An introduction to the herpetofauna of Antigua, Barbuda and Redonda, with some conservation recommendations

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Abstract. At least 29 reptiles and amphibians have been documented on Antigua, Barbuda and Redonda, of which 21 are probably native. These include four species of marine turtles, two of which (*Eretmochelys imbricata* and *Chelonia mydas*) are known to nest on the nation's numerous sandy beaches and forage in nearshore waters. The low-lying and largely sedimentary islands of Antigua (280 km^2) and Barbuda (161 km^2) formed a single island as recently as 12,000 years ago and exhibit a similar herpetofauna with high endemicity. At least four terrestrial species are endemic to the Antigua and Barbuda bank: *Alsophis antiguae, Ameiva griswoldi, Anolis wattsi, Sphaerodactylus elegantulus* (a possible fifth being Barbuda's *Anolis forresti*, if not synonymous with *A wattsi*), and a further five are Lesser Antillean endemics. Only six species have been documented on the small, rugged volcanic island of Redonda (1 km^2), but as many as half of them occur nowhere else (*Ameiva atrata, Anolis nubilus,* and a potentially new *Sphaerodactylus* sp.). Centuries of forest clearance, overgrazing and development, coupled with the introduction of small Asian mongooses (*Herpestes javanicus*), black rats (*Rattus rattus*) and other alien invasive species, has endangered many of the nation's wildlife, and at least four indigenous reptiles have been extirpated (*Boa constrictor, Clelia clelia, Iguana delicatissima,* and *Leiocephalus cuneus*). Recent moves to enlarge the nation's protected area network are encouraging, but need to be supported with stronger legislation and proper investment in management staff and resources. This paper presents conservation recommendations and describes two projects that have adopted innovative approaches to save the most critically endangered reptiles — the Jumby Bay Hawksbill Project and the Antiguan Racer Conservation Project.

Key words: *Alsophis antiguae*; Antigua; Antiguan Racer Conservation Project; Barbuda; invasive species; Jumby Bay Hawksbill Project; marine turtles; mongoose; rats.

Introduction

Ecology and biogeography

Situated near the centre of the Lesser Antillean Archipelago, the nation of Antigua and Barbuda comprises the islands of the Antigua Bank (Antigua, 280 km^2 and

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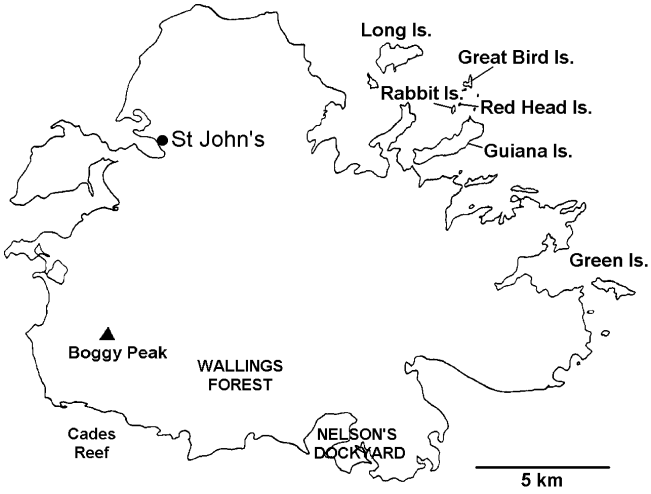


Figure 1. Map of Antigua.

Barbuda, 161 km^2) and the uninhabited volcanic island of Redonda (approximately 1 km^2).

Antigua (fig. 1), at 17°10′N, 61°55′W, is geologically and biologically the most diverse of the three main islands, with flat and scrubby plains giving rise to gently rolling limestone hills in the north and to higher volcanic hills in the south (maximum height 402 m, Boggy Peak). Its coastline is deeply indented with, as the local saying goes, "one beach for every day of the year", together with numerous fringing coral reefs and shoals. Scant natural vegetation remains, with the best examples around Ayers Creek, Half Moon Bay, Nonsuch Bay and on the small offshore islands strewn along the northeast and east coast. Wallings Forest, a small area of secondary moist evergreen forest, has been protected by law since 1912 and is regenerating well. Though this is a relatively dry island, averaging only 1,050 mm rainfall per year, there is considerable variation in rainfall between years and between different parts of the island (TAC, 2005). Like Barbuda and Redonda, Antigua lacks rivers and is frequently subject to severe droughts.

Barbuda (fig. 2; 17°35′N, 61°48′W) is one of the lowest-lying inhabited islands in the Caribbean, with 'The Highlands' reaching no more than 39 m above sea level. It is also one of the driest, with rainfall averaging between 750 mm and 900 mm per annum (TAC, 2005). A scrubby coralline limestone island, Barbuda is more uniform in appearance than Antigua and is mostly covered in limestone and sand, including a well developed dune system. The island's most notable geographic feature is Codrington Lagoon, the largest lagoon in the Eastern Caribbean, running along most of its western flank. Barbuda and Antigua are 43 km apart, but share the same shallow Antigua Bank and would have formed a single large island during periods of reduced sea level in the past (most recently approximately 12,000 years ago). This shared history accounts for their very similar native herpetofauna.

Figure 2. Map of Barbuda.

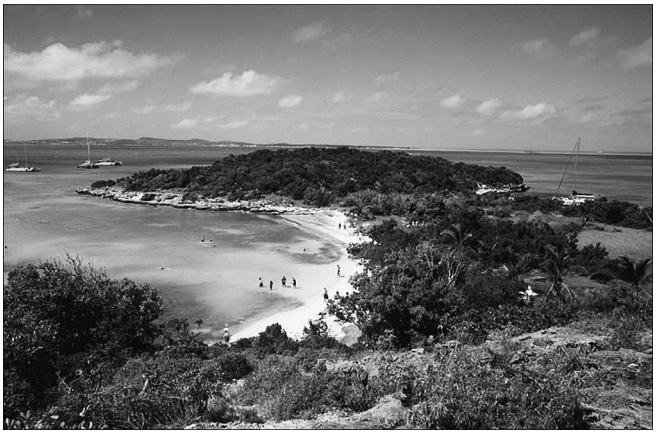
Redonda (fig. 3a) has never been physically connected to these or any other islands. Only 2.4 km long, 480 m wide and 297 m high, this small, rugged volcanic island is surrounded by steep cliffs which make landing difficult. Redonda is 48.5 km from Antigua, 19.5 km from Montserrat and 28.5 km from Nevis.

Lindsay and Horwith (1997) identified 54 vegetation types on Antigua, Barbuda and Redonda, most of which can be seen on Antigua. Not surprisingly, the three islands share many plant and animal species with other Lesser Antillean islands, but diversity and level of endemicity varies widely among different taxonomic groups. For example, 1,158 terrestrial species of plants have been recorded in Antigua, Barbuda and Redonda, but only one (0.09%) is suspected to be nationally endemic. The national bird list contains 182 species (Horwith and Lindsay, 1997), two-thirds of which are migratory, and only one or two (0.5-1.1%) are endemic subspecies. The low level of endemicity among plants and birds contrasts sharply with the high level seen among the native herpetofauna, with at least 42% of species on Antigua and Barbuda endemic to these islands, and 50% on Redonda (see below). Native terrestrial mammals comprise 10 species of bats (three of which are nationally extinct) as well as an extinct muskrat, and an extinct rice rat or Oryzomyine rodent (Lindsay and Horwith, 1997). The terrestrial invertebrates are largely unknown, but research on other Caribbean islands suggests that as many as 80% of beetles could be endemic (Michael Ivie, pers. comm.).

Human history

According to archaeological evidence, a non-agricultural and aceramic Amerindian people inhabited Antigua continuously or sporadically from about 3500 to 100 BC. Between 50 and 1100 AD, a second group of agricultural and pottery-making peoples, generally called Arawaks, migrated from South America and occupied the

(a)



(b)

Figure 3. Important offshore habitats include (a) the uninhabited volcanic island of Redonda, located approximately 50 km west of Antigua (photo John Cacalosi), and (b) Great Bird Island, one of the last islets where the Antiguan racer occurs, but which is visited regularly by tourists. (Colour originals — see www.ahailey.f9.co.uk/appliedherpetology/cariherp.htm).

northern and eastern parts of Antigua. A third ethnic group, the Caribs, conducted foraging trips to Antigua from Dominica and St Kitts, and their raids continued well into the European settlement period. Columbus sighted Antigua in 1493, but the island was not colonized by Europeans until 1642. English settlers brought Irish and, later, African slaves, and established sugar, cotton and other plantations, which replaced the native vegetation across 92% of Antigua. Being less suitable for arable farming, Barbuda was used to raise grazing animals. These various waves of human settlers brought with them a number of invasive mammals, including agouti, rats, rabbits, deer, goats, pigs, and mongooses, many of which still remain (Horwith and Lindsay, 1997).

Redonda was largely spared from human disturbance apart from a short but intensive period of guano mining by the Redonda Phosphate Company from 1869

until the First World War, using labour from Montserrat. The legacies of this industry include some ruins, a herd of feral goats and countless black or ship rats (*Rattus rattus*).

Antigua, Barbuda and Redonda became fully independent from Great Britain in 1981. Redonda remains uninhabited, while the population of Antigua and Barbuda has stabilized at around 67,000 and 1,200 respectively. The end of the plantation era in the 1960s was marked by many arable fields falling into disuse and developing into secondary forest or scrubland. The economy was rejuvenated by tourism, which currently accounts for 60% of the GDP. Nearly three-quarters of a million visitors come to Antigua and Barbuda every year (http://www.ab.gov.ag/). Most are cruise ship passengers who stay for only one day and head for the beach.

Beach-based tourism has stimulated the rapid growth of coastal developments, with resulting problems for native herpetofauna, especially turtles. Antigua's accessibility and central position in the Lesser Antillean archipelago has also made it a popular hub for people and cargo moving into and out of this region. Arrivals are projected to increase, which is likely to exacerbate the risk of more non-native species being introduced (see under Threats).

Herpetofauna

Amphibians

The abundant Lesser Antillean whistling frog *Eleutherodactylus johnstonei*, is a highly successful Lesser Antilles endemic that has become widespread across the Caribbean. This diminutive frog is not known from Redonda, but is probably indigenous to Antigua and Barbuda: fossil remains formerly identified as *Hyla barbudensis* (Auffenberg, 1958) are now considered to belong to this species. The similar *E. martinicensis* was first documented on Antigua by Schwartz (1967) and a map presented by Schwartz and Henderson (1991) illustrates a number of confirmed localities across the main island. Although *E. martinicensis* has become widespread in the Lesser Antilles, it is suspected to have originated somewhere in the French West Indies (Kaiser, 1992; Censky and Kaiser, 1999). The two *Eleutherodactylus* are not easy to tell apart, and further research is warranted to determine the current status and distribution of *E. martinicensis.*

The mountain chicken (*Leptodactylus fallax*) has also been listed as a historical record for Antigua, based on Dunn (1934). According to Kaiser and Hardy (1994), however, the evidence is weak and not supported by a voucher specimen. Mountain chickens still occur in the wet forests of Dominica and Montserrat, and it is not uncommon for live specimens to be taken to Antigua for food (Mark Day, pers. comm.).

At least two amphibians have been introduced in recent times. The cane toad (*Bufo marinus*) was intentionally brought to Antigua during the 1800s and is still very common, especially around villages and fields. It has not spread to

Antigua's offshore islands, Redonda or Barbuda. The Cuban tree frog (*Osteopilus septentrionalis*) was recently recorded on Long Island, northeast Antigua, and is suspected to have been introduced accidentally on ornamental plants (Horwith and Lindsay, 1997). It has already spread to several sites in the northern part of Antigua (pers. obs.).

Marine turtles

Four of the country's five chelonians are marine turtles — the hawksbill (*Eretmochelys imbricata*), the green (*Chelonia mydas*), the leatherback (*Dermochelys coriacea*) and the loggerhead (*Caretta caretta*) (table 1). Hawksbill turtles are by far the most numerous, with some 400-500 nests per year (Fuller et al., 1992), especially on the Antiguan beaches of Jabberwock, Rendezvous Bay, Turtle Bay, Green Island, Long Island, Sandy Island and Long Bay, and Barbuda's Welcher Bay. Green turtles are scarcer and have been hunted more intensively for their meat. Though nesting has been reported on more than 20 Antiguan beaches to date, the number of nests has 'declined dramatically' (Anon, 2001). Leatherback turtles are seasonal visitors and nest only infrequently. No loggerhead nests have been recorded, despite this species being recorded in national waters.

Neither the Kemp's ridley (*Lepidochelys kempii*) nor the olive ridley (*L. olivacea*) has been confirmed in Antiguan waters, but there have been anecdotal accounts of olive ridley turtles being caught in Barbuda (summarized by Fuller et al., 1992).

Terrestrial reptiles

18 indigenous terrestrial reptiles have been recorded on Antigua, Barbuda and/or Redonda, together with at least four species that were probably brought to the islands by humans. The red-footed tortoise (*Geochelone carbonaria*) was almost certainly introduced to Antigua and Barbuda from South America by early Amerindian visitors (see Censky, 1988). These tortoises are not uncommon, and are often kept as pets and even relocated. For example, 22 captive-bred tortoises have been released on Antigua's Green Island during the past decade and are occasionally sighted there (Varnham, 2001).

The national reptile list contains four geckos. The common woodslave or house gecko (*Hemidactylus mabouia*) is abundant on Antigua, especially around buildings, and was recently reported on Redonda (Censky and Kaiser, 1999), but curiously, it is absent from Barbuda. The giant woodslave (*Thecadactylus rapicaudus*), which is also widespread in the Lesser Antilles, is common on Barbuda, Antigua and its larger offshore islands. The dwarf gecko *Sphaerodactylus elegantulus* (fig. 4a) is strictly endemic to Antigua and Barbuda, and is common on the main islands and offshore islands. An as-yet unidentified *Sphaerodactylus* was collected from Redonda in the late 1990s (Hinrich Kaiser, pers. comm.) and could be a new species or subspecies. The only known skink in the Lesser Antilles, *Mabuya sloanii* (previously identified as *M. bistriata* or *M. mabouya*), has been documented on Redonda

Table 1. Amphibians and reptiles of Antigua, Barbuda and Redonda.

Species	Native/ Introduced	Conservation status (IUCN, 2004)	CITES	SPAW Protocol	Distribution			Comments
					Antigua	Barbuda	Redonda	
Eleutherodactylus johnstonei	Native			App. II	Yes	Yes	No	A Lesser Antillean endemic. Abundant
Eleutherodactylus martinicensis	Introduced			App. II	Yes	No	No	Endemic to Lesser Antilles. Recorded on Antigua, but considered by Hedges (1999) to have been introduced
Bufo marinus	Introduced				Yes	No	No	Introduced during 19th century. Common
Osteopilus septentrionalis	Introduced				Yes	No	No	Contemporary sightings on northern parts of Antigua, including Long Island
Eretmochelys imbricata	Native	Critically Endangered	App. I	App. II	Yes	Yes	Yes	Population appears stable (rising on Long Island). Nests on Antigua and Barbuda
Chelonia mydas	Native	Endangered	App. I	App. II	Yes	Yes	Yes	Reported to be declining. Nests on Antigua and Barbuda
Dermochelys coriacea	Native	Critically Endangered	App. I	App. II	Yes	Yes	Yes	Rarely nests on Antigua or Barbuda
Caretta caretta	Native	Endangered	App. I	App. II	Yes	Yes	Yes	Documented in national waters, but no records of nesting
Geochelonia carbonaria	Introduced		App. II		Yes	Yes	No	Common on Antigua (especially Green Island) and Barbuda
Hemidactylus mabouia	Native?	(Not assessed)			Yes	Yes (Extinct)	Yes	This species may have originated from Africa, but fossils have been found on both Antigua and Barbuda that date from the late Quaternary. A specimen on Redonda was identified from a photograph (Censky and Kaiser, 1999)

Continued

Table 1. (Continued).

Species	Native/ Introduced	Conservation status (IUCN, 2004)	CITES	SPAW Protocol	Distribution			Comments
					Antigua	Barbuda	Redonda	
Thecadactylus rapicaudus	Native	(Not assessed)			Yes	Yes	No	Not uncommon
Sphaerodactylus elegantulus	Native	(Not assessed)			Yes	Yes	No	Endemic to Antigua and Barbuda
Sphaerodactylus sp.	Native?	(Not assessed)			No	No	Yes	Specimen collected from Redonda by Kevel Lindsay and Hinrich Kaiser is yet to be identified, presumed endemic
Mabuya sloanii	Native?	(Not assessed)			No	No	Yes	
Gymnophthalamus underwoodi	Introduced	(Not assessed)			Yes	Yes	No?	*G. pleei* may also be present
Iguana delicatissima	Native	Vulnerable	App. II		Yes (Extinct)	Yes? (Extinct)	Yes? (Extinct)	A Lesser Antillean endemic
Iguana iguana	Introduced?		App. II		Yes (Extinct)	No?	Yes? (Extinct)	The origin and taxonomic status of West Indian *Iguana iguana* is unresolved
Anolis leachi	Native	(Not assessed)			Yes	Yes	No	Endemic to Antigua and Barbuda. Common
Anolis wattsi	Native	(Not assessed)			Yes	Yes	No	Endemic to Antigua and Barbuda. Abundant. Some authors consider the Barbuda population to be a separate subspecies or species (*forresti*)
Anolis nubilus	Native	(Not assessed)			No	No	Yes	Endemic to Redonda. Status unknown
Leiocephalus cuneus	Native?	(Not assessed)			Yes (Extinct)	Yes (Extinct)	No	Known from fossil record. Extinct Lesser Antillean endemic

Continued

Table 1. (Continued).

Species	Native/ Introduced	Conservation status (IUCN, 2004)	CITES	SPAW Protocol	Distribution			Comments
					Antigua	Barbuda	Redonda	
Ameiva griswoldi	Native	(Not assessed)			Yes	Yes	No	Endemic to Antigua and Barbuda. Probably qualifies as Vulnerable, based on decreasing range (unpubl. data)
Ameiva atrata	Native	(Not assessed)			No	No	Yes	Endemic to Redonda. Status unknown
Typhlops monastus	Native	(Not assessed)			Yes	Yes	No	A Lesser Antillean endemic. Identified as the subspecies *geotomus*, which also occurs on St Kitts and Nevis
Boa constrictor	Native?			App. III	Yes (Extinct)	No	No	Known only from sub-fossil record
Elaphe guttata	(Introduced)				(Yes)	No	No	Listed on Antigua by Kairo et al. (2005), but no voucher specimen collected
Alsophis antiguae	Native	Critically endangered			Yes	Yes (Extinct)	No	Endemic to Antigua and Barbuda. Scarce, but increasing
Leptotyphlops tenella	Introduced?	(Not assessed)			Yes?	No	No	One dubious record on Antigua
Clelia clelia	Native?	(Not assessed)			No?	Yes (Extinct)	No	Fossil evidence

(a)

(b)

Figure 4. Two endemics (a) the dwarf gecko, *Sphaerodactylus elegantulus* and (b) the Antiguan racer, *Alsophis antiguae.* (Colour originals — see www.ahailey.f9.co.uk/appliedherpetology/cariherp.htm).

(Dunn, 1936), but its status is unknown. The skink also occurs on neighbouring Montserrat and other volcanic leeward islands.

The Lesser Antillean iguana (*Iguana delicatissima*), has been confirmed from sub-fossils on Antigua and was still reported well into the late 20th Century, but is probably no longer present (Kevel Lindsay, pers. comm.). Etheridge (1964) and Pregill et al. (1994) describe unidentified iguana remains from Barbuda, which might have been the same species. Iguana bones are often unearthed in Amerindian middens around the islands (Reginald Murphy, pers. comm.), and it is likely that iguanas were dispersed around the Eastern Caribbean by people (Steadman et al., 1984). The common iguana (*Iguana iguana* species complex) has also occasionally been recorded on Antigua. These iguanas may have been brought from Montserrat or other islands (as pets or for food) and/or dispersed on debris during hurricanes: at least a dozen worn-looking individuals appeared in coastal areas within a few days following Hurricane Luis in 1995 (Censky et al., 1998), and were identified by their biometrics as having originated from the introduced population on Guadeloupe.

Most if not all of the common iguanas subsequently died, or were kept as pets or killed for their meat (Day et al., 2000). An unidentified iguana has also been recorded on Redonda (Underwood, 1962), but no sightings have been reported in over 60 years. In view of Redonda's proximity to Montserrat and Antigua, either species of *Iguana* could feasibly occur there.

Fossils of the curly-tailed tropidurid lizard *Leiocephalus cuneus* have been found on both Antigua and Barbuda (Etheridge, 1964; Watters et al., 1984), and the cause and timing of its extinction is not known. Lanagan (1844), cited by Horwith and Lindsay (1997), describes a ground lizard of 'disgusting appearance' with a tail 'of extreme length … giving the creature, when walking, a kind of snake-like motion'. When alarmed, it reportedly 'throws this unwieldy member over its back, and starts away with the greatest activity'. No other lizard on Antigua today fits this description, which might suggest that the curly-tailed lizard was still present in the 19th century.

At least three species of anole lizards are present, all of which are endemic and still common. *Anolis leachi* is endemic to Antigua and Barbuda, but has been introduced to Bermuda. The smaller Watts' anole (*A. wattsi*), is probably endemic to Antigua and Barbuda, but has been introduced to St. Lucia (Horwith and Lindsay, 1997), and Trinidad (White and Hailey, 2006). Some authors (e.g., Malhotra and Thorpe, 1999) consider the populations on Barbuda to be a separate, endemic species, *A. forresti*, which has recently invaded St Kitts. The final anole, *A. nubilus,* is endemic to Redonda.

The Teiidae family is represented by three species. The omnivorous Antiguan ground lizard (*Ameiva griswoldi*) (fig. 5a) is clearly endemic to Antigua and Barbuda, but is patchily distributed and shows considerable geographic variation in size and colour pattern (Smith et al., 2002). The largest and most brightly specimens can be seen on Great Bird Island (fig. 3b), whereas those on mainland Antigua tend to be smaller and more cryptic in appearance, perhaps in response to higher predation pressure (i.e., mongooses, cats and hawks). Ground lizards are still locally abundant on parts of Barbuda and on approximately half of Antigua's mongoose-free offshore islands (Galley Islands, Great Bird, Green, Lobster, Long, Red Head, Prickly Pear and York Islands), but their area of distribution is decreasing steadily (Smith et al., 2002). For that reason, this endemic species would probably qualify as Vulnerable or Endangered under IUCN criteria. A second endemic macroteiid, the little-known and almost entirely black *A. atrata* (fig. 5b), is confined to Redonda and is most closely affiliated to Montserrat's *A. pluvionotata*. (Censky and Kaiser, 1999, list both *A. atrata* and *A. pluvionotata* on Redonda, but this may have been in error.) It is not known how many remain.

The parthenogenic microteiid *Gymnophthalamus underwoodi* is a relative newcomer, but has quickly become established across Antigua and Barbuda (Censky and Lindsay, 1997). The astonishing speed with which this lizard can increase was recently illustrated on Great Bird Island, off the northeast coast of Antigua. In spite

of extensive herpetological studies through the 1990s, this species was not recorded on the island until 2001, when two were seen (Brian Smith, pers. comm.). 23 individuals were seen the following year (McIntyre and Phillpot, 2002), and by 2005 this species was so abundant that as many as five individuals could be found within one square metre (pers. obs.).

Horwith and Lindsay (1997) also cite anecdotal reports of 'a shiny greenish colored lizard about 0.6 metres in length'. No specimens have been seen by scientists, but the reports raise the intriguing possibility of another species, perhaps akin to the rarely-seen galliwasp (*Diploglossus montiserrati*) of Montserrat.

No snakes have been recorded on Redonda. As many as six species have been credited to Antigua and Barbuda, but some of the reports are dubious and only two species are currently confirmed present. The blind snake (*Typhlops monastus geotomus*) is common on both Antigua and Barbuda. Remains have been found of *Boa constrictor* on Antigua and *Clelia clelia* on Barbuda (Auffenberg, 1958; Steadman et al.,1984; Pregill et al., 1994). There is a lone Antiguan record of *Leptotyphlops tenella*, but many authors have cast doubt on its validity because this South American snake has not been found anywhere else in the Antilles (Schwartz and Henderson, 1991).

The nation's best-known endemic is the Critically Endangered Antiguan racer (*Alsophis antiguae*) (fig. 4b), first described as a subspecies of Lesser Antillean racer (*A. antillensis*) by Parker in 1933. Three years later, Parker (1936) elevated the racer to the rank of full species and declared it extinct. The type locality was given as the main island of Antigua, but no racers have been collected here since the 1940s, probably largely due to the introduction of small Asian mongooses in the late 19th century (Henderson and Sajdak, 1986; Henderson, 1989). The Antiguan racer is also known from Barbuda, from sub-fossil remains (Pregill et al., 1994), and the timing and reason for its extinction there is unknown. The snakes persisted for a few more decades on some of the offshore islands, but by the 1980s, they were confined to Great Bird Island (fig. 3b) (Sajdak and Henderson, 1991). Three specimens were collected from Great Bird in the 1960s (Lazell, 1967), and a fourth in 1987 by Robert Henderson (1989). A census in 1995 found only 51 individuals remained (Daltry and Day, 1996). Since then, however, the racer has also been reintroduced to two more offshore islands, and its numbers are climbing steadily (see below). The Antiguan racer exhibits some unusual characteristics, including strong sexual dichromaticism and ambush-hunting behaviour (Daltry and Day, 1996; Henderson et al., 1996), which are rare among colubrid snakes.

Kairo et al. (2005) list another colubrid — the American corn snake (*Elaphe guttata*) — as an alien invasive species on Antigua, but do not provide the source of this information. Sightings of arboreal snakes have been reported by a number of Antiguans in recent years, and a specimen of an unidentified colubrid was deposited at the Environmental Awareness Group office in 2006 (pers. obs.). The identity and origin of these snakes deserves further investigation.

Significance of Antigua, Barbuda and Redonda

When each island is viewed individually, the number of reptiles and amphibians is fairly low, as one would expect from their small size and considerable distance from South America or large islands (Censky and Kaiser, 1999). Combined, however, the three islands contain approximately 21 indigenous species (four marine, 17 terrestrial: table 2), which compares favourably with other Lesser Antillean nations.

What is even more significant about this herpetofauna is its high level of endemicity. 8 reptiles (47% of the native land herpetofauna) are national endemics, and at least one frog and three reptiles (24% of native land species) are Lesser Antillean endemics. Unfortunately, extinction rates have also been high, with at least four indigenous species lost: *Iguana delicatissima, Leiocephalus cuneus*, *Boa constrictor* and *Clelia clelia.*

As on many other Eastern Caribbean islands, the density of amphibian and reptile species can be remarkably high. *Anolis wattsi* attains record densities of 7,143/ha on forested parts of Great Bird Island, while even the large *Ameiva griswoldi* has been recorded at densities of 483/ha on Red Head Island (Smith and Colbert, 2002; Smith et al., 2001, 2002). This high lizard biomass undoubtedly has a significant influence upon the island's ecosystem, not least through the consumption of millions of invertebrates every day. Buoyed by the prolific lizard populations, the *Alsophis antiguae* population on Great Bird Island has reached densities of 16.2/ha, which is among the highest recorded density of any one snake species.

Six species are rated as globally threatened by IUCN (2004), but it is important to remember that only a small percentage of squamate reptiles have been assessed and this figure may well rise upon further investigation. The threatened reptiles include the Critically Endangered (cf. IUCN) *Alsophis antiguae* and *Eretmochelys imbricata*, both the foci of two long-running conservation programmes (see below).

Threats

Alien invasive species

Alien invasive species are widely regarded as the second greatest threat to biodiversity worldwide after habitat loss (IUCN, 1998), and the number one threat to biodiversity on small islands (Kairo et al., 2005). Alien species can endanger native wildlife populations through increased predation, competition, hybridization, disease transmission and/or habitat alteration. On Antigua, Barbuda and even Redonda, at least 18 alien invasive species have become established, the second highest national total in the Lesser Antilles (after Barbados: Kairo et al., 2005). The greatest hazards from the standpoint of the reptiles and amphibians are discussed below.

Carnivores. The small Asian mongoose (*Herpestes javanicus*, often incorrectly called by the junior synonym *auropunctatus*), was introduced to Antigua in the

(a) (b)

Figure 5. Two ground lizards (a) male *Ameiva griswoldi* and (b) Redonda ground lizard (*Ameiva atrata*). (Colour originals — see www.ahailey.f9.co.uk/appliedherpetology/cariherp.htm).

Table 2. Summary of the herpetofauna of Antigua, Barbuda and Redonda.

	Land area (km^2)	No. of native marine reptiles	Indigenous land species			No. of introduced alien species	Total no. of species documented	Total no. of species extant in 2006
			No. of native land species	No. of national (bank) endemics	No. of Lesser Antillean endemics			
Antigua	280	4	12	5	4	8	24	20
Barbuda	161	4	12	5	4	2	18	13
Redonda	1	4	6	3	(1)	0	10	9
All islands	441	4	17	8	4	8	29	23

1890s in a largely futile attempt to control rats. Mongooses are highly proficient diurnal hunters that frequently kill more than they need to eat, and their arrival coincided with the decline of a number of indigenous animals on the main island of Antigua, including the Antigua burrowing owl (*Speotyla cunicularia amaura*), *Alsophis antiguae* and *Ameiva griswoldi* (Faaborg and Arendt, 1985). Studies elsewhere in the Caribbean have found that mongooses can have a significant impact on marine turtle nests (Eckert, 1995). Fortunately, the mongoose has not yet reached Barbuda, Redonda or some of the offshore islands, and it certainly must be prevented from doing so. Feral and pet cats (*Felis catus*) present similar dangers and are well established on mainland Antigua and Barbuda. Feral dogs (*Canis familiaris*) are less widespread and not such effective hunters, but were indicated as a concern on Antigua and Barbuda by Kairo et al. (2005).

Rats. The black rat (*Rattus rattus*) and the larger brown rat (*R. norvegicus*) were probably introduced during early European settlement. Both species are highly fecund and adaptable, and the black rat especially has spread throughout Antigua, Barbuda and Redonda, including nearly all of the offshore islands. Specific problems attributed to rats include predation on eggs and juveniles, and modification of habitats by preying on seeds and seedlings. Black rats have even been documented attacking snakes: in 1995, many Antiguan racers exhibited severe rat bite injuries, including amputated tails in 50% of females and 31% of males. The Antiguan Racer Conservation Project eradicated rats from Great Bird Island in 1995 and have removed them from a further ten islands since, but constant vigilance is required to prevent rats from reinvading via the many boats in Antiguan waters.

Invasive large herbivores. These include feral goats (*Capra hircus*) on Redonda, goats, sheep (*Ovis aries*) and fallow deer (*Dama dama*) on Antigua, and goats and donkeys (*Equus asinus*) on Barbuda. At high densities, all of these animals are prone to overgraze fragile island vegetation, leading to loss of food and cover for iguanas and other native herpetofauna, and the wider problems of desertification (TAC, 2005). Feral goats are especially destructive in small island ecosystems (see citations in Campbell and Donlan, 2005). Up until 1995, the long list of feral ungulates included a herd of Andean llamas (*Lama glama*), which severely degraded the natural vegetation on Codrington Island (pers. obs.).

Alien invasive herpetofauna. As shown in table 1, a number of non-native reptiles and amphibians have invaded Antigua and Barbuda, including *Bufo bufo*, *Iguana iguana* and *Gymnophthalamus underwoodi*. Their effects on the indigenous herpetofauna are poorly documented, but experience elsewhere within this region has shown the harm that such alien amphibians and reptiles can cause. *Bufo bufo*, for example, is known to be highly capable of destroying native wildlife by means of predation, competition, and even poisoning of snakes and other animals that attempt to eat them (Lever, 2001). On Dominica, the recently arrived *Anolis*

cristatellus (native to the Puerto Rican Bank) appears to be steadily displacing the endemic *Anolis oculatus* as it spreads across the island (Kairo et al., 2005; Roger Thorpe, pers. comm.), while on Guadeloupe, common iguanas have extirpated the indigenous Lesser Antillean iguanas from many areas by means of aggressive competition and hybridization (Day et al., 2000). Alien reptiles and amphibians could potentially also bring deadly parasites and pathogens to Antigua, as described below.

Alien pathogens and parasites. Two non-native parasites are of immediate concern, though there are undoubtedly others. First, the Antiguan racer has been found to be allergic to the common snake mite *Ophionyssus natricis* (Gibson, 1997), which could feasibly be brought into its habitat on the bodies of introduced reptiles or even on the clothes of visitors. This tiny parasite is difficult to detect and unfed protonymphs can live for as many as 19 days before dying of starvation (Camin, 1953). Second, the indigenous *Eleutherodactylus johnstonei* may be at risk from the chytrid fungus *Batrachochytrium dendrobatidis*. Amphibian chytridiomycosis was first described in 1998 from carcasses collected at the sites of mass mortality in the montane rain forests of Australia, Costa Rica and Panama (Daszak et al., 1999) and has since been linked to the population declines and extinctions of more than 90 species on five continents. It made its debut in the Lesser Antilles in late 2001 or 2002 on Dominica, with devastating results for the resident mountain chicken frogs (Magin, 2003). The fungus can survive outside amphibians in damp conditions, and can be transported on other organisms, ornamental plants, soil, boots and clothes. It will be difficult to prevent it from spreading throughout the Caribbean.

Of the above, the mongoose, domestic goat, domestic cat, black rat, cane toad and the chytrid fungus all rank among "100 of the world's worst invasive alien species". More details of these species and the problems they cause can be found at: http://www.issg.org/.

Habitat loss and alteration

Though never as lushly vegetated as Dominica, St Lucia or some of the other, more mountainous islands in the Lesser Antilles, Antigua would probably be unrecognisable to Columbus today. No primary forest remains and, while secondary woodland is now fairly extensive (34% of Antigua, 66% of Barbuda), some changes to the watersheds and soils during the plantation era were irreversible (CARICOM/FAO/ODA, 1993; TAC, 2005). Natural forest regeneration continues to be suppressed by grazing animals, fire and by the spread of the highly invasive lemon grass (*Cymbopogon citratus*) and neem tree (*Azadirachta indica*). Lindsay and Horwith (1997) rated as many as half of the nation's 54 vegetation types as threatened.

The loss of nesting habitat is perhaps the greatest threat to the turtles that nest on Antigua and Barbuda habitat (Horwith and Lindsay, 1997). Sand-mining and ever-expanding residential and tourism developments have led to the clearance

of stabilizing native beachside vegetation (all too often replaced by lawns and ornamental plants) and severe beach erosion by the wind and sea, which has been further exacerbated by recent hurricanes (e.g., Ryder et al., 1989). Furthermore, lights from beachside hotels and holiday homes can draw newly-hatched turtles dangerously inland, away from the sea (see Horrocks et al., 1989; Witherington and Martin, 2000). Coral reefs and sea grass beds — where marine turtles feed — have been severely damaged by dredging, divers, boat moorings, pollution, and other problems. More than 95% of the hard corals in surveyed waters at depths of less than 9 m are dead (Horwith and Lindsay, 1997).

Hunting and other human disturbance

Antigua's larger reptiles have traditionally been hunted for their meat and other products. Hoyle (1994) estimated that approximately 30 turtles and several thousand eggs were taken every year through the 1990s, and observed a wide range of turtle products on sale in Antigua. The same problem could have contributed to the demise of Antigua's indigenous iguanas, and might jeopardise any attempt to reintroduce them. In recent decades, Caribbean reptiles have also received increased attention from collectors and pet keepers. Even though Antiguan racers are difficult to keep in captivity (Gibson, 1997), expatriates living in Antigua have admitted to taking snakes from Great Bird Island. In 2005, tour operators and local fishermen combined forces to evict a foreign visitor who was observed walking around the island with snake bags (Aldrick Nicholas, pers. comm.).

The presence of large numbers of people in some of Antigua's important wildlife habitats can be damaging in multiple ways. Some of the most worrying examples have been observed on Great Bird Island, which contains globally important populations of *Alsophis antiguae* and *Ameiva griswoldi*. As many as 400 visitors have been recorded on this 9.9 ha islet simultaneously (Daltry, 1999), and the annual total has climbed from 17,000 to 40,000 in the past decade (unpubl. data). Most people come to enjoy the attractive scenery, swim or snorkel around the fringing reefs, and have a barbecue on the beach. An increasing number of groups stay overnight: with dozens of tents recorded at Easter. On busy weekends, vibrations from amplified music can often literally be felt hundreds of metres inland. Such intensive human activity is likely to place additional stresses on the native reptiles by interrupting their hunting and other normal activities and causing them to flee as much as several times a day: indeed, local biologists have noticed a significant shift in snake numbers away from the busiest areas in recent years (Ingrid Sylvester, pers. comm.). Tourists have been observed killing lizards, while even those with a more enlightened attitude towards reptiles can cause harm, as exemplified by two British visitors who unwittingly drove a young male *Alsophis antiguae* into the sea while attempting to take its photograph (Daltry, 1999). Other problems include trampling of turtle nesting sites, bush fires, cutting of trees for firewood, the clearance of undergrowth using strimmers, littering, and the spread of alien invasive species.

As the previous paragraph illustrates, the recreational use of Great Bird Island currently predominates over all other uses, conservation included. While this is an extreme example, similar problems plague many turtle nesting beaches and other heavily visited sites around Antigua. Foreign visitors especially often express astonishment that no money from tourism feeds back into supporting the management of these sensitive areas.

Restricted population sizes and distribution ranges

The fact that many of the nation's endemics are restricted to small islands makes them inherently vulnerable to the hazards of demographic stochasticity (chance variation in births, deaths and sex ratio), environmental catastrophes such as hurricanes, and the loss of genetic diversity in successive generations (Gilpin, 1996). Possible examples of this theme include small colonies of *Ameiva griswoldi* on Maiden Island and Rabbit Island, which dwindled and eventually died out in 1997 and 1999 respectively, for no obvious reason (pers. obs.).

Many workers have suggested that a population size of at least 500 breeding adults is required to enable species to persist and retain the ability to adaptively evolve (e.g., Frankel and Soulé, 1981; Lande and Barrowclough, 1996). The Antiguan racers on Great Bird Island have been reduced to only 50 individuals in the past, and can have only rarely exceeded 120. This population now exhibits many classic symptoms of inbreeding, including low fertility (Gibson, 1997) and a high prevalence (at least 20% of individuals) of visible congenital defects such as kinked tails, fused scales and deformed eyes (Daltry, 1999).

Climate change and hurricanes

While hurricanes are a natural hazard in this region, historically striking at the rate of one every 50 years, many workers predict an increase in the number and severity of hurricanes in the Caribbean (e.g., Goldenberg et al., 2001). As possible evidence of this trend, no less than four severe (Categories 3-5) hurricanes struck Antigua between 1995 and 2005, causing immense damage to infrastructure, beaches, vegetation and reefs (TAC, 2005). Turtle nests and wildlife on low-lying islands are especially at risk of flooding during hurricanes, and this hazard could worsen in view of projected sea level rises of around 50 cm by the end of the 21st century (e.g., Church et al., 2001). The Antiguan Racer Conservation Project reported a 20% decrease in the Antiguan racer population in the wake of Hurricane Georges, which caused the inundation of 20% of Great Bird Island by rough seas in September 1998 (Daltry, 1999).

Some of the effects of climate changes may be more insidious. For example, reptiles that exhibit temperature sex determination, including all of Antigua's marine turtles, could potentially develop skewed sex ratios in response to global warming, especially if their choice of nesting areas is limited (see Glen and Mrosovsky, 2004).

Legal Protection

International treaties

Antigua and Barbuda was among the first nations to sign the Convention on Biological Diversity in 1992. It has also ratified the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region and signed the convention's Protocol Concerning Specially Protected Areas and Wildlife ("SPAW Protocol"). All six Caribbean sea turtles and, surprisingly, *Eleutherodactylus johnstonei* and *E. martinicensis*, are on Annex II, which indicates that they merit strict protection by all parties. *Iguana delicatissima* and *Iguana iguana* have been placed on Annex III, which indicates that their use requires careful regulation.

Antigua and Barbuda has been a party to the Convention on the International Trade in Endangered Species (CITES) since 1997, which places restrictions on the international trade of species listed in CITES Appendices, including all of the Caribbean sea turtles, *Geochelone carbonaria*, and all members of the genus *Iguana*.

National legislation

In spite of the above international signals of its firm commitment to conserve native species and habitats, Antigua and Barbuda's national legislation still leaves much to be desired. Legislation relative to the protection of wildlife outside of protected areas is found only in the Wild Birds Protection Ordinance (1913) and the Turtle Ordinance (1927). The latter imposed size and seasonal bans on turtle hunting and egg collection, but illegal hunting is not uncommon and is rarely punished (Hoyle, 1994; James, 2001). Even the Critically Endangered *Alsophis antiguae* is not protected by law and it appears that this and other endemic species can be freely caught, killed, kept as pets or traded. A Forestry and Wildlife Act was drafted in 1988, which could potentially provide better protection to endangered species (Jeffrey and Henry, 2000). The draft new Environment Law also makes stronger provision for the protection of native wildlife (Carol-Faye George, pers. comm.).

There are also worryingly few legal mechanisms to control the introduction and dispersal of foreign herpetofauna or other potentially invasive alien species on Antigua and Barbuda. The Animals (International Movement and Disease) Act, however, usefully prohibits the entry of reptiles, birds and insects without a license (Kairo et al., 2005).

Legislation to protect habitats is also fairly weak. In practice, private land owners often appear to have considerable freedom to modify their land, even those areas that are known to be used by nesting sea turtles or other endangered species. CCA (1991) bemoaned the confusion over institutional responsibilities to manage important habitats, as well as inadequate staffing and budgets. Coastal habitats in particular still seem to fall into a grey area where no government institution appears to have clear management authority.

The protection of important areas is feasible under the Forest Ordinance Act (1941) and Forestry Regulations (1952), which provide for the protection of forested lands, but are 'no longer enforced' (CARICOM/FAO/ODA, 1993). Marine parks are mandated by the Marine Areas (Preservation and Enhancement) Act of 1972 and Fisheries Act of 1983, which provides for the declaration of restricted marine areas to preserve and protect flora and fauna. The Act also authorizes the declaration of any area of Antigua and Barbuda waters and adjacent land to be 'a marine reserve for the purpose of giving special protection to the area's natural beauty, flora, fauna and habitats'. Both the Forestry Unit and Fisheries Division urgently need more trained staff and resources to establish and manage such areas, however. At the time of writing, for example, the Fisheries Division does not even have a boat!

The National Parks Act of 1984 created the Antigua and Barbuda National Parks Authority to 'preserve, protect, manage and develop the natural physical and ecological resources of the historical and cultural heritage of Antigua and Barbuda'. Unfortunately, the National Parks Act does not provide a definition of 'national park', and the first and only operational national park has apparently delivered only a limited environmental benefit so far (see below).

Mounting concern at the loss of Antigua's biodiversity and natural beauty has, however, triggered a number of important new initiatives to bring more habitats under protection, including areas that are known to be of particular importance to endemic and endangered herpetofauna. Some of these are outlined below.

Protected areas

Only one national park — Nelson's Dockyard National Park — is fully operational and is managed primarily for its tourism attractions, which include the historic Nelson's Dockyard and other historical and archaeological sites. This multiple-use park covers 8% of Antigua and Barbuda's land mass (more than 3,100 ha) but has a small staff that is chiefly concerned with services at the dockyard. CCA (1991) criticized the lack of effective land use and development control in the park, which suffers from severe overgrazing (CARICOM/FAO/ODA, 1993). This is a pity because the park's substantial terrestrial and marine areas could potentially be made more suitable for turtles and other native reptiles.

Several additional national parks have been very recently decreed or proposed, including the Great Bird Island National Park, which has been gazetted three times but is awaiting final approval from Parliament. It remains to be seen how this popular yet fragile park will be managed. Recent consultations, led by the Environmental Awareness Group, found that the majority of local stakeholders wished for these islands to 'remain unchanged' and some called for controls over the number of visitors (Lucia Mings, pers. comm.).

The Wallings Conservation Area (Forest Reserve) was established in 1912, when five hectares of trees were planted to restore and protect an important watershed in Antigua's southern hills. It is managed by the Forestry Unit and has become a popular recreational site for local and foreign visitors. Few native reptiles remain,

but the area could potentially support more species (e.g., *Iguana delicatissima*) if mongooses can be controlled.

Barbuda's Codrington Lagoon features a Bird Sanctuary for an impressive colony of frigate birds, and the sandy beaches of the lagoon are known to be important for nesting turtles. The Diamond Reef Marine Park (2,000 ha), north of Antigua, and Palaster Marine Park (500 ha), south of Barbuda, were established in 1973. Both parks have been demarcated with buoys and, while they might have a useful role in preserving turtle feeding grounds, they are not actively managed.

Several additional marine protected areas have been identified and designated, perhaps the most significant of which is the North East Marine Management Area. Declared in 2006, this provides protection under the Fisheries Act for approximately 2,100 ha from the northern tip of Antigua to the south-east, including Great Bird Island, Rabbit Island, Green Island, Long Island and other coastal sites of outstanding herpetological importance (Philmore James, pers. comm.). Again, it is unclear how this protected area will be managed.

Herpetofaunal Conservation Programmes

There are two long-running herpetological conservation projects, both of which have a strong focus on Antigua's offshore islands. Neither receives government funding, and both rely heavily on grants, donations and the efforts of volunteers.

Jumby Bay Hawksbill Project

This project (www.jbhawksbillproject.org) was founded by John Fuller, Esq. (St John's, Antigua) and Dr Jim Richardson (University of Georgia) in 1986, after being alerted by informed residents that Pasture Beach was an important hawksbill nesting beach on Long Island, a 122 ha island in Antigua's North Sound. The mission of the Jumby Bay Hawksbill Project is 'to better understand the life history of the hawksbill turtle, in hopes that our findings will serve as a foundation for wise management and policy making. We seek to increase public awareness of sea turtles regionally and internationally through school visits and educational turtle watches for residents and tourists. Only through long-term public support will Antigua and Barbuda's hawksbills have a chance at survival and recovery' (www.jbhawksbillproject.org).

The project is maintained by the Wider Caribbean Sea Turtle Conservation Network (WIDECAST), with financial and logistical support provided annually by the Jumby Bay Island Company (JBIC) and local landowners. From 15 June to 15 November every year, project researchers conduct nightly nine-hour beach patrols to monitor nesting activity, and thereby encounter nearly 100% of all nesting females. Every female receives two tags (issued by the WIDECAST Marine Turtle Tagging Centre based at the University of the West Indies, Barbados), or is identified by existing tags, and information about the turtle's size, condition, nest-placement and

timing is gathered. To minimize stress, biometric data is generally collected during egg-laying (Stapleton and Stapleton, 2006). Small numbers of guests frequently accompany the researchers to help spot nests and, perhaps more importantly, to learn about hawksbill turtles and the need to conserve both the turtles and the habitats on which they rely.

After two decades of research, much has been learned about the reproductive behaviour and population dynamics of the Jumby Bay hawksbills (Corliss et al., 1989; Richardson et al., 1989, 1999; Ryder et al., 1989; Mrosovsky et al., 1992; Hoyle and Richardson, 1993; Kerr et al., 1999; Frick et al., 2003; Glen and Mrosovsky, 2004; Mason et al., in press). The comprehensive nature of the project has meant that the data are useful far beyond the national context, and they are often cited in international assessments and policy documents (e.g., IUCN, 2002).

In addition to the regular programme of population studies, other research initiatives include a genetic study, conducted in collaboration with the University of West Indies as part of a wider investigation into the diversity and international movements of hawksbill turtles (Bass, 1999). A telemetry study conducted in partnership with NOAA/NMFS also helped to shed light on the movements of the Long Island turtles. Satellite transmitters were attached to four female hawksbills in 1998 and during that first year, one turtle remained close to Jumby Bay while the other three dispersed to forage around St. Kitts, St. Eustatius, and Redonda respectively. The three dispersed turtles eventually returned to nest on Pasture Beach but the resident turtle did not, leading researchers to believe that her transmitter had fallen off in near-shore waters; her fate remains unknown (Andrews and Richardson, unpubl. data). Gravid females tagged at Pasture Bay have subsequently been recaptured in St. Kitts and Dominica (Meylan, 1999) and elsewhere, underscoring the management complexity surrounding these highly migratory species.

Since the first studies began, the Jumby Bay Hotel has been established on Long Island, together with a number of exclusive homes, a putting green and other facilities, co-managed by the JBIC. The project team works very closely with the hotel and homeowners. Many guests and residents enjoy viewing the turtles during the nesting season, while the project researchers benefit from transport and a field office provided by the JBIC. The ongoing residential developments have inevitably led to changes in the island's natural vegetation, but the project team has worked with island residents since 1998 to make sure that beachside vegetation is preserved or restored with indigenous species. 'Beach gardens', comprised of railroad vines, scaveola, sea-grapes and other plants, have been planted in areas where vegetation has been lost, and appear to have successfully attracted more nesting females (Muenz and Andrews, 2002, in press).

Probably in no small part due to increased protection in this region, public education and nesting habitat restoration efforts, recent analyses have shown a significant increase in the local hawksbill turtle population (fig. 6). Sixty-three nesting females, including 23 neophytes (untagged and presumed new recruits into the breeding population), were observed and tagged on Long Island 2005, exceeding

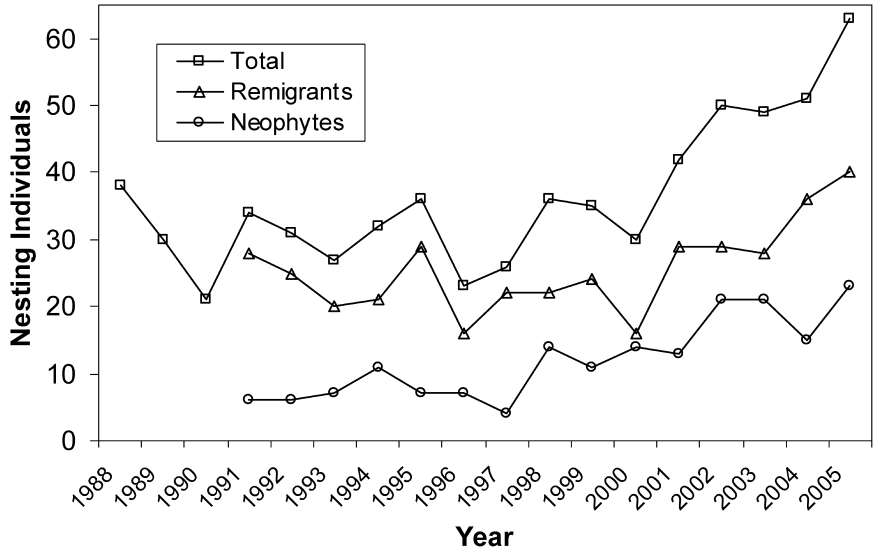


Figure 6. Neophytes, remigrants, and total nesting females documented on Long Island, Antigua, West Indies, during monitoring from 1987 to 2005. (Data courtesy of Peri Mason, Jumby Bay Hawksbill Project.)

by more than 20% the previous record of nesting turtles in a single year. A total of 195 nests were deposited on Pasture Bay Beach during the patrol season (15 June to 16 November 2005), and an additional 26 nests laid on peripheral beaches (Stapleton and Stapleton, 2006).

Antiguan Racer Conservation Project

The Antiguan Racer Conservation Project (www.antiguanracer.org) was formed in 1995 by a consortium of governmental and non-governmental organisations with the primary goal of saving the 'world rarest snake' from extinction. The founders were the Environmental Awareness Group, Antiguan Forestry Unit, Fauna & Flora International, Island Resources Foundation and Durrell Wildlife Conservation Trust, which were joined by Dr Brian Smith of Black Hills State University in 1999. In 2003, a Steering Committee was created to enlist the help of additional government agencies in project planning, including the Fisheries Division, Ministry of Tourism, Environment Division and National Parks Authority. The distribution range of the Antiguan racer had shrunk to the mongoose-free Great Bird Island (9.9 ha), and the population numbered no more than 51 individuals (Daltry and Day, 1996). Two were found dead in 1995, apparently killed by visitors, but the most immediate threat to the species was inferred to be the large number of *Rattus rattus* on the island (see Threats above).

Among the first direct interventions by the project was the eradication of rats from Great Bird Island using waxy briquettes impregnated with brodifacoum (Day

and Daltry, 1996). The effort succeeded, and within 18 months, the racers had increased to just over 100 adults and subadults (snakes aged one year or more) (Cooper, 1997; Daltry and Day, 1997). The snake carrying capacity of Great Bird is constrained, however, by its relatively small area and the fluctuating number of lizards (Daltry et al., 2001). To enable the racers to increase to a more viable level, the project team embarked on an ambitious reintroduction program to restore the snakes on at least five offshore islands that could support a total meta-population of at least 500 breeding adults (ARCP, 1999). First, it was necessary to eradicate rats and, where present, mongooses from potentially suitable islands and neighbouring islands (to reduce the risk of the mammals reinvading) (Varnham et al., 1998; Varnham, 2001). The Antiguan racer was successfully introduced to Rabbit Island (2 ha) in 1999 and to Green Island (43 ha) in 2001 (Daltry, 2000; Daltry et al., 2002), and plans are underway to reintroduce the snakes to an additional island in 2007. Post-release monitoring using radiotelemetry and direct observations have revealed that the racers adapted easily to the new islands and even exhibit growth spurts when released from the competitive environment on Great Bird Island (Buley, 2000; Daltry et al., 2003).

To monitor changes in the population size, all captured racers are individually marked with microchip tags, which have greatly aided understanding of their biology. For example, we now know that racers can live for up to 10 years, but the population turnover is very high, with an annual mortality rate of 44% that is independent of age (Daltry et al., 2003; Wright et al., 2004). This finding suggests that the population inherently unstable and liable to crash within as little as 18 months if breeding is suppressed. Every year, a census lasting approximately 40 days is conducted by project staff and volunteers using a standard mark-recapture method, with estimates generated using Begon's (1979) weighted mean (Daltry et al., 2001). Although the accuracy of estimates has inevitably decreased as the area of distribution has increased, the number of racers is projected to exceed 250 adults and subadults in 2006, a five-fold increase since the project began (see fig. 7). The snakes' main prey species — *Anolis wattsi, A. leachi* and *Ameiva griswoldi* — have also been the subject of intensive field-based investigations (e.g., Smith and Baum, 2000; Smith and Colbert, 2002; Smith et al., 2001, 2002).

The success of the racer reintroduction program to date has been in no small part due to more than ten years of hard work to raise public awareness of these harmless snakes, by means of the media, production of publicity materials, school visits, guided field trips and even input into the national standard primary and secondary school curriculum (McCauley, 1999a, 1999b). Acceptance of, and even pride in, Antigua's native snake has grown measurably since the mid 1990s. In spite of increased human-snake encounters, there have been no reported deliberate killings for several years. Many tourist boat crews and other regular visitors to the islands have helped to support the project in many ways, including teaching new visitors that the racers are harmless and rare. An ongoing problem, however, is the

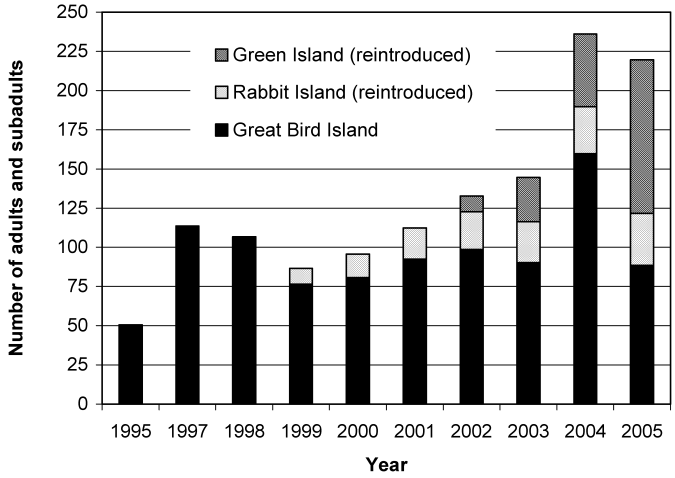


Figure 7. Changes in the total number of adult and subadult Antiguan racers (*Alsophis antiguae*), 1995 to 2005.

perennial risk of rats reinvading the islands, carried as stowaways on boats. *Rattus rattus* reappeared on Great Bird Island in 2001 but were immediately destroyed. The same species reinvaded Green Island in 2005, and a second eradication attempt will take place in 2006.

As the racer meta-population has become more secure, the project has expanded its focus to conserving the biodiversity of Antigua's offshore islands, and has gained the synonym Offshore Islands Conservation Project. The eradication of invasive rats from ten islands has led to a conspicuous increase in bird populations, including a number of regionally threatened seabirds, and is thought to have reduced predation on sea turtle eggs (Varnham, 2001, 2005). The project researchers also conduct annual student internship schemes whereby local and foreign students study the island wildlife and contribute to conservation planning. Other project activities include training teachers and tour operators, running 'floating classrooms' for local schools, social surveys, and protected area planning (e.g., Anthonyson and McCauley, 2002). The recent gazetting of Great Bird, Red Head, Rabbit, Green and many other islands as part of a new national park and marine reserve will, it is hoped, help to maintain the beauty and diversity of this landscape.

Also of particular relevance to this paper is a new initiative by the project members to reintroduce Lesser Antillean iguanas *Iguana delicatissima*, to Antigua from other populations in the West Indies. The offshore islands could provide suitable initial release sites, where threats from invasive species and hunters can be more easily controlled. The findings of recent feasibility studies suggest that at least two of the larger offshore islands have suitable habitat to support several thousand iguanas (Matthew Morton, pers. comm.).

Conclusions and Recommendations

Antigua, Barbuda and Redonda collectively support a diverse herpetofauna, with exceptionally high levels of endemicity. Ten of the native species are endemic, and six are ranked as globally threatened (IUCN, 2004), including the Critically Endangered hawksbill turtle, leatherback turtle and Antiguan racer. No fewer than four indigenous species have already been lost and further measures are needed to ensure the survival of the rest. A comprehensive national Sea Turtle Recovery Action Plan (Fuller et al., 1992) provides many recommended actions to conserve marine turtles and their habitats, while ARCP (1999) and Daltry (1999) detail specific actions for the Antiguan racer. The National Biodiversity Strategy and Action Plan also details many objectives and actions to enhance the conservation of Antigua and Barbuda's biological diversity, including its reptiles and amphibians (Jeffrey and Henry, 2000). While some of these are now being addressed, such as the expansion of the national protected area network, many issues still require urgent attention.

Space does not permit details here, so the following checklist is merely an outline of what needs to be done to conserve the indigenous herpetofauna of Antigua, Barbuda and Redonda. While government agencies such as Forestry, Environment, Fisheries and National Parks should necessarily take a prominent role, greater success could be achieved by working in collaboration with non-governmental organisations such as the Environmental Awareness Group, the scientific community, schools and youth groups, tourism industry, private land owners and the general public.

1. Develop and enforce protective national and international legislation for all globally threatened species. The draft Forestry and Wildlife Act (1988) should be updated and enacted to make it a criminal offence to capture, kill or trade in endangered terrestrial species without a license. Priority species for inclusion are: *Alsophis antiguae*, *Ameiva griswoldi*, *Ameiva atrata*, *Anolis nubilus* and *Iguana delicatissima*. Fuller et al. (1992) identified a number of deficiencies in the 1990 Fisheries Regulations that comprise the current legal framework for the management of marine turtle exploitation in Antigua and Barbuda, with the most important of these deficiencies being: minimum size limits that focus exploitation on large juveniles and breeding-age adults, and a closed season that does not fully encompass the breeding season (as the majority of hawksbills are still nesting when the season opens on 1 September, much of the breeding population could be legally exterminated). Legislation pertaining to marine turtles should be reviewed, and consideration given to the banning of hunting and egg collection until and unless it can be demonstrated to be genuinely sustainable. The draft new Environment Law also offers stronger protection for marine and terrestrial biodiversity and should be enacted as a matter of urgency.

2. Develop and implement management plans and management structures for all protected areas, which take into account the needs of herpetofauna. All of the existing and proposed protected areas need management plans, developed in consultation with a wide range of stakeholders, including wildlife conservation experts. For environmentally sensitive areas such as Great Bird Island National Park, the protected area managers must take great care to ensure that recreational and other human uses do not degrade habitats or disturb wildlife. Another important consideration (for all areas) is how to prevent and/or remove harmful alien invasive species. Effective management will undoubtedly require many more trained staff and resources than are currently available, and self-financing mechanisms (e.g., user fees, tourism concessions) will need to be explored.

3. Develop management agreements with landowners and local communities for priority sites which reflect the needs of herpetofauna. Owners of homes and hotels situated along known turtle nesting beaches, for example, could be more positively engaged in ensuring the beaches remain safe and attractive for turtles. The Jumby Bay Hawksbill Project has valuable experience of this approach, and the WIDECAST network as a whole has been proactive in creating a variety of best practices documents (e.g., Choi and Eckert, 2006) to assist beachfront property owners in designing and implementing 'turtle-friendly lighting' and taking other conservation-oriented actions. Agreements may be informal or legally binding in the form of a covenant or contract: the Mill Reef Club, for example, established a 99 year covenant to protect Green Island, Smith Island and York Island from development.

4. Eradicate invasive mammals from priority conservation sites, including Antigua's North Sound islands and Redonda, and implement measures to prevent invasion. Mongoose, rats and goats are among the principle threats to native herpetofauna and other wildlife. Their removal tends to be easier on small offshore islands, but significant control could be exerted even on larger areas. Preventing (re)invasion by invasive alien species is also a considerable challenge, requiring a combination of public awareness, legislation, and, ideally, rigorous screening of incoming goods and vessels (IUCN, 2000; Kairo et al., 2005). Particular attention should be paid to preventing mongooses from invading Barbuda or Redonda, where they would decimate endemic reptile populations and other wildlife. The Antiguan Racer Conservation Project has useful experience in eradicating rats from small islands and rat prevention techniques.

5. Control the introduction of alien reptiles and amphibians. Non-native reptiles and amphibians may transmit diseases or parasites to indigenous species, and can potentially become feral and invasive. The import and trade of iguanas, boa constrictors and other pets to Antigua and Barbuda should be subject to strict controls, preferably prohibited.

6. Continue to reintroduce endangered reptiles to islands within their former range. To achieve a more viable population size, Antiguan racers must be reintroduced to at least five islands to provide a total area of at least 70 ha, and these islands need to be well-vegetated and free of alien predators, notably mongooses, rats and cats. The feasibility of reintroduction to Barbuda should also explored, in view of the absence of mongooses and availability of suitable prey. Lesser Antillean iguanas have been extirpated from Antigua and Barbuda, but could potentially be returned from other Lesser Antillean states, if hunting, habitat degradation and predation by mongooses can be prevented. Probably the best release site or sites in the short term would be Antigua's larger offshore islands, where such threats can be controlled more easily (Matthew Morton, pers. comm.).

7. Enlist greater public and political interest and support for indigenous herpetofauna and their habitats through education. To reach a wide audience, the awareness strategy should make use of a wide range of approaches, including all varieties of media. In the case of reptiles that people find repulsive or frightening, previous studies have shown that providing information alone may do disappointingly little to modify opinions or behaviour — the target audience often needs to see the animal at close quarters (Morgan and Gramann, 1989). Special attention should be given to the reasons and methods for preventing the spread of alien invasive species, because effective control requires public cooperation. To achieve greater political attention for conservation in Antigua and Barbuda, it may be necessary to demonstrate links between conservation and tourism, for example, by promoting turtle-watching on Antigua or nature tours to Redonda.

8. Encourage and enable more research on herpetofauna. Research can play an important role in conservation by revealing threats to wildlife, identifying possible solutions, and evaluating whether conservation interventions have had the desired effect. Biological research in Antigua and Barbuda is commonly conducted by foreign scientists, and it very important to enable and encourage local students and naturalists to get involved and improve their skills and knowledge. Suggested topics for research include:

(a) Study and monitor the distribution, status and ecology of all endemic and endangered species, including the endemic lizards of Redonda.
(b) Elucidate the impact of *Gymnophthalamus* lizards on native herpetofauna, and, if necessary, develop a strategy to contain their spread.
(c) Resolve the taxonomic relationship of *Anolis forresti* and *Anolis wattsi.*
(d) Resolve the status and distribution of *Eleutherodactylus martinicensis.*
(e) Verify the presence of *Elaphe guttata*, or other alien snakes, and assess their distribution and status.

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References

Anon (2001): Antigua and Barbuda's First National Report to the Convention on Biological Diversity. Office of the Prime Minister, St John's, Antigua and Barbuda.

Anthonyson, D., McCauley, C. (2002): A Survey of Fishermen: North Sound, Antigua. Antiguan Racer Conservation Project, Environmental Awareness Group, St John's, Antigua.

Auffenberg, W.A. (1958): A small fossil herpetofauna from Barbuda, Leeward Islands. Quart. J. Flor. Acad. Sci. **21**: 248-254.

ARCP — Antiguan Racer Conservation Project (1999): Re-introduction of the Antiguan Racer, *Alsophis antiguae* (Serpentes: Colubridae) to Offshore Islands Around Antigua, West Indies. Proposal to the IUCN/SSC Re-introduction Specialist Group, Cambridge, Fauna & Flora International.

Bass, A.L. (1999): Genetic analysis to elucidate the natural history and behavior of hawksbill turtles (*Eretmochelys imbricata*) in the Wider Caribbean: a review and reanalysis. Chel. Conserv. Biol. **3**: 195-199.

Begon, M. (1979): Investigating Animal Abundance. London, Edward Arnold.

Buley, K. (2000): The Reintroduction of the Antiguan Racer *Alsophis antiguae*: 2nd Phase of Radiotelemetry Study (19th February-6th March 2000). Antiguan Racer Conservation Project, Durrell Wildlife Conservation Trust, Jersey, Channel Islands.

Camin, J.H. (1953): Observations on the life history and sensory behaviour of the snake mite, *Ophionyssus natricis* (Gervais) (Acarina, Macronyssidae). Chicago Acad. Sci. Spec. Publ. **10**: 1-75.

Campbell, K., Donlan, C.J. (2005): Feral goat eradications on islands. Conserv. Biol. **19**: 1362-1374.

CCA — Caribbean Conservation Association (1991): Country Environmental Profile: Antigua and Barbuda. Caribbean Conservation Association, St Michael, Barbados.

CARICOM/FAO/ODA (1993): National Forestry Action Plan: Antigua and Barbuda: Main Report. Tropical Forests Action Programme, Food and Agriculture Organization.

Censky, E. (1988): *Geochelone carbonaria* (Reptilia: Testudines) in the West Indies. Flor. Sci. **50**: 108-114.

Censky, E., Lindsay, K. (1997): Note on *Gymnophthalamus underwoodi* (Antillean lizard). Herpetol. Rev. **28**: 210.

Censky, E.J., Hodge, K., Dudley, J. (1998): Evidence of over-water dispersal of lizards due to hurricanes. Nature **395**: 556.

Censky, E., Kaiser, H., (1999): The lesser Antillean fauna. In: Caribbean Amphibians and Reptiles, p. 181-221. Crowther, B.I., Ed. San Diego, Academic Press.

Choi, G.-Y., Eckert, K.L. (2006): Sea Turtles and the Hotel Industry: Best Practices Manual for Beachfront Properties in the Wider Caribbean Region. Wider Caribbean Sea Turtle Conservation Network (WIDECAST) and the Caribbean Alliance for Sustainable Tourism (CAST). WIDECAST Technical Report No. 6. Beaufort, North Carolina.

Church, J.A., Gregory, J.M., Huybrechts, P., Kuhn, M., Lambeck, K., Nhuan, M.T., Qin, D., Woodworth, P.L. (2001): Changes in sea level. In: Climate Change 2001: The Scientific Basis, p. 639-693. Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Xiaosu, D., Eds. Cambridge, Cambridge University Press.

Cooper, G. (1997): Antigua racer population up more than 50%. The EAGer (newsletter of the Environmental Awareness Group, St Johns, Antigua) **3**: 1.

Corliss, L.A., Richardson, J.I., Ryder, C., Bell, R. (1989): The hawksbills of Jumby Bay, Antigua, West Indies. In: Proc. of the Ninth Ann. Workshop on Sea Turtle Conserv. Biol. p. 33-35. Eckert, S.A., Eckert, K.L., Richardson, T.H., Eds, NOAA Technical Memorandum NMFS-SEFC-232, U.S. Department of Commerce, Miami, Florida.

Daltry, J.C. (1999): Status, Distribution and Natural History of the Antiguan Racer (*Alsophis antiguae*): Field Research and Conservation Technical Report. Antiguan Racer Conservation Project Report No. 4. Cambridge UK, Fauna & Flora International.

Daltry, J.C. (2000): Re-introduction of the Antiguan Racer *Alsophis antiguae*, November-December 1999. Cambridge, UK, Fauna & Flora International.

Daltry, J.C., Day, M.L. (1996): The Status, Distribution and Natural History of the Antiguan Racer (*Alsophis antiguae*): Findings of the First Field Study. Antiguan Racer Conservation Project Report No. 1. Cambridge, UK, Fauna & Flora International.

Daltry, J.C., Day, M.L. (1997): The Status, Distribution and Natural History of the Antiguan Racer (*Alsophis antiguae*): Findings of the Second Field Study. Antiguan Racer Conservation Project Report No. 3, Cambridge, UK, Fauna & Flora International.

Daltry, J.C., Bloxam, Q., Cooper, G., Day, M.L., Hartley, J., Henry, M., Lindsay, K., Smith, B.E. (2001): Five years of conserving the 'world's rarest snake', the Antiguan racer *Alsophis antiguae*. Oryx **35**: 119-127.

Daltry, J.C., McCauley, C., Morton, M. (2002): Re-introduction of the Antiguan Racer *Alsophis antiguae*, to Green Island: Interim Report. Antiguan Racer Conservation Project, St John's, Antigua and Barbuda.

Daltry, J.C., Morton, M., Smith, B.E., Sylvester, I. (2003): The 2003 Antiguan Racer Census and Reintroduction. Antiguan Racer Conservation Project, St John's, Antigua and Barbuda.

Day, M.L., Daltry, J.C. (1996): Rat eradication to save the Antiguan racer. Aliens (journal of the IUCN/SSC Invasive Species Specialist Group) **3**: 14-15.

Daszak, P., Berger, L., Cunningham, A.A., Hyatt, A.D., Green, D.E.., Speare, R. (1999): Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases Journal **5**: 735-748. http://www.cdc.gov/ncidod/eid/vol5no6/daszak.htm

Day, M.L., Breuil, M., Reichling, S. (2000): Lesser Antillean iguana *Iguana delicatissima*. In West Indian Iguanas: Status Survey and Conservation Action Plan, p. 62-67. Alberts, A., Ed., IUCN/SSC West Indian Iguana Specialist Group.

Dunn, E.R. (1936): Notes on American mabuyas. Proc. Acad. Nat. Sci., Phil. **87**: 553-557.

Eckert, K.L. (1995): Hawksbill Sea Turtle, *Eretmochelys imbricata*. In: National Marine Fisheries Service and U.S. Fish and Wildlife Service Status Reviews for Sea Turtles Listed Under the Endangered Species Act of 1973, p. 76-108. Plotkin, P.T., Ed., National Marine Fisheries Service, Silver Spring, Maryland, USA.

Etheridge, R. (1964): Late Pleistocene lizards from Barbuda, British West Indies. Bull. Flor. State Mus. Biol. Sci. **9**: 43-75.

Faaborg, J., Arendt, W. (1985): Wildlife assessments in the Caribbean. U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry, Rio Piedras, Puerto Rico.

Frankel, O.H., Soulé, M.J. (1981): Conservation and Evolution. Cambridge, Cambridge University Press.

Frick, M.G., Mason, P.A., Williams, K.L., Andrews, K., Gerstung, H. (2003): Epibionts of hawksbill turtles, *Eretmochelys imbricata*, in a Caribbean nesting ground: a potentially unique association with snapping shrimp. Mar. Turt. News. **99**: 8-11.

Fuller, J., Eckert, K,L., Richardson, J.I. (1992): WIDECAST Sea Turtle Recovery Action Plan for Antigua and Barbuda. CEP Technical Report No. 16. UNEP Caribbean Environment Programme, Kingston, Jamaica. 88 pp.

Gibson, R. (1997): Conservation of the Antiguan racer *Alsophis antiguae*: the captive component. Proc. 1997 Int. Herpetol. Soc. Symp., International Herpetological Society.

Gilpin, M.E. (1996): Spatial structure and population vulnerability. In: Viable Populations for Conservation, p. 125-139. Soulé, M.E., Ed. Cambridge, Cambridge University Press.

Glen, F., Mrosovsky, N. (2004): Antigua revisited: the impact of climate change on sand and nest temperatures at a hawksbill turtle (*Eretmochelys imbricata*) nesting beach. Glob. Change Biol. **10**: 2036-2045.

Goldenberg, S.B., Landsea, C.W., Mestas-Nuñez, A.M., Gray, W.M. (2001): The recent increase in Atlantic hurricane activity: causes and implications. Science **20**: 474-479.

Hedges, S.B. (1999): Distribution patterns of amphibians in the West Indies. In: Patterns of Distribution of Amphibians: A Global Perspective, p. 211-254. Duellman, W.E., Ed. Baltimore, Johns Hopkins University Press.

Henderson, R.W. (1989): A new subspecies of *Alsophis antiguae* (Serpentes: Colubridae) from Great Bird Island (Antigua), Lesser Antilles. Carib. J. Sci. **25**: 119-122.

Henderson, R.W., Sajdak, R.A. (1986): West Indian racers: a disappearing act or a second chance? Lore **36**: 13-18.

Henderson, R.W., Powell, R., Daltry, J.C., Day, M.L. (1996): *Alsophis antiguae* Parker. Cat. Amer. Amph. Rept. **632**: 11-13.

Horrocks, J.A., Oxenford, H.A., Willoughby, S. (1989): Nest site location and clutch mortality of hawksbill turtles *Eretmochelys imbricata* in Barbados, West Indies. In: Proc. of the Ninth Ann. Workshop on Sea Turtle Conserv. Biol., p. 239-241. Eckert, S.A., Eckert, K.L., Richardson, T.H., Eds, NOAA Technical Memorandum NMFS-SEFC-232, U.S. Department of Commerce, Miami, FL.

Horwith, B., Lindsay, K. (1997): A Biodiversity Profile: Antigua, Barbuda, Redonda. Eastern Caribbean Biodiversity Programme Biodiversity Publication 3, Island Resources Foundation.

Hoyle, M. (1994): Continuing sea turtle exploitation in Antigua and Barbuda, West Indies. Mar. Turt. News. **64**: 21-22.

Hoyle, M., Richardson, J.I. (1993): The Jumby Bay Hawksbill Project: Survivorship, Mortality, Recruitment and Reproductive Biology and Behavior of Adult Female Hawksbill Sea Turtles (*Eretmochelys imbricata*) Nesting at Pasture Bay, Long Island, Antigua, W. I. Unpublished Technical Report, Georgia Sea Turtle Cooperative, Institute of Ecology, University of Georgia, Athens, GA. 76 pp.

IUCN — The World Conservation Union (1998): Invaders from Planet Earth. World Conservation **28**, **29** (double issue): 63 pp.

IUCN — The World Conservation Union (2000): Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species. IUCN/SSC Invasive Species Specialist Group, The World Conservation Union, Gland, Switzerland.

IUCN – The World Conservation Union (2002): Hawksbill Turtles in the Caribbean Region: Basic Biological Characteristics and Population Status. CITES Wider Caribbean Range State Hawksbill Turtle Dialogue meetings. www.cites.org

IUCN — The World Conservation Union (2004): 2004 IUCN Red List of Threatened Species. www.iucnredlist.org, downloaded on 10 April 2006.

James, S. (2001): Coastal stewardship in Antigua and Barbuda. Paper presented to IUCN/CSI Conference on Environment and Development in Coastal Regions and in Small Islands, Dominica.

Jeffery, C., Henry McR. (2000): Antigua & Barbuda Biodiversity Strategy and Action Plan. St John's, Antigua.

Kairo, M., Ali, B., Cheeseman, O., Haysom, K., Murphy, S. (2005): Invasive Species Threats in the Caribbean Region: Report to the Nature Conservancy. Egham, United Kingdom, CABI Bioscience.

Kerr, R., Richardson, J.I., Richardson, T.H. (1999): Estimating the annual size of hawksbill (*Eretmochelys imbricata*) nesting populations from mark-recapture studies: the use of long-term data to provide statistics for optimizing survey effort. Chel. Cons. Biol. **3**: 251-256.

Kaiser, H. (1992): The trade-mediated introduction of *Eleutherodactylus martinicensis* (Anura: Leptodactyliidae) on St Bathelemy, French Antilles, and its implications for Lesser Antillean biogeography. J. Herpetol. **26**: 264-273.

Kaiser, H., Hardy, J.D. (1994): *Eleutherodactylus martinicensis*. Catalogue of America Amphibians and Reptiles, Soc. Stud. Amph. Rep. **582**: 1-4.

Lanagan, F.T. (1844): Antigua and the Antiguans, Vol II. Saunders and Otley, London. 355 pp.

Lande, R., Barrowclough, G.F. (1996): Effective population size, genetic variation, and their use in population viability analysis. In: Viable Populations for Conservation, p. 87-124. Soulé, M.E., Ed., Cambridge, UK, Cambridge University Press.

Lazell, J.D. Jr. (1967): Wiederentdeckung von zwei angeblich ausgestorbenen Schlangenarten der westindischen Inseln. Salamandra **3**: 91-97.

Lever, C. (2001): The Cane Toad: The History and Ecology of a Successful Colonist. West Yorkshire, Westbury Publishing. 230 pp.

Lindsay, K., Horwith, B. (1997): A Vegetation Classification: Antigua, Barbuda, Redonda. Eastern Caribbean Biodiversity Programme Biodiversity Publication 2, Island Resources Foundation.

Magin, C. (2003): Chytridiomycosis on Dominica: Briefing Sheet 1. Cambridge UK, Fauna & Flora International.

Malhotra, A., Thorpe, R.S. (1999): Reptiles and Amphibians of the Eastern Caribbean. London and Oxford, MacMillan Education.

Mason, P., Stapleton, S., Ballentine, A. (in press): Nest site selection in hawksbill turtles (*Eretmochelys imbricata*) within and among seasons, Antigua, West Indies. In: Proc. Twenty-Fourth Ann. Symp. Sea Turtle Biol. Conserv.

McCauley, C. (1999a): Environmental Education Status Report. Antiguan Racer Conservation Project, Report No. 6. Environmental Awareness Group, St Johns, Antigua.

McCauley, C. (1999b): Report on offshore island workshop for tour operators. Environmental Awareness Group, St Johns, Antigua.

McIntyre, S., Phillpot, P. (2002): Antiguan Racer Census 2002 Report. Unpublished report to the Antiguan Racer Conservation Project.

Meylan, A.B. (1999): International movements of immature and adult hawksbill turtles (*Eretmochelys imbricata*) in the Caribbean Region. Chel. Conserv. Biol. **3**: 289-194.

Morgan, J.M., Gramann, J.H. (1989): Predicting effectiveness of wildlife education programs: a study of students' attitudes and knowledge towards snakes. Wildl. Soc. Bull. **17**: 501-509.

Mrosovsky, N., Bass, A.L., Corliss, L.A., Richardson, J.I., Richardson, T.H. (1992): Pivotal and beach temperatures for hawksbill turtles nesting in Antigua. Can. J. Zool. **70**: 1920-1925.

Muenz, T.K., Andrews, K.M. (2002): The recovery of nesting habitat: A proactive approach for conservation of the hawksbill sea turtle, *Eretmochelys imbricata*, Long Island, Antigua, West Indies. In: Proc. 22nd Ann. Symp. Sea Turtle Biol. Conserv. p. 105. Seminoff, J.A., Ed., NOAA Technical Memorandum NMFS-SEFSC-503.

Muenz, T.K., Andrews, K.M. (in press): The reconciliation of hawksbill habitat with vegetation islands on Long Island, Antigua, West Indies. In: Proc. 24th Ann. Symp. on Sea Turtle Biol. Conserv.

Parker, H.W. (1933): Some amphibians and reptiles from the Lesser Antilles. Ann. Mag. Nat. Hist. **11**: 151-158.

Parker, H.W. (1936): Some extinct snakes of the West Indies. Ann. Mag. Nat. Hist. **18**: 227-233.

Pregill, G.K., Steadman, D.W., Waters, D.R. (1994): Late Quaternary vertebrate faunas of the Lesser Antilles: historical components of Caribbean biogeography. Bull. Carnegie Mus. Nat. Hist. **30**: iv + 51p.

Richardson, J.I., Bell, R., Richardson, T.H. (1999): Population ecology and demographic implications drawn from an 11-year study of nesting hawksbill turtles, *Eretmochelys imbricata*, at Jumby Bay, Long Island, Antigua, West Indies. Chel. Conserv. Biol. **3**: 244-250.

Richardson, J.I., Corliss, L.A., Ryder, C., Bell, R. (1989): Demographic patterns of Caribbean hawksbills, Jumby Bay, Antigua. In: Proc. 9th Ann. Workshop on Sea Turtle Conserv. Biol., p. 253-256. Eckert, S.A., Eckert, K.L., Richardson, T.H., Eds. NOAA Tech. Memo. NMFS-SEFC-232.

Ryder, C., Richardson, J.I., Corliss, L.A., Bell, R. (1989): Habitat preference and beach management for nesting hawksbills, Jumby Bay, Antigua, West Indies. In: Proc. 9th Ann. Workshop on Sea Turtle Conserv. Biol., p. 263-266. Eckert, S.A., Eckert, K.L., Richardson, T.H., Eds. NOAA Tech. Mem. NMFS-SEFC-232.

Sajdak, R.A., Henderson, R.W. (1991): Status of West Indian racers in the Lesser Antilles. Oryx **25**: 33-38.

Schwartz, A. (1967): Frogs of the genus *Eleutherodactylus* in the Lesser Antilles. Stud. Fauna Curacao and Caribbean Islands **23**: 1-62.

Schwartz, A., Henderson, R.W. (1991): Amphibians and Reptiles of the West Indies: Descriptions, Distributions and Natural History. Gainesville, University of Florida Press. 720 pp.

Smith, B.E., Baum, R.E. (2000): Surveys of the Lizards *Anolis wattsi* and *Ameiva griswoldi* on Antiguan Offshore Islands I. Summer 1999. Antiguan Racer Conservation Project. Report No.5. Pre-publication Draft Report.

Smith, B.E, Colbert, P.L. (2002): Surveys of the Lizard *Anolis wattsi* on Antiguan Offshore Islands III: Summer 2001. Antiguan Racer Conservation Project Report No. 7. South Dakota, Black Hills State University.

Smith, B.E., Baum, R.E., Massie, J.L., Davis, O. (2001): Surveys of the Lizards *Anolis wattsi* and *Ameiva griswoldi* on Antiguan Offshore Islands II: Summer 2000. Antiguan Racer Conservation Project Report No. 6. South Dakota, Black Hills State University.

Smith, B.E., Davis, O., Bartscher, N.S. (2002): Surveys of the lizard *Ameiva griswoldi* on Antiguan offshore islands III: Summer 2001. Antiguan Racer Conservation Project Report No. 8. South Dakota, Black Hills State University.

Stapleton, S., Stapleton, C. (2006): Tagging and Nesting Research on Hawksbill Turtles (*Eretmochelys imbricata*) at Jumby Bay, Long Island, Antigua, West Indies: 2005 Annual Report. Prepared for the Jumby Bay Island Company, Ltd. by the Wider Caribbean Sea Turtle Conservation Network (WIDECAST). 22 pp.

Steadman, D.W., Watters, D.R., Pregill, G.K., Olson, S.L. (1984): Fossil vertebrates from Antigua, Lesser Antilles: Evidence for late Holocene human-caused extinctions in the West Indies. Proc. Nat. Acad. Sci **81**: 4448-4451.

TAC — Technical Advisory Committee (2005): United Nations Convention to Combat Desertification: Draft National Action Plan for Antigua and Barbuda. Report commissioned by the Environment Division, Ministry of Public Works and Environment, St John's, Antigua.

Underwood, G. (1962): Reptiles of the Eastern Caribbean. Caribbean Affairs (new series) no. 1. University of the West Indies, Trinidad.

Varnham, K. (2001): Restoration of Green Island, Antigua, West Indies, Rat Eradication Project: Interim Report, July 2001. Antiguan Racer Conservation Project, St John's, Antigua.

Varnham, K. (2005): Rats and Antiguan racer snakes. Biol. Sci. Rev. Sept 2005: 7-10.

Varnham, K., Ross, T., Daltry, J., Day, M., Cooper, G., Lindsay, K. (1998): Recovery of the Antiguan racer. Aliens (journal of the IUCN/SSC Invasive Species Specialist Group) **8**: 21.

Watters, D.R., Reitz, E.J., Steadman, D.W., Pregill, D.K. (1984): Vertebrate from archaeological sites on Barbuda, West Indies. Ann. Carnegie Mus. **53**: 383-412.

White, G.L., Hailey, A. (2006): The establishment of *Anolis wattsi* as a naturalized exotic lizard in Trinidad. Appl. Herpetol. **3**: 11-26.

Witherington, B.E., Martin, R.E. (2000): Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches (revised edition). Florida Fish and Wildlife Conservation Commission, FMRI Technical Report TR-2. 73 pp.

Wright, K.M., Sylvester, I., Daltry, J.C. (2004): Ten years after: A look at the recovery of the "world's most endangered snake", the Antiguan racer (*Alsophis antiguae*). Proc. Assoc. Rept. Amph. Vet. Ann. Conf., 2004.

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