association institutions (Christie, 1995). The actual number may be higher considering holdings at some European zoos and many private collections.

Critical conservation initiatives

- Strengthening of current regulations and legislation protecting iguana populations by increasing fines and designating selected areas as critical habitat whether outside or inside existing protected area boundaries.
- Development of educational awareness campaigns to promote iguana conservation, particu-

larly to discourage subsistence hunting of iguanas for food, local trade, and habitat conversion for charcoal production.

- Development of a national conservation and recovery strategy and working group to include government agencies, non-governmental conservation organizations, and iguana researchers.
- Establishment of research, management, and monitoring programs for wild populations and critical habitats.
- Involvement of local organizations and communities in all iguana conservation, education, and research activities.

Priority projects

- 1) Assess the current status of wild populations and remaining habitats throughout the species' range.
- 2) Investigate natural history and ecology, habitat use, and factors limiting numbers in order to develop a conservation strategy and recovery plan for the species. Such studies should be concentrated in areas where rhinoceros iguanas are sympatric with Ricord's iguanas.
- 3) Control or eradicate exotic predators and herbivore competitors on Isla Cabritos in Lago Enriquillo and Isla Beata.

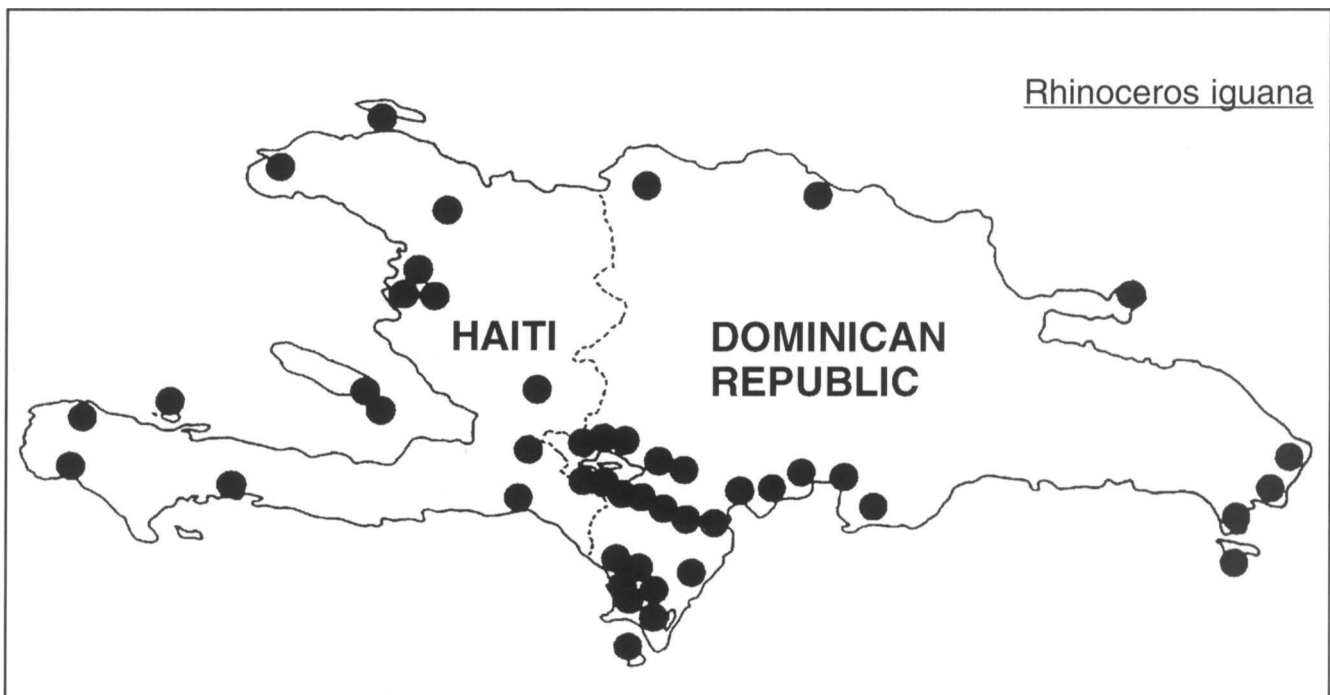


Fig. 3. Recent distribution of the rhinoceros iguana on Hispaniola. Localities for Haiti consist of survey data gathered between 1977 and 1985 (P. Meylan and J. Ottenwalder, unpublished) and may not represent the full extent of available suitable habitat existing today.

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Mona Island iguana

Cyclura cornuta stejnegeri

By Thomas Wiewandt and Miguel Garcia

Description

The Mona Island iguana is a large, robust member of the genus. Adult males and females average 517 and 475mm SVL, and 6.1 and 4.7kg body mass, respectively. Both sexes are ornamented with protruding facial scales and a horn-like, conical scale atop the snout. Also typical of adults are huge, sagging jowl muscles and two prominent pads of fatty connective tissue crowning the head. Body coloration is a uniform gray, olive, or brown in adults. Hatchlings are light gray or tan with dark bands.

At the conclusion of his three-year study, T. Wiewandt (1977, 1982) chose to retain the name *C. stejnegeri* for this taxon (Barbour and Noble 1916) on the basis of significant differences between the reproductive biologies of the Mona population and its closest living relative on Hispaniola, the rhinoceros iguana, *C. cornuta cornuta*. In their 1977 revision of the genus, Schwartz and Carey renamed the Mona population *C. cornuta stejnegeri* based on scale counts of

about a dozen individuals of mixed age and sex. Further investigation of all populations in question is clearly needed before meaningful subspecies/species designations can be made. M. Garcia is planning a detailed investigation of systematics in the *cornuta* complex which should help resolve taxonomy within this group.

Distribution

The Mona Island iguana is endemic to the remote island of Mona, a low-profile limestone plateau situated midway between Puerto Rico and Hispaniola. The 11 by 7km island lies within a deep sea channel known as the Mona Passage, and present submarine banks offer no evidence of former connections with either Puerto Rico or Hispaniola. Mona is part of the Commonwealth of Puerto Rico, administered as a natural reserve by the Division of Natural Reserves and Refuges within the Puerto Rico Department of Natural Resources and the Environment (PR-DNRE). Mona Island has been designated as a National Historical Landmark. The U.S. Fish and Wildlife Service provides some funding for projects related to hunting, fishing, and endangered species. The entire island is occupied by iguanas, and the soil-rich coastal terraces and inland sinkhole depressions are essential for reproduction (Fig. 4).

Status of population in the wild

Based on island-wide surveys conducted from 1972 to 1975, T. Wiewandt calculated a mean density of iguanas on Mona of 0.33/ha and an estimated minimum population size of 2,000. A follow-up census was carried out by J. Moreno in late March and early April, 1995. Moreno's estimate of 1,155 individuals suggested to him that the Mona population had declined over the past 20 years. However, there were significant differences in methodology between the two surveys. Wiewandt utilized a transect width of 12m, whereas Moreno utilized a transect width of 16m. Had Moreno assumed a 12m transect width, his population estimate would rise to 1,540. Conversely, had Wiewandt assumed a 16m transect width, his population estimate would drop to 1,500. It is important to note that because these iguanas have greatly staggered activity patterns, varying between seasons and individuals, the population could conceivably be twice the estimated size. Meaningful comparisons will require established guidelines for future surveys, defined by location, time of day and year, weather conditions, and number of trained observers.

No matter how current census figures are interpreted, it is clear that the Mona iguana population is abnormally small. A survey of the similarly-sized rhinoceros iguana on Petite Gonave Island in Haiti indi-

cated densities 26 times greater than those found on Mona (P. Meylan, personal communication). T. Wiewandt found that immature iguanas were scarce on Mona, representing only 5-10% of the population, and J. Moreno sighted only two juveniles among 118 iguanas seen. This contrasts sharply with M. Garcia's unpublished data for rhinoceros iguanas (*C. cornuta cornuta*) on Isla Beata in the Dominican Republic, where all age classes are abundant and juveniles comprise approximately one-third of the population (see Grupo Jaragua, 1994). Low iguana densities and the scarcity of juveniles on Mona suggest a senescent and declining population.

Ecology and Natural History

Mona's climate is dry subtropical (800mm rainfall per year), supporting an open canopy forest of short, seasonally deciduous trees, shrubs, cacti, and bromeliads. Rainwater percolates rapidly through the porous limestone substrate, allowing no freshwater streams or ponds. Solution channels and sinkholes that penetrate the island's rock topography offer underground shelters that are utilized by both male and female iguanas, and retreats attractive to females are vigorously defended by males. Some males hold territories year-round, while others defend them only during the brief June mating season.

Because more than 95% of Mona's surface is rock, females must migrate to scarce soil deposits for nesting. The onset of the two-week, mid-summer nesting season appears to be cued by photoperiod and females are especially wary at this time. Most egg laying (74%) occurs in sandy clearings on the island's southern coastal terraces, with the remaining 26% in sinkhole depressions (Haneke 1995). Nesting females fight over favored nest sites and defend completed nests. Mean clutch size is 12 eggs. Surviving eggs hatch approximately 83 days after laying, during the latter half of October. Newly emerged young are large and only the smallest juveniles are susceptible to indigenous predators. Coloration and behavior of hatchlings suggests that aerial predators have long been a threat to this age class (Wiewandt 1977).

Juvenile iguanas are slow-growing, and females require 6 to 7 years to reach sexual maturity. Although longevity records are not available, Mona iguanas, like all large rock iguanas, are probably among the longest lived lizards in the world. Consequently, populations are slow to recover from losses over time.

Mona iguanas are primarily herbivorous, with a strong preference for fruits that fall from native trees. Some animal matter is eagerly taken, especially caterpillars when available. Trees reach their greatest size and diversity in scattered sinkhole depressions, areas

that are of particular importance to the welfare of the iguana population.

Habitat

During his surveys, T. Wiewandt sighted iguanas on Mona's plateau at a density of 0.8/km traversed, except on routes along major escarpments and cliff-side talus slopes, where iguanas were three to four times more numerous. In contrast, iguanas were rare on much of the island's flat, sandy southwestern coastal terrace, presumably because natural food and shelter are scarce there. Roughly half of the area has been cleared and reforested in mahogany and *Casuarina* trees, which are of little value to the iguanas because they shade out native understory and bear no edible fruits. Iguana density rises dramatically on this terrace during the summer nesting season when females migrate to coastal lowlands in search of sandy, sunlit clearings (Wiewandt 1977; Haneke 1995).

Historically, Mona's iguanas have been adversely affected by man for centuries, dating back to land use practices of pre-Columbian Indians and continuing to the present (Wadsworth 1973). People settling subtropical dry limestone islands have traditionally concentrated their activities near beaches and within soil-rich sinkhole depressions, thereby inadvertently disrupting the life cycle of iguanas during nesting and hatching. Although there are presently no permanent human residents on Mona, a variety of domestic animals inhabit the island, including feral goats, pigs, and cats.

Threats

The most pressing conservation management challenge on Mona today is that of exotic species. Having evolved in the near absence of predators, insular iguanas lack the behavioral and demographic attributes to cope with introduced mammals. Feral pigs regularly plunder iguana nests. Nesting females are unable to protect their eggs from pigs and will cover an empty nest with soil, not recognizing that their eggs are gone. The extent of pig predation in any given year appears to be correlated with nest location and total rainfall during the three months prior to nesting. T. Wiewandt found that along the south coast nest loss ranged from 65-100% in the driest year to less than 5% in an unusually wet year. Haneke's (1995) comparison between coastal and inland nest sites revealed complete failure of all inland nests surveyed. Coastal nesting attempts were more successful, with the highest success in areas protected by pig-proof fences.

Feral cats are also present on Mona, and constitute the most serious threat currently impacting young iguanas. These elusive predators are extremely diffi-

cult to study and control. Their dietary preference for small reptiles has been established (Wiewandt 1977) and their interest in young Mona iguanas observed (Moreno 1995). The devastating impact of cats on a population of Turks and Caicos iguanas was clearly documented (Iverson 1978), and there is little doubt that the present scarcity of juveniles on Mona is due primarily to the combined effects of pigs consuming eggs and cats preying on young.

Over 20 years ago, botanist R. Woodbury expressed concern that most of Mona's sinkhole depression forest trees appeared unable to propagate successfully because of intense browsing pressure by feral goats. A follow-up study of forest regeneration within a fenced study plot (Cintron 1976) confirmed these observations, noting not only a marked increase in the number of native tree seedlings during the first year, but also a 100% increase in accumulated leaf litter within the enclosure. Despite higher than normal rainfall that year, recovery of the plant community was slower than expected. Cintron and Rogers (1991) further note that successional patterns island-wide are becoming skewed toward toxic, unpalatable plant species. Within depression forest communities, unpalatable shrubs and trees are starting to dominate the understory and also predominate in secondary growth on the plateau in places that were burned or cleared of vegetation during the past 60 years (Wiewandt 1977). Fortunately, Mona's trees are long-lived, allowing them to continue to survive despite heavy browsing pressure. Mona's history of human occupation suggests that goats and pigs were intensely hunted for food by island residents as late as 1942 (Wadsworth 1973). Consequently, much of the damage to vegetation evident today may be relatively recent (Wiewandt 1977).

Although lacking permanent settlements, Mona is a haven for recreational activities, including camping, fishing, swimming, scuba diving, beach combing, exploring, and hunting. Most of these activities are concentrated along the island's sandy coastal terraces and within sinkhole depressions, areas of critical importance for iguana nesting. Haneke (1995) observed that new camping facilities had been recently added in iguana nesting areas at Playa de Pajaros. Mona iguanas are wary and easily disturbed while nesting, and visitors can unintentionally disrupt the egg-laying process. People and feral animals walking through nest site clearings during incubation may cause nest chambers to capsize, denying oxygen to developing eggs. These and other conflicts between iguanas and visitors are bound to intensify as recreational use of the island continues to expand. Goats regularly gather in sinkhole depressions on Mona's plateau, and this may partially explain Heneke's

(1995) observation of complete nest failure there. Mona may have already exceeded its carrying capacity for low impact tourist visitation. Better supervision over visitors, particularly by strengthening educational programs, will become increasingly important as the number of people coming to Mona continues to grow.

Another recent concern for conservation of Mona iguanas is the emergence of an undefined disease or parasite that causes blindness. Throughout T. Wiewandt's three-year study, only one animal with cloudy eyes that was obviously blind and emaciated was found. Recently, Haneke (1995) observed 15 blind adults on Mona, all with opaque, bluish eyes and apparently severely undernourished. Ramos (1964; cited in Kuns et al. 1965) lists 16 species of eye flies (family Chloropidae) occurring on Mona, including *Hippelates pusio*, which has been incriminated in the spread of catarrhal conjunctivitis in the United States. Studies are urgently needed to identify potential pathogens and vectors responsible for blindness in the Mona iguana population.

Current conservation programs

The Mona iguana is listed as threatened by the U.S. Fish and Wildlife Service and the PR-DNRE. In 1984, the U.S. Fish and Wildlife Service approved a recovery plan for the Mona iguana prepared by C. Diaz, PR-DNRE (Diaz 1984). Bringing feral pig and goat populations down to ecologically tolerable levels and maintaining them there would require that 50-70% of each population be removed annually (Baker and Reeser 1972), an extremely costly undertaking that would be a monumental task in Mona's rugged terrain. Realistically, these animals will never be truly brought under control.

During the last 25 years, the PR-DNRE has instituted some important changes. The hunting season on Mona has been moved to a time outside the iguana nesting and incubation seasons. Together with the local herpetological society, Sociedad Chelonia, the government has created several new nesting areas on the southwestern coastal terrace. A number of clearings in the *Casuarina* forest have been established that are fenced off from goats and pigs but allow iguanas to pass freely. Iguanas have been observed nesting successfully in the new clearings (Chelonia 1993). Fencing of remote nest sites (two 20m x 15m plots) is currently being undertaken by the PR-DNRE, the U.S. Fish and Wildlife Service Caribbean Office, the U.S. Coast Guard, the Sociedad Chelonia, and the Toledo Zoo. Researchers at the PR-DNRE and the Toledo Zoo have additionally begun to assess the nature of the blindness syndrome seen in several adult iguanas. For his graduate research, N. Perez, University of

Puerto Rico, will be measuring overall population size, studying recruitment and survivorship of juveniles, quantifying egg loss to pigs and rats, and determining the effect of exotic vegetation on incubation of iguana eggs. A total of 33 blood samples from wild iguanas has been provided to S. Davis for phylogenetic analysis. Over the years, feral cats have occasionally been trapped or shot on Mona. Currently, PR-DNRE is conducting a long-term study to quantify the impact of feral cats on Mona Island wildlife.

Critical conservation initiatives

- Enforcement of existing laws for protection of wildlife and other natural resources.
- Implementation of an active and long-term educational campaign about Mona Island and the conservation of its natural, environmental, and historical resources.

Priority projects

- 1) Determine the cause of blindness in wild Mona iguanas by pathology examinations of afflicted animals.
- 2) Monitor and continue to repair existing feral mammal control fences, and expand the fencing program by installing new goat and pig exclosures for sinkhole depressions utilized by nesting iguanas. Care must be taken to locate fences in places that will neither destroy Taino archeological sites nor mar the intrinsic beauty of these areas.
- 3) Continue to evaluate Mona's plant communities in conjunction with construction of pig and goat exclosures around sinkhole depressions.
- 4) Expand educational programs for visitors and mon-

itor their activities on Mona.

5) Make follow-up field assessments in order to allow meaningful comparisons between past and present conditions on Mona to be made and to facilitate establishment of a viable population. This work could offer educational opportunities for island personnel.

6) Establish a rigorous procedure for yearly censusing of the iguana population.

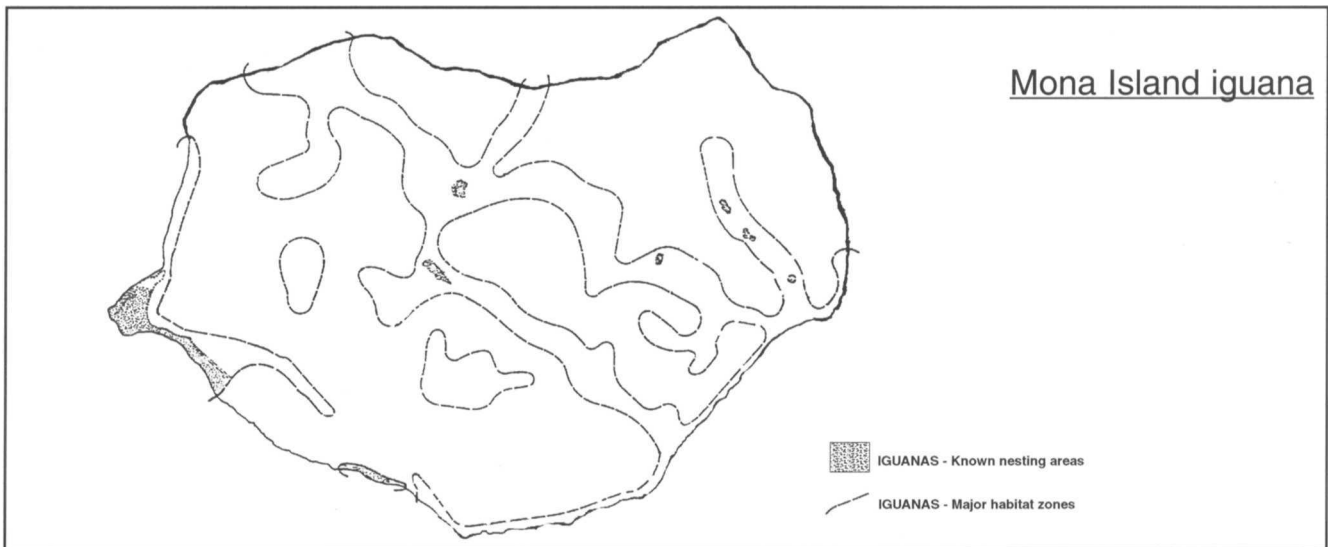
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Fig. 4. Map of Mona island showing known nesting areas and major iguana habitat zones.



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Andros Island iguana *Cyclura cyclura cyclura*

By Sandra Buckner and David Blair

Description

The Andros Island iguana is a large rock iguana which attains a total length of close to 1500mm (Auffenberg 1976). The subspecies is dark-gray to black, with yellowish green or orange tinged scales on the legs, dorsal crest, and particularly the head. With maturity, the yellow slowly changes to orange-red, especially in large males (Auffenberg 1976).

Distribution

This subspecies is found on Andros Island on the western edge of the Great Bahama Bank. Andros is the largest of the Bahamian islands with an area of 5,959km² and a human population of 8,000-9,000 concentrated in the eastern coastal region. Andros iguanas are scattered through North Andros, Mangrove Cay, and South Andros, which are separated from each other by the North, Middle, and Southern Bights. The subspecies range is ill-defined with only assumptions and speculations available as to its status. North Andros, with extensive pine barrens and blue holes and creeks, is the area where most sightings of iguanas currently occur. This is the more populated area where old logging roads allow access

to the interior. According to Auffenberg (1976), "though historically found over all of Andros, iguanas are now largely restricted to the western two-thirds of the island group, with the range becoming generally broader southward. They reach maximum abundance and size at the present time in the 'pine-yards,' particularly where they are broken into small islands separated by extensive low mangrove and marl flats."

Status of populations in the wild

While estimates put the wild population at 2,500 to 5,000 distributed in three or more subpopulations (Hudson et al. 1994), these figures could be much too optimistic as only occasional animals are observed, and these in scattered locations. Alternatively, due to the remoteness and difficulty in accessing much of the region, large subpopulations could be encountered, particularly in the central and southern regions of the island and in the western reaches of north Andros.

Ecology and natural history

While it is expected that the natural history of these iguanas is similar to that of the other two *C. cyclura* subspecies, no in-depth research studies have been conducted.

Habitat

The Andros rock iguana is the only iguana in the Bahamas that is not now confined to small cays. One preferred habitat of this subspecies is under the open canopy of the pine barrens (*Pinus caribaea* var. *bahamensis*), which offers a variety of fruits, flowers, and leaves of plants suitable for consumption by rock iguanas. The karst rock provides suitable retreats.

Threats

In the absence of any detailed research, the major threat to the Andros Island iguana is the proliferation and expansion of the range of feral pigs. While this is recognized both locally and nationally, appropriate methods of control have yet to be determined. Particularly in north Andros, feral pigs pose a very real threat to the recruitment of iguanas as they are known to rout out eggs from iguana nests. Feral and domestic dogs are also a threat to both juvenile and adult animals. The status and degree of threat posed by feral cats on Andros is unknown. Many local residents are apparently unaware of the protected status of the Andros iguanas and may occasionally take them for human consumption.

Current conservation programs

Like all Bahamian rock iguanas, this subspecies is protected in the Bahamas under the Wild Animals Protection Act of 1968. However, no areas have been specifically designated for the protection of iguanas

on Andros and no specific conservation programs are in place.

There are currently no captive programs for this subspecies. There is one old individual at Ardastra Gardens and Zoo in Nassau. No one has been located who recalls the iguana being brought to the zoo and as yet no records have been found. This iguana, first observed and photographed by S. Buckner in 1991, was still alive as of June, 1997. One large male, a long term captive held by a private resident of South Andros, was still alive in 1984. Attempts to breed this animal have resulted in the death of at least two other iguanas, presumably females.

Critical conservation initiatives

- Education of local people regarding the protected status of this iguana and its vulnerability to introduced mammals, particularly dogs and pigs.
- Institutional strengthening of responsible agencies to develop enforcement capabilities.
- Protection of suitable iguana habitat and possible relocation sites.
- Initiation of a national education program for tourists and residents.

Priority projects

- 1) Determine the status of the population and its range, including the existence of viable subpopulations on south Andros.
- 2) Conduct ecological studies and collect natural history data, ideally with the involvement of local residents.
- 3) Establish captive breeding programs.
- 4) Institute control measures for introduced species.

Note: Conducting comprehensive research on Andros will be both logistically difficult and time consuming. The northern part of north Andros has old logging roads that would enable access by appropriate vehicles. Over the rest of Andros, lack of roads or even tracks, myriads of mangrove islands, swamps and very shallow waterways make travelling in all but the eastern coastal region extremely difficult and hazardous. In terms of personal safety, it is not recommended at this time that a solo or even two-person party attempt such a project in any part of Andros. Research trips might be conducted in conjunction with other projects such as ongoing research into the blue holes of Andros. Suitable vehicles, shallow draft boats, and other equipment would be required.

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Exuma Island iguana

Cyclura cyclura figginsi

By Chuck Knapp

Description

The Exuma Island iguana is often regarded as the smallest of the three subspecies of *C. cyclura*. Although Schwartz and Carey (1977) list the animal as obtaining a maximum size of 315mm SVL, recent studies by C. Knapp indicate that individuals occasionally reach 470mm and 3.25kg (Bitter Guana Cay) to 542mm and 8.15kg (Leaf Cay). Barbour (1923) describes the Exuma Island iguana as being conspicuously different from the other subspecies in having tiny supranasals usually separated by a small, azygous scale and two pairs of prefrontals, the posterior pair of which is greatly enlarged.

Coloration is variable between populations. Adults from Bitter Guana and Gaulin Cays are dull gray-black with diffuse pale gray spots. The crest scales are either white or a light red. The head scales are black tinged with orange on the snout and infralabials (Schwartz and Carey 1977). Adults from Guana Cay are dull black with diffuse pale white ventral and gular coloration. The upper labial, temporal, parietal, nuchal and ocular scales are light blue, while the dorsal crest scales are either gray with red tinge or intense scarlet. Schwartz and Carey (1977) describe juveniles as possessing approximately seven black bands which become slightly diagonal laterally and alternate with pale gray bands. All bands are heavily mottled with small pale dots.

Distribution

The subspecies is known from seven small cays scat-

tered over 80km throughout the central and southern Exuma island chain of the Bahamas. Anecdotal information suggests additional inhabited cays, but verification is necessary. The determination of range through historic records is problematic due to certain cays sharing multiple names (e.g., Guana = Prickly Pear = Noddy). Bitter Guana and Gaulin Cays constitute the northern extent of the population. Four cays, White Bay, Noddy, North Adderly, and Leaf Cays, all located northeast of Norman's Pond Cay, compose the nucleus of the range. Guana Cay, southwest of Great Exuma, forms the southern boundary of the population.

Status of populations in the wild

The exact size of the total population is not known. Formal surveys using standardized transect techniques have been conducted only on Guana, Gaulin, and White Bay Cays (Carey, 1976; Windrow, 1977; C. Knapp, unpublished data). The extent of the remaining population is based on estimations of iguana densities through comparative observations (J. Iverson, unpublished data; C. Knapp, unpublished data). Standardized and subjective survey techniques estimate the population to be between 1,000-1,200 animals.

While the majority of subpopulations appear relatively stable, some are in need of monitoring. Barbour (1923) refers to Bailey's collecting expedition on Bitter Guana Cay, from which the holotype specimen was procured, noting that "the iguana was found abundant on the Cay, no less than nineteen being taken in an hour or so." Three surveys of Bitter Guana in 1993, 1995, and 1997 yielded only seven total iguana sightings. Conversations with yachtsmen familiar with the area confirm that the iguanas are being taken as a food source.

Ecology and natural history

Except for the Guana Cay population, few formal natural history studies have been conducted. The Guana Cay population was studied in the 1970s (Wilcox et al. 1973; Carey 1976; Windrow 1977; Coenen 1995) and is currently being reinvestigated along with the other remaining populations (Knapp 1995; 1996).

Adult iguanas are herbivorous, and are arboreal as well as terrestrial feeders. Preferred food items are seasonally dependent and primarily consist of flowers, fruits, young buds, and leaves of *Rachicallis americana*, *Reynosa septentrionalis*, *Strumpfia maritima*, *Jacquinia keyensis*, *Erithalis fruticosa*, *Coccoloba uvifera*, *Coccothrinax argentata*, *Eugenia axillaris*, *Suriana maritima*, and the rotting fruit of *Casasia clusiifolia* (Windrow 1977; C. Knapp, unpublished data). Coenen (1955) reports the iguanas as

coprophagous. They actively forage for the feces of the zenaida dove, *Zenaida leucocephala*, and the white-crowned pigeon, *Columba leucocephala*.

The iguana populations exhibit an unusual social system for the genus, displaying neither territorial nor hierarchical behavior. Carey (1976) suggests that this relaxed social structure allows the population to remain dense under conditions of limited resources. He further states that a hierarchical social system on small cays would retard genetic variation by restricting prime nesting sites, food supplies, and retreats to a few dominant animals. Adult iguanas have been seen basking in large aggregations without evidence of aggression towards conspecifics throughout the majority of their range (C. Knapp, unpublished data). At times, the iguanas demonstrate assertive and/or challenge displays in the form of headbobs. These usually only occur when one lizard violates the space of another or during sex recognition. When minor skirmishes do occur over preferred food items, the largest animal is always victorious (Windrow 1977; Coenen 1995).

Nesting has been observed on Guana Cay, with females digging a nest burrow approximately 61cm long and 8-13cm deep. Gravid females will actively defend an incomplete tunnel from conspecifics but will not defend the nest site after oviposition. The only excavations of nest chambers revealed three eggs each in two nests (Coenen 1995).

Habitat

The Exuma Island iguana utilizes a variety of habitats, including sandy beaches, xeric limestone devoid of vegetation, and areas of vegetation with or without sand or rock substrates. Limestone crevices and sand burrows are used as retreats at night and in adverse weather conditions. Presently, habitat appears to be relatively secure as cays supporting iguanas are small and free from human settlement. However, recent observations on White Bay Cay uncovered trails hacked through the interior and coconut palms planted on the beach. The island is currently for sale and in danger of tourist development.

Threats

Conversations with locals suggest that removal of animals from their home cays for tourist attractions elsewhere could constitute a significant threat. Although such activities probably occur on a small scale, they may reflect the larger problem of smuggling of iguanas from the Bahamas for illegal wildlife trade. Some cays are visited regularly by locals and yachtsmen, and dog tracks have been observed on Bitter Guana Cay. In addition to possible hunting pressure, predation by dogs may be contributing to the apparent

decline of that population. In 1981, J. Iverson reported the presence of rats on Gualin Cay; this was subsequently confirmed by C. Knapp in 1995 (unpublished data). The effect of rats on this population is unknown, but past research indicates the detrimental consequences of rats on island reptiles (Cree et al. 1995). Certain cays possess diminutive nesting sites and the possibility of a season's recruitment being decimated by severe weather conditions is genuine.

The isolation of iguana-inhabited cays creates a problem for consistent population monitoring. Discrete environmental events including hurricanes could endanger certain populations. For example, Hurricane Lily engulfed Great Exuma and her satellite cays on 18 October 1996. The effects of Lily on the Guana Cay iguana population were not observed until May, 1997 (S. Buckner, personal communication).

Current conservation programs

All Bahamian rock iguanas are protected under the Wild Animals Protection Act of 1968. C. Knapp is continuing field surveys to assess current populations and to better define the geographic distribution of the subspecies. The Leaf Cay population was newly discovered in 1997. Blood samples are being collected from each study population to establish genetic profiles for different cays. Potential threats unique to each cay are being documented in order to provide the Bahamian government with information that will aid in setting conservation policies. Also, the vegetation and habitat condition on cays not currently supporting iguanas is being investigated for possible translocation programs.

The Bahamas National Trust has erected signs on Gualin Cay notifying the public of the protected status of the iguanas. The Bahamian government currently does not recognize any captive breeding programs, although unsanctioned breeding of these iguanas is apparently taking place in the United States.

Critical conservation initiatives

- Establishment of additional national parks to afford iguana populations more protection. Additional wardens and funds will need to be made available to patrol parks and monitor iguana populations.
- Implementation of an education program for locals and cruising yachtsmen to inform people of the rarity of Bahamian iguanas. Such programs should stress the detrimental impact that dogs, cats, and smuggling exert on small iguana populations.
- Continuation of efforts to instill in all Bahamian citizens national pride regarding their unique iguanas.

Priority projects

- 1) Determine the status of the population throughout its range.
- 2) Examine the possibility of translocations to other suitable cays.
- 3) Carry out genetic studies on all populations.
- 4) Conduct ecological, behavioral, and natural history studies on each population.
- 5) Establish a captive breeding program.

Note: The remoteness and inaccessibility of cays inhabited by iguanas makes field research expensive and time-consuming. The John G. Shedd Aquarium is currently funding research but other avenues for support need to be developed in order to accomplish the research goals in a timely manner.

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Allen's Cay iguana

Cyclura cyclura inornata

By John Iverson

Description

The Allen's Cay iguana is a large (to 1000mm total

length) subspecies of *C. cyathura* characterized by a lack of horn-like frontal or prefrontal scales, rostral scale in contact with the nasal scales, slightly enlarged prefrontal scales separated from frontal scale by four scale rows, usually two portmental scales, and dorsum pigmented gray-black with cream, pink, or orange mottling. Pink or orange pigment is most obvious on the posterior lower labial scales, the preauricular scales, and the enlarged mid-dorsal scale row.

Distribution

Only two breeding populations of this subspecies are known, on Leaf Cay (4ha) and U Cay (also known as Southwest Allen's Cay; 3ha) in the northern Exuma Island chain in the Bahamas. Probably less than seven adults also occur on Allen's Cay (7ha), but no evidence of breeding has been found there during 12 years of study.

Status of populations in the wild

Based on a 17-year mark and recapture study, approximately 130 subadult and adult iguanas (> 8 years old) occur on Leaf Cay and 100 on U Cay. Juvenile population estimates are not precise, but in March are probably near 100 for each island. The entire wild population of this subspecies is less than 500 individuals. The populations have generally been stable over the past 17 years, with recruitment occurring on both islands every year. However, some removals from Leaf Cay by poachers and Bahamian zoo and park personnel are known to have occurred over the past decade. Although the two main populations are generally stable, the two cays are heavily visited by tourists.

Ecology and natural history

Most of the details of the life history of this iguana remain unstudied. What is known has been accumulated during approximately biennial visits by J. Iverson. During these trips, lizards have been marked and recaptured, primarily for growth and survivorship studies. These iguanas can apparently survive on the very smallest rocky islets as long as sufficient vegetation is present for food; however, areas of sand are necessary for nesting. Hatched egg shells have been found on several occasions, but always in sandy areas. The lack of breeding on Allen's Cay may be due to insufficient areas of exposed sand above tidal influence.

Recapture studies have shown that Allen's Cay iguanas average about 113mm SVL (157mm tail length, 56g) in March at approximately six months of age. Average growth rates are over 20mm SVL per year during the first year, declining to about 15mm per year by age 5.5 at about 206mm SVL (Iverson and

Mamula 1989; J. Iverson, unpublished). Growth in females then begins to slow, whereas in males growth continues at the same rate until about 300mm SVL. The result is considerable sexual dimorphism in size. The largest known adult male was 476mm SVL and weighed 4.8kg, whereas the largest female was 368mm SVL and weighed only 2.1kg. Large adults of both sexes usually grow less than 10mm per year. Males and females cannot be sexed externally, but can be sexed fairly reliably by hemipenial probing. Based on minimum age for adults first caught in 1980 and still alive in 1992 and/or 1993, some of these iguanas live beyond 25 years of age.

Allen's Cay iguanas are active diurnally, spending the night in burrows they have dug or in natural retreats in or under rocks. They are primarily herbivorous, feeding on fruits, leaves, and flowers of most of the plants present on their tiny islands. They will climb up into the vegetation to feed. They are also opportunistically carnivorous, as evidenced by crab claws in their feces. In addition, humans regularly feed the iguanas (particularly on Leaf Cay) everything from table scraps to fresh produce. The effect of food supplementation on the life history of these lizards remains unknown, but deserves study.

Nothing is known about reproduction in this species, but mating probably occurs in May, with egg-laying commencing in June. Jolly-Seber models of recapture data suggest that survivorship of subadults and adults exceeds 90% per year. During the non-breeding season, these lizards appear to have dominance hierarchies rather than strictly defended territories; however, this may be because tourists frequently feed the iguanas on the main beach areas, perhaps causing a breakdown in the natural social system. Their behavior during the breeding season is unknown.

Habitat

The natural habitat of this iguana on Leaf and U Cays has not been significantly disturbed by human activity, even though a number of introduced ornamental plants occur on these cays (e.g., *Casuarina*, lilies, palms). All potential habitats on both Leaf and U Cays are occupied by iguanas, including some suboptimal areas of bare, honey-comb limestone. Additional habitat is available on Allen's Cay, but without sandy areas for nesting, the island apparently cannot support a breeding population. Dredging of sand from the harbor between Allen's Cay and Leaf Cay to upland areas on Allen's Cay could double the potential habitat area for this iguana.

Threats

The only significant current threat to these popula-

tions is the removal of iguanas by humans. The problem is exacerbated by the fact that these cays offer good anchorage less than a day's sail from Nassau; for example, during March, 15-20 yachts and 1-2 native boats are anchored there each night. Regular reports of actual or attempted poaching are made to the warden of the Exumas Land and Sea Park to the south. In addition, iguanas are occasionally removed for exhibit purposes in Bahamian zoos, parks, and gardens. Illegal exploitation for international trade is undocumented, but probably occurs.

Current conservation programs

The Allen's Cays iguanas are protected nationally under Bahamian law, but enforcement is difficult without a warden present. The warden of the nearby Exumas Land and Sea Park can potentially respond to reports of poaching, but that is not always practical. Fortunately, signs erected on the islands explain the vulnerability of these lizards, and most visitors on yachts radio the authorities if anyone is seen harassing the iguanas. Unfortunately, visitors also enjoy feeding them unnatural foods. Long-term investigations of growth, survivorship, and population status of these iguanas are ongoing by J. Iverson, but a study of their reproductive ecology is urgently needed.

A few captive Allen's Cay iguanas are currently maintained at the Ardastra Zoo and Nature Centre Different on Abaco. Captive breeding is a goal, but long-term plans for any offspring produced need to be developed.

Critical Conservation Initiatives

- Establishment of regular patrols to enforce protection, prevent exploitation, and discourage feeding of iguanas.
- Initiation of a national education program for tourists and residents.

Priority projects

- 1) Collect age-specific reproductive data on the marked population of Allen's Cay iguanas for which long-term growth data already exist.
- 2) Explore the feasibility of modifying sinkholes on Allen's Cay to create nesting habitat for iguanas.
- 3) Continued monitoring of the introduced population on Alligator Cay

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Cuban iguana

Cyclura nubila nubila

By Antonio Perera

Description

The Cuban iguana reaches a very large adult size, with a mean SVL of 405mm for males and 320mm for females. This subspecies is usually gray in color, stippled or mottled with tan, and has a tan head and tail. Adults are somewhat greenish in color and may be stippled with yellow. The juvenile pattern consists of a series of five to ten pale chevrons which expand mid-dorsally to give a longitudinal series of subcircular or subrectangular pale blotches. Between the pale dorsal chevrons are black chevrons which form the margins of the lateral pale pattern. In adults, a conspicuous feature is very high dorsal crest scales (Schwartz and Carey 1977).

Distribution

The Cuban iguana is well distributed around Cuba, mainly in xerophilic coastal areas, but relatively safe populations are found only on some islets along the north and south coasts and in isolated protected areas on the mainland. These include Guanahacabibes Biosphere Reserve in the west, Desembarco del Granma National Park, Hatibonico Wildlife Refuge, Punta Negra-Quemados Ecological Reserve, and Delta del Cauto Wildlife Refuge, all in eastern Cuba (Fig. 5). This subspecies has also been introduced to Isla Magueyes, southwest of Puerto Rico. Because of its wide distribution, accurate information about the number of distinct subpopulations of Cuban iguanas is currently unavailable, yet it may be present on as many as 4,000 islets surrounding the Cuban mainland. The population on the U.S. Naval Base at Guantanamo Bay has been estimated at 2,000-3,000 individuals (A. Alberts and J. Phillips, unpublished data).

Status of populations in the wild

Not many decades ago, the subspecies was extremely widespread on Cuba. However, populations on the

mainland have decreased dramatically or disappeared entirely in most areas since the end of the last century. On many islets, populations are still relatively safe, but this situation is changing with the transformation of many islets for tourist developments. Nevertheless, if strictly protected areas on the mainland and islets continue to remain untouched, 60 to 80% of the remaining population will probably be safe. Any population analyses should be carried out with two distinct components: one for populations living on the mainland, and one for populations inhabiting small islands and islets.

Subpopulations of the Cuban iguana show great variation in density according to habitat quality and level of protection. On three natural, undisturbed islets, Perera (1985b) found densities of 25.01/ha; 9.64/ha, and 4.42/ha. V. Berovides found densities of 7.71/ha and H. Gonzalez found densities of between 9 and 11/ha on Cayo Rosario. Those authors estimate the total population of Cayo Rosario to be 10,000 individuals. Recently, V. Berovides (personal communication) found a density of 40/ha on a rocky islet. The total population of this subspecies in Cuba is estimated at between 40,000 and 60,000 individuals.

In general, the population is declining, more quickly on the mainland than in other areas. Most disturbing is the rapidity of the loss of this subspecies in disturbed areas. Iguanas are now absent from the northeastern Havana coast, the Hicacos peninsula, and Key Largo, where they were known to be very abundant some 30-40 years ago. Whereas habitat transformation and disturbance on the mainland seem to be responsible for local extinctions, populations appear stable on many untouched islands and islets. Mainland populations have probably been declining at a rate of greater than 1 % per year for the last ten years, primarily as a result of habitat alteration and interactions with domestic and feral introduced species, including cats, dogs, and pigs.

Ecology and natural history

Cuban iguanas can be found in relatively undisturbed xerophilic coastal lands on both mainland Cuba and surrounding islets, primarily in rocky limestone areas where natural refuges and appropriate nesting sites are available. Foraging is commonly observed in concentrations of coastal mangroves. In western Cuba, there is an isolated population inhabiting an inland karstic mountain area. Apparently, semiarid lands several kilometers inland from the coast can still support iguana populations.

The Cuban iguana is a phytophagous generalist, and the diversity of its diet depends on the floristic diversity and abundance of vegetation in each locality. Perera (1985a) found 25 different vegetation types in

the diet of these iguanas. The most frequent plants (flowers, fruits, or leaves) in the diet were *Andropogon*, *Avicenia*, *Canavalia*, *Capparis*, *Chrysobalanus*, *Conocarpus*, *Eragrostis*, *Laguncularia*, *Opuntia*, *Rachilcalis*, *Rizophora*, *Sporobolus*, *Strumpfia*, *Suriana*, and *Thrinax*. If readily available with little effort, Cuban iguanas will also feed on animal matter. The most common animal item in the diet is the crab *Cardisoma guandhumi*. Some seasonal changes in diet are evident, especially during the rainy season when fruits from *Opuntia*, *Chrysobalanus*, *Strumpfia*, and *Suriana* become available.

Cuban iguanas reach sexual maturity at an age of two to three years. Reproductive behavior in this subspecies is similar to that described for other members of the genus. Males become aggressive, and vigorously defend territories in competition for females. Females lay 15 to 30 eggs annually in a single clutch in a nest which they dig in the sand.

Habitat

Previously suitable habitats have been losing the conditions necessary to support iguanas since 1900. Many coastal areas with sandy beaches have been progressively assimilated for tourist resort development. Although this process was initially restricted to the mainland, in recent years many islets have been rendered unsuitable for iguanas for the same reason. Even if habitat is not lost directly, the disturbances associated with development appear severe enough to cause iguana populations to disappear in some areas. Fig. 5 shows the area presently occupied by Cuban iguanas. It is possible to identify 12 historical concentrations of iguanas in the Cuban archipelago:

(1) ***Guanahacabibes peninsula:*** No major habitat transformation. The original distribution of iguanas remains basically unchanged, but density has decreased as a result of predation by feral dogs, cats, and pigs and local habitat destruction. In general, the area retains its natural features.

(2) ***Canarreos subarchipelago, including Isla de Juventad:*** The best remaining populations are located in this area, although some local extinctions due to habitat loss caused by fires or development of tourist resorts have been reported on Cayo Largo. On Isla de Juventad, iguanas are still abundant along the south coast and adjacent inland areas.

(3) ***Zapata peninsula:*** No major habitat transformation. Iguanas are still abundant in coastal areas and on surrounding islets. Density has declined in some areas as a result of predation by feral cats, dogs, and pigs and local habitat degradation.

(4) **South coast and islets of Sancti Spiritus Province:** In mainland coastal areas, iguana populations are highly impacted or extinct. On some islets, iguanas are still very abundant.

(5) **Jardines de la Reina subarchipelago:** A well-preserved subarchipelago with healthy populations of iguanas on some islets.

(6) **Delta del Cauto Wildlife Refuge:** Iguanas are abundant in sandy areas of the delta as well as on many islets.

(7) **Desembarco del Granma National Park:** One of the best preserved areas in the country which includes a marine limestone terrace system on which iguanas are particularly abundant.

(8) **Santiago de Cuba and Guantánamo semi-arid coast:** Although density has declined and distribution has contracted in some areas due to habitat loss and the introduction of exotic predators, good populations remain in some protected areas.

(9) **Holguín Province coast:** As above, although density has declined and distribution has contracted in some areas due to habitat loss and the introduction of exotic predators, good populations remain in some protected areas.

(10) **Sabana-Camaguey subarchipelago and north-central coast of Cuba:** This is the second major concentration of iguanas. Although some local extinctions have occurred due to habitat loss (Hicacos peninsula) and other areas are under pressure from tourist development, iguana populations are dense in protected areas.

(11) **Northeast Havana coast:** Almost all populations became extinct in the last 30 to 40 years as a result of habitat loss and transformation.

(12) **Vinales:** This is the only iguana population known to live inland. Iguanas inhabit some karstic hills, but their density is very low in this habitat.

Threats

Habitat transformation and human disturbance represent the main threats to Cuban iguana populations. Other important threats include predation by wild and domestic dogs on both adults and juveniles, predation by cats on juveniles, and egg predation by pigs. Hunting is not a major threat because there is not a widespread tradition of consumption of iguana meat or eggs.

Current conservation programs

With the exception of area 11 above, all of the major iguana concentrations are either partially or fully protected. Fig. 5 shows strictly protected areas, resource management areas, and gaps where iguanas are present but formal protection is lacking. At selected localities within the National System of Protected Areas, projects directed toward conservation and reproduction of Cuban iguanas are being carried out by the Centro Nacional de Areas Protegidas in collaboration with researchers from Havana University. Ecological and systematic studies are being conducted at the Institute of Ecology and Systematics, Cuban Academy of Sciences.

No captive programs currently exist within Cuba, but are a future component of the research-management program of the Centro Nacional de Areas Protegidas. Although a fairly large captive population exists within the U.S., a moratorium on breeding has been recommended to provide space for more critically endangered taxa (American Zoo and Aquarium Association, 1995).

Critical conservation initiatives

- Establishment of an integrated research and management program for Cuban iguanas within the national system of protected areas.
- Education of local people regarding the vulnerability of iguanas to feral dogs, cats, and pigs.
- Construction of facilities for forest guards.

Priority projects

- 1) Conduct field research and surveys to assess the present status of the species in the wild, analyze habitat requirements, and identify natural and anthropogenic factors influencing iguana populations.
- 2) Undertake natural history studies, including feeding ecology, social behavior, and reproduction. Results from these studies have the potential to serve as a valuable model for other, more endangered taxa.
- 3) Establish an *in situ* captive breeding program, including development of methods for artificial and seminatural egg incubation.

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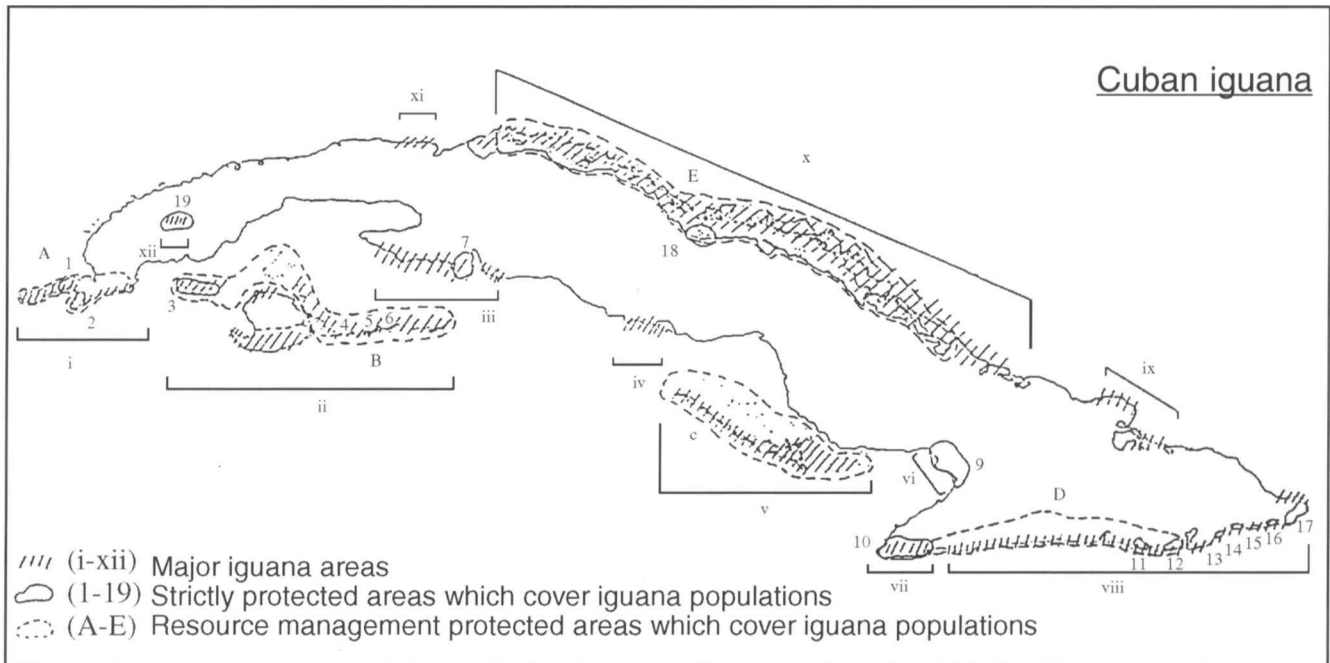


Fig. 5. Distribution of the Cuban iguana and protected areas that cover iguana populations.

Strictly protected areas which cover iguana populations:

- 1) El Veral Nature Preserve
- 2) Cabo Corrientes Nature Preserve
- 3) Cayos de San Felipe Wildlife Refuge
- 4) Cayo Campos Wildlife Refuge
- 5) Cayo Cantiles Wildlife Refuge
- 6) Cayo Rosario Wildlife Refuge
- 7) Las Salinas Wildlife Refuge
- 8) Tunas de Zaza Wildlife Refuge
- 9) Delta de Cauto Wildlife Refuge
- 10) Desembarco del Granma National Park
- 11) El Retiro Nature Preserve
- 12) Hatibonico Wildlife Refuge
- 13) Baitiquirí Nature Preserve
- 14) Imías Nature Preserve
- 15) Pan de Azucar Nature Preserve
- 16) Tacre Nature Preserve
- 17) Punta Negra-Quemados Ecological Preserve
- 18) Cayo Caguanes National Park

Resource management areas which cover iguana populations:

- A) Guanahacabibes Biosphere Reserve
- B) Subarchipiélago de los Canarreos Multiple Use Area
- C) Subarchipiélago Jardines de la Reina Multiple Use Area
- D) Sierra Maestra Great National Park
- E) Subarchipiélago Sabana Camagüey Multiple Use Area

Lesser Caymans iguana

Cyclura nubila caymanensis

By Glenn Gerber

Description

Lesser Caymans iguanas are very large iguanas (to 1360mm total length) with pronounced sexual size dimorphism. Maximum recorded SVL and mass of adult males and females are 570mm and 8.5kg, and 472mm and 5.2kg, respectively (G. Gerber, unpublished data). Mean (\pm SD) SVL and mass of the 10 largest males and females captured on Little Cayman were 544 ± 14 mm and 7.6 ± 0.6 kg, and 440 ± 18 mm and 3.9 ± 0.7 kg, respectively. Based on these data, adult females average 81 % of the SVL and 51 % of the mass of adult males.

Coloration is also variable. Typically, adult males are light gray with tan on the head, tail, limbs, and dorsal mid-line of the body. The dorsal crest scales and head often have a light-blue or reddish-pink hue. Diagonal black bars partially ring the body and tail, but frequently fade with age. The chest and belly are sometimes burnt-orange or rust colored. Females are less brightly colored, lack any blue or red coloration on the head, and frequently have a greenish wash to the entire body. Adults of both sexes have black forefeet. Juveniles are tan or brown with 5-10 pale dorsal chevrons, bordered by black, which break up laterally to form ocelli.

Scale counts distinguishing Lesser Caymans iguanas from other subspecies of *C. nubila* are given in Schwartz and Carey (1977), and recent molecular studies (S. Davis, personal communication) have revealed genetic differences between the subspecies.

Distribution

The Lesser Caymans iguana is native to two islands: Cayman Brac (38km²) and Little Cayman (28.5km²). The islands are 7.5km apart and are well isolated from other land masses. Grand Cayman is 100km to the WSW, and Cuba and Jamaica are over 200km to the NE and SE, respectively. The Cayman Islands, composed of carbonate rock, are emergent sections of the otherwise submerged Cayman Ridge (Jones 1994). Little Cayman is low-lying with a maximum elevation of 14m, whereas Cayman Brac steadily rises from sea level in the west to 43m in the east. The climate is sub-humid tropical with distinct wet (May-November) and dry (December-April) seasons (Burton 1994a). Vegetation is similar to that which occurs on other limestone formations in the West Indies (Brunt 1994). Both islands have been continually inhabited since the early 1800s. Current human populations for Cayman Brac and Little Cayman are

approximately 1,000 and 200, respectively.

Status of populations in the wild

In 1938, iguanas were abundant on Cayman Brac and Little Cayman. At that time, C. Lewis (in Grant 1940) reported that iguanas "are found all over the Brac and Little Cayman" and (in Lewis 1944) that "the colonies of *Cyclura* on these two islands are reproducing, generally flourishing and are in no danger of extinction." However, in contradiction to the previous statements, Lewis also reported (in Grant 1940) that "the populations are rapidly being reduced by dogs, which these lizards seem unable to escape." Since that time, populations of Lesser Caymans iguanas have declined and are clearly in danger of extinction, particularly on Cayman Brac.

In 1965, Lesser Caymans iguanas were abundant on Cayman Brac only along a relatively small section of the southwest coastline (Carey 1966). Today, the subspecies is nearly extinct on Cayman Brac. Over the last four years, F. Burton (personal communication) has seen only two iguanas on Cayman Brac (both juveniles) and received only two reports of sightings (both adults; Fig. 6). Based on these results, the population probably numbers fewer than 50 individuals.

Presently, Little Cayman still supports a widely, although patchily, distributed iguana population (G. Gerber, unpublished data). The population is reproducing and all age classes are represented, although juvenile mortality is very high due to predation by feral cats. During nine months of field work on Little Cayman in 1993, over 200 iguanas were captured and marked (Fig. 6). However, due to the inaccessibility of much of the interior of the island and the patchy distribution of iguanas, good population estimates are not available; mature iguanas possibly number between 750 and 1,500. The population appears not to have declined significantly since the 1970s (Townson 1980, Stoddart 1980) and 1980s (Blair 1983), and may even be larger today. Nonetheless, dense concentrations of iguanas which occupied the mid-northern (B. Ryan, personal communication) and mid-southern (Grant 1940) coasts of Little Cayman 50+ years ago no longer exist, and a growing population of feral cats and increasing human development severely threaten the long-term survival of iguanas on Little Cayman.

Ecology and natural history

Like other rock iguanas, Lesser Caymans iguanas require suitable forage plants, basking areas, retreats, and nesting sites. On Little Cayman, these requirements are met in a variety of coastal and interior habitats, and iguanas are widely dispersed. Maximum

densities occur in dry evergreen bushlands and thickets (*sensu* Brunt 1994) growing on exposed and highly weathered limestone or dolomite. These habitats provide a diverse assemblage of forage plants, a mosaic of sun and shade for thermoregulation, and an abundance of solution holes in the rock substrate which iguanas of all sizes use as retreats. However, suitable nesting sites in these habitats are restricted to shallow patches of soil that accumulate in small depressions. Consequently, many females migrate to coastal areas with relatively deep sandy soils to nest.

The diet of all age classes consists almost entirely of leaves, flowers, and fruits; however, iguanas occasionally scavenge on animal carcasses (e.g., land crabs) or prey on slow-moving insects (e.g., Lepidopteran larvae). Over 40 plant species have been identified in the diet of iguanas on Little Cayman (G. Gerber, unpublished data). Leaves of *Bauhinia divaricata*, *Capparis flexuosa*, *C. cynophallophora*, *Styloanthus hamata*, *Ipomea pes-caprae*, *I. violacea*, and *Canavalia rosea* form a significant portion of the diet year-round. When available, flowers of *Tabebuia heterophylla*, *Ipomea sp.*, and *Canavalia rosea*, and fruits of *Picrodendron baccatum*, *Hippomane mancinella*, *Cordia sebestena*, *Myrcianthes fragrans*, *Guapira discolor*, *Coccoloba uvifera*, and *Citharexylum fruticosum* are consumed in great quantities. However, many of these fruits are too large to be eaten by hatchling iguanas. Adult iguanas (primarily female) sometimes congregate in areas with fruiting *Coccoloba uvifera* or *Hippomane mancinella* trees.

Courtship and mating occur in April and early May, coinciding with the end of the dry season when temperatures and photoperiod are increasing. Mating is polygynous and copulation takes place in male territories. Males compete intensely for territories which are occupied in all seasons. The largest males hold territories in the best habitats and acquire the most matings. Male territories are large, on the order of 1ha, and during the breeding season as many as 10 females may temporarily reside within a single territory. The smallest, youngest males do not hold territories and during the breeding season move from one territory to another attempting to court females and avoid detection by resident males. They sometimes move several kilometers in the process and probably acquire few copulations. Females typically occupy smaller home ranges than males, although they frequently leave their home range to mate or nest, and appear to be territorial only when nesting. The adult sex ratio appears to be skewed toward females.

Females lay a single clutch of 7-25 eggs (mean 15) annually, between late-May and mid-June, coinciding with the beginning of the wet season. Mean SVL of

all reproductive females is 385mm (range 308-472). The clutch is deposited in a chamber excavated by the female 10-50cm below the surface. Females nest either in small soil patches within the rocky interior or in large sandy tracts along the coast, and may migrate considerable distances to nest sites. After closing their nest, some females guard the site for periods ranging from one day to several weeks. Guarding appears to be correlated with availability of other suitable nesting sites in the area, and thus the probability that another female will attempt to nest in that location. Females that migrate to large coastal tracts of sand to nest rarely guard, whereas females that nest in small soil patches almost always guard.

Hatchling emergence occurs from early August to early September and incubation averages 72 days (range 63-80). The median percentage of fertile eggs per clutch is 97.5 (range 35-100), and the median percentage of hatchlings emerging from each nest is 91.5 (range 0-100). The sex ratio of hatchlings is unity. Hatchlings average 107mm SVL (range 97-121) and 50g (range 33-69). Juveniles disperse from nest sites soon after emerging and may move long distances before settling. Most juveniles marked after emergence from nests were never seen again, but one was later located 5.2km away. Compared with other rock iguanas, juvenile growth is rapid, averaging approximately 100mm SVL per year during the first two years (G. Gerber, unpublished data). The smallest female observed nesting was 308mm SVL and in her second year.

Habitat

Little Cayman contains large areas of undisturbed habitat where Lesser Caymans iguanas are still widely distributed, although much less abundant than in the past. Many areas appearing to support prime iguana habitat have few if any iguanas. In addition, the pace of development on Little Cayman is accelerating and native habitats are being destroyed and fragmented at an unprecedented rate, especially along the coast where many iguanas nest. Cayman Brac, due to a larger human population, has much less undisturbed habitat than Little Cayman and the population there is nearly extinct. On both islands, populations are far below carrying capacity.

Threats

Threats to Lesser Caymans iguanas include habitat destruction from road construction, commercial and residential real estate development, livestock grazing (on Cayman Brac) and farming practices, predation by feral cats and domestic dogs (and possibly introduced rats), disturbance of sensitive nesting areas, and road casualties. Since the construction of a municipal

power generating station on Little Cayman in the early 1990s, habitat destruction associated with road construction and real estate development have increased dramatically and the human population, although still small, has increased several fold. Under the present socioeconomic conditions this pattern can be expected to accelerate. Plans to replace the existing, grass airstrip on Little Cayman with a new, paved airstrip are underway. Proposed sites for this project overlap areas of prime iguana habitat on the west end of the island. Aside from the loss of habitat, such an airstrip will significantly increase human visitation to the island and promote further development. The continued destruction and disturbance of coastal nesting areas on Little Cayman is of particular concern as nesting opportunities for iguanas in the interior appear to be limited due to the paucity of suitable soil patches. Also, the increasing number of feral cats on Little Cayman pose an immediate threat to population recruitment.

Current conservation programs

Iguanas are protected within the Cayman Islands by the Animals Law of 1976 (Davies 1994), but protection of native habitats is lacking. The Development and Planning Law of 1971 provides a legal mechanism to prevent the destruction of terrestrial habitats in the Cayman Islands, but has never been implemented (Davies 1994). Currently, the only protected areas on Cayman Brac and Little Cayman are the Cayman Brac Parrot Preserve (a 65ha tract of potentially important iguana habitat) and the Little Cayman Ramsar Site (an 82ha preserve encompassing Booby Pond and surrounding mangroves; Fig. 6).

The National Trust for the Cayman Islands has had an active iguana conservation program since 1990; however, due to limited resources, efforts have largely concentrated on the Grand Cayman iguana. An intensive field study of Lesser Caymans iguanas was conducted on Little Cayman in 1993 by G. Gerber. Plans to continue this research await further funding.

A captive breeding program does not exist for this subspecies, but may be warranted for the Cayman Brac population if it is genetically distinct from the Little Cayman population. This possibility needs to be investigated. No pure Lesser Caymans iguanas are presently held in zoological institutions (B. Christie, personal communication).

Critical conservation initiatives

- Acquisition and protection of terrestrial habitats on Little Cayman and Cayman Brac.
- Development and enforcement of strict regulations to control domestic and feral animals.
- Control of real estate development, road building, and use of motor vehicles.
- Increased commitment to environmental issues among governmental and private sectors.

Priority projects

- 1) Eradicate or control feral cats.
- 2) Conduct field surveys to determine the status of iguanas on Cayman Brac, identify more local subpopulations and nest areas in need of protection on Little Cayman, and obtain accurate population estimates for both islands.
- 3) Carry out molecular studies to determine the amount of intra- and inter-island genetic variation.
- 4) Assess feasibility for construction of small supplemental nest areas on Little Cayman. This may provide a simple and cost-effective means of bolstering recruitment against increasing habitat losses.
- 5) Undertake long-term field studies on Little Cayman to quantify reproductive and other life history parameters. Radiotelemetry will help determine where and how far females travel to nest, dispersal patterns of hatchlings and juveniles, and movements of young males prior to establishing territories.

Contact persons

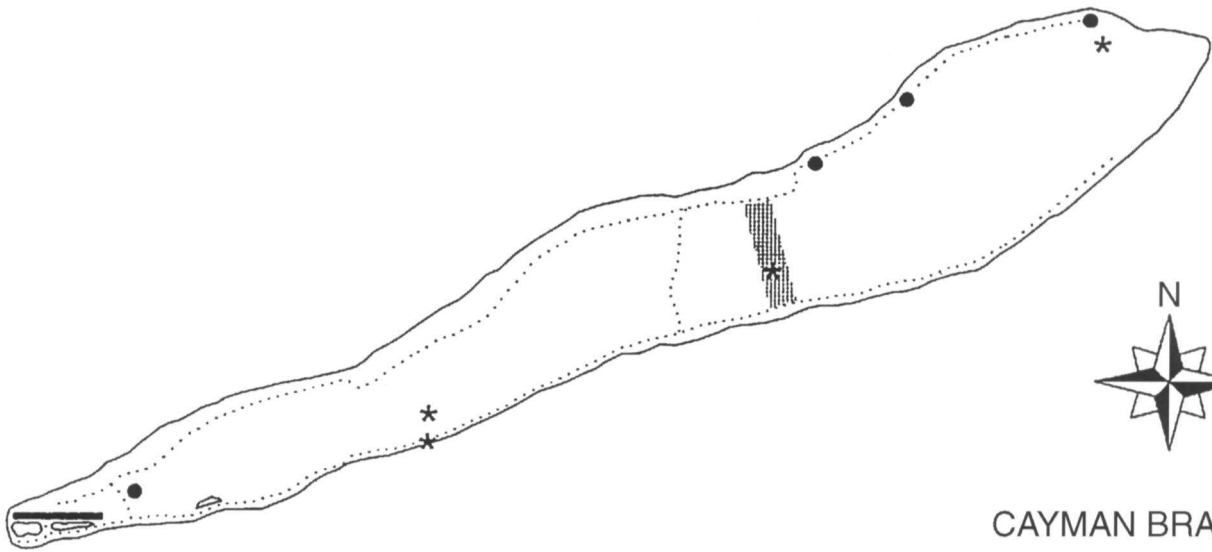
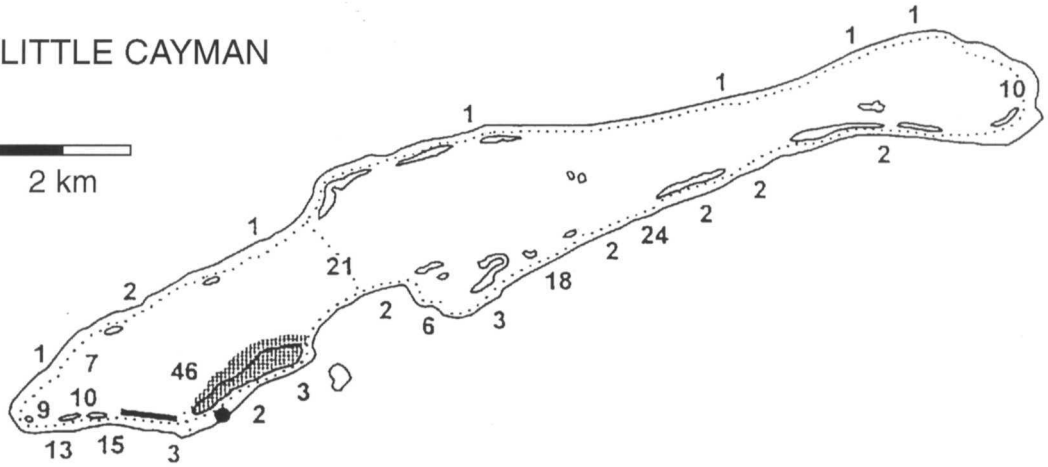
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Lesser Caymans iguana

LITTLE CAYMAN

2 km



CAYMAN BRAC

Fig. 6. Map of the lesser Cayman Islands showing town centers (solid circles), primary roads (dotted lines), airstrips (solid rectangles), ponds (shaded), protected areas (crosshatched), iguanas sighted on Cayman Brac since 1992 (asterisks), and numbers of iguanas marked on Little Cayman in 1993 (numbers; those around perimeter indicate coastal localities).

Grand Cayman iguana

Cyclura nubila lewisi

By Fred Burton

Description

The Grand Cayman iguana was originally described by Grant (1940). Although its distinction from the other two subspecies was based at that time only on its striking blue body coloration and caudal spine lengths, its status as a unique form has been upheld by recent genetic studies (S. Davis, unpublished data). Minor differences in scalation, particularly in the subocular region, are evident but of limited diagnostic value. The Grand Cayman iguana is a large form, similar in size range to the Lesser Caymans iguana, although size statistics have not been obtained from large numbers of animals due to their rarity.

Distribution

Iguanas now survive as three or possibly four partially fragmented subpopulations scattered over approximately 5km² in eastern Grand Cayman. However, reports dating from the early 1980s suggest that at that time a small population still survived in the Lower Valley and Spotts area of Grand Cayman. A local newspaper report detailed the death of an adult in the extreme northwest of the island in the late 1940s, and Morgan (1994) found fossil remains of iguanas throughout Grand Cayman. Taken together, these reports suggest that the Grand Cayman iguana was distributed widely in dry habitats over the entire island before the advent of human settlement. The present contraction in range to the eastern districts is probably a reflection of human activities impacting primarily the western districts, as 78% of the island's human population lives on this half of the island. Unfortunately, the remaining iguana habitat is also some of the best of Grand Cayman's generally poor agricultural land, making its protection socially and politically difficult.

Status of population in the wild

Based on observations made in 1938 by B. Lewis, who stated "the species is nearly extinct, and I doubt whether more than a dozen individuals still exist on the island. In past years they are said to have been numerous in the interior of the east and north...East end people say that since 1925 the 'guanas' have become so scarce that is no longer worthwhile to hunt them," the population appears to have persisted in the low hundreds over the last 70 years. The total wild population is currently estimated to be no more than 100 to 175 individuals (0.2 adults/ha in suitable

areas), orders of magnitude below what the habitat appears able to support (Burton and Gould, in preparation). Although this taxon is strictly protected under the Animals Law enacted in 1976, it faces increasing threats and appears to be at high risk of extinction over the next 20-30 years.

Ecology and natural history

Similar to other rock iguanas, the Grand Cayman iguana is almost exclusively herbivorous, occupies rock hole retreats, and nests in inland deposits of red soil. This subspecies is known to consume at least 45 different plant species in 24 different families, with an emphasis on the Fabaceae and the Rubiaceae. Particularly important species include leaves of *Rhynchosia minima*, *Chamaecrista nictitans*, and *Stylosanthes hamata*, whole plants of *Spermacoce confusa*, and seedlings of *Waltheria indica* (Burton and Gould, in preparation). All are herbaceous weeds which thrive in disturbed, open areas. When available, iguanas have also been observed to gorge themselves on fruits of plants usually inhabiting stands of primary vegetation, including *Picrodendron baccatum*, *Hippomane mancinella*, and *Myrcianthes fragrans*. Iguanas appear to exploit both primary and disturbed habitats to obtain the variety of foods they consume, indicating that their present diet is probably significantly different from what it was prior to human intervention.

Scat analysis conducted by F. Burton and K. Gould revealed that iguanas consume approximately 80% leaf material and 20% fruits. During the dry season when fruits are unavailable, leaves are consumed exclusively. Because iguanas feed mostly on the leaves of weeds and fruits falling from wild trees, it appears that their purported damage to farmer's crops has been exaggerated. Exceptions to strict herbivory include observations of iguanas feeding on fungus, crabs, and cicadas, although the latter two instances were more likely examples of scavenging rather than active predation. Coprophagy and soil ingestion have also occasionally been observed.

Iguanas on Grand Cayman occur at such low density that it is difficult to assess the degree to which individual spacing patterns are attributable to the availability of suitable retreats rather than territorial behavior or other factors. Whereas males show little long-term fidelity to individual retreats, females appear to occupy small, fixed territories centered on one or two favored retreats. The abundance of suitable refugia may be important in controlling female distribution, while male density may be regulated primarily by intraspecific territorial interactions (Burton and Gould, in preparation).

Habitat

Grand Cayman iguanas are usually observed in dry evergreen thickets and bushlands, as well as traditional agricultural and other man-modified habitats derived from these vegetation communities (Burton and Gould, in preparation). Rather than being confined to a single habitat type, individual iguanas appear to utilize a mosaic of natural and semi-disturbed habitats in response to thermoregulatory opportunity, food, nesting substrate, predator pressure, and human interference.

The interaction between traditional agricultural practices and iguanas is complex, having both benefits and disadvantages. Small scale clearings provide good basking spots and abundant edible herbaceous vegetation, and the mosaic of habitats resulting from small scale agricultural activity likely provides a greater habitat diversity than existed previously. It is possible that these factors to some degree balance the impacts of exotic predators and grasses, trapping, and cattle grazing that accompany agricultural land use (Burton and Gould, in preparation).

At present, inland red earth deposits provide the only natural nesting substrate for iguanas on Grand Cayman. These deposits are essentially restricted to dry evergreen thickets, dry evergreen bushlands, and the agricultural lands derived from these formations. Nesting attempts have not been observed in soil areas converted to grasslands.

Threats

All sites where iguanas are known to occur are subject to human-related threats, including predation by wild and domestic cats and dogs, conversion of land to cattle grazing or intensive farming, habitat destruction for real estate development, road casualties, and trapping or shooting by farmers who perceive iguanas as a threat to their crops. In particular, the intensity of large scale deforestation and new road construction has increased enormously in the eastern districts over the last decade, and under present socioeconomic conditions this trend is expected to accelerate.

Current conservation programs

An integrated conservation program for the Grand Cayman iguana is being implemented by the National Trust for the Cayman Islands. This project incorporates research, habitat protection, captive breeding, reintroduction/restocking, and conservation education. Iguanas feature prominently in the annual National Trust Fair, where 2,000 to 3,000 school children have the opportunity to learn about this and other endangered species. The ultimate goal of the Trust's iguana program is to secure and protect a stable, breeding wild population capable of surviving indefi-

nitely without ongoing human intervention. In addition to the direct goal of preventing the extinction of the iguana, the Trust views this program as a flagship species approach to its more fundamental mission of protecting the unique natural environments of the Cayman Islands.

To help insure a future for the Grand Cayman iguana in the wild, a nature reserve plan for eastern Grand Cayman is in the early stages of development. To date, the National Trust has acquired conservation land through grants of Government land, through donations by U.S. citizens owning land in the Cayman Islands, and by direct purchase using funds raised by popular appeals. At present, the most promising possibility for future introductions appears to be the Salina Reserve in the northeastern part of the island, a 253ha area which contains a small but viable amount of iguana habitat (approximately 2ha). Although there is currently no evidence of wild iguanas in this area, trial translocations indicate that it may be suitable for supporting a limited number of iguanas. The area has subsequently been mapped, its vegetation catalogued, and a low-impact trail network established. The Queen Elizabeth II Botanic Park, a 26ha property jointly managed by the National Trust and the government, has also shown considerable potential as iguana habitat, and is a strong candidate for restocking efforts.

Field research designed to elucidate the status and ecology of Grand Cayman iguanas in the wild has been underway since 1991 in collaboration with the Friends of the National Zoo (Washington, D.C.). Work to date includes assessment of the diet of wild and released captive iguanas, acclimatization to the wild and territorial interactions among released captives, population distribution and habitat utilization, and limited studies of nesting behavior.

A captive breeding program was initiated at the National Trust in 1990. The original breeding stock consisted of animals already in captivity on Grand Cayman, animals donated to the National Trust by the Life Fellowship Sanctuary (Seffner, Florida), and a few wild hatchlings which had roamed into developed areas with traffic and feral predators. As a result of genetic studies undertaken by S. Davis, animals bred in 1990 and 1991 from Life Fellowship were subsequently found to have hybrid ancestry involving Lesser Caymans iguanas, *C. nubila caymanensis*. These animals were surgically sterilized to exclude them permanently from the breeding program. Additional analysis of captive Grand Cayman iguanas in both the Cayman Islands and U.S. captive collections has shown that genetic variation is low by comparison with Jamaican iguanas and Lesser Caymans iguanas from Little Cayman.

The *in situ* captive program is intended to function as an integral part of conservation efforts in the wild, and includes release of captive-bred iguanas into protected areas. Sterilized hybrids outfitted with radio-transmitters have proven to be an important means for evaluating release protocols for iguanas into various candidate habitats. By tracking and studying released hybrids, a small area within the Trust's existing Salina Reserve capable of supporting at least one breeding female has been identified. These studies have also verified the ability of captive born and reared iguanas to adapt naturally, without pre-release conditioning, to life in the wild. On the basis of these studies, a pair of genetically pure adults was released into the area in 1994.

With funding from the Zoological Society of Milwaukee County and the Foundation for Wildlife Conservation, the National Trust recently constructed a new captive facility where iguanas can be bred and reared for eventual release back into their native habitat. The facility will house up to 12 adults and 32 juveniles.

Critical conservation initiatives

- Establishment of sufficiently large protected and managed areas remote from habitation, where exotic predators and adverse human interference can be effectively controlled and a large breeding population restored.
- Implementation of program for farmers to discourage iguana trapping, shooting, and the practice of allowing domestic dogs and cats to roam freely in areas where iguanas are known to occur.

Priority projects

- 1) Enhance habitat at the Queen Elizabeth II Botanic Park.
- 2) Institute feral predator control, particularly for cats in remote agricultural areas of eastern Grand Cayman.
- 3) Conduct field research and monitoring of the wild population.
- 4) Produce an educational poster for Grand Cayman iguanas and red-footed boobies.
- 5) Acquire habitat, particularly agricultural land that could support iguanas and thickets with potential natural iguana habitat adjacent to the Salina Reserve and the Queen Elizabeth II Botanic Park.

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Anegada Island iguana

Cyclura pinguis

By Numi Mitchell

Description

The Anegada Island iguana is a relatively large, stout member of its genus. Males have been recorded with SVL reaching 560mm and may grow larger. Juveniles are faintly or boldly patterned with wide gray to moss green bands interspersed with wide gray to black anteriorly directed chevrons. The bands fade and are generally lost as the animals mature. Adults are grayish or brownish-black dorsally with varying amounts of turquoise on the dorsal spines, tail base, fore and hind legs. Occasionally the bluish coloration extends up onto the sides of the individual, particularly in males. Females tend to be relatively dull in color, exhibiting less brilliant blue if any. Ventral coloration of juveniles and adults varies from a solid buffy white to light gray. Sclera of eyes are dull yellow when animals are calm, but flush pink to red with increasing levels of agitation.

Distribution

The common name of the Anegada Island iguana is misleading, as the animal was once distributed over the entire Puerto Rico Bank. Fossils are known from Saint Thomas and Puerto Rico. The iguanas were likely extirpated when localities became densely settled by humans. Vulnerability to predation by humans and their dogs and cats may have resulted in a contraction of its distribution to Anegada. The numerous escape holes coupled with a large expanse of undeveloped land supporting few non-native predators may

have allowed the iguana population to persist there. The distribution of iguanas on Anegada today is closely tied to porous limestone habitats.

Status of populations in the wild

Population density in 1968 was estimated at 2.03/ha (Carey 1975). In 1991, this figure had dropped to 0.36/ha in comparable habitat. Extrapolation of density estimates, distribution, and relative habitat quality yields a population estimate for Anegada of 164 individuals (Mitchell, in review). A small restored population also exists on Guana Island with eight founding adults (Goodyear and Lazell 1994), from which three juveniles have been translocated to Necker Island. The total population, including individuals on Anegada, Guana, and Necker, probably consists of fewer than 200 individuals.

Ecology and natural history

Estimates in the late 1960s (Carey, 1975), made before the introduction of domestic livestock, showed small home ranges for both sexes (<0.1 ha), one principal burrow per animal, a 1:1 sex ratio, and habits that indicated monogamy (apparent pairs inhabited separate but proximate burrows in a joint home range isolated from other pairs). The current population structure is quite different. While previous studies may not have been sensitive to long range movements, it now appears that home ranges are quite large on Anegada: males average 6.6ha (range 2.2-12.3) and females average 4.2ha (range 2.8-5.6). Home ranges broadly overlap and have one or two centers of activity. For males, activity centers may be associated with home ranges of females; one male may have two centers almost a kilometer apart. In 1991, the sex ratio had dropped to 1 female:2 males. Thus male competition for limited females may be responsible for the high degree of home range overlap.

Burrows of both sexes may be located on the old limestone reef-tract or in sandy areas adjacent to it. If available, iguanas will use additional holes or crevices as emergency retreats. Female centers of activity are usually associated with one or several principal burrows. Whereas degraded vegetation may provide for male subsistence, it may not provide females with sufficient energy to allow them both to produce eggs and compete with other animals for forage to support their own growth and metabolism. Reproducing females may have low survivorship, resulting in the present skewed sex ratio. Females usually lay one clutch of about 12-16 eggs per year in late spring or early summer.

Although largely facultative herbivores, all age-groups of these iguanas are opportunistic carnivores. Invertebrates (beetles, caterpillars, centipedes, roach-

es) form <1% of the natural diet, although this may be a result of limited availability. The bulk of the diet consists of leaves and fruits.

Habitat

Over the past 20 years, since domestic livestock were released to breed freely island-wide, grazing pressure by goats, sheep, burros, and cattle has radically changed the vegetational composition of Anegada. Not surprisingly, the diet of the iguana is now composed of plant species the feral animals reject. Almost 30% of the iguanas' diet consists of a plant containing secondary compounds (*Croton discolor*) apparently toxic to ungulates. Over 55% of the diet is composed of fruits (*Byrsonima*, *Coccoloba*, *Eleaodendron*, *Eugenia*) that the livestock ignore.

Threats

Areas on Anegada that once contained dense populations of iguanas now support few or none. Research indicates that this is due to three major causes, including competitive grazing pressure from free-ranging livestock, predation by feral dogs, and predation of juveniles by feral cats.

Current conservation programs

A major grant has been received from the Environment, Science, and Energy Department of the UK Foreign and Commonwealth Office to facilitate conservation activities on Anegada. Goals of this program are to 1) implement a cat eradication/control feasibility study, 2) expand the current headstart facility, 3) train Senior Terrestrial Warden Rondel Smith in iguana husbandry and facility maintenance, 4) conduct population censusing and mapping at nesting sites and other potential sites where adults may be found, and 5) develop environmental education materials to raise public awareness of the importance and vulnerability of iguanas on Anegada.

In the 1980s, eight iguanas were moved from Anegada to Guana Island, British Virgin Islands, to start a second population in part of the species' former range (Goodyear and Lazell 1994). This is not a limestone island, and does not provide as many natural retreats as Anegada. In the absence of introduced predators, however, the iguanas appear to do well and reproduce in areas that are free of sheep (the only feral grazing competitor present). Currently, approximately 20 adult iguanas are estimated to inhabit Guana. Offspring have been seen each year since 1987, but recruitment is very low over much of the island. Guana Island Wildlife Sanctuary continues to try to rid the island of sheep, which may improve the habitat for iguanas.

Critical conservation initiatives

- Creation of a national park to protect iguanas on Anegada, and maintenance of a reservoir of breeding animals on Guana whose offspring may be used to restock depleted areas on Anegada. Although a national park has been approved in concept by the Anegada Lands Committee, land title issues must be resolved before this project can move forward.
- Livestock purchase and removal from designated protected areas, including Guana Island.

Priority projects

- 1) Construct livestock exclosure fences around designated protected areas.
- 2) Assess status and density assessment of iguanas throughout Anegada.
- 3) Examine the physiology of the declining female population.
- 4) Conduct vegetation recovery experiments to assess potential for restoration.
- 5) Expand the headstarting program on Anegada to produce hatchlings for release into restored areas.
- 6) Carry out genetic studies on both Anegada and Guana Islands.
- 7) Organize a PHVA workshop to raise local, national, and international awareness.

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Ricord's iguana

Cyclura ricordi

By Jose Ottenwalder

Description

Ricord's iguana is a large (SVL to 495mm in males, 430mm in females) iguana that can be readily distinguished by greatly enlarged and spinose scales at each caudal verticil in both adults and juveniles. Color patterns show little individual or ontogenetic variation, consisting of five to six bold pale gray chevrons alternating with dark gray to black chevrons, of which five continue as bold but narrow lines diagonally onto the venter. In adults, the dark chevrons are less contrasting than in juveniles.

Distribution

Ricord's iguana is known only from southwestern Dominican Republic, where it is restricted to the arid Valle de Neiba and the most xeric portion of the Peninsula de Barahona coastal lowlands (Fig. 8). The two populations are separated by the mesic Sierra de Bahoruco (Massif de la Selle in Haiti), with three peaks exceeding 2000m that form an extensive ecological barrier. Past drier Pleistocene climates may have allowed genetic exchange between the two sub-populations. Throughout their range, Ricord's iguanas are sympatric with rhinoceros iguanas.

The Neiba Valley population includes Isla Cabritos, a 12 by 2km island in Lago Enriquillo, a hypersaline lake that undergoes extreme reductions every 15-30 years due to severe droughts and high evapotranspiration. In the past, this has caused the island to become connected with the southwestern lakeshore, producing a peninsular effect and allowing two-way population exchange of Ricord's iguana and rhinoceros iguanas inhabiting the lake periphery. Return to previous insular conditions occurs during years of unusually heavy rainfall. The 1979-1980 cyclic episode resulted in lake levels rising more than 3m. Following a two-year period of increased drought and reduced rainfall, as of March, 1997, Isla Cabritos again became connected with the mainland, at the southwestern portion of the lake's shoreline near Jimani. J. Ottenwalder suspects that one-way migration from Isla Cabritos to the lake's south shore allows for dispersal between cyclic peninsular events. Over-water dispersal of iguanas could be aided by water surface currents generated by strong daily winds from Neiba Bay through the Neiba Valley, together with increased buoyancy provided by hypersaline water. Both Ricord's iguanas and rhinoceros iguanas will float and swim in fresh water (J. Ottenwalder, personal observation).

In the Barahona Peninsula range, the distribution of Ricord's iguana has yet to be accurately established. Areas of occupancy include lowlands to the north, northeast, and east of the Cabo Rojo region, below the lower foothills of Sierra de Bahoruco, and on the western side of the Parque Nacional Jaragua. The oldest known occurrence inside the park is the northwestern corner at Tru Nicola, although the precise extent to which the species distribution continues east and south is insufficiently known. However, park wardens have recently observed Ricord's iguanas in the eastern and southwestern portions of the park, including the Oviedo Lagoon, where the species inhabits limestone areas of the shoreline and several small cays inside the lagoon.

The presence of Ricord's iguanas in the Haitian extension of the Neiba Valley plain has been presumed (Schwartz and Carey 1977). However, the species has never been recorded from the Lake Etang Saumatre basin or the dry coastal fringe extending from Anse-a-Pitres to Marigot across the Dominican border at Pedernales.

Status of populations in the wild

All available data indicate that the historical range of Ricord's iguana was small and disjunct. Several factors indicate that the population is currently declining, including direct observation, reduction in the extent and quality of available habitat, and documentation of the negative effects of introduced species. Researchers and local inhabitants agree that until the mid-1970s, population densities of mature individuals were much higher than they are at present. Lacking more accurate data, a current population estimate of 2,000 to 4,000 is probably conservative but fair.

Ecology and natural history

Compared to rhinoceros iguanas, Ricord's iguanas are quite specialized. Several key environmental factors, including soil depth and texture, landform, bedrock parental material, and climate seem to determine their presence. Ricord's iguanas inhabit the most arid regions of the Dominican Republic, where the climate is highly seasonal. Representative localities include Duverge (annual rainfall 470.6[178.4-812.8]mm, 46.6 days/year; 28.8[23.1-33.0]°C) and Pedernales (annual rainfall 633.3[160.2-1922.8]mm, 34.7 days/year; 27.9[21.5-34.1]°C). Annual precipitation is distributed in two rainy periods, May-June and September-October, while December-March is exceedingly dry.

Ricord's iguanas are strongly associated with thorn scrub woodlands, particularly with the thorn scrub-dry forest ecotone. Typical habitat can be found north of Cabo Rojo inside the fork of the Oviedo-Pedernales and Cabo Rojo-Acetillar bauxite mine roads. The

topography of the area consists of a series of broad, flat plains punctuated by rocky steps and marine terraces with very fine soil over exposed dogtooth limestone. The plant community is disturbed and not very diverse, consisting of only about 35 species of tracheophytes (18% endemic) (Fisher-Meerow 1983; Fisher-Meerow and Judd 1989). Members of the Cactaceae, Fabaceae, and Euphorbiaceae are common. A single species, *Acacia macracantha*, comprises 50% of the cover. Other common trees are *Capparis ferruginea*, *Guaiacum officinale*, *Haitiella ekmanii*, *Metopium brownei*, *Opuntia moniliformis*, and *Phyllostylon brasiliense*. Common shrubs include *Croton origanifolius*, *Croton discolor*, and *Lipia alba*. Among the succulents, *Agave brevipedata*, *Cephalocereus polygonus*, *Harrisia nashii*, *Melocactus communis*, *Cylindropuntia caribea*, and *Opuntia dillenii* predominate. Trees and shrubs are widely spaced, without forming a closed canopy. Further north, only rhinoceros iguanas are present at a second, higher elevation site, with similar temperature but greater rainfall. This area consists of a marginal subtropical dry forest community on eroded dogtooth limestone and gently sloping terrain with occasional step cliffs and terraces. Here, plant diversity is higher (45 species, 9% endemic), and Malvaceae, Euphorbiaceae, and Fabaceae are the most abundant families in number of species and individuals. *Capparis ferruginea*, *Zizyphus rignoni*, *Cameraria angustifolia*, *Cordia buchii*, and *Plumeria obtusa* are common, although some species are restricted to limestone outcrops. Shrubs include *Abutilon abutiloides*, *Comocladia dodonea*, *Croton ciliato-glandulifera*, *Cryptorhiza haitiensis*, *Guaiacum sanctum*, *Hybanthus havanensis*, *Lantana camara*, and *Turnera diffusa*. Vines are very common, as is the herb *Callisia repens*. Plants with spines are nearly absent from less disturbed areas, while vegetation approaches thorn woodland in the most disturbed areas. These are generally dominated by open-canopy legumes, including *Acacia macracantha*, *Prosopis juliflora*, and *Senna atomaria*. Acacia-dominated areas probably represent secondary reductions of more diverse past communities. In the transition zone between these two sites, both iguana species are present, sharing the more diverse edge habitat.

On Cabritos Island, where Ricord's iguanas have historically outnumbered rhinoceros iguanas based on frequency of sightings by visiting researchers, the plant community is a succulent-dominated 5-6m dry forest on white sandy soil with low topography. Ricord's iguanas occur on north and south gentle slopes as well as on the central plateau, where soil conditions are favorable for their extensive burrows.

Among other shrubs, *Cylindropuntia caribea* is common. On the south mainland shores, Ricord's iguanas outnumber rhinoceros iguanas by a factor of nine in the flatlands surrounding Laguna del Medio near El Limon, considered the driest area in the country. The soil is very fine, porous, and from dark to whitish gray color, without rock exposure. Savanna vegetation cover is about 25%, dominated by *Jacquinia* (two species), *Piscidia ekmanii*, *Maytenus buxifolia*, and the less common *Prosopis juliflora*; shrubs include *Mimosa* sp., *Pictelia spinifolia*, *Crossopetalum decussatum*, *Turnera diffusa*, *Croton discolor*, *Malpighia* sp., and *Lantana decussatum*; grasses include *Portulaca* sp., *Evolvulus sericeus*, *Stylosanthes hamata*, and members of Poaceae (DVS/SEA 1990). Ricord's iguanas feed on a wide variety of plants and plant parts, depending on local availability, including *Consolea*, *Opuntia*, *Croton*, *Prosopis*, *Melocactus*, *Cordia*, and *Guaiacum*. Insects and crustaceans are also taken opportunistically.

Seemingly optimal habitats are characterized by alluvial powdery-clay soils bordered by marine sediments and low forested hills with high plant diversity. Flat topography, low precipitation, and local soil conditions (e.g. fine texture, slow permeability, low flooding risk, good drainage) allow for low erosion rates and maximum soil stability. While rhinoceros iguanas make extensive use of limestone crevices in addition to soil burrows, Ricord's iguanas prefer to dig soil burrows which they continue to expand over time. Hollow tree trunks and rock cavities are also used for retreats when soil is unavailable. Retreat entrances are generally dug under dense thorny vegetation, shrubs, stumps, or exposed rocks.

Nesting sites are separate from retreats, in fine sandy soils. Egg laying is highly synchronized with the first rainy period (May-June). Females lay 2-18 eggs per clutch (mean 11.1 ± 4.2). Egg chamber depth is about 40cm, with a stable temperature of 30-31°C. Incubation lasts 95-100 days, and hatching is synchronized with the second rainy season (September-October). Average SVL and mass of hatchlings is 87.4mm and 30g. Females reach sexual maturity at about 2-3 years of age. In captivity, first time clutches are usually very small (2-4) and often infertile. The social behavior of Ricord's iguana generally resembles that of other rock iguanas, although wild males defend females much more aggressively in captivity than do wild male rhinoceros iguanas maintained at lower densities in comparable enclosures. Although of major research interest and significant conservation importance, little is known of interspecific interactions between Ricord's and rhinoceros iguanas.

Habitat

The total range of Ricord's iguana in the Dominican Republic is under 100km², and less than 60% of the historical range is occupied, most of it showing various levels of disturbance. Suitable habitat has been severely reduced by clearing, fragmentation, and transformation, including some of the oldest and best known iguana sites. The area along the south shore of Lake Enriquillo between Duvergé-Las Baitoas and El Limon has suffered considerable habitat loss as a result of agricultural development, free-ranging livestock, charcoal production, fuelwood extraction, and drainage of a lagoon and small seasonal wetlands. The Isla Cabritos range, which used to be intensively exploited for hardwood cutting, charcoal, and livestock grazing (up to 500 goats, 200 burros, and some cattle), has experienced extensive natural regeneration during the past 15 years. Since 1992, protective management has improved, and present conditions are stable.

The distribution of Ricord's iguana in the Barahona Peninsula range is insufficiently known due to the impenetrable, dense nature of the vast dry forest that extends inside Parque Nacional Jaragua. Confirmed areas of occurrence include relatively small patches of lowland thorn scrub and thorn scrub-dry forest ecotone in the Cabo Rojo region north of the Oviedo-Pedernales road, lowlands 150m to the north and northeast of Cabo Rojo at the base of lower foothills of Sierra de Bahoruco, and on the western side of the park. Inside the park boundaries, Ricord's iguanas are best documented from the northwestern corner and from the Oviedo Lagoon area. As penetration of the forest along this section is extremely difficult due to thick thorny forest and uneven dogtooth limestone terrain, the extent to which the species range continues to the east and south is still uncertain. Outside the park, iguana habitats are being reduced by conversion to farmlands, limestone mining, charcoal production, fuelwood collection, hardwoods extraction, and grazing livestock. Habitat protection inside the park has improved, although similar human impacts on forest communities supporting iguanas still occur inside and along buffer zones areas.

Threats

The major threats to Ricord's iguanas are from human activities resulting in habitat reduction and degradation (clearing of vegetation for agricultural use, charcoal production, harvesting of fuelwood and hardwoods, overbrowsing by free-ranging livestock, mining of limestone, illegal collection of live cacti for local and international trade), in combination with local subsistence hunting for food and predation from introduced carnivores (dogs, cats, and mongooses). Competition from mammalian herbivores probably

also occurs. Hunting of Ricord's iguanas for food and trade has increased gradually since the mid 1970s, both for local consumption as well as at a few oriental restaurants in Santo Domingo where iguanas were offered as a specialty dish. In the past, some hunters used to set up to 100 snare traps per day at the entrance of retreats, with 30-50% trapping success. Although current populations no longer support the numbers harvested 15 years ago, iguanas continue to be captured opportunistically in all areas with remaining populations, except on Isla Cabritos where law enforcement is presently effective.

Current conservation programs

Aside from occasional smuggling of animals across the Haitian border, compliance with international CITES trade regulations is effective. Enforcement of national protective legislation in the Dominican Republic has improved during the past few years, but effective control is adversely influenced by a number of factors. Clearing of natural habitat for development is not being prevented nor regulated and illegal hunting for food and the local pet market continues.

Ricord's iguana is partially protected in two areas. In the Neiba Valley, about 60% of the area supporting iguanas, including Isla Cabritos and a section of the south shore of Lake Enriquillo, is protected within the recently created Lago Enriquillo National Park. The Isla Cabritos population has been protected within Isla Cabritos National Park since 1974.

In the Barahona Peninsula range, two protected areas, Parque Nacional Jaragua and the Acetillar Scenic Reserve, cover most of the remaining distribution of the species to the north and east of Cabo Rojo. Ricord's iguanas are only known from the park's western boundary, where conflicts with limestone mining concessions on both sides of the park border continue to be unresolved. Until now, no formal management has been established in the Acetillar reserve, and the habitat is impacted by a variety of activities.

As of November, 1995, the total captive population of Ricord's iguana was 5.9 individuals in two collections (Indianapolis Zoo and one private collection; B. Christie, personal communication). Successful captive breeding has been achieved in both, but survivorship of young has been low (J. Ottenwalder and B. Christie, unpublished data). The only other significant captive breeding program was developed at the Parque Zoológico Nacional (ZooDom). Although adversely affected by institutional problems, the program lasted for a number of years with comparable success. There are plans to re-establish new breeding colonies at both ZooDom and the Indianapolis Zoo, as part of a collaborative program between the two institutions. ZooDom recently completed a breeding

exhibit to house a founder group once ongoing population surveys indicate it is safe to remove animals from the wild.

Critical conservation initiatives

- Effective enforcement of current regulations protecting populations.
- Strengthening of current regulations and legislation protecting iguana populations by increasing fines and designating selected areas as critical habitat whether outside or inside existing protected area boundaries.
- Development of educational awareness campaigns to promote iguana conservation, particularly to discourage subsistence hunting of iguanas for food and local trade, and habitat conversion for charcoal production.
- Development of a national conservation and recovery strategy and working group to include government agencies, non-governmental conservation organizations, and iguana researchers.
- Establishment of research, management, and monitoring programs for wild populations and critical habitats.
- Involvement of local organizations and communities in any iguana conservation, education, and research activities.

Priority projects

- 1) Conduct status surveys of the Parque Nacional Jaragua-Cabo Rojo and Lake Enriquillo iguana populations.
- 2) Carry out field studies on natural history and ecology, and assessments of population trends and threats in order to develop a recovery strategy.
- 3) Immediately eradicate cats from Isla Cabritos.
- 4) Establish local and national educational programs

in order to reduce current causes of mortality, raise awareness concerning threatened status, and promote support for proposals to expand boundaries of existing protected areas.

- 5) Re-establish a captive breeding and research program at ZooDom, while continuing to strengthen the ongoing program at the Indianapolis Zoo.

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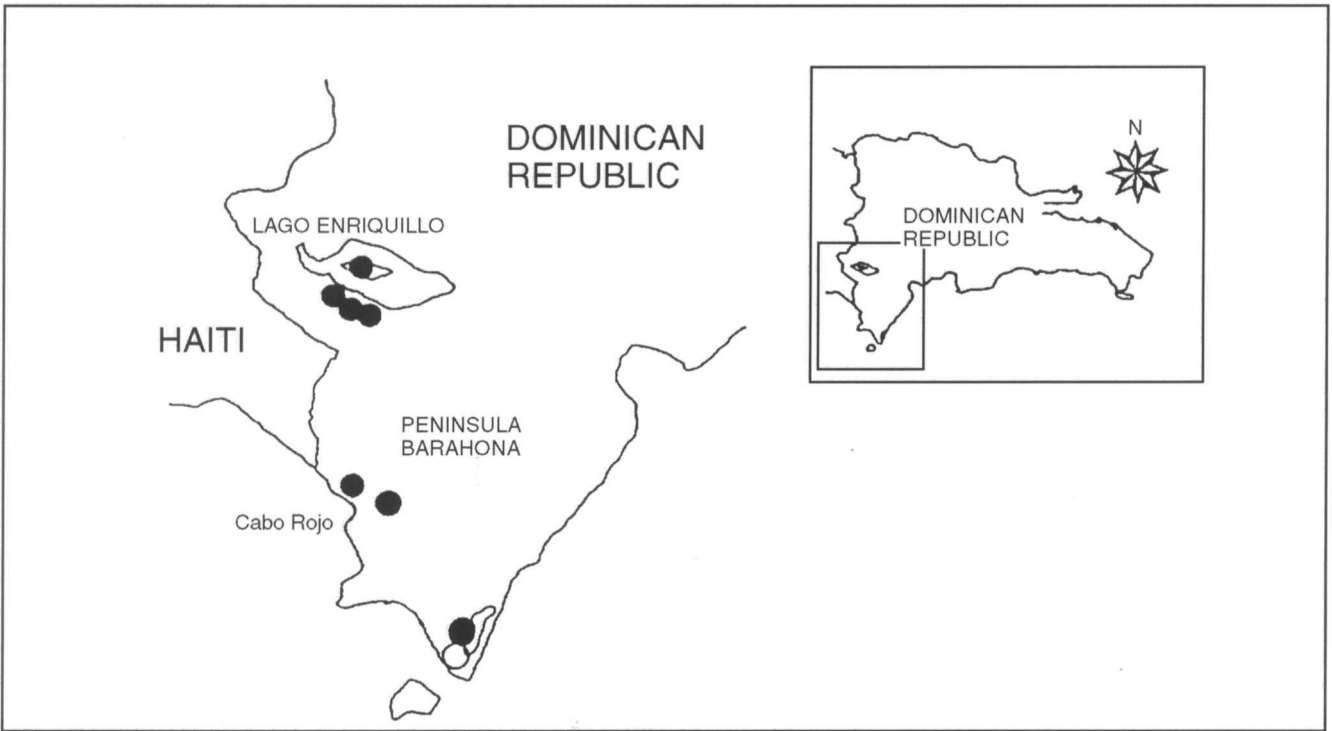
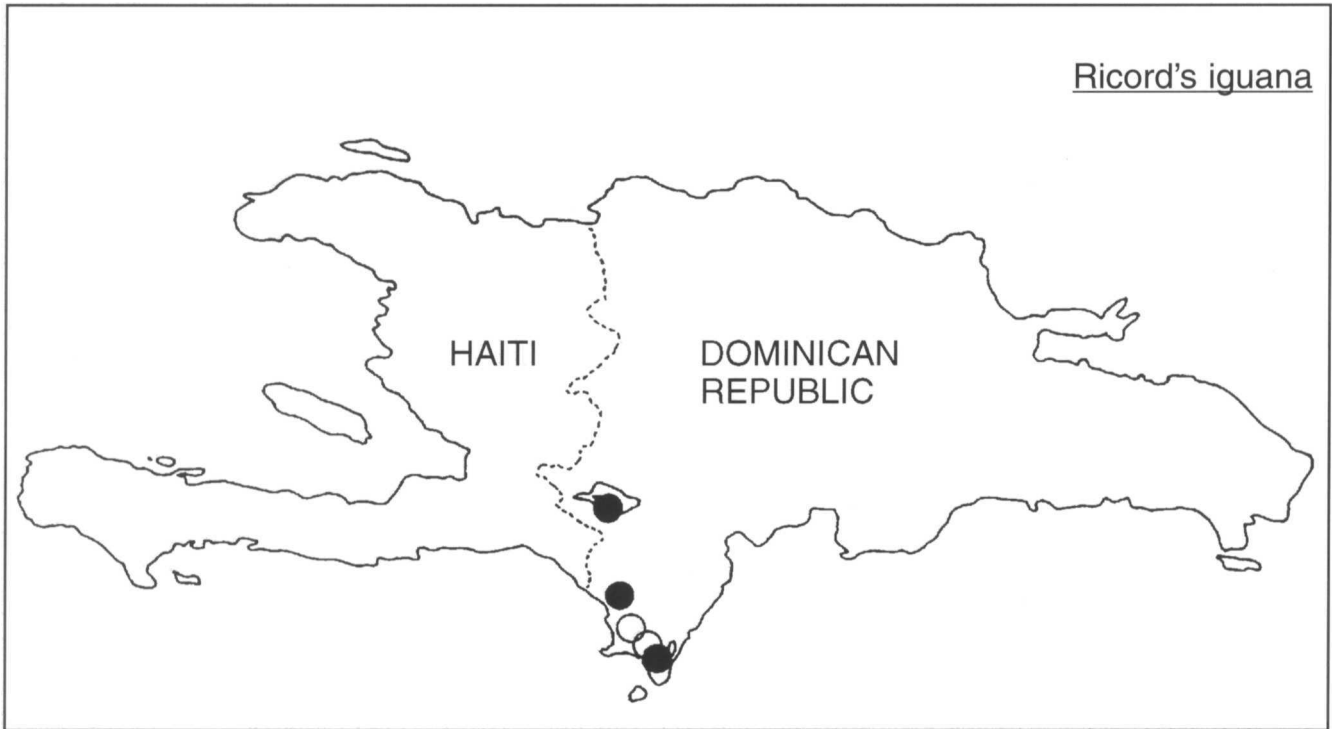


Fig. 8. Present distribution of Ricord's iguana in the Dominican Republic. The solid circles represent the current known distribution. The open circles indicate areas where the presence of populations is suspected but currently uncertain and in need of confirmation.

San Salvador iguana

Cyclura rileyi rileyi

By William Hayes

Description

Schwartz and Carey (1977) concluded that the San Salvador iguana is the largest subspecies of *C. rileyi*, with a maximum size of 307mm SVL. More recent studies (Hayes et al., unpublished) indicate that many individuals of the San Salvador iguana on Low Cay, a satellite of San Salvador Island, exceed 350mm SVL, and attain a size of up to 395mm SVL (890mm total length). Although iguanas on Guana Cay within San Salvador's Great Lake also average over 300mm SVL, those on other cays rarely do.

The species is characterized by the absence of azygous scales in the prefrontal suture, rostral scale always in contact with nasals, first prefrontal never in contact with precanthal, dorsal crest scales on the neck always higher than on the body, body crest scales almost never higher than postsacral crest scales, and a variety of other scale-count features (Schwartz and Carey 1977). Characters that distinguish San Salvador iguanas from the other two subspecies include several features of facial scalation and poorly defined postsacral crest scales.

Dorsal coloration of San Salvador iguanas is striking but variable. Dorsum colors of red, orange, yellow, green, or brown are usually punctuated by darker markings and fine vermiculations. Males generally exhibit more color (red, orange, or yellow) and contrast than females, especially at warmer body temperatures. Juveniles are solid brown or gray, often with a slightly paler middorsal band having faint longitudinal stripes or indistinct darker areas near the middorsal crest. Juveniles lack the brighter coloration and vermiculations of adults, as well as the dorsal chevrons or pale diagonal markings present on juveniles of other taxa.

Distribution

Fossil remains found by Olson et al. (1990) indicate that San Salvador iguanas once occurred throughout the island of San Salvador (area 150km²). Today, however, sightings on the mainland are exceedingly rare, occurring most often on the eastern side between Great Lake and Storrs Lake. Although the Lucayan Indians may have hunted iguanas in earlier centuries, the extensive agricultural practices and other human activities of the last 100 years likely represent the greatest contribution to the iguana's demise. At present, San Salvador iguanas appear to be restricted largely to five tiny offshore cays (Gaulin, Goulding, Green, Low, Manhead) and two cays within Great

Lake (Guana and Pigeon; Hayes et al. 1995). They were presumably extirpated on at least six additional cays, with two extinctions occurring in recent decades (discounting an unconfirmed sighting on High Cay in 1991). The seven inhabited cays range in size from 1-12ha and total approximately 26ha of marginal to excellent habitat.

Status of populations in the wild

Recent censuses by Hayes et al. (1995) suggested that approximately 500-600 individuals remain. However, they suspected that juveniles were underestimated in their surveys, and have since learned that a moderate population thrives on Pigeon Cay, the one known population they had not yet visited. Nevertheless, this subspecies likely numbers fewer than 1,000. Populations on the isolated cays vary from perhaps as few as 10 (Gaulin Cay) to as many as 250 (Green Cay). Several populations are threatened by human-related causes and appear to be declining.

Ecology and natural history

The habitat on cays presently occupied by iguanas varies greatly. Vegetation on offshore cays is similar in varying degrees to coastal rock, sand strand and sea oat, and coastal coppice plant communities described on the mainland (Smith 1993). However, for cays within inland lakes, the vegetation resembles the blacklands coppice (Guana Cay) and mangrove (Pigeon Cay) communities on the mainland. Habitats on the mainland of San Salvador are highly diversified and suitable enough to harbor large iguana populations, but feral animals are numerous in many areas.

The number of plant species on each cay varies from ten on Green and Gaulin Cays to more than 40 on Guana and Low Cays (Moyroud and Ehrig 1994; Hayes et al., unpublished data). Mean and maximum body sizes of iguanas vary significantly from cay to cay, and are positively correlated with plant diversity, suggesting nutritional constraints on body size (W. Hayes et al., unpublished data). Iguanas are largest on Low Cay and smallest on Manhead Cay. Previously reported measurements of body size (Schwartz and Carey 1977) were limited to samples from cays having low plant diversity. Thus, prior recognition of *C. rileyi* as the smallest of the rock iguanas may be an artifact of historical extinctions resulting in extant populations being confined today largely to the most inaccessible cays having minimal plant diversity.

Iguanas are locally most common in the vicinity of limestone rock outcrops and/or patches of sea grape (*Coccoloba uvifera*). On some cays they are numerous in patches of buttonwood (*Conocarpus erectus*) where they ascend into the foliage to browse. On Pigeon Cay they are frequently encountered basking

on the limbs of mangrove trees, often several meters or more above the ground. The iguanas share their habitat with nesting seabirds on several cays, most notably on Gaulin Cay where brown noddies (*Anous stolidus*) and sooty terns (*Sterna fuscata*) are extremely dense (100+ nests/ha).

Aspects of feeding and reproductive ecology remain unstudied but are likely similar to other rock iguana species. Adult males appear to be territorial throughout the year. As in other Bahamian taxa, courtship and mating probably occur in May, followed by nesting and egg-laying in June or July. Copulations have been observed by investigators visiting the cays during the last week of May (W. Hayes, unpublished data). Stejneger (1903) reported a clutch that numbered five eggs. Hatchlings probably emerge from nest burrows in September or October. Like other rock iguanas, San Salvador iguanas presumably require sandy areas for nest construction. Such habitat appears to be limited on Guana Cay, but the presence of several juveniles in 1994 is indicative of successful nesting there.

Habitat

On most cays, iguanas range widely throughout all available habitats. However, on Low Cay iguanas are largely restricted to areas of sea grape that comprise a relatively small portion of the island. Although a man-made structure is under construction on High Cay where iguanas are thought to be extirpated, none of the other cays are inhabited and, at present, are seldom visited. On several cays where iguanas have disappeared the habitat appears suitable for reintroduction; however, these cays may harbor feral rats that could be incompatible with reintroduction efforts unless they are first extirpated.

Considerable habitat has been lost on the main island of San Salvador. Nevertheless, extensive areas of excellent but very remote habitat remain which could support large populations of iguanas if development on the island could be halted (which appears unlikely). Thus, while habitat availability does not presently limit the mainland population, it may well hinder the prospect of increasing the total population size via future reintroductions.

Threats

Although remote and relatively difficult to access, populations on the cays are still threatened by human-related causes (Hayes et al. 1995). All size classes of iguanas are readily seen on Goulding, Green, Manhead and Pigeon Cays, which suggest the presence of healthy, stable populations. However, juveniles are conspicuously scarce on Guana and Low Cays, and possibly absent on Gaulin Cay. The scarci-

ty of juveniles on Low Cay is probably attributable to the presence of feral rats only recently detected there (Hayes et al. 1995). The iguana population consists almost entirely of large, aged adults. More recently, rats have also been seen on Guana, High, and Pigeon Cays. Considering the apparent impact of rats on insular populations of the tuatara (*Sphenodon punctatus*), an iguana-sized burrow-nesting reptile in New Zealand (Cree et al. 1995), rats probably pose a serious threat to survival of iguanas on several cays and need to be exterminated soon. Rats may also impact iguana populations indirectly by affecting vegetation, especially on cays with low plant diversity.

The once dense population on Guana Cay (Ostrander 1982) has become greatly reduced in recent years. A mysterious die-off occurred in spring 1994, as evidenced by the discovery of eight adult carcasses and an estimated surviving population of only 24 individuals (Hayes et al. 1995). Because the carcasses all appeared to be in similar states of decay, they may have died within a narrow time frame from similar, but unknown, causes. Although natural disease is a possible cause, so too might be mosquito control efforts, recently implemented for the benefit of the growing tourism industry. The ticks which infest these iguanas have not been found on any other cay, and may have rendered the lizards more vulnerable to the agent(s) causing their deaths. Juvenile iguanas may also be scarce as a consequence of the die-off; their carcasses may have decayed quickly or escaped detection. However, nesting habitat appears to be restricted, which could limit the numbers of juveniles and affect future recruitment. Nesting habitat is also limited on Pigeon Cay and nesting failure is inevitable in wet years when lake surface level inundates the nests. It is unclear why the population on Gaulin Cay is so low (possibly fewer than 10) and juveniles appear to be absent. This small, potentially inbreeding-depressed population may no longer be viable.

The larvae of a moth (*Cactoblastis cactorum*) introduced decades ago to the West Indies are now rapidly devastating prickly-pear cacti (*Opuntia stricta*), an important food source for iguanas, on several cays. The dense population of lizards on Green Cay is especially vulnerable, particularly since destruction of the cacti will be nearly complete within a matter of years, there are no known means of controlling the moth, and the remaining vegetation (nine plant species) represents a meager diet compared to other rock iguana species (Auffenberg 1982). The impact of this ecological disturbance needs to be closely monitored.

Rapid development on the island of San Salvador will undoubtedly threaten the populations further. Feral dogs and cats are already numerous in local

areas, but will increase as more resorts and housing tracts are constructed. This would seriously jeopardize any possible reintroductions of iguanas to the mainland, unless protected areas of considerable size could be set aside. Pollution of Great Lake due to environmentally unsound landfill practices may threaten the fragile mangrove community that harbors a moderate iguana population on Pigeon Cay. Eventually, tourists may discover the attributes of the iguanas themselves, which could increase potentially detrimental human-iguana contacts.

Current conservation programs

At present, W. Hayes and R. Carter are collecting baseline data on all populations of *C. rileyi* to aid conservation management decisions. Initial efforts involve population surveys, assessment of threats to survival, and genetic sampling. Genetic analyses are essential to resolve the taxonomic identities of the nominate taxa, to assess the degree of divergence among individual populations, and to evaluate heterozygosity (which may reveal inbreeding depression). Divergence may be sufficient that the genetic identity of most or all populations will need to be maintained.

Further steps include concentrated searches for isolated colonies on the mainland and on the southernmost lakes, as well as reintroductions of iguanas to previously inhabited cays. For San Salvador iguanas, candidate cays for reintroduction (and source animals) include Barn Cay (from Guana Cay), Cato Cay (from Green Cay), Cut Cay (from Manhead Cay), and High Cay (from Low Cay). However, further research is necessary to determine the suitability of each cay, and to assess what corrective actions would be necessary to render each suitable for reintroduction (e.g., removal of feral rats or supplementation of nesting habitat). Reintroduction of iguanas on the mainland should be undertaken only if protection of a large area can be assured. Excellent mainland areas presently uninhabited by humans include the land bridge east of Storrs Lake (where a major resort and marina are planned), the area between Storrs Lake and Great Lake, and the peninsula east of Pigeon Creek. Additional comparative research planned for the isolated populations of this taxon includes vegetation analyses and studies of reproductive strategies, seasonal dietary shifts, and behavioral ecology.

At present, no legal captive breeding programs exist outside the Bahamas. The Bahamian government has wisely refused to issue export permits for any rock iguana taxa. However, Ardastra Gardens in Nassau (New Providence Island, Bahamas) currently holds two juveniles and plans to implement an *in situ* program. Captive programs could be highly valuable

for repatriation efforts, particularly if the genetic integrity of individual populations needs to be preserved.

A public relations campaign is planned to heighten awareness and appreciation among island residents for their endemic iguana. Brochures have the potential to provide basic information and to promote the need for complete protection of the cays on which the iguanas live. Residents should be alerted to the protected status of the iguanas and urged to report to authorities anyone seen visiting the cays. Bringing feral animals to any cay should be legally forbidden. If possible, especially if the tourism industry continues to escalate, the Bahamas National Trust should declare the cays a land and sea park and hire a warden to patrol the region.

Critical conservation initiatives

- Limitation of access to cays, particularly to discourage feeding of iguanas by tourists.
- Further protection of the cays by incorporation into a national park by the Bahamas National Trust. As some of the cays are privately owned, this will require working with landowners.
- Institutional strengthening of responsible agencies to develop enforcement capabilities.
- Initiation of a national education program for tourists and residents.

Priority projects

- 1) Continue to sample and survey individual populations on an annual or biannual basis.
- 2) Eradicate rats on infested cays.
- 3) Monitor the impact of the *Cactoblastis* moths and rats on vegetation.

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Little Cayman iguana, *Cyclura nubila caymanensis*; Little Cayman Island; first-year juvenile. Photo by Glenn P. Gerber



Grand Cayman or Blue iguana, *Cyclura nubila lewisi*; Grand Cayman Island; adult male. Photo by Glenn P. Gerber



Lesser Antilles iguana, *Iguana delicatissima*; St. Eustatius, Lesser Antilles; adult male. (Left) Photo by Glenn P. Gerber



Anegada Island iguana, *Cyclura pinguis*, Anegada, British Virgin Islands; adult male. (Right) Photo by Glenn P. Gerber



Anegada Island iguana, *Cyclura pinguis*; Anegada, British Virgin Islands; adult female. Photo by Glenn R Gerber



Anegada Island iguana, *Cyclura pinguis*; Anegada, British Virgin Islands, recently emerged hatchling. Photo by Glenn P. Gerber



Ricord's iguana, *Cyclura ricordi*; Isla Cabritos, Dominican Republic; adult male. Photo by Bill Christie



Ricord's iguana, *Cyclura ricordi*; adult male. Photo by Jeff Wines



San Salvador Island iguana, *Cyclura rileyi rileyi*; vicinity of San Salvador Island; adult male. Photo by D. S. Lee/Tortoise Reserve



San Salvador Island iguana, *Cyclura rileyi rileyi*; vicinity of San Salvador Island; adult male. Photo by Glenn P. Gerber



White Cay iguana, *Cyclura rileyi cristate*; White (Sandy) Cay, Bahamas; adult male. Photo by Bruno Dittmar



Grand Cayman or Blue iguana, *Cyclura nubila lewisi*; Grand Cayman Island; adult male. Photo by Frederic J. Burton



Lesser Antilles iguana, *Iguana delicatissima*; St. Barthelemy, Lesser Antilles; adult male basking in tree. Photo by Mark Day



Green iguana, *Iguana iguana*; St. Lucia; adult male. Photo by Mark Day



Lesser Antilles iguana, *Iguana delicatissima*; St. Eustatius, Lesser Antilles; first-year juvenile. (Left) Photo by Glenn P. Gerber

Green iguana, *Iguana iguana*; Saba, Lesser Antilles; partially melanistic adult male displaying. (Right) Photo by Glenn P. Gerber





Turks and Caicos iguana, *Cyclura carinata carinata*; Chalk Sound, Turks and Caicos Islands; adult males fighting. Photo by Glenn P. Gerber



Turks and Caicos iguana, *Cyclura carinata carinata*; Chalk Sound, TCI; adult male basking in tree. Photo by Glenn R Gerber



Bartsch's iguana, *Cyclura carinata bartschi*; Booby Cay, Mayaguana; hatchling. Photo by Glenn R Gerber



Bartsch's iguana, *Cyclura carinata bartschi*; Booby Cay, Mayaguana; adult female. Photo by Glenn P. Gerber



Rhinoceros iguana, *Cyclura cornuta cornuta*; adult female. Photo by Glenn P. Gerber



Mona Island iguana, *Cyclura cornuta stejnegeri*; Mona island; adult female. Photo by Glenn P. Gerber



Jamaican iguana, *Cyclura collei*; adult male; Hellshire Hills, Jamaica. Photo by Peter Vogel



Jamaican iguana, *Cyclura collei*; adult female digging nest; Hellshire Hills, Jamaica. Photo by Glenn P. Getter



Jamaican iguana, *Cyclura collei*; at nest site, Hellshire Hills, Jamaica; adult female. Photo by Glenn P. Gerber



Allen's Cay iguana, *Cyclura cyclura inornata*; Allen's Cay, Exuma Islands, Bahamas; adult male. Photo by John Iverson



Exuma Islands iguana, *Cyclura cyclura figginsi*; Central Exuma Islands, Bahamas; adult male. Photo by Chuck Knapp



Andros Island iguana, *Cyclura cyclura cyclura*; Andros Island, Bahamas; adult male. Photo by Chuck Knapp



Andros Island iguana, *Cyclura cyclura cyclura*; Andros Island, Bahamas; juvenile. Photo by Chuck Knapp



Cuban iguana, *Cyclura nubila nubila*; Guantanamo Bay, Cuba; adult male. Photo by Glenn P. Gerber



Cuban iguana, *Cyclura nubila nubila*; Guantanamo Bay, Cuba; adult males fighting. Photo by Glenn R Gerber



Little Cayman iguana, *Cyclura nubila caymanensis*; Little Cayman Island; adult male basking. Photo by Glenn P. Gerber

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White Cay iguana *Cyclura rileyi cristata*

By William Hayes

Description

The White Cay iguana is smaller than the San Salvador iguana (up to 280mm SVL), and can be distinguished by a combination of several scale features, including well-defined postsacral crest scales (Schwartz and Carey 1977). The dorsum of adults is usually gray with brown to orange-brown vermiculations. The dorsal crest scales, forelimbs, and portions of the head and face are typically highlighted in orange. Juveniles resemble young San Salvador iguanas, but lack a dark area in the pale zone of the mid-dorsum.

Distribution

This subspecies occurs on only a single island, White (Sandy) Cay, in the southern Exumas of the Bahamas. This island is small, comprising about 25ha (Schwartz and Carey 1977). The iguanas were probably much more widely distributed during the last ice age when many of the Exuma Cays were presumably connected due to lower sea levels. They possibly occupied additional adjacent cays in recent centuries, but if so have vanished without a trace.

Status of population in the wild

The single population is confined to only one island, which can support only a limited number of iguanas. According to Lincoln-Peterson surveys conducted in 1997, the size of the population has been estimated at 150 to 200 individuals.

Ecology and natural history

Except for informal visits mainly to collect specimens, this isolated subspecies has been largely ignored by scientists. Essentially nothing has been published about its ecology or natural history.

Habitat

The vegetation of White Cay is fairly typical of the coastal rock habitat described by Smith (1993). The

northwestern portion of the cay, where iguanas are least common, is comprised of a dense forest of thatch palm (*Thrinax morrisii*). The remainder of the cay is dominated by *Strumpfia maritima* and sea grape (*Coccoloba uvifera*) interspersed among rock and sand. Introduced Australian Pine (*Casuarina litorea*) is well-established along the low dunes of the southern shoreline. Seven-year apple (*Casasia clusiifolia*) dominates the sand dunes of several smaller cays to the south that are separated from White Cay by a narrow tidal flat that iguanas presently do not cross. In 1997, the vegetation appeared to be unaffected by Hurricane Lily, which scored a near-direct hit in October 1996. Iguana density is greatest along the periphery of the cay where rocky crevices are most numerous.

Threats

Illicit smuggling and the possibility of introduced animals are likely the greatest threats to this population. From photos that appeared in the April 1994 issue of a popular reptile magazine, it is clear that at least some *C. rileyi*, potentially from White Cay, have been recently smuggled. At least eight individuals of *C. rileyi*, presumably of this subspecies, were discreetly exhibited in the showrooms of several Florida reptile wholesalers in 1993 (R. Ehrig, personal communication), which suggests that more than a trivial number of animals were taken. Another potential threat is inbreeding depression, due to centuries or longer of effective isolation.

In 1996, S. Buckner, R. Carter, J. Iverson, and W. Hayes observed footprints of a raccoon on White Cay. It may have dispersed there on its own after several were formerly introduced to nearby Hog Cay. Although that animal has since been confirmed dead, it appears to have predated a significant proportion of the iguana population, particularly juveniles and females. Black rats formerly threatened the iguana population, but have since been removed from the cay.

Current conservation programs

A grant from the Chicago Zoological Society has facilitated eradication of black rats from White Cay. The project was a collaborative effort of the West Indian Iguana Specialist Group, the Bahamas National Trust, the Bahamas Department of Agriculture, Fauna and Flora International, Loma Linda University, and Zeneca Agrochemicals, Inc., which donated the rodenticide used in the eradication. Two cays that appear promising as potential sites for establishment of a second wild population of the White Cay iguana have been identified. Although they have yet to be surveyed on the ground, both look appropriate from the air, both are Crown land, and

both have active seabird nesting colonies, a good sign that introduced predators are absent. W. Hayes and R. Carter visited White Cay in 1996 to obtain blood samples and other measurements from the iguanas and to evaluate their status.

Critical conservation initiatives

- Acquisition of White Cay within the park system of the Bahamas National Trust. The island is remote enough that local policing of the cay is unlikely.
- Institutional strengthening of responsible agencies to develop enforcement capabilities.
- Education programs discouraging visitors to the cay from dumping garbage and feeding iguanas.

Priority projects

- 1) Maintain a program of rat control.
- 2) Assess the current status of the population, and consider candidate cays for establishing a secondary population. It might be wise to consider a distant location (such as in the Land and Sea Park of the northern Exumas) as a safeguard against extinction resulting from weather.
- 3) Conduct annual or biannual censuses of the population.

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Acklins iguana

Cyclura rileyi nuchalis

By William Hayes and
Richard Montanucci

Description

The Acklins iguana can be distinguished from the San Salvador and White Cay iguanas by a combination of several scale features, including four rows of scales between prefrontals and frontals, three rows of loreals, and eight supercilliaris (Schwartz and Carey 1977). As in San Salvador iguanas, the caudal verticils in Acklins iguanas are not as enlarged as in White Cay iguanas and the enlarged postsacral scales form a shorter row. In addition, recent data suggest that the Acklins iguana has significantly more femoral pores than the other two subspecies (W. Hayes and R. Carter, unpublished data). Like the other subspecies of *C. rileyi*, adult Acklins iguanas are strikingly handsome, resembling San Salvador iguanas with orange/yellow highlights on a darker gray to brown background. Juveniles are also similar to those of young San Salvador iguanas.

Distribution

Natural populations of Acklins iguanas are found only on Fish Cay and North Cay in the Acklins Bight, Bahamas. They formerly occurred on at least Long (Fortune) Cay, and probably once roamed other cays in the vicinity, including the much larger Crooked and Acklins Islands. An additional introduced population with five founding individuals became established on a small cay in the early 1970s.

Status of populations in the wild

The two remaining populations in the Acklins Bight appeared to be reasonably healthy when visited by D. Blair in 1991 (Blair 1992a). All size classes were well represented on Fish Cay, but fewer juveniles were seen on North Cay. In May, 1997, R. Carter and W. Hayes estimated iguana populations on North and Fish Cays to be approximately 3,000 and 10,000 individuals, respectively. R. Ehrig and R. Montanucci visited the introduced population in 1993. They esti-

mated 140 to 180 individuals present on the cay, presumably all descendents of five founder animals from the Acklins Bight (S. Buckner, personal communication). By 1997, the introduced population was assessed by R. Carter and W. Hayes to consist of 300 individuals. The total population is currently estimated at 13,000 or more iguanas.

Ecology and natural history

Only anecdotal information on the natural history of this subspecies is available. Like other rock iguanas, male Acklins iguanas appear to be highly territorial. Males have been observed in jousting matches involving open-mouthed territorial displays, and will chase other males out of defended areas. Scars in the form of bite marks have been observed which probably result from these activities.

Habitat

Habitat on Fish and North Cays has not been adequately evaluated. The introduced population is probably at or near carrying capacity. Vegetation on this cay appears to be in excellent condition as determined by R. Moyroud.

Threats

No evidence of feral animals or other threats have been identified in the Acklins Bight populations. Introduced hutia (*Geocapromys ingrahami*) may be affecting the vegetation on the cay adjacent to that harboring the introduced population, although they have not yet crossed the channel separating the two cays. Further, with only five founder animals, genetic heterozygosity of this population may be compromised. On all cays, the potential for illegal poaching remains a threat.

Current conservation programs

W. Hayes and R. Carter are currently evaluating body size and genetic relationships among the three populations. They visited the Acklins Bight in 1996, as well as the introduced population, in order to obtain blood samples and measurements from the iguanas and to evaluate their status.

Critical conservation initiatives

- Acquisition of North and Fish Cays as a park by the Bahamas National Trust. Both islands will need to be purchased, as they are privately owned.
- Institutional strengthening of responsible agencies to develop enforcement capabilities.
- Initiation of a national education program.

Priority projects

- 1) Accurately census the three extant populations to determine population size.
- 2) Assess current threats to each population. Should they become a problem, introduced hutia will need to be controlled.
- 3) Explore the potential for restocking vacant cays in the Acklins Bight with iguanas.
- 4) Conduct genetic studies similar those being carried out for the San Salvador iguana. In particular, the introduced population should be examined.

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Lesser Antillean iguana *Iguana delicatissima*

By Mark Day, Michel Breuil,
and Steve Reichling

Description

The Lesser Antillean iguana attains a smaller overall size than its only congener the common iguana (*I. iguana*), with males reaching 430mm SVL (3.5kg) and females 390mm SVL (2.6kg, gravid). Lesser Antillean iguanas are relatively stout, and in combination with body color and some convergent behavior, bear a superficial resemblance to rock iguanas. The Lesser Antillean iguana can be readily distinguished at any age from the common iguana by the absence of an enlarged subtympanic plate. The two species can also be distinguished by dark barring on the tail of common iguanas, absent on the tail of Lesser Antillean iguanas. The only exceptions are hybrids found on Les Iles des Saintes and Basse Terre, Guadeloupe. The genus *Iguana* is distinguished morphologically from *Cyclura* by the presence of gular spikes on the dewlap, and its continuous dorsal crest, which in *Cyclura* is divided into distinct nuchal, dorsal, and caudal regions.

Adult Lesser Antillean iguanas exhibit sexual dimorphism in a number of characters. Males possess enlarged dorsal crest scales, especially in the nuchal region, enlarged gular spikes on the dewlap, and greater development of the occipital scales. All dimorphic features give an exaggerated lateral profile which is accentuated fully during territorial disputes. In dominant males, both body and tail are dark gray. When males become reproductively active, the jowls flush pink and the fleshy occipital scales develop a pale blue color. Observations of captive individuals indicate that when two males are kept together as part of a group, one will become dominant. If the dominant male is later removed, the subordinate male will then acquire the dimorphic and dichromatic characteristics typical of dominance. Sexual dichromatism is distinct in the more mesic southern part of the species' range, but is much less pronounced in the xeric subpopulations on limestone islands where large females

eventually develop an overall gray color.

Hatchlings and juveniles are bright green. White flashes on the jaws and shoulders are linked, and these together with usually three vertical white bars on the flanks form disruptive coloration. Dorsal chevrons of juveniles darken in response to stress and improve camouflage, and as a result body color ranges from green to green with brown flashes. Ontogenetic changes result in the gradual loss of white flashes, and a significant reduction in color change ability. Head coloration lightens until both sexes have pale heads and uniform green bodies. Early in development, the tail begins to turn brown at the tip and becomes progressively darker rostrally.

No subspecies are recognized. Analysis of geographic variation using multivariate statistical and molecular genetic techniques is ongoing. Preliminary results indicate a low level of geographic variation, but patterns that correlate with island banks.

Distribution

Unless indicated, populations refer only to main islands, and do not imply additional offshore populations on islets (Fig. 9).

- 1) Anguilla
- 2) St. Martin
- 3) St. Eustatius
- 4) St. Barthelemy, including Ilet au Vent, east of Ile Fourchue
- 5) Antigua
- 6) Guadeloupe, including Basse Terre, La Désirade, Iles de la Petite Terre, and Les Iles des Saintes (possibly extinct)
- 7) Commonwealth of Dominica
- 8) Martinique, including Ilet Chancel

Historically, this species is believed to have existed throughout the northern Lesser Antilles, from Anguilla to Martinique, from sea level up to 300m, in xeric scrub, dry scrub woodland, littoral woodland, and lower altitude portions of transitional rainforest.

Status of populations in the wild

Insufficient data currently prevent accurate estimation of population size for the Lesser Antillean iguana. Formal surveys using standardized transect techniques have only been conducted for Ilet Chancel (population estimate 200-300) and Terre de Bas (Les Iles de la Petite Terre, population estimate 4,000-6,000). Rough population estimates for the remaining islands are based on limited surveys designed predominantly to locate iguanas for morphometric and genetic data collection. These population estimates are based subjectively on comparisons of observed density of iguanas and the extent of their range within each island. In qualitative terms, the

Commonwealth of Dominica is believed to support the largest single population due to the extent of available coastal habitat and known distribution, while Les Iles de la Petite Terre support the highest population density. However, many populations have been reduced to extremely low levels in very limited areas such that their long-term viability is questionable.

Les Iles de la Petite Terre represent the only stable population throughout the species' range. In La Desirade and the Commonwealth of Dominica where populations are sizeable, there are localized decreases as a result of habitat loss and hunting, but at present these pressures affect a small percentage of the range within each island. In all other cases, populations are believed to be decreasing due to a combination of habitat loss and fragmentation, introduced predators, browsing competitors, or hybridization with common iguanas. Museum specimens and publications indicate that Lesser Antillean iguanas existed historically on Barbuda, Grande Terre (Guadeloupe), Ile Fourchue, Ile Frégate and Ile Chevreau (St. Barthélemy), Marie Galante, Nevis, and St. Kitts, although precise extinction dates are unknown.

Overall population status appears Vulnerable at present due to an estimated population decline of greater than 10% per generation for the last two generations and the fact that only two populations exceed 5,000 individuals. Populations are critical on Antigua, Anguilla, Ilet au Vent, Les Iles des Saintes, St. Eustatius, and St. Martin. Populations on Basse Terre, Ilet Chancel, Martinique, and St. Barthelemy are endangered, estimated at between 250 and 2,500 individuals. Although populations are somewhat larger on Dominica, Iles de la Petite Terre, and La Desirade, they are still considered vulnerable due to habitat alteration and/or the threat of introduction of common iguanas.

Ecology and natural history

The Lesser Antillean iguana occupies islands of the northern Lesser Antilles from sea level to approximately 300m elevation, and appears to be limited by thermal requirements. The species exists in xeric scrub, dry scrub woodland, littoral woodland, and mangrove, as well as lower altitude portions of transitional rainforest. The condition of these habitats varies from island to island, with Lesser Antillean iguanas able to survive in extremely xeric degraded habitats (< 1,000mm annual rainfall) to mesic forests (3,000 to 4,000mm annual rainfall), in the absence of introduced predators or competitors.

Upon emergence from nests, hatchlings disperse into surrounding vegetation. Both hatchlings and juveniles live predominantly among bushes and low trees, usually in thick vegetation offering protection,

basking sites, and a wide range of food. With age, they climb higher and utilize larger trees. Sexual maturity appears to be reached at approximately three years, although breeding in males is unlikely to begin at this time due to inability to achieve dominance and defend a suitable territory.

Longevity studies have yet to be conducted, but reliable observations of a population acclimated to humans include individuals at least 15 years old. Natural predators of juveniles include snakes (*Alsophis* spp., *Boa constrictor nebulosa*), birds (*Buteo* spp., *Falco sparverius*), and possibly opossums (*Didelphis marsupialis*). Teiid lizards (*Ameiva fuscata*) have been observed predating eggs from nests, although it is unclear if they actively dig to expose them. No known natural predators of adult iguanas have been identified.

The Lesser Antillean iguana is a generalist herbivore, feeding primarily in the morning, with a diet that includes leaves, flowers, and fruits of a wide range of shrubs and trees including *Capparis*, *Eugenia*, *Hippomane*, *Ipomea*, *Opuntia*, *Solanum*, and *Tabebuia*. *Hippomane* possesses toxic compounds that render it unpalatable to birds and mammals, but do not appear to affect iguanas. Seasonal variation in feeding ecology exists, with folivory during the dry season shifting to florivory and frugivory during the wet season. Feeding is selective with fresh leaf growth, flower buds, and ripe fruits preferred. Seed dispersal by iguanas may be significant for a number of coastal forest plant species, especially those with large or unpalatable fruits which are not dispersed by small birds or bats. Differences between populations in feeding ecology exist, reflecting local variation in plant species composition (either natural or as a result of introduced browsers). Like its congener the common iguana, the Lesser Antillean iguana has been observed by some to be opportunistically carnivorous (Lazell 1973).

Adult males actively defend small territories, at least during the reproductive period. Most territorial defense consists of headbobbing and laterally compressed profile displays. When in close proximity, side-walking displays give way to head-to-head pushing contests accompanied by arching of the tail. Fighting occurs infrequently, although severe head, limb, and crest damage has been recorded. Courtship is limited and mating is typical of other large iguanids. The Lesser Antillean iguana exhibits a polygynous mating system, with male/female sex ratios ranging from 1:1 to 1:7. Adult females occupy larger home ranges than adult males, and do not defend them. Female home ranges overlap other females and sometimes multiple males. Anecdotal observations suggest a hierarchical structure among females associated

with a dominant male. In the wet season, groups of individuals converge upon certain fruiting trees, or those with fresh leaves. In these cases, juveniles of both sexes feed communally, whereas adults feed together only if a single dominant male is present.

Reproduction is timed to maximize hatchlings' ability to feed on nutritionally-rich wet season plant growth and grow rapidly prior to the onset of the dry season. In xeric habitats where seasonal conditions are most marked, reproduction appears to be roughly synchronous (e.g., Petite Terre), whereas more mesic populations are much less synchronous (e.g., in the Commonwealth of Dominica, gravid females can be found from February to August). The breeding season is so prolonged in the Commonwealth of Dominica that more than one clutch per year may be possible. Females migrate to nesting sites outside their normal home range, travelling a mean distance of 460m, up to a known maximum of 900m. As migrating females often pass other active nest sites, natal homing may occur in this species. Nest sites occur in sandy, well-drained soil exposed to prolonged sunlight, with simple 1m long excavated tunnels ending in a chamber sufficient for the female to turn around. Clutch size, which may vary geographically, ranges from 8-18 (mean egg mass 25g), and is strongly correlated with female size. Anecdotal evidence suggests an incubation period of approximately three months.

As Lesser Antillean iguanas occur in several different habitats with variable environmental conditions, differences between populations in ecology and natural history exist. In particular, xeric conditions are associated with low-lying coralline limestone islands whereas more mesic conditions occur on mountainous volcanic islands. Xeric scrub is structurally less complex and reaches a lower canopy height than dry scrub or littoral woodland. In these habitats, iguanas exhibit terrestriality frequently, and will readily drop to the ground to escape if disturbed. Terrestrial refugia between rocks or in limestone caverns are used for both escape and sleeping. In more mesic habitats, iguanas are almost exclusively arboreal, feeding in tree crowns 30m or more above the ground and moving by jumping between tree crowns.

Habitat

Due to extensive habitat alteration, particularly since European colonization, for agriculture, timber extraction, and housing, little to no coastal habitat remains in its primary state in the Lesser Antilles. The only possible exception is the proposed Reserve Biologique Dominiale de la Montagne Pelée in Martinique. Nevertheless, rapid natural regeneration is characteristic of hurricane-adapted vegetation, such that significant areas of habitat capable of supporting

iguanas still exist. Localized clearance or disturbance of land for timber extraction or charcoal production may result in initial displacement of iguanas, with subsequent recolonization accompanying recovery of the vegetation. Lesser Antillean iguanas cannot tolerate large scale clearance. Continuous degradation by free-ranging goats and other herbivores has a slow but serious effect due to the shift in species composition towards a high proportion of plants which are either toxic or unpalatable (*Croton*, *Lantana*, *Agave*). Areas subjected to browsing pressure support significantly lower iguana populations than comparable habitats which are free of introduced browsers.

Suitable habitat is currently shrinking, mostly due to development. Exclusion or removal of introduced predators and/or herbivores as part of an ecological restoration program would permit a significant increase in the amount of habitat available. Les Iles de la Petite Terre now support the highest known population density of Lesser Antillean iguanas despite the fact that the islands experienced extensive cultivation and grazing until the early 1960s.

Threats

Habitat loss and fragmentation were historically most extensive on the least mountainous islands, which have been systematically cleared for agriculture, especially sugarcane. On these islands, the Lesser Antillean iguana has either become extinct (e.g., St. Kitts, Nevis) or remains only in tiny remnant populations (e.g., Basse Terre, St. Eustatius). As tourism has superseded agriculture in importance, coastal development has further reduced the remaining habitat and significantly affected already-limited communal nest sites.

Lesser Antillean iguanas are impacted by a range of introduced predators. Feral and house cats are believed to be significant predators of juvenile iguanas on Anguilla. On St. Barthelemy, feral predators are few, but adult iguanas are known to be killed by guard dogs that run free within fenced property compounds where iguanas move to feed. Indian mongooses (*Herpestes javanicus* [= *auropunctatus*]) were introduced to many islands with the intention of eradicating rats and snakes. Hatchlings and juveniles fall within the prey range of mongooses, and on all islands where mongooses occur, the Lesser Antillean iguana is either extinct or highly threatened. However, it is unclear how significant the impact of the mongoose is compared to other factors.

Free-ranging and feral browsing competitors exist alongside almost all iguana populations, with the notable exceptions of Iles de la Petite Terre and most of the Commonwealth of Dominica. Goat and sheep populations are particularly large, and of most con-

cern on Anguilla, Ilet Chancel, La Desirade, and St. Eustatius, where extensive overbrowsing continues to cause a shift in plant species composition and habitat structure. Lazell (1973) reported that "huge colonies swarm on the Ile Fourchue, Les Iles Fregate, and the Ile Chevreau, or Bonhomme." Subsequently, massive overbrowsing by introduced goats in combination with a series of droughts resulted in the extinction of these St. Barthélemy offshore populations by the early 1990s.

Historically, hunting occurred throughout the range of the Lesser Antillean iguana since the time of the Amerindians. Hunting is now illegal throughout the species' range. However, St. Eustatius has recently experienced dramatic rises in iguana hunting, causing a crash in the population. Increased hunting was linked to the influx of construction workers for the expansion of oil storage facilities on the island, and economic problems caused by changes in European Community regulations. Despite recent local legislation, iguana meat continues to be sold locally and transported to restaurants in nearby St. Martin. Hunting also remains locally prevalent in parts of the Commonwealth of Dominica, where certain populations have experienced rapid unsustainable exploitation.

Hybridization between Lesser Antillean iguanas and common iguanas has now been confirmed through both molecular genetic and morphometric analyses from samples taken in Basse Terre (Guadeloupe) and Les Iles des Saintes. The process appears to occur rapidly. In Les Saintes, Lazell (1973) estimated qualitatively that the two species were equally abundant in the 1960s, and concluded that they occurred sympatrically. Morphometric analysis of specimens collected at that time by Lazell show that in fact hybridization was already progressing. By 1995, less than 10 individuals recognizable as Lesser Antillean iguanas could be located, all of which exhibited intermediate species characteristics. In contrast, the common iguana remains extremely abundant and has extended its range within the archipelago. Invasive displacement through competition and hybridization appears to be the dominant factor in the disappearance of Lesser Antillean iguanas from Les Iles des Saintes, due to the absence of other identifiable environmental changes. The same situation has been documented in Basse Terre (Guadeloupe) and St. Barthelemy, although in both cases it is less advanced. Deliberate introduction and subsequent expansion of common iguanas in Antigua, Martinique, and St. Martin have also been recorded. At present, these are not known to have led to hybridization in Antigua and Martinique, where the two species' distributions remain discrete. In St.

Martin, the situation is unclear. Hybridization and aggressive displacement of Lesser Antillean iguanas by common iguanas should be considered potentially serious threats to all remaining populations. In 1995, as a result of Hurricane Luis, at least 12 common iguanas believed to have originated from the Guadeloupe Bank washed up in Antigua, Barbuda, and Anguilla, although most either subsequently died or were killed for food. Nevertheless, this demonstrates that overwater dispersal of iguanas between different islands banks may occur.

Road casualties occur regularly along coastal roads which bisect iguana habitat in the Commonwealth of Dominica, Basse Terre (Guadeloupe), La Desirade, and St. Barthelemy. In the Commonwealth of Dominica, casualties peak late in the dry season when numerous gravid females are killed while migrating to coastal nest sites and early in the wet season when hatchlings disperse from nests.

Current conservation programs

The Lesser Antillean iguana is legally protected from hunting throughout its range, but enforcement of these regulations is extremely difficult and therefore limited. Currently, only a single protected area, the Cabrits National Park (Commonwealth of Dominica) contains a small population. Five additional areas, Les Iles de la Petite Terre (Guadeloupe), the Quill and the Boven (St. Eustatius), and Ilet Chancel and the Reserve Biologique Domaniale de la Montagne Pelée (Martinique), are presently proposed as nature reserves which will protect Lesser Antillean iguanas. Additionally, a number of satellite islets around Anguilla, Antigua, Guadeloupe, Martinique, and St. Barthelemy offer significant potential as protected areas. Following suitable legislative protection and ecological restoration, a number of additional islands would be feasible for translocation or reintroduction.

M. Day is undertaking doctoral research (University of Aberdeen and University College of North Wales) on the population biology of iguanas throughout the Lesser Antilles. Aspects of the research include geographic variation using molecular genetic and multivariate statistical techniques, hybridization, home range and habitat use, diet, and ectoparasites. M. Breuil is undertaking ecological research on both species in Guadeloupe, Martinique, St. Barthelemy, and St. Martin. In collaboration with Association pour l'Etude et la Protection des Vertébrés des Petites Antilles, he has begun surveys of the proposed nature reserves within the French West Indies, and is gathering data required for development of a conservation management plan for the proposed protected areas in Guadeloupe and Martinique. A. Alberts is conducting research on variability in the

protein composition of femoral gland secretions of Lesser Antillean iguanas and common iguanas at the interpopulation level.

Captive Lesser Antillean iguanas are currently held at the Durrell Wildlife Conservation Trust (1.1.1), Memphis Zoo (2.2), and the San Diego Zoo's Center for Reproduction of Endangered Species (1.1). All individuals originate from the Commonwealth of Dominica. Mating has been observed and eggs laid at each institution. Although most eggs have been infertile or non-viable, a single individual was successfully hatched at the Durrell Wildlife Conservation Trust in 1997. As the Dominican population is presently healthy, these individuals and their future offspring should remain in captivity in order to gather husbandry expertise, as well as growth and reproductive data. The long term aim is to gain captive breeding expertise which can then be applied *in situ*. Captive-bred individuals could be used for reintroduction to offshore islands and other protected areas known to have supported Lesser Antillean iguanas historically, or for restocking depleted populations. Due to considerations of geographic variation, reintroduction should utilize iguanas from the same population or island bank whenever possible.

Critical conservation initiatives

- Implementation of protected areas management plans for designated nature reserves on les Iles de la Petite Terre, Ilet Chancel, and Reserve Biologique Domaniale de la Montagne Pelée.
- Identification and development of protected areas at key sites on major islands which remain, or have the potential to be restored to, important habitat for Lesser Antillean iguanas.
- Development of an inter-governmental agreement, including production of accompanying publicity materials for airports and ports, to reduce or prevent further introduction of common iguanas onto islands supporting Lesser Antillean iguanas.
- Development of a species conservation plan for the Lesser Antillean iguana which would result in the coordinated implementation of both regional and national conservation initiatives. The plan would incorporate, but not be limited to, the priority projects outlined below.

Priority projects

1) Implement a series of comprehensive population surveys for all populations. The first of these was undertaken in Anguilla in 1997, with support from the

U.K. Foreign and Commonwealth Office.

2) Assess the potential of additional satellite islands to become protected areas for maintaining or establishing populations of the Lesser Antillean iguana through reintroduction and/or habitat restoration (Anguilla, Antigua, Guadeloupe, Martinique, St. Barthelemy, St. Martin).

3) Carry out a long-term ecological study of the xeric adapted Lesser Antillean iguana population on les Iles de la Petite Terre, which, because it is free from ongoing habitat destruction, feral predators, and competitors, represents the most dense and least threatened remaining population.

4) Develop regional and national education programs for schools, other residents, and visitors, utilizing a broad range of media to illustrate the plight of the Lesser Antillean iguana and its importance to forest ecosystems. National (Breuil, in press) and regional (Malhotra and Thorpe, in press) herpetological guides can assist in these efforts.

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Fig. 9. Present distribution of the Lesser Antillean iguana, indicating the island distribution (but not the distribution on each island) as of March, 1999.

Chapter 3. Action Plan

Summary of Recommendations

Priorities for recommended conservation action on behalf of West Indian iguanas are summarized in Table 5. In the subsections that follow, specific guidelines for implementation are outlined. For the majority of taxa, further survey work is required in order to design effective management and recovery plans. For some taxa, existing data are outdated, while for others only a limited part of the range has been adequately documented. In other cases, populations are known to be declining, but quantitative data on rates of population change and their demographic effects are lacking. For all taxa, population monitoring in the form of standardized annual or biannual surveys is critical to updating conservation priorities and to detecting population declines before they have significant demographic impacts and while management intervention is still a viable option.

Many West Indian iguanas remain without adequate protection, either because no habitat has officially been set aside for them or because existing legislation is only sporadically enforced. To insure the survival of all taxa, at least enough suitable habitat to support a minimum viable population should be protected by national law in each country of origin. Because the biology of these iguanas varies considerably across taxa, particularly in terms of social structure and reproductive ecology, as does the carrying capacity of the islands they inhabit, the amount of habitat required for adequate protection will need to be determined on a taxon-by-taxon basis.

Control of introduced mammalian predators and livestock removal are two activities which are crucial to the survival of many West Indian iguanas. For almost all taxa inhabiting larger islands, dogs and cats are having devastating consequences, particularly for juveniles. The recent introduction of black rats to several iguana-inhabited cays in the Bahamas is also cause for great concern. Because these iguanas have evolved in the absence of mammalian predators, they have no natural defenses against them and population declines can occur with alarming rapidity. On at least some islands, browsing by feral livestock has radically affected the vegetation structure and altered the diversity and palatability of food plants available to iguanas. In addition, trampling of nest and burrow sites by livestock is a serious problem.

Basic research is critical to many if not all of the proposed conservation initiatives for West Indian iguanas. In order to conserve and potentially augment

wild populations, it is necessary to have enough life history data from wild populations to predict the long-term effects of management strategies before they are implemented. Such data are critical to assessing the carrying capacity of proposed reserve sites, and to determining if and when reintroduction or translocation is warranted and feasible. Population modeling, particularly to estimate minimum viable population sizes and to explore the effects of headstarting, is crucial to designing practical conservation strategies that will have a high probability of success. Behavioral studies are needed to understand the conservation implications of variation across populations and to assess the influence of human impacts. Finally, a complete study of phylogenetic relationships among West Indian iguanas, including both molecular genetic and morphological data, is a necessary beginning in order to adequately rank priority projects and conservation initiatives. The availability of such data will contribute toward a better understanding of adaptive trends within the group and permit informed extrapolations from one taxon to another to be made.

For virtually all taxa of West Indian iguanas, public education is essential. Without effective education at the local, national, and international levels, other conservation initiatives are likely to prove futile. For West Indian iguanas, educational needs range from discouraging people from feeding, hunting, and transporting iguanas between islands, to inspiring local and national pride for these impressive lizards and their unique habitats. Raising public awareness regarding the vulnerability of iguanas to dogs, cats, pigs, and livestock is critical to preventing their intentional introduction to new islands.

Captive breeding programs are recommended for five of the West Indian iguanas ranked as Critically Endangered. Because these taxa have experienced significant population reductions, documented low population size or a severely restricted range, or an extinction probability of at least 20% within five generations, a captive reservoir is imperative as insurance in the event of extinction in the wild. While such programs have already been undertaken for two Critically Endangered taxa (Jamaican and Grand Cayman iguanas) and are in the planning stages for a third (Ricord's iguana), they still need to be implemented for two others. A captive program to gain husbandry expertise has also been recommended for the Lesser Antillean iguana. For those taxa for which reduced juvenile recruitment due to unnatural causes is known to be a severe threat to survival of the wild population (Jamaican, Grand Cayman, and Anegada iguanas),

headstarting programs, in conjunction with rigorous predator control, are recommended as an interim measure to allow for population recovery.

Priority Projects

Based on the degree of endangerment, immediacy of need, taxonomic uniqueness, feasibility, and applicability of results to other taxa, the following list of projects requiring immediate action has been developed. In the absence of these activities, extinction may be imminent. Additional high priority projects essential to long-term population viability or the assessment of such are listed within individual taxon accounts. Each of these projects is critical to the survival of the taxon in question and should be initiated as soon as possible.

Each of the projects below is coded to indicate the groups which would probably take primary responsibility for the recommended actions (1 = Government Agencies, 2 = Non-Governmental Organizations, 3 = Protected Area Managers, 4 = Professional Researchers, 5 = Local Communities). However, for any given project, ideally all of the above groups would be active participants. Cost estimates are available on request. Projects that are currently underway are denoted by †.

- Management of the wild population of the Anegada iguana, including feral animal control, headstarting, and public education (2,4,5) †
- Protection of the Hellshire Hills and extended management of the wild population of the Jamaican iguana, including release of headstarted individuals and control of invasive predators (1,2,4,5) †
- Protected area planning and habitat acquisition adjacent to present protected areas for the Grand Cayman iguana (1,2,5)
- Maintenance of the Hope Zoo headstart and captive breeding program for the Jamaican iguana (1,2,4) †
- Initiation of control programs for cats and rats on Grand Cayman, Little Cayman, and Cayman Brac (1,2,4)
- Rat eradication on islands supporting San Salvador iguanas and continued monitoring of the White Cay population (1,2,4) †
- Replacement and extension of pig and goat enclosure fences at nest sites of the Mona Island iguana (1,2,3) †
- Mitigation of the Big Ambergris Cay development, including the establishment of a reintroduction program for the Turks and Caicos iguana (1,2,4)
- Implementation of a long-term field monitoring program for wild and released Grand Cayman iguanas (2,4,5) †
- Field surveys and ecological studies of Ricord's iguana in the wild, including cat control on Isla Cabritos in Lago Enriquillo (1,2,3,4)
- Genetic and taxonomic studies of West Indian iguanas, especially populations in immediate danger of extinction (4) †
- Feasibility studies for establishing satellite populations of the Jamaican iguana (1,2,4,5)
- Enhancement of captive facilities and population surveys for the St. Lucia iguana (1,2,4)
- Development of a feral animal control program for the Turks and Caicos iguana (2,4)
- Establishment of protected areas to conserve the Lesser Antillean iguana in Anguilla, including feral predator and livestock control programs (1,2,4,5)
- Establishment of satellite populations of the White Cay iguana on suitable restored cays (1,2,4,5)
- Goat removal, rat eradication, and monitoring of the population of Bartsch's iguana on Booby Cay (1,2,4,5) †
- Field surveys to determine population status, range, and extent of poaching of the Andros Island iguana (1,2,4) †
- Implementation of a model public awareness and environmental education program using the Lesser Antillean iguana as a flagship species for dry forest conservation (1,2,4,5)
- Initiation of a cat control program for Mona Island (1,2,3)

Table 5. Summary of Recommended Conservation Action for *Cyclura* and *Iguana*.

Taxon	Surveys	Protected areas	Predator control	Livestock control	Field research	Genetic studies	Education	Captive Breeding/ Headstarting
Turks and Caicos iguana	•	•	•	•	•	•	•	
Bartsch's iguana	•	•		•	•	•	•	•
Jamaican iguana		•	•	•	•		•	•
Rhinoceros iguana	•		•	•	•		•	
Mona Island iguana		•	•	•			•	
Andros Island iguana	•				•		•	
Exuma Island iguana	•	•			•	•	•	
Allen's Cay iguana					•		•	
Cuban iguana	•				•			
Lesser Caymans iguana	•	•	•		•	•		
Grand Cayman iguana		•	•		•			•
Anegada Island iguana	•	•	•	•	•	•	•	•
Ricord's iguana	•	•	•		•		•	•
San Salvador iguana	•	•	•		•	•	•	
White Cay iguana	•	•	•		•	•	•	
Acklins iguana	•	•				•	•	
Lesser Antillean iguana	•	•		•	•	•	•	•

Reintroduction Guidelines

By Richard Hudson

Relocation, repatriation, and translocation (RRT) programs involving reptiles have become an extremely popular conservation strategy to mitigate the loss of habitat, individuals, or populations in areas that have experienced declines or extirpations (Dodd and Seigel 1991). However, few reptile RRT programs have been successful or properly monitored to determine success or failure. Some notable exceptions include the introduction of captive-reared gharials, *Gavialis gangeticus*, to areas where they had been reduced or eliminated (Choudhury and Choudhury, 1986); the release of over 600 headstarted Orinoco crocodiles, *Crocodylus intermedius*, in Venezuela (Thorbjarnarson, 1997); the restoration of Galapagos land iguanas, *Conolophus subcristatus*, and Galapagos tortoises, *Geochelone elephantopus*, to areas of former abundance (Cayot et al 1994); and the reintroduction of Anegada iguanas to part of their former range (Goodyear and Lazell 1994). Preliminary observations by Tolson (1996) indicate a successful restocking of Virgin Islands tree boas, *Epicrates monensis granti*, to an island rendered free of introduced predators, and J. Behler (personal communication) reports successful reintroduction of a group of 76 Gopher tortoises, *Gopherus polyphemus*, to St. Catherine's Island, Georgia. While representatives from most reptilian orders have been successfully repatriated

with encouraging results, the outcomes of other well-publicized headstart/release efforts, [e.g. Kemp's ridley, *Lepidochelys kempi*, and other sea turtles (Jacobsen 1993; Bowen et al., 1994) and the Puerto Rican crested toad, *Peltophryne lemur* (Johnson 1994)], have proved difficult to monitor and remain questionable.

While various authors disagree as to what constitutes a successful reintroduction (Burke 1991), it is clear that the fledgling science of conservation biology, including restoration ecology and RRT, cannot stand still while these issues are rectified. Given the enormous loss of biodiversity today, wildlife managers need to be willing to consider RRT programs as viable strategies to combat the impending extinction crisis. Although by no means a panacea, RRT programs should be considered an option in any recovery effort (Burke 1991). However, the technology needs to be refined and improved if these programs are to become widely utilized. The methodology and results of both successful and unsuccessful RRT experiments need to be presented in detail to ensure that future efforts benefit from past experience (Dodd and Seigel 1991).

For West Indian iguanas, it is apparent that at least three taxa, the Jamaican iguana, the Anegada iguana, and the Grand Cayman iguana, will require assistance from captive headstart/release programs if their wild populations are to recover and survive into the future. Both taxa have been reduced to critically low numbers and, given current circumstances and rates of decline,

appear headed for extinction unless immediate action is taken.

General Concerns

Conservation biology has been described as a crisis science (Soulé 1985) and as such may not always be subject to the same statistical standards as other scientific fields (Burke 1991). Likewise RRT programs, an integral part of conservation biology, are in the experimental stages. Unfortunately, for some taxa the need to undertake active recovery strategies, including RRT programs, is urgent and little time remains for experimentation. There are few tested standards on which to rely, but this alone must not thwart well-conceived RRT plans. Bold actions, though exercised with due caution, must be taken within the next several decades if several of the more highly endangered large iguanas are to be preserved. Throughout this process, establishment of feedback loops to alter decisions based on new and changing data is critical.

Dodd and Seigel (1991) have addressed a number of topics that should be considered prior to advocating or undertaking RRT projects, including known causes of decline; biological, habitat, demographic, and biophysical constraints; population genetics and social structure; and disease transmission. Reinert (1991) has expressed concern regarding genetic as well as social considerations, citing examples of aberrant behaviors in translocated snakes. Burke (1991) questions whether RRT programs are cost effective for improving species survival, and both Reinert (1991) and Dodd and Seigel (1991) stress the importance of long-term monitoring to ascertain success. Prior to any reintroduction, the original threats to the population must be understood and potentially controlled.

The potential to introduce exotic pathogens into naive natural populations through release of captive reptiles is widely recognized. This route of transmission has been implicated in an epizootic outbreak of upper respiratory tract disease (URTD) in wild desert tortoises, *Gopherus agassizii*, in the Mojave Desert of California (Jacobsen et al. 1991). Jacobsen (1993, 1994) stresses that while reptiles can harbor an array of pathogens, the ability to screen for those few that are known to be significant is crude at best. The importance of developing pre-release health screening protocols and methods has been emphasized by a number of workers (Beck 1992; Dodd and Seigel 1991; Jacobsen 1994; Raphael 1994). Whenever feasible, *in situ* rearing and headstarting facilities are preferable to reduce the chances of introduction of exotic pathogens.

One of the factors that can inhibit the success of RRT programs is the potential inability of the progeny of captive populations to withstand the rigors of

natural environments (Murphy and Chiszar 1989). Chiszar et al. (1994) defined competent offspring as those possessing the behavioral, anatomical, and physiological characteristics necessary for survival in natural habitats. The ability of captive-raised animals to find food and mates, avoid predation, locate refugia, and select appropriate microhabitats once released should be investigated (Chiszar et al. 1993). At least in part, deficits in competence may account for the lower success rate of reintroductions involving captive-born rather than wild specimens (Griffith et al. 1989). Stressing that factors such as strength, endurance, and immunological function are crucial to the success or failure of RRT programs, Murphy and Chiszar (1989) strongly advocate research that rigorously assesses competence. In some cases, releasing larger numbers of animals can at least partially compensate for reduced fitness and/or competence of captive-reared specimens (B. Johnson, personal communication).

Although it is commonly assumed that natural behaviors are innate in amphibians and reptiles and therefore present in healthy specimens regardless of rearing history, no research exists verifying that effective coping skills exist in captive-raised individuals (Chiszar et al. 1993). However, it appears that certain species of reptiles can, in the absence of any pre-release training, adapt, survive, and even reproduce following release into natural habitat. A recent example is the monitored release of captive Virgin Islands tree boas onto Cayo Ratones (Tolson 1996). More than half of the released snakes survived their first year, and at least four of these were neonates. One female released as an adult was recently recaptured gravid.

Several recent conservation programs for iguanas in the Galapagos and West Indies suggest that large iguanid lizards may be genetically hard-wired for many critical natural behaviors and should be considered viable candidates for reintroduction and population supplementation.

1) The release of 710 Galapagos land iguanas into the wild over a 10-year period was initiated in 1976 following the near extirpation of populations on Isabella and Santa Cruz by wild dogs (Cayot et al. 1994). A third island, Baltra, had not supported iguanas since World War II. The majority of repatriated iguanas were captive-bred from adults collected from declining populations and reared under captive and semi-captive conditions. The Baltra breeding stock was taken from a previously relocated population experiencing poor recruitment. The success of this program has been impressive, with nearly 400 juveniles and 21 adults repatriated on Isabella since 1982. Annual

monitoring indicates a growing population. In 1991-92, 59 5-year old iguanas were established on Baltra, the first to have existed there in over 40 years. The success of these programs is encouraging and is closely linked to active predator control efforts. Dogs were eradicated prior to releasing iguanas, and cats are poisoned semi-annually (Cayot et al 1994).

2) The reintroduction of a group of wild-caught Anegada Island iguanas to Guana Island in the British Virgin Islands has resulted in the successful establishment of a second population reservoir for this endangered lizard (Goodyear and Lazell 1994). Between 1984 and 1987, three males and five females, two of which were gravid, were released on Guana. One female apparently nested successfully, as subadults were subsequently seen in 1987 and are believed to represent some of the adults seen in 1991-92. A reproducing population is now established, and a 1992 census estimates that about 20 adults and several juveniles now inhabit the cay. Although still preliminary, these results bode well for re-establishing iguanas within their former range. As on the Galapagos, this project has entailed the elimination of feral cats.

3) In 1990, the National Trust for the Cayman Islands initiated an integrated conservation program for the highly endangered Grand Cayman iguana, with the long-term goal of securing wild, reproducing populations in protected areas without the need for constant human intervention. The program includes five components: field research, captive breeding, public education, habitat protection, and supplementation of the wild population. All components are now in progress, including the first releases, which have proved successful (Burton 1994b). Although no evidence was found of wild iguanas at the potential release site, the Salina Reserve, the area supports suitable habitat. The first three releases were captive-bred, sterilized hybrid males with internal radiotransmitters. The releases occurred in June and July 1993, and the lizards were tracked at regular intervals. Although one animal was killed by a dog outside the reserve, the remaining two individuals were still well established at the study site in December, 1993. These results are encouraging in that naive captive-bred iguanas demonstrated a surprising ability to adapt to life in the wild, locate food and retreats, and exhibit characteristic territorial behavior. These results indicate that captive-bred iguanas can be successfully re-established in the wild provided adequate protected habitat can be secured.

Criteria for RRT programs

According to the IUCN (1995), translocation is the deliberate and mediated movement of wild individuals



Cayman Islands National Trust iguana headstarting facility at the Queen Elizabeth II Botanic Park, Grand Cayman.

to an existing population of conspecifics. Reintroduction is an attempt to establish a species in an area that was once part of its historical range, but from which it has been extirpated or become extinct. Reinforcement/supplementation is the addition of individuals to an existing population of conspecifics. Conservation/benign introductions are attempts to establish a species outside its recorded distribution, but within an appropriate habitat and eco-geographical area. These latter introductions should be attempted only when there is no remaining area within a species' historical range and enhanced survival of the species will result. Although reintroduction is often used to describe the release of animals into presently occupied habitat, the term translocation may be more appropriate in such circumstances. Kleiman et al. (1984) emphasize that the origin of released animals (wild versus captive) may have a major impact on the potential success of translocation efforts. The Reintroduction Advisory Group of the American Zoo and Aquarium Association has prepared a comprehensive set of guidelines pertaining specifically to animals born or held in captivity (Beck 1992).

According to the Guidelines for Re-introductions provided by the IUCN/SSC Reintroduction Specialist Group (IUCN 1995), the objectives of reintroduction are to: a) enhance the long-term survival of a species, b) re-establish a keystone species (in the ecological or cultural sense) in an ecosystem, c) maintain and/or restore natural biodiversity, d) provide long-term economic benefits to local people and/or national economy, or e) promote conservation awareness. The success of any RRT effort should be measured in terms of its goals and objectives. In most cases, success is defined as a stable, self-sustaining, viable population at the reintroduction site (Kleiman et al 1984; Dodd and Seigel 1991). Burke (1991) discusses concerns

regarding the point at which a population can be called self-sustaining and how stability can be objectively determined.

Currently, recovery efforts are underway for two Critically Endangered West Indian iguanas, the Jamaican iguana and the Grand Cayman iguana. For both taxa, headstarting and supplementation of the wild population are among the primary goals, and preliminary releases have already been attempted.

The Cayman Islands National Trust program for the Grand Cayman iguana has multiple objectives, one of which is to generate sufficient offspring for release into suitable habitat. Unfortunately such habitat is becoming scarce on Grand Cayman, and feral predators are an increasing problem. Establishing a stable population on protected property is critical, and the proposed Salina Reserve site is promising in this regard. A Trust-owned property, the Queen Elizabeth II Botanic Park, is protected and may provide suitable iguana habitat as evidenced by the presence of a resident male over the past three years and a successful pilot release in 1994. Park development has improved habitat suitability in recent years, and the area lacks only nesting sites and associated retreats. It is hoped that the release of females within the park will attract roaming males, which usually maintain extensive home ranges, from outlying areas, thus providing a second area from which to repopulate other sites. While it is apparent that recovery of Grand Cayman iguanas will require a multi-faceted approach, reintroduction clearly constitutes a necessary component of this program.

A similar situation exists for the Jamaican iguana. Considered extinct for nearly half a century, the Jamaican iguana was rediscovered in 1990 and has since become the subject of intense conservation and research efforts. Existing only in the dry limestone

forests of the Hellshire Hills region of southeast Jamaica, a remnant population of perhaps 100 animals survives. Two active nesting sites were discovered in 1991, and field work has focused on protecting these sites and deterring hunters and charcoal burners from core iguana areas. High juvenile mortality associated with mongoose predation is widely recognized as the single most important factor keeping this population at low levels. A 1993 Population and Habitat Viability Assessment workshop indicated that without reducing juvenile mortality through headstarting, this small population was headed for extinction within 50 years. The recovery strategy includes guarding nests and harvesting 50% of the hatchlings for headstarting at the Hope Zoo in Kingston. Headstarted iguanas will be released after 4-5 years, when presumably they will be large enough to avoid mongoose predation. Control of feral dogs and mongooses will need to be implemented concurrently to increase survival of the released iguanas.

Pre-release considerations

In preparation for the eventual release of headstarted Jamaican iguanas into the wild, a pre-release medical screening protocol was developed in 1994 to assess the health status of the captive colony at the Hope Zoo. Cloacal cultures and fecal exams were conducted to screen for abnormal internal parasites and bacterial pathogens, and blood chemistry panels were performed to establish normal values. Attempts to sample the wild population in order to correlate captive values with those of free-ranging counterparts also need to be made. Similar health screening programs should be incorporated into pre-release preparations for any iguana species destined for release to the wild (Alberts et al., 1998). This is especially important if iguanas have been in captivity for a long period of time, or have lived in colonies that have experienced any health problems or disease. An Amphibian and Reptile Veterinary Advisory Committee, established under the American Zoo and Aquarium Association, has published recommended protocols for quarantine and pre-release health screening. This group is available to assist with this process, and information can be obtained from: Bonnie Raphael, D.V.M., Animal Health Center, Bronx Zoo/Wildlife Conservation Park, 2300 Southern Boulevard, Bronx, New York, 10460 U.S.A., Tel: (718) 220-7104.

Other forms of pre-release conditioning may be necessary as well. The original release strategy for Jamaican iguanas called for a hardening facility to be built in the Hellshire Hills for acclimating headstarted iguanas to wild forage and local conditions. Due to financial and logistical constraints, this idea was temporarily abandoned in order to assess the survival rate



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A group of headstarted iguanas at the Hope Zoo in Kingston, Jamaica.

of iguanas taken directly from the Zoo. After five years of headstarting, the first pair of iguanas was fitted with radiotransmitters and released at their hatch sites in March 1996. Experiences from 1995 had shown that radiotagged hatchlings released near the nest site tended to remain in the same vicinity, and it was hoped that older iguanas would display a similar site fidelity. Results were mixed, with both animals experiencing some initial weight loss and the male losing his transmitter. Whether this was related to weight loss is unknown; the female also lost considerable weight and was recaptured so that her transmitter attachment could be secured. She was released again, and was apparently feeding and doing well soon afterward (N. Mitchell, personal communication). Six additional iguanas released in 1997 all appear to have adapted well.



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Radiotracking released iguanas in the Hellshire Hills, Jamaica.

Significant differences exist in the feeding regimes of the Grand Cayman and Jamaican iguana headstart programs that may have serious implications for the survival of released iguanas. Captive Grand Cayman iguanas are raised almost entirely on commercially available alfalfa-based livestock pellets. Because they are unfamiliar with fruits and vegetables, they may be more inclined to feed on native vegetation once released. In contrast, Jamaican iguanas are primarily fed commercially available fruits and vegetables. This diet is highly palatable to the iguanas, and they consume it readily and grow rapidly. However, its high moisture content may predispose iguanas to substantial water weight loss following release. Furthermore, ingestion of a highly palatable fruit diet as a primary food source may cause iguanas to adapt

more slowly to native vegetation. Given this, acclimation of headstarted iguanas to natural foods prior to release may be advisable.

Financial considerations

Based on limited experiences with iguana headstart/release programs on both Grand Cayman and Jamaica, it is apparent that practical financial considerations must be evaluated prior to developing a release strategy. Depending on the length of the program, the headstarting process itself represents a substantial monetary commitment, although this is reduced somewhat if done within the range country. Although over \$20,000 was raised in the United States to fund the new iguana management facility at the Hope Zoo, the 2-year old facility is at capacity and needs expansion. The National Trust's new iguana facility cost a total of \$14,700, donated from a single outside source. In addition to the expenses of pre-release conditioning and health screening, facility construction alone can impose a considerable financial burden on local conservation efforts.

Expenses do not end once animals have been returned to the wild. In fact, the most costly aspect of headstart/release programs may be field monitoring, which is critical to all RRT programs. If radiotelemetry is utilized, and this certainly appears to be the most effective method of gauging short-term survival, then costs increase considerably. Even after the initial expenses of equipment purchase, the annual cost of the Jamaican iguana field project is estimated at a minimum of \$10,000 U.S., excluding an additional full-time employee. According to Kleiman et al. (1984), the most effective and successful RRT programs have been comprehensive efforts involving a large multidisciplinary team and considerable resources. These authors discuss 13 criteria that should be considered prior to implementing a reintroduction (Table 6).

RRT technology and its application to iguana conservation is in its infancy, and there is much to be learned as this process moves forward. But is it only by moving forward that we will begin to gain the experience and insights necessary to make these strategies successful. In particular, radiotelemetry techniques must be further developed and openly shared. Conservation strategies must be developed while time remains to refine the methodology and perfect the techniques that will ultimately prove to be an essential component of recovery strategies not only for endangered iguanids, but other taxa as well.

Table 6. Translocation/Reintroduction of Grand Cayman and Jamaican iguanas: Do appropriate conditions exist? (Scale 5 = best).

	Grand Cayman iguana	Jamaican iguana
Condition		
1. Need to augment wild population	Yes	Yes
2. Available stock	Yes	Yes
3. No jeopardy to wild population	?	?
Environmental condition		
4. Causes of decline removed †	No	No
5. Sufficient protected habitat ‡	No	No
6. Unsaturated habitat	Yes	Yes
Biopolitical conditions		
7. No negative impact for local people	Yes	Yes
8. Community support exists	Yes	Yes
9. GOs/NGOs supportive/involved	Yes	Yes
10. Conformity with all laws/regulations	Yes	Yes
Biological and other resources		
11. Reintroduction technology known/ in development	3	3
12. Knowledge of species' biology	3	3
13. Sufficient resources exist for program	Yes	Yes
Recommended reintroduction/translocation?	Yes	Yes

† Although the causes of decline have not been eliminated, they have been researched and plans to mitigate them are underway.

‡ Key habitats for both taxa have been identified but have yet to achieve formal protection.

Translocation to Unoccupied Habitat

By James Lazell

West Indian iguanas seem in general to be a resilient group of organisms able to survive in depauperate ecosystems and arid situations. These large lizards seem not to have been affected by Holocene climatic changes that arguably contributed to historical extinctions of rodents, monkeys, sloths, and tortoises. Even the arrival of Amerindians three or four thousand years ago seems not to have exterminated any taxa. European colonizations, however, and especially the exotic species accompanying them, have been devas-

tating. Nevertheless, West Indian iguanas have been successfully introduced to many areas now dominated by human disturbance. The prospects for restoration of iguanas to previously occupied portions of their ranges seem quite sanguine. In selecting sites for translocation, the following issues should be considered.

Historical presence

Museum specimens, literature records, fossil and sub-fossil remains, and local testimony can all serve to indicate previous presence, and this is the best initial evidence for at least potential habitat suitability. It can probably be presumed that iguanas occurred

throughout the coastal lowlands of any island bank that has an island on it where iguanas demonstrably occur or occurred in the recent past. Given glacial maximum low sea levels as recently as 10,000 years ago, there appears to be little that would have deterred iguana dispersal. Tiny islands, of course, might fail to sustain populations following post-glacial rise in sea levels. For example, rock islets like Monito might provide no suitable nesting soils or even sufficient vegetation to feed a viable iguana population. Still, it is expected that iguanas would have originally been present on most islands on occupied banks down to at least 100ha in area. The propensity of West Indian iguanas to survive, often in abundance, on very small cays is heartening.

Exotic predators and competitors

The different species of iguanas show a spectrum of abilities to deal with predators, especially mammalian carnivores. Some forms, like the rhinoceros iguana on Hispaniola or the Cuban iguana now introduced to Puerto Rico, seem able to survive and reproduce in sympatry with dogs, cats, mongooses, and even people who eat them. Other forms, like *cornuta onchiopsis* of Navassa and *pinguis* on Puerto Rico, went extinct so rapidly after European colonization that their existence has been very scantily recorded. Sites which are free of exotic predators, especially dogs, cats, and mongooses, hold the greatest promise for re-establishing populations.

Goats are the most efficient and detrimental of competitors, and it is often very difficult to extirpate them. Because goats are so versatile and opportunistic in their diets (to the extent of climbing trees and devouring plants often toxic to other species) iguanas would probably be unable to establish populations on islands with saturated goat populations. That iguana populations dwindle in the presence of introduced livestock is evidenced by the situation on Anegada in the British Virgin Islands. Although active reproduction is occurring and seemingly healthy hatchlings can be found, lack of available plant food may preclude juveniles from ever adopting a diverse and healthy herbaceous diet. The presence of young iguanas cannot be taken as evidence of a healthy population because exotic competitors may prevent them from ever reaching maturity.

Other iguana species, such as the now widely introduced common iguana, may be very effective competitors. Further, introgressive hybridization may occur between an introduced iguana species and the previously incumbent native, as seems to have happened in Les Iles des Saintes. In sympatry, it generally appears that one iguana taxon either out-competes or genetically swamps another. Therefore, attempts to

establish sympatry should be avoided.

Microhabitat conditions

Iguanas have to be able to dig holes to lay eggs. Many species utilize beach berms, while others excavate inland soils. The requirements of each must be accommodated. Very small islands are especially likely to lack potential nesting sites.

Iguanas seem to do best in places where the sun reaches them early in the morning, particularly on flat islands, ridge tops, and east-facing slopes. On Guana Island, Goodyear and Lazell (1994) found that even large males climb trees in the evening, seemingly to be in good positions for early insolation. This may mean that densities on hilly islands with west-facing slopes will be lower (other factors being equal) than on flat islands. Circumstantial evidence on Guana Island indicates that hatchlings move from their nest sites principally into areas with early morning direct sun. This may limit dispersal on hilly islands to east-facing slopes that rise west of suitable nest sites. Evidence on these points is scanty at best, but their consideration can only improve restoration prospects, and suggest valuable lines of future research.

Potential for human interactions

Generally, human interactions with wild iguanas are negatively perceived. Traditionally, people have killed iguanas in the West Indies to eat them, or because they viewed them as agricultural pests, or because they fear any large wild animal, or for sport. All of these reasons are potential causes for concern over the fate of translocated iguanas, and should be among the most obvious factors considered in such planning. On the other hand, human interactions can sometimes also be very beneficial. Many people, including tourists, are enthusiastically fond of iguanas. They will go out of their way to see and photograph iguanas, and delight in the antics of semi-tame individuals. On Anegada, at least a few iguanas did well despite dogs, cats, goats, and usually hostile humans because one individual liked them enough to set up a feeding station.

While a dim view of subsidizing wild animals is usually taken because this is not regarded as being in their long-term interest, feeding stations may be appropriate during the early stages of translocation. Also, the popularity of iguanas at a particular site may be a factor in their protection (e.g., from dogs), and may help insure that new populations are monitored at least informally.

Genetic considerations

Much has been made of inbreeding depression and genetic problems associated with small numbers of

founders. However, it is a certainty that many natural populations of West Indian iguanas were derived from one or a few founders, and subsequently did quite well. Different taxa vary in their reproductive capacity, but all are relatively fecund. Although a greater number of founders is preferable, it is probably the case that even a single healthy, gravid female can establish a successful population. From a dispersalist point of view, this is most likely the way all known taxa of West Indian iguanas originated.

Conclusions

In summary, iguanas are apt to do very well on small islands, provided these islands have been cleared of goats, mongooses, and other detrimental exotics, and that the vegetation either remains in or has recovered to a near-natural state. Islands with tourist presence may be especially suitable because feral livestock are often removed from them and interested people will tend to mitigate deleterious acts, such as killing by dogs or humans, and help to monitor iguana numbers.

Marking Techniques

By William Hayes, Ronald Carter,
and Numi Mitchell

Iguanas can be marked for research purposes either temporarily or permanently using a variety of methodologies. Some techniques allow for individual identity, while others indicate only whether the animal has been sampled or not. Further, while some methods require recapture to determine individual identity, several techniques allow recognition of individuals without the need for recapture. The importance of choosing an appropriate marking technique is illustrated by the experience of workers at the Hope Zoo in Jamaica (Hudson 1994). Captive-hatched Jamaican iguanas were initially marked with paint and photos were taken of head scalation patterns. Over time, however, the paint markings vanished and the scalation patterns proved unreliable. As a result, the identities of individuals had to be verified later by genetic analyses.

Selection of marking method depends on the nature of the study, and should take into consideration the number of times animals will be sampled, whether data from individuals are important, and constraints of time and money. Also important is whether a particular marking system might compromise collection of certain data. For survivorship studies, conspicuous marks could increase risk of predation, particularly for juveniles. In addition, the regulating agency granting permission for the work may object to or favor

certain techniques, especially when endangered taxa are involved.

Temporary marks

Painting and tagging are commonly used techniques which permit recognition of previously sampled individuals over the short term. Moreover, they can be used for individual recognition without the need for recapture. For example, J. Iverson (personal communication) and C. Knapp (1995) applied fingernail polish or enamel paint to the dorsum of Allen's Cay iguanas and Exuma Island iguanas in the field to recognize and avoid recapturing animals. Wiewandt (1977), using a plastic dart gun, and Iverson (1979), employing a squirt gun-like syringe, painted the dorsum of iguanas from a distance to individually mark and study the behavior of Mona Island iguanas and Turks and Caicos iguanas without the need for disruptive capture and handling. Alphanumeric characters painted on the dorsum have been used in the field to recognize individuals of Exuma Island iguanas (Coenen 1995), desert iguanas (Glinski and Krekorian 1985), chuckwalla (Smits 1985) and marine iguanas (Laurie 1989; Wikelski and Trillmich 1994). In general, enamel paint will remain on the integument of iguanas for months, usually until the animal sheds. Henderson (1974) used a felt-tip pen to mark numbers on the dorsum of common iguanas but the marks faded after several weeks. As a general rule, red marks should probably be avoided because iguanas are highly attracted to this color and will bite at it persistently (J. Lazell and N. Mitchell, personal observation).

Tags of various sorts can also be employed for marking purposes. For example, Minnich and Shoemaker (1970) marked desert iguanas with colored cloth tape around the base of the tail, Henderson (1974) tied small bells to the necks of common iguanas with fishing line, and Rao and Rajabai (1972) tagged agamid lizards with different shapes of colored aluminum rings placed around the thigh. Leg bands are used routinely for marking birds and could also work well for iguanas.

Permanent marks

Although many permanent marking systems require recapture of study animals to establish individual identity, some allow for recognition of free-ranging individuals without the need for recapture. Toe-clipping is the most widely used technique for permanently marking lizards (Ferner 1979), and has been employed in long-term field studies of Allen's Cay iguanas (J. Iverson, personal communication). Using a coded system, the number of individuals that can be uniquely marked is substantial (Ferner 1979). While concerns about pain and potential harmful effects

resulting from missing toes exist, toes are frequently lost naturally and no studies to date have shown that toe loss compromises survival of lizards (Dodd 1993). When toe-clipping is the only method used, animals must be recaptured to confirm individual identities, and confusion may result if additional toes are lost subsequent to marking. Branding the integument of animals with unique marks can be accomplished by heat or freezing (Ferner 1979; Honneger 1979). M. Wikelski and D. Werner (personal communication) have used heat branding to mark alphanumeric codes on marine and common iguanas with no ill effects. These brands can be read only at close distances, but can be combined with more visible but temporary paint marks.

Affixing colored glass beads to the nuchal crest has recently become popular among investigators studying large iguanas (Rodda et al. 1988; van Marken Lichtenbelt et al. 1993; G. Gerber and A. Alberts, personal communication; W. Hayes and R. Carter, unpublished studies). This method, developed for iguanas by Rodda et al. (1988), can be applied not only to adult iguanas but also to juveniles, as the number and sizes of beads affixed to the crest can be adjusted for animal size. Pain and ill effects associated with the procedure appear to be minimal. Occasional loss of the beads has been noted (Rodda et al. 1988; W. Hayes and R. Carter, unpublished observations), most likely resulting from degradation of beads (especially if plastic) and suture material (usually monofilament line), or biting of the beads by conspecifics. Glass beads not only retain their color better than plastic beads, but are also superior in resistance to crushing. Suture material should be selected for resistance to degradation by ultraviolet light. The beads are fairly visible from a distance, especially with the aid of binoculars, making this technique valuable for mark-recapture studies.

A potential drawback to color-coded beads is that their conspicuousness may render marked animals more visible to predators. This evidently was not a problem for common iguanas on the mainland (Rodda et al. 1988), and the adults of large insular taxa such as rock iguanas are generally under reduced predation pressure. Because iguanas are inclined to taste or tongue-touch brightly colored objects, juveniles marked by this method could potentially be injured or killed by curious adults. Conceivably, the brightly colored beads could also influence mate choice, as has been demonstrated for colored leg bands in certain birds (Harvey 1986). Finally, visitors to natural iguana populations may find the color markers to be of interest, as evidence that someone cares enough to study the animals, or as an unattractive distraction. More study of the consequences of colored bead



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Color-coded glass beads attached to the crest are being used increasingly for permanent marking of iguanas.

marking is needed to adequately evaluate their effectiveness.

Passive integrated transponder (PIT) tags have received attention recently as a means of permanently marking animals for unambiguous individual identification. PIT tags contain a unique magnetic signature packaged within a tiny glass capsule, and a virtually unlimited number of codes are available. They are usually inserted by syringe just beneath the surface of the skin. For larger animals, insertion into the thigh is recommended, while for hatchlings and smaller juveniles, the inguinal region is preferred. Upon recapture, a hand-held, battery-powered transponder is passed within a few centimeters of the animal to obtain a reading of the tag's unique identification code. Although this technique has primarily been used in captive recovery programs (e.g., Grand Cayman and Jamaican iguanas, R. Hudson, personal communication), J. Iverson, F. Burton, P. Vogel, and A. Alberts have begun to use the method in the field. PIT tags have the added advantage of offering law enforcement officials the possibility of proving smuggling charges should animals having implants appear in the international wildlife trade. All field investigators of endangered taxa should consider adopting this technique, at least as a secondary marking system. Unfortunately, some of the more sophisticated animal smugglers and dealers have become alert to the possible presence of PIT tags, and purchase their own receivers to detect and remove them.

Radiotelemetry

Radiotelemetry has proven to be a useful tool in evaluating aspects of West Indian iguana ecology and management strategy. It has provided information

about home range and social structure for iguanas on Anegada Island and in the Lesser Antilles, and is being used to monitor the reintroduction of headstartcd Jamaican iguanas, released as subadults into the Hellshire Hills region.

Two-stage external transmitters have been most effective for studies of wild iguanas because they can support relatively large antennas (e.g., 1/4l whips) which give greater range of reception. This is important for species with large home ranges or those using underground refugia. External tags may also be fitted with larger batteries than internal tags, which decreases the frequency of battery replacement and handling of animals. Externally mounted tags, however, are more apt to be damaged by sun or battered in rocky habitats than internal tags.

Transmitters have been mounted successfully on neck collars (M. Day, personal communication), waist belts (N. Mitchell, 1999), and shoulder harnesses (R. Hudson, personal communication). For more approachable animals, two-stage tags with small wire loop antennas (originally designed for rats) have been imbedded in paraffin, coated by a thin layer of dental acrylic, wrapped in chicken skin, and placed in locations where iguanas will encounter and ingest them. This technique has yielded four to seven days of data after which the tag is expelled with the feces (Goodyear and Lazell 1994). An advantage of this method is that the animal need not be handled. Animal positions have been determined by triangulating remotely using receivers at fixed telemetry stations or by directly approaching the animal and recording its location using a global positioning system. Collapsible yagi antennas used with small receivers work well in the dense scrub and forest habitats occupied by many iguanas.

Population Monitoring

By William Hayes and Ronald Carter

A first step in developing conservation plans to protect or restore remaining iguana populations is to assess the status of populations in the wild. Once a conservation plan has been implemented, continued population monitoring is essential to evaluate the effectiveness of the program. Despite the recent attention given to several taxa, information as basic as population size is still lacking for many West Indian iguanas (Blair 1991a, 1994). For some taxa, the only data available are subjective impressions based on only a few hours of observation (Blair 1991b, 1992a,b; Ostrander 1982). Some estimates of abundance are decades old, whereas others urgently need to be reassessed due to recent threats to the population. Although rough estimates are important when nothing else is available, they are of limited value for establishing priorities and developing long-term survival plans.

Population estimates based on rigorous sampling are sorely needed, not only to update the endangered status of many taxa but also to monitor the success of conservation efforts. While numbers at or near carrying capacity suggest a healthy population, declining numbers or the absence or scarcity of certain size classes may be indicative of deteriorating habitat, disease, or the presence of introduced flora or fauna. Population viability can be better understood by repeated surveys that yield information on growth

A shoulder harness attachment for radiotransmitters has been used successfully in the Hellshire Hills, Jamaica.



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rates, sex ratios, reproduction, age of sexual maturation, and survivorship. Likewise, injury frequencies, habitat requirements and preferences, and movement patterns can be ascertained. Accurate surveys are particularly important for setting conservation priorities and allocating limited resources appropriately.

Standardization of all iguana population surveys, regardless of taxa, location, and purpose of study, is probably not possible because different habitats and study objectives require different techniques. Nevertheless, population estimates should be based on appropriate considerations, and uniformity of multiple sampling efforts is necessary for comparative or experimental studies. Because objectives of abundance estimation and hypothesis testing are different, as are their design requirements, investigators should determine whether the purpose of the study is to evaluate population density, population size, or rate of population change before embarking on any study of population numbers (Skalski and Robson 1992). Inferential studies are especially important to understand how population density changes across a gradient, varies over time, or differs among islands or treatment conditions. Constraints involving costs, manpower, and time must also be considered. Knowledge of methodological assumptions is critical in order that steps can be taken to ensure they are met in the field. Preliminary sampling can provide valuable insights on how to design an effective study, and prior familiarity with data treatment and adequate training of observers are essential.

A vast array of population estimation techniques are available, many of which are tailored to meet specific sampling conditions and requirements. Their specialized applications, assumptions, and calculations have been treated in detail by other investigators (Bibby et al. 1992; Skalski and Robson 1992; Buckland et al. 1993). Although less complex, single-sample techniques are not as accurate as many of the more complicated methods involving repeated sampling. The latter can be particularly sophisticated, and computer programs are now available to simplify computation.

While the terms census and survey are often used interchangeably, Buckland et al. (1993) emphasize that a census requires counting all subjects within a sample area (only rarely accomplished), whereas a survey samples only a portion of animals within an area. There are two basic approaches used for conducting population surveys. Distance sampling focuses on representative transects, estimates population density for those areas, and then extrapolates population size assuming a similar density for the entire area. Mark-recapture studies involve the capture and marking of a subset of animals in the population which,

based on the ratio of marked to unmarked animals determined from subsequent sampling, is used to estimate total population size. The advantages and disadvantages of each approach are outlined in Table 7. Two of the most important considerations regardless of the approach are the need for control populations when possible and the use of randomization and replication of treatments whenever possible to increase precision (repeatability) and accuracy (proximity to actual population density or size) of estimates and provide valid and appropriate inferences on population abundance (Skalski and Robson 1992).

Distance sampling methods

Many West Indian iguanas occupy relatively large islands where it is not practical to count animals over the entire island. In such cases, population estimates must be based on population subsampling, for which distance sampling is particularly useful. Classical transect studies are a subset of, but distinct from, distance sampling models (Buckland et al. 1993). In classical transects, several linear transects or circular plots are randomly situated in appropriate habitat. Observers then proceed along the transect line or remain stationary at the center of the circular plot, counting all animals detected within a predetermined distance from the transect line or central point. No distances between the animal and the transect line or central point are measured. These methods assume that all animals within the sample area are encountered, which in virtually all cases is a practical impossibility. Because of this, classical transects nearly always underestimate animal density. Consequently, despite the much greater effort and expense required, mark-recapture studies have often been employed when precision is important.

Distance models, refined over the last two decades (Buckland et al. 1993), require measuring the perpendicular distance between the transect line or central point to where an animal is first seen. Boundaries of the sample area need not be established, and use of a unique detectability function precludes the assumption that all animals in the sample area are detected. The detection function specifies probabilities of detecting an animal in relation to distance from the transect line or central point, allowing estimates of density to be made under mild assumptions with greater accuracy than is normally achieved with classical transect methods. Assumptions of classical and distance models are compared in Table 8. Use of the computer program DISTANCE greatly facilitates analysis of data generated by distance sampling (Laake et al. 1993).

For distance sampling, line transects are most often used, especially in relatively open habitat, but point

sampling may be preferable in denser habitat or under other circumstances. Other applications of distance sampling, such as trapping webs and indirect counts of scats, burrows (Iverson 1979), or other signs, can be regarded as modifications to the basic distance theory (Buckland et al. 1993). The lengths of line transects must be known, and care must be taken to establish transects that are straight, randomly placed within representative habitats, far enough apart to avoid double-counting of animals, and preferably parallel to one another and to any known density gradient. Established routes such as roads and ridgetop trails are subject to bias and should be avoided, and clustered populations warrant special consideration (Buckland et al. 1993). Preliminary surveys are particularly important for making decisions on transect design. Buckland et al. (1993) offer an excellent discussion on strategies for placement of lines or points across areas to be sampled.

The measurement of distances can be unwieldy, making distance methods more time-consuming than classical transects, particularly when departure from the transect line is necessary to mark or measure the point where each animal is initially seen. Such interruptions may also disturb nearby animals. New and relatively inexpensive technologies, however, can greatly expedite data collection. Rangefinders or binoculars with reticles can be used to estimate distance without the need to leave the transect line, and simultaneous estimation of the sighting angle relative to the transect line can be accomplished using a hand held angle board or an angle plate on a tripod (Buckland et al. 1993). By rapidly collecting and recording distance and angle measurements for each animal seen, perpendicular distances can be easily calculated later using a trigonometric function. Cruder methods such as pacing and visual distance estimation can be used if the sacrifice in accuracy is acceptable. However, accuracy of distance measurements is critical when close to the transect line due to the mathematical properties of distance models. When distance estimates are less accurate, rounding to convenient values and collapsing of data into distance categories is commonly practiced, as is truncation, the setting of a limit to the furthest distance animals are counted. Although outliers can be removed before analyses, caution must be taken not to introduce systematic bias.

The transect design should provide for adequate sample size. As a general rule, the minimum sample size of all transects combined should be 60-80 individuals, although 40 may still provide reasonable precision (Buckland et al. 1993). Somewhat larger samples are recommended for point sampling (25% more) and when sampling clustered populations. Of course,

for studies of rare or endangered animals these numbers may be unachievable, and alternative methods of analysis may prove more informative. In contrast to mark-recapture studies, the absolute size of the sample is important for distance sampling, rather than the fraction of the population sampled.

Iverson (1978) employed distance sampling to estimate population size of the Turks and Caicos iguana on Pine Cay. He established permanent transect lines through representative habitats in six sectors of the island and conducted numerous surveys at various times of the day over a three-year period. The perpendicular distance between the trail and where each iguana was initially seen or heard (generally flushed from cover) was measured and iguana density calculated using a classical transect model and three distance formulas, two of which incorporated detectability functions. Agreement among the computation methods was reasonable, but the classical transect calculations resulted in lower density estimates than those incorporating detectability functions.

Additional distance sampling considerations

During any given survey, some lizards inevitably will be underground or hidden in vegetation, refusing to flush. Activity, and hence detectability, of iguanas varies with time of day, season, and size and sex of individuals (Iverson 1979; Wiewandt 1977). Juveniles often are very secretive, so estimates may need to be restricted to adults (Iverson 1978). Adult males may be more conspicuous during the mating season when they defend territories, while adult females may be disproportionately under-represented subsequent to mating and during egg-laying. Recent weather conditions may also influence iguana activity. Because an unknown proportion of animals cannot be detected, both classical transect models and distance techniques often underestimate true population size.

Population underestimation can be minimized by repeated sampling at optimal times and inclusion of data for only the highest counts obtained, as done by Iverson (1978). It is also possible to adjust estimates if information about the percentage of animals encountered during a given survey is available. For example, Hayes et al. (1995) discovered in surveys of two cays that only a third of marked San Salvador iguanas were detected. Thus, they multiplied by three the number of animals counted by classical transects on other cays where few or no animals were marked to obtain more accurate estimates. With the exception of one population where iguanas have since been extirpated, estimates by Hayes et al. (1995), and even absolute numbers of iguanas seen, far exceeded earlier estimates by Gicca (1980) based only on classical line transects. Although it is possible that numbers

actually increased during the intervening years, differences between the two studies more likely reflected the timing of Gicca's visit during a season of lower activity (December, 1974 versus March-July, 1994) and violation of the assumption that all animals within the transect were encountered.

Variation in habitat may complicate estimation of total population size. On larger islands, iguanas typically occupy a range of habitats. To accurately estimate total population size, it may be necessary to conduct distance surveys in randomly selected sites within each habitat and calculate population density for each. If the island-wide distribution of each habitat is known, population estimates for all habitats can be summed to estimate total population size (Iverson 1979). For very small cays, it may even be possible to sample the entire island (Hayes et al. 1995). Critical habitat such as nesting areas should also be surveyed during the appropriate season to evaluate management needs (Haneke 1995).

Distance sampling models assume that animals do not move prior to detection and that individual iguanas are detected independently. This may become a problem at higher densities, when an observer may disturb an iguana, potentially resulting in double-counting and affecting the behavior of other nearby lizards. Obtaining distance and angle measurements may also make determining initial locations of animals difficult when a number of iguanas are in view at once, and bias may occur when selecting the next focal animal. Slow, deliberate movement can minimize disturbance, and the departing animals may offset those which remain cryptic. At low densities, it may be advantageous to occasionally leave the transect line in search of iguanas, carefully probing vegetation with a long rod to assist in detection of animals reluctant to flush (Hayes et al. 1995). More than one observer can also be of value, as long as effort is focused close to the transect line or central point and decreases smoothly with distance so as not to introduce bias. A useful approach is to have one person remain on the transect line, while additional workers systematically search for iguanas on each side of the line.

For comparative and experimental studies, standardization and repeatability of sampling method, effort, and conditions during replicate surveys becomes very important. All possible sources of bias, including sampling method, differences in habitat, iguana density, seasonal and climatic factors, and observer experience, reliability, and technique should be identified and minimized. Standardized surveys conducted on an annual basis are necessary to assess population responses to adverse effects. Population changes need to be documented when management changes are implemented, including release of head-

started juveniles and habitat restoration. Comparisons of iguana density on islands with and without introduced species are needed to confirm their negative impact. If feral animals are eradicated from infested cays, annual surveys of juvenile to adult ratios may indicate increased reproductive success and recruitment. Even indirect measures of iguana abundance, such as the density of feces or burrows or the ratio of active to inactive burrows can be valuable in monitoring conservation efforts (J. Iverson, personal communication).

Information on sex or body size of iguanas sampled is helpful in assessing population structure and effective population size. Even more useful information can be obtained if animals are captured supplementary to surveys. Measurements of body size and confirmation of sexual identity and reproductive condition are valuable for learning more about population demography, including the sex ratio, individual growth rate, frequency of injuries, reproductive rate, and age of sexual maturity (Iverson 1979).

Mark-recapture methods

Mark-recapture studies involve the initial capture of a random and representative sample of animals, which are marked and then released back into the population. At a later time, another random sample is captured, or in some circumstances sighted, and the number of animals previously marked is recorded. If certain assumptions hold, the ratio of marked animals to total animals in the second sample, together with the known number of marked animals, can be used to estimate total population size using the Lincoln-Peterson equation: $N_{\text{marked}} / N_{\text{total}} = N_{\text{recaptured}} / N_{\text{sampled}}$. Multiple capture designs with varying assumptions can be incorporated, making the approach applicable to a diversity of sampling situations that yield more precise and accurate estimates than two-sample designs. As with distance sampling, experimental studies for hypothesis testing are served well by mark-recapture programs (Skalski and Robson 1992).

Mark-recapture studies have several advantages for conducting population surveys. First, they can provide a better estimate of population size than distance sampling techniques, which generally underestimate population size. Second, repeated sampling of marked individuals can generate additional demographic and ecological data. Finally, the proportion of marked animals sighted or recaptured can indicate the proportion of each sex and size class that is active during a given population survey, which in turn can be helpful in understanding biases that influence population estimation. Compared to distance sampling, the primary drawbacks to mark-recapture studies are their cost, time demands, and labor intensity. Large num-

bers of animals may need to be tagged, and a high proportion of marked animals must be resampled in order to meet statistically acceptable standards.

Although a variety of mark-recapture models exist, the two basic classes are closed and open population models. Closed population models assume that a population does not change composition during the course of the study (i.e. births, deaths, immigration, and emigration are negligible) and are probably best applied to data collected over the short term. Because iguanas are not highly vagile and many are restricted to small islands, this assumption is often met. Although violation of this assumption can become a problem when captures are taken over a long period, allowances can be made if these rates can be measured. For two-sample experiments, the Lincoln-Peterson estimator is widely employed. K-sample models, with many capture events, can also be used. The software program CAPTURE (Rexstad and Burnham 1991) has been widely utilized by ecologists in recent years for the analysis of multiple-sample closed population models.

Open population models are designed to accommodate animals entering and leaving the population during the course of the study. Populations may be modeled as completely open (both losses and gains) or partially open (losses and no gains, or vice versa). Two of the more common models employed are the Cormack and Jolly-Seber models, which can be handled most readily by a number of software programs (Nichols 1992). The programs SURVIV (White 1983) and SURGE (Cooch et al. 1996; manual currently available on the internet at: http://mendel.mbb.sfu.ca/wildberg/cm/surge_guide.html), in particular, are extremely powerful and especially flexible for tailoring analyses to specific field situations (Nichols 1992). Assumptions of closed and open models are compared in Table 9.

In models based on multiple capture events, complete capture histories must be obtained for individual iguanas. In these cases, iguanas must be marked for individual recognition, a condition not required of two-sample studies. Capture histories generally consist of a series of Is and Os corresponding to the sequence of sampling events, the former denoting capture and the latter indicating no capture. A statistical model, the choice of which depends on assumptions about sources of variation associated with capture, can be used to evaluate probabilities of capture at each sampling event. Results can then be used to estimate population size and change over time. Because repeated sampling results in reduced sampling error, multiple-sample models can lead to greater accuracy and precision in population estimates. Although complex, multiple-sample techniques can be extremely

powerful in evaluating population viability and making management decisions. Further treatment of multiple-sample models can be found in Bibby et al. (1992), Nichols (1992), and Skalski and Robson (1992).

Hayes et al. (1995) employed mark-recapture methods to estimate population size of San Salvador iguanas. Using color-coded beads, they marked numerous animals captured on several offshore and inshore cays during May, 1993 and May, 1994. Upon returning in July, 1994, they conducted Lincoln-Peterson estimates on two cays. Investigators systematically covered each island, recording with the aid of binoculars all iguanas seen as either unmarked, marked, or too poorly seen to ascertain the presence of beads. The Lincoln-Peterson equation was then used to estimate total population size based on well-seen animals, while the number of poorly-seen iguanas was multiplied by the ratio of total marked iguanas to the number of iguanas resighted to derive a second estimate. These two estimators were then summed to yield total population size. The proportion of iguanas in the population encountered during these surveys was used as a multiplier to derive population estimates for other islands visited under similar weather conditions. The availability of marked lizards and the small sizes of the cays (each treated as a single transect) made the integration of mark-recapture and classical transect data ideal given limited time on the cays.

Additional mark-recapture considerations

Because so many iguana populations are confined to islands, the assumption of a closed population is often valid, at least over the short term. Nevertheless, as long as sufficient time is provided for animals to mingle, it is good practice to minimize the interval between marking and resampling to reduce the likelihood that marks disappear or animals die between sampling events. Fortunately, adult iguanas are long-lived and generally have high survivorship (Iverson 1979). Although difficult to fulfill, an important assumption of closed population models is that every animal in the population has an equal probability of capture. Juveniles in particular can be hard to find, wary, and difficult to capture, making it preferable in some cases to restrict inferences to adults (Iverson 1978). Differences in seasonal activity between the sexes may also influence capture rates, even among adults. Recognition of such biases can help direct capture efforts, but it may still be necessary to derive population estimates for different classes of iguanas independently. Sampling efforts must also be distributed appropriately across different habitats.

Some models assume that marking does not affect catchability or detectability, and that subsequent sam-

ples are random. Yet, certain marking systems may influence activity or survival, or lead to bias in captures, especially when animals are collected by hand. Experience with San Salvador iguanas suggests that animals marked with colored beads are conspicuous and more easily targeted for capture by researchers (W. Hayes and R. Carter, personal observation). Less conspicuous marking systems such as toe-clipping can mitigate recapture bias (J. Iverson, personal communication). When it is assumed that capture probabilities are constant for all periods, care should be taken to conduct sampling under similar weather conditions, using equal sampling effort. Permanence of marks is especially important for repeated sampling and for open models. If, however, the loss rate of marks is known, adjustments to models may be possible. Duplicate marking systems (e.g., colored beads and PIT tags) can provide a backup when one system fails.

Conclusions

Before embarking on population studies, it is important to carefully consider objectives and constraints in order to select an appropriate technique and field design. Preliminary sampling using distance methods can provide rough information on population size and structure which can be useful in appropriately designing further population surveys. The primary advantages to this technique are the expediency and cost-

effectiveness with which population estimates can be obtained. By comparison, mark-recapture studies often require specialized equipment and an extended time investment to capture and mark the animals, which then must be surveyed again at a later date. Whenever numerous populations must be surveyed in a limited amount of time, distance sampling is the clear method of choice. When attempting to survey Turks and Caicos iguanas on more than 100 cays within a period of several months, Gerber (1996) relied on distance techniques, but nevertheless captured and marked animals on many cays that can be re-surveyed in the future.

If time and resources are available to capture and obtain measurements from animals, it is of considerable value to mark animals for future studies. Mark-recapture studies can yield reliable estimates of population size, but also offer the opportunity to extract detailed demographic and ecological data. Recapture frequencies can indicate the proportion of male and female iguanas of different size classes that are active during any given sampling period. Multiple sampling designs yield by far the most information about population viability, potentially providing data on population changes, growth rates, frequency of injuries, reproductive rate, age of sexual maturation, mortality rates, survivorship, and longevity.

Both distance sampling and mark-recapture are excellent for comparative or experimental studies

Table 7. Primary advantages and disadvantages to use of classical transect, distance sampling, and mark-recapture techniques for estimation of population density, population size, or rate of population change.

Methods	Advantages	Disadvantages
Classical Transect (counts within a prescribed area)	Ideal if all animals in sampled area can in fact be detected; useful for experimental studies to test hypotheses if carefully standardized; expedient and cost-effective.	Assumes that all animals in area sampled are detected, which is rarely realistic; nearly always underestimates population density and size; less precise than distance sampling.
Distance Sampling (measurements of distances)	Yields more reliable results for population estimation than classical transects; ideal for experimental studies; expedient and cost-effective.	Nearly always underestimates population density and size; yields minimal information on population demographics compared to mark-recapture methods.
Mark-Recapture	Can yield the most reliable population estimates; yields abundance of additional demographic information; ideal for experimental studies.	Costly and time-consuming to conduct; large sample sizes needed; high proportion of marked animals need to be recaptured or resighted in second and subsequent samples.

associated with hypothesis testing, such as assessing iguana density across gradients, in different habitats, over time, or following experimental manipulation. Multiple standardized surveys can be carried out under similar field conditions to yield strong inferential data. Clearly, both transect and mark-recapture techniques can be extremely useful for analysis of iguana populations. Although one may be more suitable than the other in answering a particular question, the combined use of both approaches should be attempted whenever possible to derive maximum information from remaining iguana populations.

While publicizing the status of highly endangered

species can be essential to raising the funds and awareness important for assembling recovery programs, such publicity can arouse the murkier interests of poachers and others who may wish to exploit the situation. A further dilemma can arise when population surveys suggest that a species or population exists in greater numbers than previously believed. Integrity in reporting becomes an issue, especially when a downgrading from endangered status could jeopardize support for research and conservation programs. There are no easy answers to questions raised by these concerns, but they certainly need to be addressed by the conservation community.

Table 8. Key assumptions of classical transect and distance sampling techniques.

Assumption	Classical Transect	Distance Sampling
1. All animals in transect area are detected	X	
2. All animals exactly on transect line or point are detected	X	X
3. Entire size of sample area is known	X	
4. Animal distances from transect line or point are accurate		X
5. Animals do not move before detection	X	X
6. Individuals are counted only once	X	X
7. Individuals behave and therefore are detected independently	X	X
8. Bias (from observers, seasons, weather) is understood	X	X

Table 9. Key assumptions of mark-recapture studies for closed or open population models. Parentheses indicate that relaxation of assumptions is permitted in certain models. After Bibby et al. (1992).

Assumption	Closed Models	Open Models
1. Closed population (unless immigration and emigration rates are known)	X	
2. Every animal in population has equal probability of capture in first sampling	X	
3. Marking does not affect catchability/detectability	X	
4. Second (subsequent) sample(s) are random	(X)	
5. Marks are permanent	(X)	X
6. Capture/sighting probability constant for all time periods	(X)	
7. Every animal in population has same probability of recapture/resighting in all sampling efforts		X
8. Every marked animal has equal probability of survival		X
9. Sampling time is brief		X
10. Losses from emigration and death are permanent		(X)
11. Population closed to recruitment only		(X)

Control of Introduced Species

By Peter J. Tolson

Introduction

One of the most serious consequences of human colonization of previously undisturbed habitats is the host of exotic species which usually accompanies settlement. In the West Indies, introduced exotic mammals include the black or roof rat (*Rattus rattus*), the Norway rat (*Rattus norvegicus*), the Indian mongoose (*Herpestes javanicus* [= *auropunctatus*]), the feral house cat (*Felis catus*), the domestic dog (*Canis familiaris*), the European pig (*Sus scrofa*), and the feral goat (*Capra hircus*). Each of these animals directly threatens wild iguanas at some stage of the life cycle, and some constitute a significant threat at every stage.

It must be realized that there is a wide gap between short-term control and complete eradication of exotic species from an area. In order for reduction of populations of exotics to have a positive long-term effect on iguana populations, either complete eradication or perpetual control programs are necessary. Eradication programs are most likely to be successful on small islands (< 20ha), where some other stressor, such as lack of standing water, is also present. Control programs can thus be initiated when population numbers are at a natural low. For example, lower levels of food availability during the dry season increase the chances of an exotic consuming a poisoned bait.

Many managers of island ecosystems have had to deal with the problems of introduced predators. The most successful outcomes have been the result of a fully integrated predator management strategy which utilized a variety of control options. These are usually a combination of four basic methods: shooting, poisoning, trapping, and disease. There are always some animals in a target population which will be gun-shy, trap-shy, bait-shy, or poison and disease resistant. Thus, managers must use every means at their disposal to reduce or eliminate the target species. The efficacy of each of these methods varies with the target species and the site at which control is being attempted.

A common fault of unsuccessful exotic animal control programs is the failure to realize the extent of commitment, both in manpower and financial resources, necessary to eliminate a target species. Removal of any exotic from an ecosystem is a difficult and time-consuming task, requiring relentless attention to detail. In a typical shooting or trapping effort, the last few animals require the most effort to remove, as contact decreases in proportion to population size. In addition, the remaining animals may have devel-

oped an aversion to any type of human activity, making shooting, trapping, and poisoning much more difficult than they were initially.

It is also an inescapable fact that any exotic animal control program will face stiff opposition from some elements of society, and managers may find that themselves confronted with a well-organized, well-funded adversary that is inalterably opposed to any killing of any animal species for any reason, even if the failure to eradicate that species means the death of an entire ecosystem. The best basis for defense of any control program for exotics is a well-defined plan that absolutely minimizes any danger to humans or non-target species.

Advantages and disadvantages of various control options

Trapping. Trapping does not require constant effort, but may require considerable expense in setting up the trapline due to the need to clear vegetation for trails, transects, or grids. Live traps are often heavy and bulky, and thus are difficult to transport to interior areas where roads or trails are not available. Trapping has the major disadvantage of putting non-target species in peril. Trapping in an area populated by iguanas would have to be performed at night, with sets prepared just before dark, and traps disabled before daylight. Trapping under these conditions would be ineffective for diurnal predators such as dogs and mongooses, but could be very effective for cats. Attempts to trap larger animals such as feral pigs and goats are generally not cost-effective.

Shooting. Shooting can be a very effective form of control when the target species is large and there is minimal vegetative cover. It is most useful when there has been no previous history of hunting in the target area, and when there is no human habitation of the target area. It is generally low-cost in terms of equipment expenditures, but requires a very heavy manpower commitment. It is less effective at night.

Poisoning. Poisoning can be an effective form of control for certain exotic predators, especially as an adjunct to trapping. However, poisons are not free of disadvantages. Many poisons are toxic to fish, birds, other wildlife, and domestic animals, and pose a secondary hazard to birds of prey and carnivorous mammals. Carelessly placed baits could potentially be consumed by iguanas. Accidental poisonings can be avoided by use of bait boxes with small entry holes that exclude iguanas. Because of their hazardous nature, some poisons may be controlled by federal or local use restrictions, and may require permits for use.

Disease. Introduction of pathogens or parasites can be useful in reducing host fecundity and lowering population density of exotic species. However, such programs by themselves are unlikely to completely eradicate host populations. The major concern with this type of control program is that populations of endemic species may become infected. To ensure that this does not occur, it is important to choose a highly specific pathogen (Dobson 1988).

Black and Norway rats

The black rat is one of the most destructive introduced predators in the West Indies. Its invasion of the Greater Antilles probably began with its introduction to Hispaniola following the wreck of the Santa Maria at La Navidad in 1493, and it has continued to spread since then (Allen 1911; Atkinson 1985). Atkinson (1985) documented the invasion of western Europe by the Norway rat in the early 1700s. As a result, the Norway rat became the dominant rat in European ports, and thus the most common ship rat on sailing ships of that era. Between 1700 and 1830, Norway rats successfully invaded many islands.

Rats are extremely adaptable in their food preferences, can exist for long periods without water, and have an exceptionally high reproductive rate. Although approximately 95% of the diet consists of plant material, they are known to prey on invertebrates (Strecker et al. 1962), amphibians and reptiles (Whitaker 1978), and birds (Austin 1948; Atkinson 1985; Johnstone 1985). Rats pose an extreme hazard to many endangered species in the West Indies. Because Norway rats are significantly larger and more terrestrial than black rats, they potentially pose a more serious threat to iguana nests. However, Norway rats are far more common in urban and suburban areas, whereas outlying cays are almost exclusively populated by black rats. D. Nellis (personal communication) has evidence that the mongoose, a terrestrial predator, may effectively exclude Norway rats from natural areas in the Virgin Islands. Although many natural predators such as raptors and the West Indian boars prey on rats, the rate of reproduction for rats is so high that population numbers easily keep pace with any losses to predation. This has led to several past attempts to control rats, many of which have failed because of high rat immigration rates and lack of adequate resources and commitment.

The most effective poisons currently used today to control rats are the anticoagulant compounds such as brodifacoum and bromadiolone. The active ingredients are imbedded in a paraffin matrix which is relatively impervious to weather. Ten gram blocks of poison are easily carried and distributed, remain palatable for long periods, and do not cause bait-shyness.

Rats may consume a lethal dose in one feeding. The most successful rat poisoning attempts are those carried out during the dry season, when foods such as fruits, buds, and tender leaves are at a minimum. For complete eradication, three applications of poison of 5-10 blocks per interstice on a 10m x 10m grid spaced six months apart are recommended. Heavier applications can be made in areas which show the greatest amount of rat activity, such as rock piles and tree-root warrens. Grids need to be examined every day for three to seven days and poison replaced as it disappears. Use of bait boxes with small entry holes are important to reduce the risk to non-target species. One of the greatest problems of application is consumption of bait by insects and other invertebrates, particularly hermit crabs. There seems to be no problem with toxicity to these species, but they can rapidly deplete a bait placement. Consumption of bait by invertebrates can be reduced by anchoring the bait to trees approximately one meter above the ground.

Trapping is also often used to reduce rat populations, but usually in conjunction with poisons if complete eradication is the goal. Certain individuals are completely trap-shy and will not be captured using trapping methods. In addition, a significant number of rats escape from traps and in all probability will not be trapped again. More effective trapping can often be accomplished by minimizing human scent around the trap site through application of urine-soaked domestic rat bedding and use of rubber gloves when setting traps.

Indian mongooses

Urich (1914) reports that most of the mongooses in the New World are descended from 54 animals imported from Calcutta to Jamaica by Espuet in 1872 to combat black rats. From there, mongooses were released onto the remaining Greater Antilles. In less than 30 years, all West Indian islands supporting a sugar industry had introduced mongoose populations derived from these original sources (Nellis and Everard 1983).

Despite initial effectiveness in rat control, depredations of mongooses soon expanded to include several species of ground nesting birds, endemic snakes, and terrestrial lizards, including iguanas. Because of their small size, mongooses are not considered a major threat to adult iguanas. However, mongooses certainly have the ability to kill and eat juveniles, and they may enter nest emergence holes and eat full-term embryos in the egg. In Jamaica, 12 to 17 years after the mongoose was introduced to the Goat Islands, there were only five iguanas left (estimated decrease of 29-38% per year). The efficiency of the mongoose as a diurnal, terrestrial predator in the West Indies is unsurpassed.



Setting traps for the Indian mongoose control program in the Hellshire Hills, Jamaica.

Mongoose are readily trapped in box traps. Nellis and Everard (1983) used Tomahawk live traps baited with pork liver to capture mongooses on St. Croix, U.S. Virgin Islands. An eradication program initiated on nearby Buck Island by the National Park Service used live traps baited with chicken meat to eliminate the mongoose population. The entire island was gridded with transect lines and traps were placed every 50m on the grid. Although mongooses are susceptible to poisoning with diphinacinone, bait delivery would have to be accomplished with an exclusionary device such that iguanas would not be at risk. Shooting is ineffective due to the small size and speed of mongooses. Mongooses are apparently sensitive to canine distemper, but the extent to which this would represent a viable control option is unknown.

Feral house cats

House cats were probably introduced to the West Indies shortly after discovery by Europeans. As human habitation of an area increases, greater numbers of cats arrive, mostly brought in initially as house pets. Because they can be extremely efficient diurnal predators, house cats pose a severe threat to hatchling iguanas. The following program serves as an example of how difficult cats can be to eradicate. A four-year eradication project for cats was carried out from 1977 to 1980 on Little Barrier Island, New Zealand. The project involved 128 people, and over 950 leg-hold traps and 27,000 poisoned baits were used. One hundred sixty one cats were known to have been killed (Rauzon 1985; Veitch 1985).

Although cats may be poisoned using a compound such as sodium fluoroacetate (1080), the extreme danger of this compound, particularly the risk of secondary poisoning, is so great that its use is restricted to professional operators, and it poses a clear risk to iguanas. Trapping appears to be a better alternative,

and leg-hold trapping in particular is very effective for cats (Veitch 1985). Because they are padded, the Victor Soft Catch coil spring traps are more humane than conventional leg-hold traps. Baited Havahart or Tomahawk box traps may also be used, but are inferior to leg-hold traps. If box traps must be used, double-door cage traps with two open ends are preferred, as cats are normally reluctant to enter closed spaces. Trapping success will be enhanced if every attempt is made to minimize human scent at the trap site. Shooting is another potential control option for feral cats. At night a good light source will illuminate the tapetum and create an eyeshine that will aid in location of cats (Rauzon 1985). Finally, feline panleucopaenia virus (FPL) has been used effectively in controlling (not eradicating) cat populations on several sub-Antarctic islands such as Marion Island (South Africa), Macquarie Island (New Zealand), and Jarvis Island in the Pacific (Johnstone 1985; Rauzon 1985; Rensberg et al. 1987).

Domestic dogs

Feral dogs represent one of the earliest invaders of the West Indies, as virtually all Spanish expeditionary forces had them (Las Casas 1552). Dogs pose the most severe threat to adult iguanas, particularly nesting females. Iverson (1978) reported reduction of a population of Turks and Caicos iguanas on Pine Cay from 5,500 to a very few individuals after the introduction of a small number of dogs and cats to the island by a hotel construction crew.

Control of domestic dogs may best be accomplished by preventing owners from bringing their dogs into areas inhabited by iguanas. Personal contact between researchers, managers, and local forest users is essential in this regard. Shooting, which has been extensively used in coyote control programs in the western United States, may be the most effective option for feral dogs. Trapping of dogs with leg-hold traps is also very effective. However, because the diurnal activity of dogs corresponds to that of iguanas, traps would pose a considerable risk of injury to iguanas. As with feral cats, the risk to non-target animals precludes poisoning as a viable control option.

European pigs

Pigs were often liberated on small islands throughout the West Indies to serve as a food source for shipwrecked sailors. Pigs are primarily a threat to iguana nests. Pigs locate nests by smell, making nests most vulnerable in the three to four days following egg deposition by females. After this period, the iguana scent surrounding the nest dissipates, and pigs are much less likely to detect nests. Because pigs forage in groups, discovery of a densely-utilized communal

nesting area could result in the destruction of a significant number of iguana nests.

Pig predation can be effectively controlled by construction of enclosure fencing around nesting areas, as has been done on Mona Island, Puerto Rico. Density of pigs can also be reduced by shooting, but this can be dangerous, as wounded animals will often turn and attack. Pigs are most easily hunted with dogs, but if this strategy is adopted only neutered males and spayed females should be used to prevent establishment of feral dog packs.

Feral goats

Goats were introduced to island ecosystems by European man, probably early in the 16th century. As with pigs, they were often liberated on small islands of the West Indies to serve as a food source for shipwrecked sailors. Feral goats are notorious for habitat destruction and extirpation of endemic plants on oceanic islands (Coblentz 1978; McFarland 1991). Forest destruction by goats has been implicated in the disappearance of many species, from Hawaiian honeycreepers (Baker and Reeser 1972) to snakes (Coblentz 1978). Wiewandt (1977) considered goats to be a major competitor of Mona Island iguanas, removing high quality herbaceous iguana forage by overbrowsing. Goats have been shown to increase avian predation on juvenile Galapagos land iguanas (genus *Conolophus*) by overbrowsing and the subsequent loss of vegetative cover (Dowling 1964).

Although expensive, goat browsing can be controlled by construction of enclosure fencing. Such fencing must be at least 2m in height. Shooting of goats is probably the most effective means of control. Goats tend to congregate in sleeping areas at night where they can be ambushed. Use of bells on trapped and released "Judas goats" may be useful in locating the herd (Keegan et al. 1994). Finally, the protozoan *Trichomonas foetus* has been suggested as a potentially useful control agent for feral goats (Dobson 1988). Because this is a sexually transmitted disease, the risk that endemic species will accidentally become infected is greatly reduced.

Genetic Research Needs

By Scott Davis

Genetic research should address four major issues facing conservation efforts for West Indian iguanas: 1) genetic distinctiveness and taxonomic status of species, subspecies, and populations, 2) hybridization of genetically distinct species or subspecies in captive

and natural populations, 3) pedigree relationships among individuals used in breeding programs and reintroduction efforts, and 4) retention of genetic variation during long-term management of small West Indian iguana populations.

Given the limited resources available for conservation of West Indian Iguanas, it is important that any recommended conservation actions are based on accurate taxonomy. At present, most island populations of rock iguanas are recognized as distinct species or subspecies, but there are only limited genetic data to support this classification. Based on the experiences of researchers in other groups, it seems likely that a genetic survey of rock iguanas will identify unique genetic entities (species or subspecies) that are currently unrecognized. It may also point to significant genetic differentiation between conspecific rock iguana populations on some of the larger islands (e.g., Cuba). Finally, such a survey may identify subspecies of rock iguanas that are not genetically distinct and thus not deserving of their current taxonomic status. In combination, these findings would allow future conservation action to focus on preserving the unique gene pools within the genus. A sequence study based on mitochondrial DNA of all extant species, subspecies, and populations of rock iguanas is currently underway at Texas A & M University.

As species become rare, it is common for problems with hybridization to occur. The subspecies of *Cyclura nubila* provide a classic example of the impact of hybridization on conservation efforts. The Grand Cayman iguana has been under intense pressure by man through the alteration of habitat and introduction of feral predators. One of the largest rock iguanas, the Grand Cayman iguana occurs only on Grand Cayman (Grant 1940). Two other subspecies, the Cuban iguana and the Lesser Caymans iguana are also recognized, with their ancient distribution limited to Cuba and the Isla de Pinos, and Little Cayman and Cayman Brac, respectively (Schwartz and Carey 1977).

In 1990, the Lizard Advisory Group of the American Zoo and Aquarium Association (AZA) designated the Grand Cayman iguana as a high priority for conservation and captive management. Although this subspecies represented an excellent candidate for intensive captive breeding, two problems complicated implementation of a managed breeding program. First, reports of recent introductions of Lesser Caymans iguanas onto Grand Cayman raised the possibility that subspecific hybridization had occurred in nature (Schwartz and Carey 1977). Second, concern existed among the zoo community that some of the founders of the existing captive population may have been hybrids of Lesser Caymans iguanas and Grand

Cayman iguanas. Obviously, the existence of subspecific hybridization within the population would create problems for efforts to conserve the genetic purity of this taxon.

Life Fellowship Sanctuary (Seffner, Florida) produced all of the founding stock of captive bred Grand Cayman iguanas, which were dispersed to several zoos and returned to the Cayman Islands. The Life Fellowship group was founded with five males and two females imported from the Cayman Islands and an additional female and two of her offspring purchased from a Florida herpetologist in 1987 and 1984, respectively. Unfortunately, the two offspring purchased in 1984 may have been produced using a male Lesser Caymans iguana, and would thus be hybrids. In addition, the female parent of these potential hybrids was herself of unknown origin. These three questionable animals had made a significant contribution to the captive population; thus many of the animals under consideration for a managed program and destined for release in the wild were potentially of hybrid origin. The American Zoo and Aquarium Association's Lizard Advisory Group decided to proceed by authorizing a genetic study on the existing breeding stock.

Genetic data collected at Texas A & M University demonstrated that the questionable female was of hybrid origin (probably from a male Grand Cayman iguana and a female Lesser Caymans iguana) and thus her offspring and approximately 50% of the existing captive population, including animals returned to Grand Cayman for captive breeding, were of hybrid

origin. The hybrids have now been removed from the program, but the problems with this iguana point out the importance of collecting genetic data as early as possible.

Reports of an introduction of Lesser Caymans iguanas into the wild population of Grand Cayman iguanas were apparently unfounded. However, genetic data from the remaining wild Grand Cayman iguanas will provide an unequivocal answer. For most species of West Indian iguanas, a very real possibility of human translocation exists.

Another use for genetic data is the clarification of relationships among founders of captive breeding programs in order to maximize retention of genetic variation and minimize problems due to inbreeding depression. An example of the need for such data is provided by the Jamaican iguana. The Hope Zoo in Kingston, Jamaica, in collaboration with the AZA Lizard Advisory Group, began a headstart program for this species with over 100 individuals collected from clutches laid by wild females between 1991 and 1994. Without genetic data it was impossible to ascertain the number of wild founders represented. If each wild clutch was produced by a different pair, there could be 30 or more founders, but in the worst case, all offspring could have been the product of three females bred by a single male.

To evaluate this situation, 1ml of blood was drawn from the caudal vein (Esra et al. 1975; Gorzula et al.

Lateral entry technique for collecting blood samples from the caudal vein of iguanas.



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Ventral entry technique for collecting blood samples from the caudal vein of iguanas.

1976) of each of the hatchlings, and, where possible, from egg-laying females. A genetic analysis of the DNA in these blood samples using microsatellite markers allowed the characterization of both maternal and paternal genetic contributions. Genetic input from at least two male and four female founders was documented and this information was used in selecting founders for the captive breeding program that would maximize initial genetic diversity and avoid inbreeding. Similar analyses would benefit captive breeding programs for other West Indian iguanas.

Genetic research depends on the availability of marker systems, a variety of which have been used for genetic analyses of vertebrate populations, including protein electrophoresis, karyotyping, mitochondrial DNA restriction fragment length polymorphisms, and DNA fingerprinting. In recent years, two techniques have emerged as ideal tools for genetic analyses of populations: mitochondrial DNA sequences and nuclear DNA microsatellites. Both of these techniques provide high level resolution and both are based on the polymerase chain reaction (PCR). PCR technology offers the tremendous advantage of utilizing only minute amounts of sample and of providing data even when available samples are of very poor quality (such as museum specimens or shed skins). Mitochondrial DNA is a maternally inherited marker and microsatellites are nuclear, biparentally inherited markers. Microsatellites are similar to DNA finger-

prints but are single locus, co-dominant, Mendelian markers and are therefore much easier to interpret in pedigrees. In combination, mtDNA allows the identification of unique maternal lineages and reconstruction of evolutionary relationships, while microsatellites allow the characterization of both maternal and paternal contributions to the gene pool. Both marker systems are in place for rock iguanas, and all that is needed are samples from the appropriate animals.

Captive Management Guidelines: *Cyclura*

By Bill Christie

Captive programs are currently in place for five taxa of rock iguanas. In addition to the captive rearing program at the Hope Zoo in Jamaica, a satellite program for Jamaican iguanas in the U.S. has recently been instituted, with 2.2 individuals each at the Fort Worth and Gladys Porter zoos, 1.2 individuals each at the Indianapolis, Central Florida, and Sedgwick County Zoos, and 3.3 individuals at the San Diego Zoo's Center for Reproduction of Endangered Species. In collaboration with the National Trust for the Cayman Islands, a program for the Grand Cayman iguana is also currently underway, involving animals at the Bermuda Aquarium, the John G. Shedd Aquarium, and the Indianapolis, Central Florida, and Burnett Park Zoos. North American captive populations of both taxa will be managed under the American Zoo and Aquarium Association's first lizard Species Survival Plan. A small number of Ricord's iguanas (1.3) at the Indianapolis Zoo are being managed as part of a cooperative program with Zoodom in the Dominican Republic. Although Cuban iguanas and rhinoceros iguanas are widely held in North American collections, the primary purpose of these programs is for research and education rather than captive breeding.

Housing

Rock iguanas are large lizards that need a fair amount of space devoted to them as adults. A minimum of 10m² is recommended for an adult pair. This space coupled with several visual barriers allows adequate room and minimizes territorial aggression. Rock iguanas can be kept in groups if enough space is provided, although they are very territorial and a dominance hierarchy will quickly emerge. With the exception of Ricord's and rhinoceros iguanas, which are naturally sympatric, the other species of rock iguanas should remain separated. Equally important to the



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Cork bark tubes provide hide areas for juvenile iguanas at the Hope Zoo, Kingston, Jamaica.

housing arrangement are secure hide areas to which each animal has exclusive access. They may not each use a separate hide, but it is important that it be available. They will use these hides to escape conspecific aggression and to retire for the evening.

Ideally, iguanas should be housed outdoors, thereby providing access to natural sunlight. Year-round outdoor maintenance is preferable, with attached, heated, indoor holding for cooler periods. Care must be taken to prevent the iguanas from digging out of the enclosure. A 2.5cm x 2.5cm wire mesh is adequate for containment. A natural substrate of sand, gravel, turf or a mixture of these components is preferable. If breeding is expected, then a nest area with adequate drainage is required. As large an area as possible should be provided as female rock iguanas can dig extensive nest tunnels and chambers.

Successful maintenance of rock iguanas can be accomplished in temperate climates through movement outdoors in warm summer months. Although moving the animals in this way has been successful for maintaining and even breeding some species of rock iguanas, this method may be too stressful for long term reproduction programs. Moving animals

during critical breeding or egg-laying periods should be avoided. Rock iguanas can be maintained indoors, providing that all the above parameters are met. Accessible artificial UV light within 50cm above a basking site should be provided. Temperature gradients within iguana enclosures should range up to 40°C.

Nutrition

Rock iguanas are primarily herbivorous. Captive specimens maintained properly will feed on a wide variety of fruits, vegetables, leafy greens as well as various sources of protein. Dry, leafy, alfalfa hay may be accepted by some rock iguanas as browse. The animal protein component should make up only about 5% of the diet. Some juveniles will feed readily on insects and may have larger percentages of protein in their diet. As adults, rock iguanas seem to be opportunistic predators and will readily take meat if offered. Food should be offered to these browsers daily, although care must be taken to prevent obesity. Providing a varied diet is important and use of seasonally available produce helps maintain a lively feeding response. The addition of a powdered multivitamin and a calcium source two to three times weekly is recommended. Although they are rarely observed drinking, rock iguanas should have access to a water source.

Health

Rock iguanas are extremely healthy, long-lived animals when cared for properly. Endoparasites can be easily treated with various anti-helminthic agents, to which the animals generally respond very well. Ectoparasites can be treated by standard methods. Conspecific aggression can result in physical injuries to iguanas. Although these are usually minor scrapes or cuts, occasionally more serious injuries result which require suturing and antibiotic treatment.

Breeding

Several species of rock iguanas have bred successfully in captivity, particularly rhinoceros and Cuban iguanas. Successful reproduction can occur with single, adult pairs in an enclosure. Combat behavior could be an important stimulus for reluctant males, and if space allows, rock iguanas should be grouped to allow for pair bonding and male combat. In captivity, rock iguanas are annual, seasonal breeders. Breeding usually takes place in the spring or summer, and hatching in the fall. A fluctuating photoperiod seems to have a dominating influence on the reproductive cycle.

Impending egg laying is preceded by an arrested appetite and excessive activity by the female. Gravid

females will dig several test nests searching for an appropriate place to lay. It is important that a suitable nesting area is provided to the female. If not, she may retain the eggs longer than desired, which could cause low hatching success and/or health problems.

If the conditions are appropriate in the enclosure, eggs can be left where they were laid for incubation. If the nest chamber can be located, which can be difficult in large nesting areas, it is probably better to remove the eggs for artificial incubation. Rock iguana eggs are large and require adequate oxygen and humidity. Several incubation media, including sand, peat moss, vermiculite, or various mixtures of these, have been used with good success. A temperature of 30°C results in high hatching success and healthy, fertilized eggs will hatch in 80 to 100 days.

Care of neonates should be similar to that of adults, although extra precautions should be taken to ensure adequate hydration. With enough space, juveniles can be raised together. Some species may show more conspecific aggression than others, and this needs to be watched closely to ensure that severe problems do not arise. Diet can be similar to that of the adults. More animal protein is preferred by some species, whereas others may virtually ignore insects. Well cared for hatchlings can grow quickly and require substantial space to mature adequately.



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Eggs of the Lesser Caymans iguana.

Captive Management Guidelines: *Iguana delicatissima*

By Steve Reichling

The Lesser Antillean iguana is currently held at three institutions: Jersey Wildlife Preservation Trust (1.1.1), the Memphis Zoo (2.2), and the San Diego Zoo's Center for Reproduction of Endangered Species (1.1). All eight adult specimens are potential founders, collected on Dominica. All of the specimens are on loan from the Ministry of Agriculture (Division of Forestry) of the Commonwealth of Dominica, and transfers or movement of adults or offspring between collections can only be done with the Ministry's prior authorization.

The only U.S. Zoo having past experience in maintaining this species is the Philadelphia Zoo, which kept specimens collected by J. Lazell during the late 1950s. A private collector in Europe, L. Wijffels, has kept Lesser Antillean iguanas but reported that his specimens fared poorly, being very shy and reticent to feed. This fragility in captivity, at least with regard to wild caught specimens, appears to be a consistent trait. The recent acquisition of specimens by zoos has begun to shed more light on husbandry parameters appropriate for this species.

In general, basic husbandry parameters applicable to rock iguanas and common iguanas, which are well-documented in the literature, are appropriate for Lesser Antillean iguanas. The information below focuses on management considerations in which the Lesser Antillean iguana differs from most other West Indian iguanas.

Housing

Large enclosures seem to be important. The two Jersey specimens live in an area measuring 3m high x 4m wide x 3m deep, those at Memphis are maintained in a 6m x 8m x 3m enclosure, and those at San Diego in a 4m x 4m x 8m enclosure. Height is critical for providing security to the lizards, at least for the highly arboreal individuals from Dominica. Keepers can enter the cage without disturbing the iguanas as long as the enclosure is high enough to allow the lizards to roost well above intruders. When Lesser Antillean iguanas are kept in a cage too small or short to allow high roosting, the iguanas remain stressed and panic at the slightest disturbance. Equally important for cage security is the provision of adequate plantings and climbing surfaces. M. Day reports that in Dominica, Lesser Antillean iguanas rarely come to the ground, and instead move from tree to tree by way of interlocking branches in the canopy. In captivity, a few bare branches do not provide adequate tactile and



Lesser Antillean iguana enclosure at the Center for Reproduction of Endangered Species, San Diego Zoo.

visual security for Lesser Antillean iguanas. The Jersey, Memphis, and San Diego enclosures are heavily planted with tall, tree-like vegetation, such as banana, *Ficus*, and large *Hibiscus*. It is possible that these parameters may not be as important for specimens originating from more xeric islands.

In Dominica, female Lesser Antillean iguanas excavate deep burrows prior to oviposition (M. Day, personal communication). This fact, coupled with the observation that most egg-laying in captivity spans several days, with eggs scattered throughout enclosures, suggests that adequate nesting sites with deep substrate may be necessary to elicit normal nesting behavior and oviposition in captives.

As for *Cyclura*, high intensity, full-spectrum illumination is essential for the successful captive maintenance of Lesser Antillean iguanas. This can be provided naturally in outdoor enclosures or via UV-transmitting skylights, or artificially with a combination of full-spectrum fluorescent tubes and metal halide lamps. Temperatures suitable for rock iguanas are appropriate for this species as well.

Nutrition

Wild-caught specimens are extremely particular in the foods they will accept. Favored items include sweet potato leaves, fresh figs, *Opuntia* fruit, papaya, grapes

(especially red and black), and fresh whole cranberries. These are the best foods to offer freshly captured specimens. With patience and persistence, they will gradually begin to accept a wider variety of fruits and leaves. Captives have taken plums, lettuce, mango, cabbage, kale, collared greens, dandelion, orange, apple, banana, pineapple, and cherimoya. Many of these items are not accepted until the lizards are well-acclimated and routinely feeding on their preferred items. Unquestionably the best item to offer new captives is sweet potato leaves, made available by placing potted plants in the enclosure and allowing the lizards to graze naturally. This is usually the first, and sometimes only, food item that freshly imported captives will accept. *Hibiscus* (young leaves and red blossoms) and *Ficus benjamina* are also grazed. The food preferences of captive-born Lesser Antillean iguanas, once they become available, may prove less limited.

The native diet seems to consist almost exclusively of young vines and leaves, with some fruit in season. Field research by M. Day has included fecal analysis and stomach content studies using road-killed individuals. Results of his studies will be invaluable to better assess the suitability of the items offered to captives, and to refine the diet. Data available thus far suggest that limiting the amount of fruit may be advisable. Lazell (1973) reported observing specimens on La Desirade consuming bird eggs, carrion and *Opuntia* fruit, and induced semi-captives on Dominica to accept a variety of fruit, but noted that citrus and papaya were consistently ignored.

Health

Specimens on St. Eustatius were observed to harbor small, red mites on the head and around the eyes. Fecal examination of wild-caught specimens from Dominica revealed heavy burdens of strongyles and oxyurids, which were eliminated after three doses of fenbendazole (administered orally, 100mg/kg body weight) spaced two weeks apart. Necropsy results of a female housed at Memphis revealed *Salmonella* sp., although whether this was a contributing factor to the death of the specimen remains speculative.

Breeding

The first captive breeding of Lesser Antillean iguanas occurred on 20 May 1997, when a single egg pipped at the Jersey Wildlife Preservation Trust. No other eggs in the clutch survived. Eggs were incubated at 31°C for 73 days, on a 1:1 water to vermiculite substrate. The hatchling weighed 20g and had an SVL of 75mm (R. Gibson, personal communication). Oviposition has occurred at all three participating institutions, and copulations have been confirmed at Jersey and Memphis. In Memphis, breeding takes place in March, and eggs are laid in May and June. Except for the single viable egg at Jersey, all eggs have failed to hatch despite the fact that many were confirmed fertile. Because all captive specimens are owned by the government of Dominica, the expansion of the captive population and the placement of surplus animals will require consultation with and approval by the Dominican Ministry of Agriculture.

Education and Ecotourism

By Allison Alberts

Local community programs

Development of *in situ* education programs for West Indian iguanas should form an essential cornerstone of any efforts devoted to their conservation. First, it is imperative to educate local people living in areas where they will have direct contact with free-ranging iguanas. This is especially important when iguanas have been reintroduced to previously unoccupied habitats where the community may be unfamiliar with these animals and their habits. Schools are probably an ideal place to start, as young people are much less prone to have preconceived notions about local wildlife and may be especially likely to share their enthusiasm for preserving it with other family members. Videos, slideshows, educational brochures, and posters can all serve as effective means for spreading information **about** iguanas and their conservation



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Jamaican nationals displaying a "Save the Jamaican iguana" poster at the Hope Zoo in Kingston.

needs throughout the community and beyond. The high quality poster depicting the plight of the Jamaican iguana produced in conjunction with the PHVA workshop for this species (CBSG 1993) has been instrumental in raising funds for conservation. At the national level, commemorative stamps and coins can be useful in making the general public aware of the endemic flora and fauna inhabiting their islands.

Although education programs should probably be focused initially on localized areas of high iguana concentration, eventually they could be expanded to include surrounding areas. Even people having only occasional contact with iguanas need to be alerted as to their protected status and encouraged to immediately report any violations of regulations to local authorities. On some cays in the Bahamas, prominent signing of nesting areas has been helpful in keeping disturbance of gravid females and hatching young by visiting tourists to a minimum.

Because iguanas are large, photogenic, and charismatic, they have the potential to serve as flagship species for promoting conservation of the dry tropical forest ecosystems they inhabit. Many of these remnant forests represent the last refuge for a variety of other species, including many endemic plants. In Costa Rica and Panama, integrated management programs for iguanas have successfully raised public awareness regarding iguana conservation through an annual Iguana Day Celebration (Werner 1991). In both countries, the event is widely attended and has had a significant positive impact on the attitude of local people toward iguanas and their tropical forest habitat.

Wildlife management training

In addition to educating the general public, programs also need to be developed for training local wildlife managers. At the minimum, these programs should

incorporate information about the basic biology of iguanas. If managers could also be trained in standard methods of marking (e.g., implanted transponder tags, crest scale and toe-clipping) and censusing iguana populations, then regular patrols through iguana habitat could yield valuable survey information. Additional training in the area of plant species identification and vegetation transect methods would allow regular assessments of iguana habitats to be made. In areas where mongooses and feral pigs occur, it may also be important to instruct wildlife managers in options for nest protection and artificial incubation of eggs collected from disturbed nest sites. Where parasitism or disease is a conservation concern, it would be useful for wildlife managers to have experience in routine blood collection and sample preparation for health screening purposes. Finally, because the responsibility for any ongoing predator control programs will probably fall on local wildlife managers, they should be instructed in use of humane but effective methods that minimize the risk to iguanas and other non-target species.

Ecotourism

Ecotourism has been defined as "low impact nature tourism which contributes to the maintenance of species and habitats either directly through a contribution to conservation and/or indirectly by providing revenue to the local community sufficient for local people to value, and therefore protect, their wildlife heritage area as a source of income" (Goodwin 1996). In order to be successful, it must be ecologically sound, economically viable, and socially equitable for local communities, particularly on small islands and other fragile environments (World Tourism Organisation 1995). Ecotourism not only potentially provides a means for conservation education at the national and international levels, but also can be a valuable source of funding for habitat management. Conversely, if not conducted in a sensitive manner, ecotourism can have devastating negative effects, including pollution, overconsumption of resources, disturbance of wildlife, destruction of vegetation, and erosion (Goodwin 1996). To ensure that ecotourism results in more good than harm to the environment, it is imperative that it be carefully controlled and regulated at both the local and national levels.

The Ecotourism Society (1993) has published an excellent guidebook for conducting ecologically and culturally sensitive ecotourism programs. Among other recommendations, they emphasize that ecotourism should 1) minimize the negative effects of visitors on local habitats and cultures through provision of educational materials prior to visitors entering natural areas, 2) provide tours consisting only of small,

manageable groups with adequate leadership to minimize disturbance, 3) make a significant financial contribution to conservation of the region or species impacted, 4) employ local community members whenever possible, and 5) alert all visitors to the fragility of the habitat and needs of sensitive species, including any local legislation or regulations devoted to their protection. Local people need to be encouraged to participate in decision-making regarding the quantity, location, and timing of visits by tourists (King and Stewart, 1996). If community members do not receive direct benefits from ecotourism, there will be no incentive for them to abandon other, more destructive uses of the habitat. Before ecotourism can begin to generate significant conservation benefits, it is also important that a basic infrastructure be in place, including trained guides, interpretive materials, and visitor information centers (Jacobson and Lopez 1994).

In addition to these general considerations, special concerns for West Indian iguanas include discouraging tourists from feeding iguanas, which may not only disrupt their water balance but may also cause them to lose their fear of people and other potential predators. When photographing iguanas, tourists need to be made aware of the dangers of approaching animals too closely and trampling sensitive vegetation. Visits by tour groups during the nesting season may disrupt gravid females from digging nest holes and inhibit hatching young from dispersing away from the nest clearing. For these reasons, ecotourism at these times of year will need to be curtailed. Finally, long-term monitoring will be critical to determining whether ecotourism is having detrimental effects on reproductive success of iguanas or other native wildlife.

Iguana watching is a popular pastime at the U.S. Naval Base at Guantánamo Bay, Cuba.



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Appendix 1. List of Conservation Agencies and Organizations

Bahamas

Bahamas National Trust, PO Box N4105,
Nassau, Bahamas

Conservation Office, Department of Agriculture,
Ministry of Agriculture and Fisheries,
PO Box N3028, Nassau, Bahamas

Bermuda

Bermuda Aquarium, Natural History Museum,
and Zoo, PO Box FL 145, Flatts Fl Bx, Bermuda

Conservation and Research for Island Species
and Insular Systems (C.R.I.S.I.S.),
PO Box HM 690, Hamilton HMCX, Bermuda

British Virgin Islands

National Parks Trust, Ministry of Natural Resources,
Box 860, Road Town, Tortola, British Virgin Islands

Guana Island Wildlife Sanctuary,
administered by The Conservation Agency,
6 Swinburne Street, Jamestown, RI 02835 USA

Cayman Islands

National Trust for the Cayman Islands,
PO Box 31116 SMB, Grand Cayman,
Cayman Islands

Protection and Conservation Unit,
Department of the Environment,
Cayman Islands Government, PO Box 486 GT,
Grand Cayman, Cayman Islands

Chief Agricultural and Veterinary Officer,
Department of Agriculture,
Cayman Islands Government, PO Box 459 GT,
Grand Cayman, Cayman Islands

Cuba

Centro Nacional de Areas Protegidas, Calle 18A
No. 4114, Miramar Playa, Ciudad Habana, Cuba

Empresa Nacional para la Protección
de la Flora y Fauna,
Carretera de Batabano km. 23 1/2, San José, Cuba

Museo Nacional de Historia Natural,
Capitolio Nacional, La Habana, Cuba

Instituto de Ecología y Sistemática,
Academia de Ciencias de Cuba,
Carretera de Varone km 3 1/2, Ciudad Habana, Cuba

Dominican Republic

Proyecto Biodiversidad, Programa de las Naciones
Unidas para el Desarrollo, PO Box 1424,
Mirador Sur, Santo Domingo, Dominican Republic

Departamento Zoología, Parque Zoológico Nacional,
ZOODOM, Santo Domingo, Dominican Republic

Departamento de Vida Silvestre,
SURENA, Secretaria de Estado de Agricultura,
Santo Domingo, Dominican Republic

Grupo Jaragua, El Vergel,
Santo Domingo, Dominican Republic

Jamaica

Hope Zoo, Hope Gardens,
Ministry of Agriculture,
Kingston 6, Jamaica

Jamaica Conservation and Development Trust,
46 Duke Street, Box 1225,
Kingston 8, Jamaica

Jamaica Environment Trust,
58 Half Way Tree Road,
Kingston 10, Jamaica

Jamaican Iguana Research and Conservation Group,
c/o Peter Vogel, Department of Life Sciences,
University of the West Indies,
Kingston 7, Jamaica

National Environmental Societies Trust,
46 Duke Street,
Kingston 8, Jamaica

Natural Resources Conservation Authority,
53 1/2 Molyneux Road,
Kingston 10, Jamaica

South Coast Conservation Foundation,
91A Old Hope Road,
Kingston 6, Jamaica

Lesser Antilles

Forestry and Wildlife Division, Ministry of
Agriculture, Botanic Gardens, Roseau, Dominica

Association pour l'Etude et la protection des Vertébrés
des petites Antilles (AEVA), c/o Barré,
Belair Desrozieres, 97170 Petit Bourg, Guadeloupe,
French West Indies

Puerto Rico

Department of Natural and Environmental Resources,
PO Box 9066600, San Juan, Puerto Rico 00906

Centro de Informacion Ambiental del Caribe (CIAC),
Universidad Metropolitana,
Apartado 21150,
Río Piedras, Puerto Rico 00928

Chelonia, Sociedad Herpetologica de Puerto Rico,
Universidad Metropolitana,
Apartado 21150 (#22),
Río Piedras, Puerto Rico 00928

International Institute of Tropical Forestry,
USDA Forest Service, P.O. Box 25000,
Río Piedras, Puerto Rico 00928

Turks and Caicos Islands

Turks and Caicos National Trust, Butterfield Square,
Providenciales, Turks and Caicos Islands

Department of Environment and Coastal Resources,
Ministry of Natural Resources, South Base,
Grand Turk, Turks and Caicos Islands

Appendix 2. Criteria for IUCN Red List Threat Categories (1994)

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the following criteria:

A. Population reduction in the form of either of the following:

1. An observed, estimated, inferred, or suspected reduction of at least 80% over the last 10 years or three generations, whichever is longer, based on any of the following:

- (a) direct observation
- (b) an index of abundance appropriate for the taxon
- (c) a decline in area of occupancy, extent of occurrence, and/or quality of habitat
- (d) actual or potential levels of exploitation
- (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites.

2. A reduction of at least 80%, projected or suspected to be met within the next 10 years or three generations, whichever is longer, based on any of (b), (c), (d), or (e) above.

B. Extent of occurrence estimated to be less than 100km² or area of occupancy estimated to be less than 10km², and estimates indicating any two of the following:

1. Severely fragmented or known to exist at no more than one location.

2. Continuing decline, observed, inferred, or projected, in any of the following:

- (a) extent of occurrence
- (b) area of occupancy
- (c) area, extent, and/or quality of habitat
- (d) number of locations or subpopulations
- (e) number of mature individuals.

3. Extreme fluctuations in any of the following:

- (a) extent of occurrence
- (b) area of occupancy
- (c) number of locations or subpopulations
- (d) number of mature individuals.

C. Population estimated to number less than 250 mature individuals and either:

1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, or

2. A continuing decline, observed, inferred, or projected, in numbers of mature individuals and population structure in the forms of either:

- (a) severely fragmented (i.e., no subpopulation estimated to contain more than 50 mature individuals)
- (b) all individuals are in a single subpopulation.

D. Population estimated to number less than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is longer.

ENDANGERED (EN)

A taxon is Endangered when it is not Critically Endangered, but is facing a very high risk of extinction in the wild in the near future, as defined by any of the following criteria:

A. Population reduction in the form of either of the following:

1. An observed, estimated, inferred, or suspected reduction of at least 50% over the last 10 years or three generations, whichever is longer, based on any of the following:

- (a) direct observation
- (b) an index of abundance appropriate for the taxon
- (c) a decline in area of occupancy, extent of occurrence, and/or quality of habitat
- (d) actual or potential levels of exploitation
- (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites.

2. A reduction of at least 50%, projected or suspected to be met within the next 10 years or three generations, whichever is longer, based on any of (b), (c), (d), or (e) above.

B. Extent of occurrence estimated to be less than 5,000km² or area of occupancy estimated to be less than 500 km², and estimates indicating any two of the following:

1. Severely fragmented or known to exist at no more than five locations.
2. Continuing decline, observed, inferred, or projected, in any of the following:
 - (a) extent of occurrence
 - (b) area of occupancy
 - (c) area, extent, and/or quality of habitat
 - (d) number of locations or subpopulations
 - (e) number of mature individuals.
3. Extreme fluctuations in any of the following:
 - (a) extent of occurrence
 - (b) area of occupancy
 - (c) number of locations or subpopulations
 - (d) number of mature individuals.

C. Population estimated to number less than 2,500 mature individuals and either:

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, or
2. A continuing decline, observed, inferred, or projected, in numbers of mature individuals and population structure in the forms of either:
 - (a) severely fragmented (i.e., no subpopulation estimated to contain more than 250 mature individuals)
 - (b) all individuals are in a single subpopulation.

D. Population estimated to number less than 250 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is longer.

VULNERABLE(VU)

A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future, as defined by any of the following criteria:

A. Population reduction in the form of either of the following:

1. An observed, estimated, inferred, or suspected reduction of at least 20% over the last 10 years or three generations, whichever is longer, based on any of the following:
 - (a) direct observation
 - (b) an index of abundance appropriate for the taxon
 - (c) a decline in area of occupancy, extent of occurrence, and/or quality of habitat
 - (d) actual or potential levels of exploitation
 - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites.
2. A reduction of at least 20%, projected or suspected to be met within the next ten years or three generations, whichever is longer, based on any of (b), (c), (d), or (e) above.

B. Extent of occurrence estimated to be less than 20,000km² or area of occupancy estimated to be less than 2,000km², and estimates indicating any two of the following:

1. Severely fragmented or known to exist at no more than ten locations.
2. Continuing decline, observed, inferred, or projected, in any of the following:
 - (a) extent of occurrence
 - (b) area of occupancy
 - (c) area, extent, and/or quality of habitat
 - (d) number of locations or subpopulations
 - (e) number of mature individuals.
3. Extreme fluctuations in any of the following:
 - (a) extent of occurrence
 - (b) area of occupancy
 - (c) number of locations or subpopulations
 - (d) number of mature individuals.

C. Population estimated to number less than 10,000 mature individuals and either:

1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer,

or

2. A continuing decline, observed, inferred, or projected, in numbers of mature individuals and population structure in the forms of either:

(a) severely fragmented (i.e., no subpopulation estimated to contain more than 1,000 mature individuals)

(b) all individuals are in a single subpopulation.

D. Population very small or restricted in the form of either of the following:

1. Population estimated to number less than 1,000 mature individuals.

2. Population is characterized by an acute restriction in its area of occupancy (typically less than 100 km²) or in the number of locations (typically less than five). Such a taxon would thus be prone to the effects of human activities (or stochastic events whose impact is increased by human activities) within a very short period of time in an unforeseeable future, and is thus capable of becoming Critically Endangered or even extinct in a very short period.

E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years or five generations, whichever is longer.

IUCN/SSC Action Plans for the Conservation of Biological Diversity

Action Plan for African Primate Conservation: 1986-1990. Compiled by J.F. Oates and the IUCN/SSC Primate Specialist Group, 1986, 41 pp. (Out of print.)

Action Plan for Asian Primate Conservation: 1987-1991. Compiled by A.A. Eudey and the IUCN/SSC Primate Specialist Group, 1987, 65 pp. (Out of print.)

Antelopes. Global Survey and Regional Action Plans. Part 1. East and Northeast Africa. Compiled by R. East and the IUCN/SSC Antelope Specialist Group, 1988, 96 pp. (Out of print.)

Dolphins, Porpoises and Whales. An Action Plan for the Conservation of Biological Diversity: 1988-1992. Second Edition. Compiled by W.F. Perrin and the IUCN/SSC Cetacean Specialist Group, 1989, 27 pp. (Out of print.)

The Kouprey. An Action Plan for its Conservation. Compiled by J.R. MacKinnon, S.N. Stuart and the IUCN/SSC Asian Wild Cattle Specialist Group, 1988, 19 pp. (Out of print.)

Weasels, Civets, Mongooses and their Relatives. An Action Plan for the Conservation of Mustelids and Viverrids. Compiled by A. Schreiber, R. Wirth, M. Riffel, H. van Rompaey and the IUCN/SSC Mustelid and Viverrid Specialist Group, 1989, 99 pp. (Out of Print.)

Antelopes. Global Survey and Regional Action Plans. Part 2. Southern and South-central Africa. Compiled by R. East and the IUCN/SSC Antelope Specialist Group, 1989, 96 pp. (Out of print.)

Asian Rhinos. An Action Plan for their Conservation. Compiled by Mohd Khan bin Momin Khan and the IUCN/SSC Asian Rhino Specialist Group, 1989, 23 pp. (Out of print.)

Tortoises and Freshwater Turtles. An Action Plan for their Conservation. Compiled by the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, 1989, 47 pp.

African Elephants and Rhinos. Status Survey and Conservation Action Plan. Compiled by D.H.M. Cumming, R.F. du Toit, S.N. Stuart and the IUCN/SSC African Elephant and Rhino Specialist Group, 1990, 73 pp. (Out of print.)

Foxes, Wolves, Jackals, and Dogs. An Action Plan for the Conservation of Canids. Compiled by J.R. Ginsberg, D.W. Macdonald, and the IUCN/SSC Canid and Wolf Specialist Groups, 1990, 116 pp.

The Asian Elephant. An Action Plan for its Conservation. Compiled by C. Santiapillai, P. Jackson, and the IUCN/SSC Asian Elephant Specialist Group, 1990, 79 pp.

Antelopes. Global Survey and Regional Action Plans. Part 3. West and Central Africa. Compiled by R. East and the IUCN/SSC Antelope Specialist Group, 1990, 171 pp.

Otters. An Action Plan for their Conservation. Compiled by P. Foster-Turley, S. Macdonald, C. Mason and the IUCN/SSC Otter Specialist Group, 1990, 126 pp.

Rabbits, Hares and Pikas. Status Survey and Conservation Action Plan. Compiled by J.A. Chapman, J.E.C. Flux, and the IUCN/SSC Lagomorph Specialist Group, 1990, 168 pp.

Insectivora and Elephant-Shrews. An Action Plan for their Conservation. Compiled by M.E. Nicoll, G.B. Rathbun and the IUCN/SSC Insectivore, Tree-Shrew and Elephant-Shrew Specialist Group, 1990, 53 pp.

Swallowtail Butterflies. An Action Plan for their Conservation. Compiled by T.R. New, N.M. Collins and the IUCN/SSC Lepidoptera Specialist Group, 1991, 36 pp.

Crocodiles. An Action Plan for their Conservation. Compiled by J. Thorbjarnarson, H. Messel, F.W. King, J.P. Ross and the IUCN/SSC Crocodile Specialist Group, 1992, 136 pp.

South American Camelids. An Action Plan for their Conservation. Compiled by H. Torres and the IUCN/SSC South American Camelid Specialist Group, 1992, 58 pp.

Australasian Marsupials and Monotremes. An Action Plan for their Conservation. Compiled by M. Kennedy and the IUCN/SSC Australasian Marsupial and Monotreme Specialist Group, 1992, 103 pp.

Lemurs of Madagascar. An Action Plan for their Conservation: 1993-1999. Compiled by R.A. Mittermeier, W.R. Konstant, M.E. Nicoll, O. Langrand and the IUCN/SSC Primate Specialist Group, 1992, 58 pp. (Out of print.)

Zebras, Asses and Horses. An Action Plan for the Conservation of Wild Equids. Compiled by P. Duncan and the IUCN/SSC Equid Specialist Group, 1992, 36 pp.

Old World Fruit Bats. An Action Plan for their Conservation. Compiled by S. Mickleburgh, A.M. Hutson, P.A. Racey and the IUCN/SSC Chiroptera Specialist Group, 1992, 252 pp. (Out of print.)

Seals, Fur Seals, Sea Lions, and Walrus. Status Survey and Conservation Action Plan. Peter Reijnders, Sophie Brasseur, Jaap van der Toorn, Peter van der Wolf, Ian Boyd, John Harwood, David Lavigne, Lloyd Lowry, and the IUCN/SSC Seal Specialist Group, 1993, 88 pp.

Pigs, Peccaries, and Hippos. Status Survey and Conservation Action Plan. Edited by William L.R. Oliver and the IUCN/SSC Pigs and Peccaries Specialist Group and the IUCN/SSC Hippo Specialist Group, 1993, 202 pp.

The Red Panda, Olingos, Coatis, Raccoons, and their Relatives. Status Survey and Conservation Action Plan for Procyonids and Ailurids. (In English and Spanish) Compiled by Angela R. Glatston and the IUCN/SSC Mustelid, Viverrid, and Procyonid Specialist Group, 1994, 103 pp.

Dolphins, Porpoises, and Whales. 1994-1998 Action Plan for the Conservation of Cetaceans. Compiled by Randall R. Reeves and Stephen Leatherwood together with the IUCN/SSC Cetacean Specialist Group, 1994, 91 pp.

Megapodes. An Action Plan for their Conservation: 1995-1999. Compiled by Reni W.R.J. Dekker, Philip J.K. McGowan and the WPA/BirdLife/SSC Megapode Specialist Group, 1995, 41 pp.

Partridges, Quails, Francolins, Snowcocks and Guineafowl. Status survey and Conservation Action Plan 1995-1999. Compiled by Philip J.K. McGowan, Simon D. Dowell, John P. Carroll and Nicholas J.A. Aebischer and the WPA/BirdLife/SSC Partridge, Quail and Francolin Specialist Group, 1995, 102 pp.

Pheasants: Status Survey and Conservation Action Plan 1995-1999. Compiled by Philip J.K. McGowan and Peter J. Garson on behalf of the WPA/BirdLife/SSC Pheasant Specialist Group, 1995, 116 pp.

Wild Cats: Status Survey and Conservation Action Plan. Compiled and edited by Kristin Nowell and Peter Jackson and the IUCN/SSC Cat Specialist Group, 1996, 406 pp.

Eurasian Insectivores and Tree Shrews: Status Survey and Conservation Action Plan. Compiled by David Stone and the IUCN/SSC Insectivore, Tree Shrew and Elephant Shrew Specialist Group, 1996, 108 pp.

African Primates: Status Survey and Conservation Action Plan (Revised edition). Compiled by John F. Oates and the IUCN/SSC Primate Specialist Group, 1996, 80 pp.

The Cranes: Status Survey and Conservation Action Plan. Compiled by Curt D. Meine and George W. Archibald and the IUCN/SSC Crane Specialist Group, 1996, 401 pp.

Orchids: Status Survey and Conservation Action Plan. Edited by Eric Hagsater and Vinciane Dumont, compiled by Alec Pridgeon and the IUCN/SSC Orchid Specialist Group, 1996, 153 pp.

Palms: Their Conservation and Sustained Utilization. Status Survey and Conservation Action Plan. Edited by Dennis Johnson and the IUCN/SSC Palm Specialist Group, 1996, 116 pp.

Conservation of Mediterranean Island Plants. 1. Strategy for Action. Compiled by O. Delanok, B. de Montmolin, L. Olivier and the IUCN/SSC Mediterranean Islands Plant Specialist Group, 1996, 106 pp.

Asian Rhinos: Status Survey and Conservation Action Plan (Second edition). Edited by Thomas J. Foose and Nico van Strien and the IUCN/SSC Asian Rhino Specialist Group, 1997, 112 pp.

Wild Sheep and Goats and their relatives: Status Survey and Conservation Action Plan. Edited by David M. Shackleton and the IUCN/SSC Caprinae Specialist Group, 1997, 390 pp.

The Ethiopian Wolf: Status Survey and Conservation Action Plan. Compiled and edited by Claudio Sillero-Zubiri and David Macdonald and the IUCN/SSC Canid Specialist Group, 1997, 123pp.

Cactus and Succulent Plants. Status Survey and Conservation Action Plan. Compiled by Sara Oldfield and the IUCN/SSC Cactus and Succulent Specialist Group, 1997, 212 + x pp.

Dragonflies. Status Survey and Conservation Action Plan. Compiled by Norman W. Moore and the IUCN/SSC Odonata Specialist Group, 1997, 28 + v pp.

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Tapirs: Status Survey and Conservation Action Plan. Compiled and edited by Daniel M. Brooks, Richard E. Bodmer and Sharon Matola and the IUCN/SSC Tapir Specialist Group, 1997, viii + 164pp.

Grebes: Status Survey and Conservation Action Plan. Compiled by Colin O'Donnell and Jon Fieldse and the IUCN/SSC Grebe Specialist Group, 1997, vii + 59pp.

Crocodiles: Status Survey and Conservation Action Plan, 2nd Edition. Edited by J. Perran Ross and the IUCN/SSC Crocodile Specialist Group, 1998, viii + 96pp.

Hyaenas: Status Survey and Conservation Action Plan. Compiled by Gus Mills and Herbert Hofer and the IUCN/SSC Hyaena Specialist Group, 1998, vi + 154 pp.

North American Rodents: Status Survey and Conservation Action Plan. Compiled and edited by David J. Hafner, Eric Yensen, Gordon L. Kirkland Jr., and the IUCN/SSC Rodent Specialist Group, 1998, x + 171pp.

Deer: Status Survey and Conservation Action Plan. Compiled by C. Wemmer and the IUCN/SSC Deer Specialist Group, 1998, vi + 106pp.

Bears: Status Survey and Conservation Action Plan. Compiled by C. Servheen, H. Herrera and B. Peyton and the IUCN/SSC Bear and Polar Bear Specialist groups, 1998, x + 306pp.

Other IUCN/SSC Publications

IUCN Red Lists of Threatened Animals and Plants

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The Species Survival Commission (SSC) is one of six volunteer commissions of IUCN - The World Conservation Union, a union of sovereign states, government agencies and non-governmental organizations. IUCN has three basic conservation objectives: to secure the conservation of nature, and especially of biological diversity, as an essential foundation for the future; to ensure that where the earth's natural resources are used this is done in a wise, equitable and sustainable way; and to guide the development of human communities towards ways of life that are both of good quality and in enduring harmony with other components of the biosphere.

The SSC's mission is to conserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats. A volunteer network comprised of nearly 7,000 scientists, field researchers, government officials and conservation leaders from nearly every country of the world, the SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions and conservation organizations.

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