The amphibians and reptiles of the Cayman Islands: Conservation issues in the face of invasions

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Abstract. The four islands of Cayman Islands are among the most isolated in the West Indies. They support 25 native species of amphibians and reptiles. Fifteen additional species have been deliberately or accidently introduced. The immediate source for 11 of the 15 is the United States. Eight of the 15 have become established. There have been two introductions in which both the source and target islands are in the Cayman Islands, one successful and the other a failure. Eleven native species have been evaluated with respect to CITES and/or IUCN. Nine species have not been evaluated and some of these may be found to warrant listing. Seventeen species, some with multiple subspecies, are endemic to the Cayman Islands. Threats to the native species of the Cayman Islands include habitat modification or destruction, over-exploitation, introduced species, and the effects of anthropogenic global climate change. Conservation actions are discussed, emphasizing marine turtles and *Cyclura lewisi*, as is legal protection afforded the herpetofauna.

Key words: Amphibians; Cayman Islands; conservation; native species; non-native species; reptiles.

Introduction

Small islands, isolated from other islands and continents as possible sources of colonists, tend to have low species richness and high endemism (MacArthur and Wilson, 1967). The herpetofauna of the Cayman Islands fits this description well. In addition, the islands are all low with little topographic relief and are fairly uniform with respect to vegetation. Only Grand Cayman has large areas of fresh-brackish water. This lack of habitat diversity also contributes to the low richness of amphibians and reptiles.

This richness is, however, increasingly enhanced by the deliberate or accidental introduction of non-native amphibians and reptiles, mostly from the United States.

Some of these are native to North America, but others are derived from populations that represent earlier introductions to the United States. The number of introductions to the Cayman Islands, particularly Grand Cayman, is related to the rapid development of the islands since the 1960s and the consequent need to import products from the United States in support of a burgeoning tourism industry and an influx of non-native colonists of the human kind. The impact of the increasing human population of the Cayman Islands is obvious. The impact of other sorts of biotic introductions, including amphibians and reptiles, is less obvious and much less well-studied.

It is the purpose of this paper to (1) summarize the occurrence of non-native amphibians and reptiles on the islands, (2) discuss the conservation status of the native herpetofauna, (3) consider the threats, including non-native species, to the native herpetofauna, and (4) discuss measures being taken by the government of the Cayman Islands and NGOs to mitigate these threats. Special attention will be given to the Blue Iguana Recovery Programme, as an excellent example of a successful species recovery program, and to marine turtles.

The Cayman Islands

The Cayman Islands are among the most isolated in the West Indies (Brunt and Davies, 1994). Grand Cayman, the largest of the four islands (area 197 km^2; maximum elevation 18 m), lies about 300 km from both Cuba and Jamaica. Cayman Brac (38 km^2; 43 m and Little Cayman (28 km^2; 12 m) are separated by about 7 km and are 130 km northwest of Grand Cayman. Tiny unpopulated Owen Island (4.25 ha; <3 m) is located on South Hole Sound on the south side of Little Cayman. Grand Cayman, Cayman Brac and Little Cayman are emergent peaks on the east-west Cayman Ridge, a westward extension of the Sierra Maestra mountains of Cuba (Jones, 1994). The surface of the islands is primarily limestone or coralline, with pockets of soil where the actions of wind and water have created depressions. The shorelines of the islands are, in many areas, comprised of white beach sand. Behind these, or standing alone, are limestone ironshores that have been weathered into razor-sharp formations, often over solution tunnels and pits that when overgrown and hidden by vegetation, make field work an adventure. Cayman Brac differs from the other three islands in topography. From sea level at its west end, it slopes upward to an impressive cliff at the east end. The north and south sides of the uplifted "slab" are increasingly steep as well, with numerous caves opening out toward the sea.

The Cayman Islands have a tropical maritime climate characterized by little monthly variation in temperature and seasonal variation in precipitation (Burton, 1994). Seasons are defined by precipitation, with a summer wet season extending from May to November, and a winter dry season from November to April. The mean maximum and minimum January air temperatures are about 28°C and 22°C, respectively, and for July they are 32°C and 25°C, respectively. Mean annual rainfall for Cayman Brac is about 1100 mm, and for Little Cayman, it is about 1175 mm. On Grand Cayman, there is a pronounced east-west precipitation gradient, from

about 1100 mm annually in the east to about 1600 mm in the west. There is a less pronounced gradient on Cayman Brac, from about 1050 mm of annual rainfall in the east to 1175 mm in the central part of the island. Generally, March is the driest month and October the wettest. The islands lie within a track along which hurricanes frequently move from east to west during the wet season.

The vegetation, described in detail by Burton (2008), is characterized as Dry Forest, Xerophytic Shrubland, Seasonally Flooded Forests and Shrublands, with mangroves prominent on Grand Cayman and, especially, around North Sound, Grand Cayman. The inland vegetation of Little Cayman is dominated by xerophytic shrubland, with mangrove forests concentrated around coastal ponds, especially near the south coast. On Cayman Brac, dry and xerophytic forests dominate the central, elevated plateau, and on low coastal platforms in sheltered areas. Xerophytic shrubland dominates the eastern region and in exposed coastal settings. The vegetation of Grand Cayman reflects the east-west precipitation gradient with xerophytic shrubland in the eastern interior grading to dry forest further west, especially on higher terrain.

Cayman Islands census data (Government of the Cayman Islands, 2010; index mundi, 2010) indicate that the human population of the Cayman Islands increased slowly between 1802 (estimated population 933) and 1970 (10,068). It had reached an estimated 39,410 by 1999 and 49,035 by 2009. Most residents live on Grand Cayman. Tourism is the major industry. Most visitors arrive by either air (354,087 in 2000; 271,958 in 2009) or on cruise ships (1,030,857 in 2000; 1,520,372 in 2009). About 90 per cent of imports are from the United States, and many of these goods arrive on container ships.

The Herpetofauna

There have been two comprehensive accounts of the amphibian and reptile fauna of the Cayman Islands (Grant, 1940; Seidel and Franz, 1994). Since 1994, there have been several taxonomic changes associated with partitioning genera or elevating subspecies to species status (table 1). We have not included individual species

Table 1. Classification history of native reptiles of the Cayman Islands comparing that employed by Seigel and Franz (1994) and that used in this paper.

Seigel and Franz, 1994	This paper
Cyclura nubila lewisi	*Cyclura lewisi*
Anolis sagrei luteosignifer	*Anolis luteosignifer*
Tropidophis caymanensis caymanensis	*Tropidophis caymanensis*
Tropidophis caymanensis parkeri	*Tropidophis parkeri*
Tropidophis caymanensis schwartzi	*Tropidophis schwartzi*
Alsophis cantherigerus caymanus	*Cubophis caymanus*
Alsophis cantherigerus fuscicauda	*Cubophis fuscicauda*
Alsophis cantherigerus ruttyi	*Cubophis ruttyi*

accounts herein, referring the reader instead to Seidel and Franz (1994) and Henderson and Powell (2009).

Native amphibians and reptiles

The native herpetofauna of the Cayman Islands currently includes 25 species, some represented by multiple subspecies (table 2). The numbers of species known to inhabit each of the four islands are: Grand Cayman 15, Cayman Brac 16, Little Cayman 14, Owen Island 5. Twenty species or subspecies are endemic to the Cayman Islands (table 2).

Crocodylus rhombifer is not listed in table 2. The Cayman Islands are believed to have once supported large populations of both *C. acutus* and *C. rhombifer*. Subfossil remains of *C. rhombifer* and associated coproliths occur in abundance throughout Grand Cayman in saturated peat deposits accumulated in sinkholes (Morgan, 1994). *Crocodylus acutus* is not represented in the fossil record, presumably because its habitat offers fewer opportunities for preservation. Early maps of the Cayman Islands feature crocodilians on and around the coasts, and an April 1586 account of a visit from a vessel in Sir Francis Drake's fleet speaks of both "alligatos" and "crocadiles" both in sea and on land. Indeed, the name "Cayman Islands" is likely derived from the Spanish, "Caiman" (Craton, 2003).

Crocodylus rhombifer is extinct in the Cayman Islands, although oral history suggests that it may have survived until at least the late 19th Century. Many of the fossil sites for this species are in predominately dry land, and it seems inconceivable that crocodiles could occupy these areas in modern times. This suggests that historic climate change may have played a part in the decline of *C. rhombifer* in the Cayman Islands, though oral history confirms that persecution by humans was also a major factor toward the end.

We consider *Crocodylus acutus* native to the Cayman Islands because, although there are currently no breeding populations in the Caymans, these islands are within the overall geographic range of the species and its absence at this time is almost certainly attributable to human intervention. Rare vagrants, presumably from populations in neighboring Cuba and/or Jamaica, are still sighted from time to time on all of the Cayman Islands (Garman, 1988; Grant, 1940; Morgan, 1994). Recent sightings include an eight foot long *C. acutus/C. rhombifer* hybrid on Grand Cayman on 30 December 2007 (hybridity was confirmed by genetic analysis), a seven to eight foot crocodile, species unknown, sighted off Little Cayman on 25 November 2008, and a 1.4 m *C. acutus* observed off Grand Cayman on 26 January 2009 (Cayman Islands Department of Environment [DoE] records, courtesy of M. DaCosta-Cottam and K.D. Godbeer). The crocodiles observed in 2008 and 2009 may have come from either Cuba or Jamaica, but the hybrid must have come from Cuba. It is known that *Crocodylus porosus* ride surface currents and its wide geographic distribution in the southeast Pacific suggests that some individuals make long oceanic voyages (Campbell et al., 2010). Ocean currents between Cuba and Jamaica would facilitate similar voyages in the Caribbean. Unfortunately, poorly

Table 2. Native amphibians and reptiles currently known to occur in the Cayman Islands. GC = Grand Cayman, CB = Cayman Brac, LC = Little Cayman, OI = Owen Island. N = Not reported. An asterisk indicates a subspecies or species that is endemic to the Cayman Islands. CITES appendices are shown as I or II; IUCN Redlist status (IUCN, 2010) by CR (critically endangered), EN (endangered), NT and LR (lower risk). Crocodiles (Crocodylidae) and sea turtles (Cheloniidae) have been observed or collected in close proximity to the indicated islands.

Species		GC	CB	LC	OI	Conservation status	
						CITES	IUCN
AMPHIBIA, Anura							
Hylidae	*Osteopilus septentrionalis*	X	X	X		–	LC
Leptodactylidae	*Eleutherodactylus planirostris*	X	X			–	LC
REPTILIA, Crocodylia							
Crocodylidae	*Crocodylus acutus*	X	X	X		I	V
REPTILIA, Sauria							
Anguidae	*Celestus maculates**		X	X		–	–
Gekkonidae	*Aristelliger praesignis praesignis*	X	X	X	X	–	–
	*Sphaerodactylus a. argivus**		X			–	–
	*Sphaerodactylus a. bartschi**			X	X	–	–
	*Sphaerodactylus a. lewisi**	X				–	–
Iguanidae	*Cyclura lewisi**	X				I	CR
	*Cyclura nubila caymanensis**		X	X		I	V
Leiocephalidae	*Leiocephalus carinatus granti**		X	X		–	–
	*Leiocephalus c. varius**	X				–	–
Polychrotidae	*Anolis (Norops) conspersus conspersus**	X				–	–
	*Anolis (Norops) c. lewisi**		X			–	–
	*Anolis (Norops) luteosignifer**		X			–	–
	*Anolis maynardi**			X		–	–
	Anolis (Norops) sagrei			X		–	–
REPTILIA, Serpentes							
Dipsadidae	*Cubophis caymanus**	X				–	–
	*Cubophis fuscicauda**		X			–	–
	*Cubophis ruttyi**			X		–	–
	*Tretanorhinus variabilis lewisi**	X				–	–
Tropidophiidae	*Tropidophis caymanensis**	X				I	–
	*Tropidophis parkeri**			X		I	–
	*Tropidophis schwartzi**		X			I	–
Typhlopidae	*Typhlops caymanensis**	X				–	–
	*Typhlops epactius**		X			–	–
REPTILIA, Testudines							
Cheloniidae	*Caretta caretta*	X	X	X	X	I	EN
	Chelonia mydas	X	X	X	X	I	EN
	Eretmochelys imbricata	X	X	X	X	I	CR

informed fears for public safety weigh heavily against any chance of the re-colonization of the Cayman Islands by *C. acutus*. The hybrid crocodile mentioned above, a young male, was speared under police direction in shallow coastal waters.

Non-native amphibians and reptiles

Two amphibian species and 13 reptile species have been introduced to the Cayman Islands, and two reptile introductions have been between islands within the Cayman Island group (table 3). The immediate source of 11 of these was the United States. Of these, five (*Rhinella marina*, *Hemidactylus mabouia*, *Anolis equestris*, *Anolis (Norops) sagrei*, and *Ramphotyphlops braminus*) had been introduced to the United States from elsewhere and then secondarily introduced to the Cayman Islands. *Anolis maynardi*, endemic to Little Cayman, has been successfully introduced on Cayman Brac (Franz et al., 1987), and *Cyclura nubila caymanensis* from either Cayman Brac or Little Cayman may have been unsuccessfully introduced on Grand Cayman (Grant, 1940). Of the 15 remaining introduced species which have been reported to have arrived from outside of the Cayman Islands, two are anuran species, eight are lizards, three are snakes, and two are turtles. Eight of the 15 species have become established in the Cayman Islands and five have not. One, *Anolis equestris*, arrived so recently (M. DaCosta-Cottam, K. Godbeer and T. Austin, 2010) that it cannot yet be determined whether the introduction will be successful. The eight successful introductions raise the number of amphibian and reptiles species inhabiting the Cayman Islands to 33 (34 if *A. equestris* becomes established). On the basis of the absence its fossil remains in peat moss deposits that contain many other vertebrate taxa (Seidel and Franz, 1994), *Trachemys decussata* is presumed to be introduced, but this has not been confirmed by molecular data.

It seems apparent that the large number of tourists who visit the Cayman Islands each year are not the source of these introductions. Rather, introduced species are arriving in ships' cargo which includes live plants where stowaways can hide. Many of these are foliage plants or trees grown in nurseries in Florida and are destined to beautify homes or resorts in the Cayman Islands. Building materials account for another large fraction of imports, and a substantial part of this is used in the construction of homes and resorts. Therefore, although tourists and immigrants do not actively transport live amphibians or reptiles to the Cayman Islands, the need to provide living quarters for those who stay longer than a single day (i.e., tourists other than cruise ship passengers) has promoted the introduction of non-native species.

Conservation status

Eleven of the species of amphibians and reptiles inhabiting the Cayman Islands have been evaluated for CITES (UNEP-WCMC, 2010) and/or IUCN (2010) listing, and two of these (both anurans) have an IUCN Redlist status of "Least Concern" (table 2). This is surprising, given the high level of endemism evident in the herpetofauna. Most of the potential candidates for listing, however, have not been

Table 3. Non-native amphibians and reptiles currently known to occur in the Cayman Islands. GC = Grand Cayman, CB = Cayman Brac, LC = Little Cayman, OI = Owen Island. Status: 1 = established: apparent persistent reproducing population(s); the species may or may not be expanding geographic range from site(s) of introduction. 2 = Reported in the wild at least once but no conclusive evidence suggesting that the species has become established or, if it had for a time (e.g., *Cyclura nubila*), is no longer present (but see text).

Species		GC	CB	Source	Status	Documentation
AMPHIBIA, Anura						
Bufonidae	*Rhinella marina*	X		U.S.	2	Burton and Echternacht, 2003
Microhylidae	*Gastrophryne carolinensis*	X		U.S.	1	Seidel and Franz, 1994
REPTILIA, Sauria						
Anguidae	*Ophisaurus ventralis*	X		U.S.	2	Seidel and Franz, 1994
Gekkonidae	*Gonatodes albogularis*	X		Jamaica?	2	Williams, 1964
	Hemidactylus mabouia	X		U.S.	1	Echternacht and Burton, 2002
Iguanidae	*Cyclura nubila caymanensis*	X		CB or LC	2	Grant, 1940; Schwartz and Thomas, 1975
	Iguana iguana	X		Honduras?	1	Franz and Seidel, 1994
Polycrotidae	*Anolis carolinensis*	X		U.S.	2	Powell, 2002
	Anolis equestris	X		U.S.	?	M. DaCosta-Cottam, pers. com.
	Anolis garmani	X		Jamaica	2	Seidel and Franz, 1994
	Anolis maynardi		X	LC	1	Franz et al., 1987
	Anolis (Norops) sagrei	X		U.S.	1	Minton and Minton, 1984; Kolbe et al., 2004
REPTILIA, Serpentes						
Colubridae	*Diadophis p. punctatus*	X		U.S.	2	Seidel and Franz, 1994
	Pantherophis guttatus	X		U.S.	1	Franz et al., 1987
Typhlopidae	*Ramphotyphlops braminus*	X		U.S.	1	Echternacht and Burton, 2003
REPTILIA, Testudines						
Emydidae	*Trachemys decussata angusta*	X		Cuba?	1	Seidel and Franz, 1994
	Trachemys scripta	X		U.S.	1	Lever, 2003

evaluated with respect to the criteria employed by CITES and the IUCN so that they can be proposed for listing. For many of these species, even the most basic ecological data are lacking. These include abundance, habitat requirements, and measures of reproductive success. In particular, the two species of blindsnakes endemic to the Cayman Islands, *Typhlops caymanensis* (Grand Cayman) and *T. epactius* (Cayman Brac), are burrowers and seldom seen, and their population densities are unknown. They inhabit beach dune areas which are favored by developers (Henderson and Powell, 2009; Seidel and Franz, 1994).

Threats

The litany of threats to the species of amphibians and reptiles of the Cayman Islands is heard with respect to the biotas of small islands world-wide. At the top of the list is habitat modification or destruction, often associated with uninformed planning and a lack of awareness, or possibly a lack of caring, about the fate of components of natural (and national) heritage. Coastal beach dune habitats are especially at risk. These environments are in demand for home sites and resorts and are fast disappearing. The economy of the Cayman Islands is based in large part on tourism, and tourists expect suitable housing and entertainment (which may include golf). Often, economics wins out when the difficult decision is made to clear a piece of land which may be prime habitat for a species found in no other habitat (see *Typhlops caymanensis* and *T. epactius* below). For some species, over-exploitation is a serious concern, and has led to the loss of a major resource with the collapse of sea turtle populations in the Cayman Islands (see below). Exploitation may also come in the form of illegal poaching of amphibians and reptiles for the pet trade. The accidental or deliberate introduction of non-native species can be a serious threat to native species which have no experience with the newcomers and to which they have had no time to adapt. Such non-native species need not be amphibians or reptiles; rats and mice will eat lizard eggs, for example, and adult rats will attack and eat juvenile lizards. Feral dogs and cats, both non-native in the context of the Cayman Islands, are notorious predators on islands world-wide. Road kills are a threat on Grand Cayman, Cayman Brac, and especially Little Cayman, which has experienced a dramatic increase in road traffic since a power plant was built on the island and the rate of development increased. Anthropogenic climate change resulting in rapid global temperature increase may be expected to lead to higher sea levels, inundating the habitats of species that occupy low-lying coastal areas. Finally, the unthinkable may occur. On the morning of 4 May 2008, a volunteer keeper at the fenced *Cyclura lewisi* breeding and head-starting facility in Queen Elizabeth II Botanic Park on Grand Cayman discovered that four adult iguanas had been killed, two others left for dead (and subsequently died), and another was missing. This senseless violence, documented by Burton (2010) reduced by $1/3$ the adult breeding iguanas population at the facility.

Certain elements of the Cayman herpetofauna may be at greater risk than others and are discussed here. *Cyclura lewisi* and marine turtles are discussed in greater detail in the next section as well.

Cyclura nubila caymanensis. This species, which occurs on Cayman Brac and Little Cayman, is threatened on several fronts. Increased tourism and road improvements, especially on Little Cayman where the species has been relatively abundant, have led to an increase in road kills, and construction behind beaches threatens important nesting areas. An increase in the number of dogs and cats on these islands is also a concern.

Cyclura lewisi. Road kills and feral dogs and cats are major threats. The extent to which introduced *Iguana iguana* are a threat is unknown.

Tropidophis caymanensis (Cayman Brac), *T. parkeri* (Little Cayman) and *T. schwartzi* (Grand Cayman) are also subject to predation by feral dogs and cats and, should the introduced cane toad (*Rhinella marina*) have survived flooding associated with Hurricane Ivan, or be successfully re-introduced (two were found by customs officials in a landscaping shipment from Florida in 2003 or 2004; in lit.; Mat DaCosta-Cottam, 25 March 2010), it may pose a threat to *T. schwartzi* as well. The skin secretions of *R. marina* are highly toxic and even partial ingestion of the toads has been proven fatal to Death Adders (*Acanthophis praelongus;* Elapidae) in Australia, where the toad has also been introduced (Hagman et al., 2009), and to Jamaican boas (*Epicrates subflavus*) in Jamaica (Wilson et al., 2010). Finally, the corn snake (*Pantherophis guttatus*; Colubridae) has been introduced on Grand Cayman where it is apparently established, though still relatively uncommon. It has a generalized vertebrate diet (Perry et al., 2003) and may compete with *T. schwartzi*.

Typhlops caymanensis and *T. epactius*. As noted above, these snakes inhabit beach dune areas, and these are often given over to development.

Anolis conspersus. There was initial concern that the introduction of *Anolis sagrei* to Grand Cayman might have negative consequences for the endemic *A. conspersus*. *Anolis conspersus* is a trunk-crown anole, meaning that it most often occurs on the trunks or in the crowns of trees, whereas *A. sagrei* is a trunk-ground anole. In the southeastern United States, the introduction of *A. sagrei* has led to dramatic population declines in another trunk-crown anole, *A. carolinensis*. Thus the concern with respect to *A. conspersus*. The evidence so far, however, suggests that *A. sagrei* is not negatively impacting *A. conspersus* (Gerber, 2000).

Trachemys decussata. Should molecular data indicate that *T. decussata* is native, competition with introduced *T. scripta* should be considered a threat. The two species are ecologically similar as well as closely related (Seidel and Franz, 1994).

Of the 30 species of amphibians and terrestrial or freshwater reptiles known to occur in the Cayman Islands, nine (30%) are introduced or assumed to be introduced (tables 1, 2). This assumes that *Osteopilus septentrionalis*, *Eleutherodactylus planirostris* are confirmed to be native, and *Trachemys decussata* is confirmed to be introduced. Of the nine introduced species we consider established, all but one (*Anolis maynardi*, representing an intraisland introduction within the Cayman Islands)

occur only on Grand Cayman. For purposes of this discussion, *Anolis sagrei*, which is native to Little Cayman but introduced on Grand Cayman, is included among the nine introduced species. Grand Cayman is about five times larger than Cayman Brac, and seven times larger than Little Cayman but, excluding crocodilians and marine turtles, the number of species of amphibians and reptiles native to each of the three islands is remarkably similar (Grand Cayman = 9, Cayman Brac = 10, Little Cayman = 9). The total count for Grand Cayman, however, rises to 17 with the addition of the eight introduced species which are considered established.

This raises the question of the degree to which the terrestrial/freshwater herpetofauna of Grand Cayman is saturated. It is not possible to answer this question at this time. With the possible exception of *Trachemys decussata*, all of the introductions have almost certainly occurred in the 70 years since Lewis (1940) first documented the entire herpetofauna of the Cayman Islands, and most have been reported since 1983. The populations of several of the established species appear to be small and geographically restricted. Their long-term prospects for survival are unknown. Some species of unknown status (e.g., *Anolis equestris*) may become established, and additional successful introductions may occur. Cayman Brac and Little Cayman have not experienced the wave of introductions that have impacted Grand Cayman but vigilance is recommended. These islands are undergoing rapid development and the rate of transport of goods from Grand Cayman and elsewhere is increasing.

Conservation Actions

A first principle of effective conservation efforts is that all stake-holders must be involved. Fortunately, it has been our experience that the people and the government of the Cayman Islands generally support a conservation ethic when it comes to the preservation of elements of their national heritage (but see "Threats" above). Three examples are given below.

Illegal trade in wildlife

Some forms of exploitation of wildlife are more egregious than others. In 2000, three German men were arrested and charged with a variety of offenses associated with the illegal collecting of animals, mostly reptiles, and plants in the Cayman Islands. When apprehended at the airport as they attempted to depart Grand Cayman, they were found to have in their possession over 1000 live plants and animals, including 930 *Anolis conspersus*, 112 *Leiocephalus carinatus varius*, and four *Tropidophis caymanensis*, all to supply the pet trade and collectors in Europe. Included were species that they had smuggled out of the Bahamas before coming to the Caymans. The investigation leading up to the arrests involved The Cayman Islands National Trust, Department of Agriculture, Customs, Immigration, Department of Environment, and Civil Aviation, but the authorities had been alerted by a concerned local resident. All three were convicted, fined, and deported, but only after spending a couple of months in a prison on Grand Cayman.

The Grand Cayman blue iguana

Another example of what can be done when multiple stake-holders work together involves the Critically Endangered Grand Cayman blue iguana, *Cyclura lewisi* (Burton, 2004). When first described (Grant, 1940), the species was already close to extinction, with local farmers quoted as saying that they had been too scarce to be worth hunting since 1925. A 1988 unpublished report to the Cayman Islands Government by Roger Avery suggested that the species had remained bottlenecked at an extremely low population for over 50 years since the observations by Grant in 1938. Avery saw only two iguanas over two weeks of intensive surveys and interviews in the east interior of Grand Cayman.

Avery's findings stimulated the Cayman Islands Government to ask the newly formed National Trust for the Cayman Islands to launch a conservation initiative for *Cyclura lewisi*, which commenced with a small-scale captive breeding effort in 1990. This led in turn to a longer-term survey of the wild population in Grand Cayman's east interior over the years 1992-1993 which showed a population in the range of 100-250 surviving in small isolated clusters amid a mosaic of natural xerophytic shrubland and traditional farms (Burton, 2010). It is unlikely that this represented any increase in population since Avery's survey in 1988, rather reflecting the far greater duration of the 1992-1993 survey.

However, a repeat survey in 2002 revealed a catastrophic new decline, attributable to land use changes, road development, and incursions of free-roaming dogs, in addition to the long-extant predation pressure on hatchlings from a widespread feral cat population. Iguanas were absent from most of the locations which were active in 1992-1993. The surviving wild population was estimated to number between 10 and 25, with indications that the species was at or very near functional extinction.

The early efforts of the National Trust for the Cayman Islands gradually evolved into an integrated conservation effort for *Cyclura lewisi* and its habitat, resulting in the creation, in 2002, of the Blue Iguana Recovery Programme (Burton, 2010). By gathering founders for captive breeding from specimens held captive by members of the community, the captive breeding effort was scaled up at the same time as field research clarified key elements of the ecology of the species, such as habitat use (Goodman et al., 2005a), spatial ecology (Goodman et al., 2005b), and activity patterns and foraging behavior (Goodman, 2007).

Pilot releases of captive F1 individuals were carried out in the 26 hectare QE II Botanic Park on Grand Cayman. Many of these iguanas established permanent territories in the Park and began breeding in 2001. By 2004, the free-roaming QE II Botanic Park iguanas were nesting with sufficiently large egg clutches to supplement the production of the captive breeding program, and the numbers available for release into the wild rose rapidly. Starting in 2004, large numbers of two-year-old head-started iguanas from both captive-bred and wild nests were released into dry shrubland habitat within the 253 hectare Salina Reserve, a protected area in northeastern Grand Cayman. By 2010, some 300 young iguanas had been released

into the Salina Reserve, with another 30 permanently settled in the QE II Botanic Park. The Salina Reserve released population began to breed in 2006.

The long-term future of *Cyclura lewisi* now depends as much on protection and management of wild habitat as on the direct conservation actions which are leading to significant recovery. Suitable habitat in the Salina Reserve, only about 14% of the 253 hectares (IRCF 2009), is estimated to be able to support no more than 400 iguanas, while the QE II Botanic Park population is too small to be genetically viable without active management. Fortunately, the government of the Cayman Islands has committed to protecting an additional 81 hectares to the east of the Salina Reserve. This is expected to provide habitat for additional releases such that the total wild population in protected areas may reach ca. 1000 individuals.

Assessing the long-term effectiveness of these efforts to restore a self-sustaining wild population of Grand Cayman blue iguanas will require ongoing monitoring. Dispersal of iguanas out of the protected areas, incursion of invasive predatory mammals, and scarcity of nesting habitat remain issues of concern.

A high level of community support for the conservation of *Cyclura lewisi* is being sustained in the Cayman Islands, stimulated by the charismatic "flagship" nature of the iguanas themselves, the ongoing major effort of the Blue Iguana Recovery Programme, and the National Trust, which is devoted to awareness and education. This, together with a strong network of local and international partners, and a commitment to science-directed, results-oriented conservation, are some of the factors that have led to the successes that the Programme has achieved to date. West Indian Rock Iguanas in their own climate zones are relatively easy to breed and head-start, are adaptable to man-modified habitats, and when released from captivity, can adapt to life in the wild without significant pre-conditioning. Work with the Grand Cayman blue iguana suggests that as a group, these iguanas can be highly responsive to well-planned interventions.

Marine turtles

The Cayman Islands once hosted one of the worlds' largest marine turtle rookeries (Groombridge, 1982). Historical reports from the 18th century suggest that every summer millions of green turtles (*Chelonia mydas*) migrated to the Cayman Islands to nest — such that "vessels, which have lost their latitude in hazy weather, have steered entirely by the noise which these creatures make in swimming to attain the Caymana isles" (Long, 1774). In addition to the green turtle rookery, the islands also hosted abundant nesting by loggerhead (*Caretta caretta)*, leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*) turtles (Lewis, 1940). However, by the early 1800s, massive commercial exploitation had resulted in near-extirpation of Cayman Islands marine turtle rookeries (Lewis, 1940) and by 1900 populations were considered locally extinct (Groombridge, 1982).

In 1968, a commercial green turtle farming operation — the Cayman Turtle Farm (CTF) — was established in Grand Cayman with the aim of marketing turtle meat and other turtle products (Wood, 1991) and replenishing wild turtle stocks

through captive breeding (Wood and Wood, 1993). Between 1980 and 2001, CTF released over 30,000 hatchling and yearling green turtles into Cayman waters, of which 80% were tagged with titanium flipper tags and/or "living tags" — created by transplanting a disk of lightly colored plastron into the darker carapace (Wood and Wood, 1993; Bell et al., 2005). Overseas tag returns from farm-released green turtles have been obtained from fisheries and research programs in the Caribbean and Florida (232 returns). Within the Cayman Islands, both locally resident juvenile turtles (154 returns) and sexually dimorphic or reproductively active males and females (6 returns) have been recaptured or observed (Wood and Wood, 1994; Bell et al., 2005).

Between 1971 and 1991, ad hoc surveys by the Cayman Turtle Farm detected 79 nests in the wild by green, loggerhead, hawksbill, and leatherback turtles (Wood and Wood, 1994). Detailed monitoring of marine turtle nesting beaches by the Cayman Islands Government Department of Environment (DoE) began in 1998 (Aiken et al., 2001). The first six years of nesting data revealed no leatherback nesting and an annual mean of <1 hawksbill nest, 26 loggerhead nests and 26 green turtle nests (Bell et al., 2007). Since then, hawksbill and loggerhead nesting has remained relatively constant and a considerable increase in green turtle nesting has been observed. More than 100 green turtle nests were recorded for the first time in 2008 (DoE unpublished data).

While numbers remain low, fertilization success averages 78% for loggerhead nests and 81% for green turtle nests, showing no reduction in fertility relative to larger populations (Bell et al., 2009). This continued viability may be attributable to behavioral mechanisms enhancing mate-finding, even at low population densities (i.e., natal philopatry and congregation of male and female turtles in breeding areas) and to genetic variation maintained through multiple paternity and mating on migratory routes and foreign foraging grounds (Bell et al., 2009). Indeed, satellite tracking indicates that Cayman Islands loggerhead and green turtle nesting populations are highly migratory, with post-nesting females travelling to foraging grounds in Nicaragua, Mexico, Belize, Guatemala, Honduras, and the Florida Keys (Blumenthal et al., 2006).

In addition to supporting green and loggerhead nesting populations, the Cayman Islands host foraging aggregations of juvenile hawksbill and green turtles (Bell et al., 2008; Blumenthal et al., 2009b; Blumenthal et al., 2010). Genetic research has demonstrated that juvenile hawksbills originate from jurisdictions spanning the Caribbean basin (Blumenthal et al., 2009a). Integration of genetic and oceanographic data indicates that ocean currents drive patterns of distribution for Caribbean hawksbill neonates and thus influences connectivity and conservation requirements: while some foraging areas experience high levels of local recruitment, the Cayman Islands are more diverse, complicating management of this stock (Blumenthal et al., 2009a). For green turtles, tag returns from the Cayman Turtle Farm show recruitment of captive-raised individuals to the wild (Wood and Wood, 1993;

Bell et al., 2005; Blumenthal et al., 2010), but a genetic study has not yet been conducted to evaluate the extent of this contribution.

For juvenile turtles in the Cayman Islands, a broad size distribution (hawksbills: 20.5-62.6 cm straight carapace length, greens: 32.8-80.7 cm curved carapace length), slow growth rate (hawksbills: 3.0 cm $\pm$ 0.9 cm/yr, greens: 4.1 $\pm$ 2.2 cm/yr), and multiple local recaptures suggest long-term residence in some individuals (Blumenthal et al., 2009b; Blumenthal et al., in press). Upon nearing maturity, both hawksbills and green turtles appear to undergo a developmental migration to spatially distinct adult foraging habitats — evidenced by an absence of the larger size classes in local capture studies and by the presence of tag returns from overseas (Blumenthal et al., 2009b; DoE unpublished data).

Within the Cayman Islands, habitat use by hawksbills includes areas of hard-bottom, reef, and reef wall (Blumenthal et al., 2009b). Deployment of time depth recorders (TDRs) shows significant vertical structuring of foraging habitat, with larger turtles diving to greater depths (Blumenthal et al., 2009c). Given the narrow shelf, deep dives (to nearly 100 m) substantially increase available habitat and may buffer against anthropogenic and natural degradation of shallow reefs, as well as create a broad ecological footprint over a range of depths (Blumenthal et al., 2009c). Deployment of ultrasonic tags indicates that, during long term movements, hawksbills cross the boundaries of Cayman Islands marine protected areas (Blumenthal et al., 2009c). Similarly, deployment of TDRs and ultrasonic tags on juvenile green turtles indicates that individuals regularly travel from a shallow seagrass lagoon, where they are protected from a legal marine turtle fishery, to areas outside the reef crest, where they are exposed to legal take (see *Legal protection* below) (Blumenthal et al., 2010).

During their life-cycle, Cayman Islands marine turtles face a wide range of anthropogenic threats. Nesting turtles are threatened by coastal development and illegal take in the Cayman Islands (Bell et al., 2006; Bell et al., 2007) and by directed and incidental take during transboundary reproductive migrations (Blumenthal et al., 2006). Similarly, legal, illegal, and incidental take, entanglement in discarded fishing gear, hurricanes, predation, habitat degradation, and disease (Blumenthal et al., 2009b; Blumenthal et al., 2010; Wood and Wood, 1993) have a cumulative impact on juveniles during the many years they are present on foraging grounds (Blumenthal et al., 2009b). Thus, the continuation and expansion of both local and regional initiatives are necessary to effectively manage migratory Cayman Islands marine turtles.

Legal protection

Marine turtles and "iguanas" (*Cyclura* rather than the introduced *Iguana iguana*) are the only reptiles that are directly protected under domestic legislation in the Cayman Islands. Marine turtles in the Cayman Islands were first protected in 1978, when regulations were put into place prohibiting possession of eggs and banning taking

of nesting females from May through September (Cayman Islands Government, 1978). In 1985, legislation was amended, extending the closed season from May to October and limiting harvesting to those who had traditionally taken turtles in Cayman waters (Cayman Islands Government, 1985). Licensing conditions set a quota of six turtles per licensee, stipulated minimum size limits for legal capture (54.5 kg for green and loggerhead turtles and 36.4 kg for hawksbill turtles) and restricted capture locations to areas outside the reef crest. All captured turtles were inspected by fisheries officers, and the harvest was well monitored (Richardson et al., 2006), but setting of minimum, rather than maximum, size limits allowed rare and reproductively valuable adult turtles to be taken (Bell et al., 2006). In 2008, legislation was amended to extend the closed season from April to November, introduce gear restrictions such as banning set-nets, and institute a maximum size limit to protect subadult and adult turtles. Licensing conditions stipulate size limits of no less than 40 and no more than 60 cm curved carapace length for legal take of green and loggerhead turtles, and prohibit taking of hawksbill turtles (Cayman Islands Government, 2008).

Iguanas are protected under the Animals Law (Law 8 of 1976) which states that "iguanas" may not be killed or captured from the wild, nor kept captive. An Exemption Order permits the Cayman Islands National Trust, and by extension, the Blue Iguana Recovery Programme, to conduct conservation work including captive breeding. The Animals Law also provides some protection for birds, but no reptiles other than iguanas are included. An amendment to the Animals Law in 2010 distinguished *Cyclura* species from the introduced *Iguana iguana*, so that only *Cyclura* species remain protected.

A new National Conservation Law has been drafted which inter alia would address protection of endemic and endangered species in a modern framework. It has been considered by successive administrations but has yet to be adopted.

The Cayman Islands are party to the CITES Convention through the UK, and domestic legislation implementing CITES does place effective controls on international trade in endangered native wildlife, including Appendix I species such as *Cyclura* and Appendix II species such as *Tropidophis*.

Habitat protection in terrestrial environments is provided for primarily in the National Trust for the Cayman Islands Law, which provides for the Trust to own and protect property, including land in its natural state, in perpetuity. A weaker level of protection is afforded by the Animals Law which provides for the creation of animal sanctuaries. In practice, these have been applied only to brackish ponds of primary importance to wading birds. Marine Parks regulations protect the quite extensive land-sea mangrove interface in Grand Cayman as part of an Environmental Zone which, along with other Marine Park Categories, includes extensive sea turtle feeding habitat. Regulations under the Development and Planning Law require modest setbacks from the sea for coastal construction, but fail to address beach vegetation and lighting concerns that affect nesting marine turtles.

Conclusions

The Cayman Islands support a herpetofauna that includes a relatively large number of endemic species and a growing number of introduced species. As humans settled the islands they brought with them, deliberately or accidentally, a number of other animals which threatened the native reptiles. Over the past 40 or so years, since mosquitoes were controlled, the islands have witnessed a spectacular increase in human population, augmented by an increasing number of tourists and other visitors. The combined pressures of human population growth and density, development accompanied by inevitable habitat destruction, and the introduction of non-native species, have the potential of having serious negative consequences for the native herpetofauna, as well as other elements of the native biota. Fortunately, the citizens of the Cayman Islands have demonstrated an admirable conservation ethic and desire to preserve as much as possible of their natural heritage. We hope that they are successful.

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