Conservation of herpetofauna in the Republic of Trinidad and Tobago

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Abstract. Trinidad and Tobago present three main contrasts to other Caribbean islands in terms of herpetological conservation. (1) They are continental shelf rather than oceanic islands and have a diverse Neotropical fauna and a low level of endemism. (2) They were developed relatively late in the European colonial period, and the delayed population and agricultural growth has left relatively large areas of original habitat. (3) Industrial development is the major feature of current economic growth in the Republic of Trinidad and Tobago. Trinidad is more divergent from the typical Caribbean island than Tobago in all these respects. The herpetofauna is incompletely known, but about 112 terrestrial and freshwater species and five sea turtles have been recorded. Trinidad has 103 species, Tobago 52, with 43 species in common; 83% of the species are also found in South America. There are 12 endemic and seven introduced species. Iguana and tegu lizards, as well as caiman, are hunted under licence, and there is a legal artisanal fishery for sea turtles. Venomous snakes (absent from Tobago) are classed as vermin and may legally be destroyed. Other reptiles are classed as protected animals under the Conservation of Wild Life Act; amphibians are currently unprotected by law outside of Environmentally Sensitive Areas. The amphibian chytrid fungus is present on both islands. The endemic Critically Endangered (IUCN) golden tree frog *Phytotriades auratus* will probably receive protection as an Environmentally Sensitive Species in the near future; this status was recently rejected for the sea turtles. There is effective practical conservation of nesting turtles by community-based ecotourism projects on some beaches, recently coordinated by the Turtle Village Trust, and efforts to replace the turtle fishery by non-destructive economic use as an attraction for dive ecotourism. A large bycatch of leatherback turtles in the gillnet fishery remains a major conservation issue. Future problems related to the development of industry and effects of global climate change are discussed, and recommendations given for conservation of the herpetofauna.

Key words: *Batrachochytrium dendrobatidis*; conservation legislation; *Dermochelys coriacea*; ecotourism; hunting; incidental catch; Neotropics; *Phytotriades auratus*; protected areas; sea turtle fishery.

Introduction

Trinidad is an island of 4830 km^2, separated from Venezuela by the Gulf of Paria which is 11 km wide at the narrowest point; Tobago has an area of 300 km^2 and lies a further 36 km to the north-east (fig. 1). The shallowest channel between Trinidad and Tobago has a maximum depth of 91 m, and that between Trinidad and Venezuela of 38 m, so both islands would have been connected to the mainland during the last glacial maximum when sea level was 135 m lower (Clark and Mix, 2002). Based on channel depths and sea levels, the last separation was 14,000 BP for Tobago and 10,000 BP for Trinidad. An alternative view, based on the presence of coral remains in the Gulf of Paria, is that Trinidad was connected to Venezuela until only 1500 years ago by a land bridge, until that was breached by the Orinoco to form the south-west peninsula (Kenny, 1989, 1995). In either case, the date of separation is too recent to account for speciation, and molecular evidence indicates that endemic species in Trinidad and Tobago formed 1-5 MYA (e.g., Manzanilla et al., 2009). Murphy (1997) estimated that Trinidad was connected to the mainland for 65% of the last 140,000 years, and Tobago for 14%. The Northern Range of Trinidad (fig. 2a) is composed of Mesozoic metamorphic rocks, representing the end of the Andes mountain chain. It has a maximum height of 940 m at Mt Aripo and 936 m at El Tucuche. The Central Range of younger sedimentary rocks has a maximum height of 307 m at Mount Tamana; the Southern Range or Trinity Hills is of even

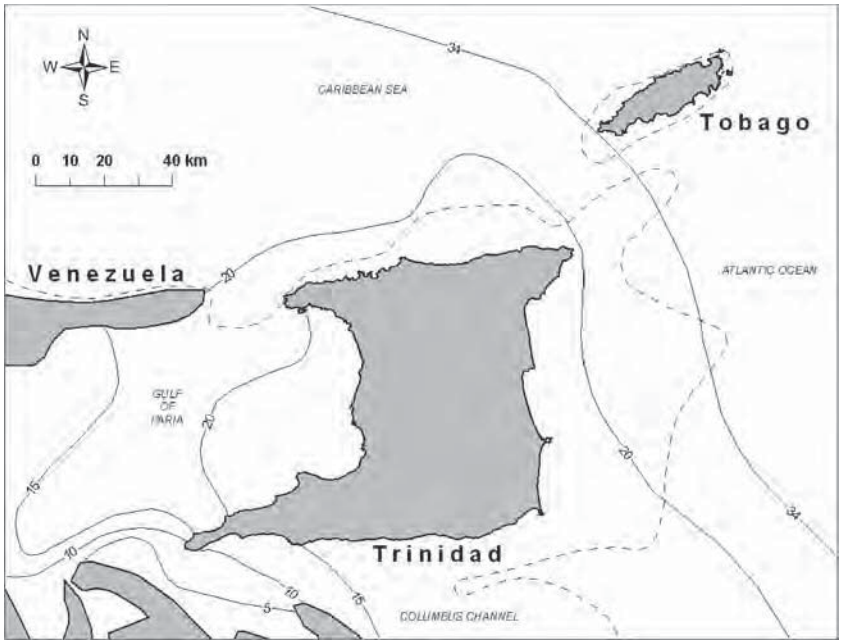
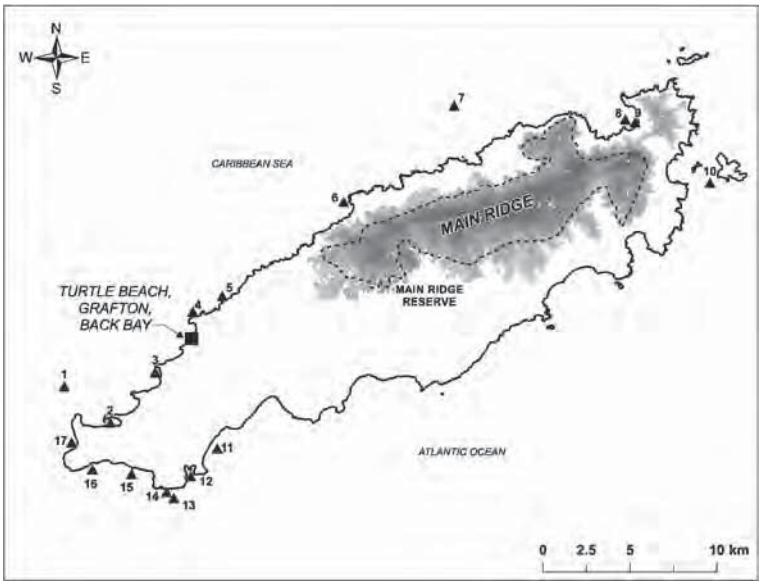


Figure 1. Trinidad, Tobago, and the adjacent coast of Venezuela. Solid lines show wet season surface salinity levels (ppt) and the dashed line shows the 54 m (30 fathom) depth contour (after Kenny, 1995, and Spalding, 2004).

(a)



(b)

Figure 2. (a) Trinidad, with highlands above 100 m and the major swamps. The dashed line shows the Matura Environmentally Sensitive Area. A, Paria; B, Tacarib; C, Madamas. The six Wildlife Section offices issuing the State Game Licence are at Port of Spain, Arima, Sangre Grande, Rio Claro, San Fernando and Siparia. (b) Tobago, with highlands above 300 m. The dashed line shows the Main Ridge Reserve. 1, Buccoo Reef; 2, Bon Accord Lagoon; 3, Mt. Irvine; 4, Plymouth; 5, Arnos Vale; 6, Castara; 7, Sisters Rocks; 8, Charlotteville; 9, Man-O-War Bay; 10, Speyside and Little Tobago; 11, Canoe Bay; 12, Petit Trou; 13, Cove; 14, Little Rockley Bay; 15, Kilgwyn; 16, Crown Point; 17, Store Bay.

lower and younger unconsolidated sediments. Between these ranges are alluvial terraces of 15-60 m asl forming the northern and southern basins (Liddle, 1946). Tobago has a more complex (and controversial) geology; it is largely of igneous island-arc origin, but accreted to the continental shelf (Frost and Snoke, 1989). The highlands in Tobago (fig. 2b) are the Main Ridge, with a maximum height of about 550 m.

There is a dry season from January to May; some rain typically falls in every month, but over 80% is in the wet season. In both islands the lowest rainfall is in the west, and the maximum occurs on the highest ground. The recorded spatial range is 1.2-3.8 m in Trinidad, probably up to 5 m on Northern Range peaks, and 1.4-2.4 m in Tobago, up to 3.8 m on the Main Ridge (Beard, 1946; MPUE, 2006). The mean ambient temperature at sea level is about 27°C, with a daily range of 11°C but a seasonal range of only 2-3°C. Beard (1946) recorded temperatures on the summit of Mt Aripo of 17.8°C at midday and 14.4°C at night. The islands are south of the hurricane belt and experience them rarely; the last severe events being in Tobago in 1963 and in Trinidad in 1933. Many streams descend from the highlands, but there are no large rivers, natural lakes or ponds in either island. Trinidad has the brackish Caroni Swamp on the west coast and the freshwater Nariva Swamp on the east coast (fig. 2a), and several smaller swamps (Kenny, 2008). The natural vegetation is typically evergreen seasonal forest up to 200-250 m, lower montane forest to 750 m, and (in Trinidad) montane forest above 750 m and elfin woodland above 850 m (Beard, 1944, 1946). Tobago has the extensive Buccoo Reef in the south-west, with that part of the island being a flat coral platform (fig. 2b). The salinity of the sea around Trinidad is mostly too low, and the opacity too high, for coral growth due to the proximity of the Orinoco mouth, but there are specialized reefs along the north coast. During peak discharge, salinity is below 20 ppt around Trinidad, falling to 15 ppt on the south-west peninsula and to only 10 ppt at its tip (fig. 1). During extreme discharge, surface waters can be almost fresh at Icacos (Kenny, 2008).

The Herpetofauna

There is a comprehensive guide to the herpetofauna of Trinidad and Tobago (Murphy, 1997), which is currently being updated, and monographs on the amphibians (Kenny, 1969, 1977) and snakes (Boos, 2001). There have been many subsequent taxonomic changes, especially among the amphibians. Names used here follow Frost (2010) and Uetz (2010).

The terrestrial and freshwater herpetofauna comprises 112 species (subject to interpretation and new discoveries): 35 anurans, 1 crocodilian, 6 chelonians, 2 amphisbaenians, 26 lizards, and 42 snakes. Trinidad has 103 species and Tobago has 52, with 43 species in common. Tobago has no venomous snakes — hence the normally mimetic genus *Erythrolamprus* is represented by *E. ocellatus*, a form with ocelli rather than bands (Emsley, 1966). Jaccard's binary index of similarity $S_j = a/(a + b + c)$ (where a is the number of species common to both islands,

and b and c are the number of species found on only one island; Krebs, 1999) is equal to 0.38 overall and 0.39 excluding introduced species. Sorensen's index ($S_s = 2a/(2a + b + c)$) is 0.55 overall, and 0.56 excluding introduced species. The latter index weights similarities more than differences, and is equal to Duellman's Faunal Resemblance Factor used by Murphy (1997). The similarity between the herpetofaunas of Trinidad and of Tobago is thus limited, largely due to the absence of some species from Tobago, rather than a high proportion of island endemics.

The great majority (93, or 83%) of the 112 species are also found in South America (table 1). Some other Neotropical species may also be, or have been at one time, part of the Trinidad herpetofauna. *Leptodactylus knudseni* was recorded from a single specimen before 1919, but may be present as subfossil material associated with humans. This large frog may have been extirpated by humans or by the mongoose. *Crocodylus acutus* was also possibly extirpated by humans, and there are records of a *Typhlonectes* sp. (caecilian), the river turtles *Podocnemis expansa* and *P. unifilis*, *Anolis* cf. *lemurinus*, the gecko *Gymnodactylus geckoides* and the colubrid *Erythrolamprus bizona* in Trinidad (Murphy, 1997). On the other hand, Kenny (2008) suggests that some species accepted as part of the Trinidad herpetofauna may not form breeding populations, but be vagrant individuals from the Orinoco; e.g., *Chelus fimbriatus*, which are often covered in barnacles indicating passage in brackish water.

Twelve species are endemic to Trinidad and/or Tobago (table 2a). Recent work on *Mannophryne trinitatis* shows that the Venezuelan populations are distinct from those in Trinidad (Manzanilla et al., 2007), which thus become an endemic species. As with most of the Caribbean herpetofauna (Wilson et al., 2006) the endemic species of Trinidad and Tobago are little known; only *M. trinitatis* can be considered well-studied, especially its tadpole transport and deposition behaviour (e.g., Downie et al., 2005; Jowers and Downie, 2005). This species is widely distributed in the Northern and Central Ranges (Jowers and Downie, 2004) and shows variation in ecology (Cummins and Swan, 1995) and behaviour (Jowers et al., 2006) between populations. The similar Bloody Bay frog *M. olmonae* is a Tobago endemic. *Pristimantis urichi* and *Typhlops trinitatus* are widespread in both islands. The golden tree frog *Phytotriades auratus* has recently been assigned to a new genus separate from *Phyllodytes* (Jowers et al., 2008); such generic recognition will help to promote *P. auratus* as an important endemic worthy of conservation. It is only found at high elevation, on Mt Aripo, El Tucuche, and (perhaps formerly) on other high peaks (Kenny, 2008). Its lower elevation limit is between 800-900 m asl, apparently corresponding to that of its breeding habitat, the giant tank bromeliad *Glomeropitcairnia erectiflora*, although individuals have occasionally been found in other bromeliad species (and will use them, and artificial bromeliads, in captivity; A. Hailey, pers. obs.). The so-called "luminous lizard" (Knight et al., 2004), *Riama shrevei*, also has a montane distribution in the Northern Range, down to about 600 m asl, and is mostly associated with caves at the lower levels. *Leptodactylus nesiotus* is known from a few specimens from the south-west peninsula of Trinidad, and

Table 1. Native terrestrial and freshwater herpetofauna species in Trinidad and Tobago having a South American distribution. The number of species in each area, and the IUCN Red List category or CITES Appendix (CA), are shown in parentheses. Red List categories are: EN = Endangered; VU = Vulnerable; LC = Least Concern; LR/lc = Lower Risk/least concern; LR/cd = Lower Risk/conservation dependent. *Species, genus and/or family name has changed since Murphy (1997).

Both Trinidad and Tobago (39)

Bufonidae: *Rhinella marina** (LC).
Amphignathodontidae: *Flectonotus fitzgeraldi** (EN).
Hylidae: *Dendropsophus minutus** (LC); *Hypsiboas crepitans** (LC); *Scinax ruber** (LC); *Trachycephalus venulosus** (LC).
Leiuperidae: *Engystomops pustulosus** (LC).
Leptodactylidae: *Leptodactylus fuscus* (LC); *Leptodactylus validus* (LC).
Alligatoridae: *Caiman crocodilus* (LR/lc, CAII).
Gekkonidae: *Gonatodes vittatus*; *Hemidactylus palaichthus*; *Sphaerodactylus molei*; *Thecadactylus rapicauda*.
Gymnophthalmidae: *Bachia heteropa*.
Iguanidae: *Iguana iguana* (CAII).
Polychrotidae: *Polychrus marmoratus**.
Scincidae: *Mabuya bistriata*.
Teiidae: *Ameiva ameiva*; *Cnemidophorus lemniscatus*; *Tupinambis teguixin* (CAII).
Boidae: *Boa constrictor* (CAII); *Corallus hortulanus* (CAII); *Epicrates cenchria* (CAII).
Colubridae: *Atractus trilineatus*; *Drymarchon corais*; *Imantodes cenchoa*; *Leptodeira annulata*; *Leptophis ahaetulla*; *Liophis melanotus*; *Liophis reginae*; *Mastigodryas boddaerti*; *Ninia atrata*; *Oxybelis aeneus*; *Oxyrhopus petola*; *Pseudoboa neuwiedii*; *Sibon nebulata*; *Spilotes pullatus*; *Tantilla melanocephala*.

Trinidad Only (51)

Bufonidae: *Rhinella beebei** (LC).
Hylidae: *Dendropsophus microcephalus** (LC); *Dendropsophus minisculus** (LC); *Hypsiboas boans** (LC); *Hypsiboas geographicus** (LC); *Hypsiboas punctatus** (LC); *Phyllomedusa trinitatis* (LC); *Pseudis paradoxa** (LC); *Sphaenorhynchus lacteus* (LC).
Leptodactylidae: *Leptodactylus bolivianus* (LC); *Leptodactylus hylaedactylus** (LC); *Leptodactylus lineatus** (LC); *Leptodactylus ocellatus** (= *L. macrosternum*) (LC).
Microhylidae: *Elachistocleis ovalis* (LC); *Elachistocleis surinamensis* (LC).
Pipidae: *Pipa pipa* (LC).
Ranidae: *Lithobates palmipes** (LC).
Chelidae: *Chelus fimbriatus*; *Mesoclemmys gibba**.
Bataguridae: *Rhinoclemmys punctularia**.
Kinosternidae: *Kinosternon scorpioides*.
Testudinidae: *Chelonoidis denticulata** (VU, CAII).
Amphisbaenidae: *Amphisbaena alba*; *Amphisbaena fuliginosa*.
Gekkonidae: *Gonatodes ceciliae*; *Gonatodes humeralis*.
Gymnophthalmidae: *Gymnophthalmus speciosus*; *Gymnophthalmus underwoodi*.
Polychrotidae: *Anolis chrysolepis**.
Teiidae: *Kentropyx striata**.
Tropiduridae: *Plica plica**.
Boidae: *Eunectes murinus*.
Colubridae: *Chironius carinatus*; *Clelia clelia* (CAII); *Dipsas variegata*; *Erythrolamprus aesculapii*; *Helicops angulatus*; *Hydrops triangularis*; *Leptophis riveti*; *Liophis cobella*; *Pseustes poecilonotus* (LC); *Pseustes sulphureus*; *Siphlophis cervinus*; *Siphlophis compressus**; *Thamnodynastes* sp.
Elapidae: *Micrurus circinalis*; *Micrurus lemniscatus*.

Table 1. (Continued).

Leptotyphlopidae: *Epictia tenella** (= *Leptotyphlops albifrons*).
Typhlopidae: *Typhlops brongersmianus*.
Viperidae: *Bothrops atrox**; *Lachesis muta*.

Tobago Only (3)
Centrolenidae: *Hyalinobatrachium orientale* (VU).
Gymnophthalmidae: *Bachia flavescens*.
Colubridae: *Atractus univittatus*.

the anomalepid blind snake *Helminthophis* sp. from a single specimen. The four endemic amphibians in Tobago all have similar recorded distributions, in the north-east of the island, but are possibly more widespread. In addition to endemic species, there are probably endemic subspecies of *Bachia heteropa*, *Liophis reginae* and *Mastigodryas boddaerti* on Tobago, and of *Dipsas variegata* on Trinidad (Murphy, 1997).

The only Antillean elements in the Trinidad and Tobago herpetofauna are the human introductions, *Eleutherodactylus johnstonei* and *Anolis* spp. Seven introduced species of herpetofauna are currently known from Trinidad and/or Tobago (table 2b), and another species (*Anolis extremus*) is now extinct in Trinidad (Hailey et al., 2009). *Hemidactylus mabouia* is nearly cosmopolitan, but apparently originated from Africa (Carranza and Arnold, 2006); it may have displaced the native *H. palaichthus* which is currently known only from small offshore islands (Monos and Chacachacare, off north-west Trinidad, and from Little Tobago). *Chelonoidis carbonaria* is likely to have been an ancient introduction for food. The most recent introductions *E. johnstonei* and *Anolis wattsi* are spreading rapidly in suburban areas (Manickchan, 2003; White and Hailey, 2006).

The herpetofauna of Trinidad and Tobago is incompletely documented. There are possibly two (at least) additional frogs; a new *Pristimantis* species in the Northern Range (M. Patrikeev and S.B. Hedges, pers. comm., April 2010) and a Scarthylid in the south-west peninsula (Ogilvy et al., 2007; Smith, 2007). *Anolis aeneus* has recently been found in Tobago (G. White, pers. comm., 2 April 2008). Natural invasions of Orinoco species are always possible, from the strong flow of almost fresh water reaching the south-west peninsula at times; this may be responsible for the several species found only (as yet) in that area. Anacondas are frequently washed up (e.g., Charan, 2007), and rafting amphibians are a strong possibility.

Sea turtles

Five species of sea turtles occur in Trinidad and Tobago.

Dermochelys coriacea. Gravid female leatherbacks are seasonal visitors to the Caribbean (males are rarely encountered) and observations are largely confined to the peak breeding months from March to August (Eckert, 2001). There is a large breeding population using beaches in Trinidad, mostly on the north and east coasts

Table 2. Endemic and introduced species of terrestrial and freshwater herpetofauna in Trinidad and Tobago. The number of species in each area and the IUCN Red List category or CITES Appendix (CA), are shown in parentheses. Red List categories are: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern. *Species, genus and/or family name has changed since Murphy (1997).

(a) Endemic Species

Both Trinidad and Tobago (2)	**Trinidad Only (5)**	**Tobago Only (5)**
Strabomantidae:	Aromobatidae:	Aromobatidae:
*Pristimantis urichi** (EN)	*Mannophryne trinitatis** (VU)	*Mannophryne olmonae** (CR)
Typhlopidae:	Hylidae:	Strabomantidae:
Typhlops trinitatus	*Phytotriades auratus* (CR)	*Pristimantis charlottevillensis** (VU)
		*Pristimantis turpinorum** (VU)
	Leptodactylidae:	
	Leptodactylus nesiotus (VU)	
	Gymnophthalmidae:	Gekkonidae:
	*Riama shrevei**	*Gonatodes ocellatus*
	Anomalepidae:	Colubridae:
	Helminthophis sp.	*Erythrolamprus ocellatus*

(b) Introduced Species

Both Trinidad and Tobago (2)	**Trinidad Only (4)**	**Tobago Only (1)**
Gekkonidae:	Eleutherodactylidae:	Polychrotidae:
Hemidactylus mabouia	*Eleutherodactylus johnstonei** (LC)	*Anolis richardii**
Polychrotidae:	Testudinidae:	
*Anolis aeneus**	*Chelonoidis carbonaria** (CAII)	
	Polychrotidae:	
	*Anolis trinitatis**	
	*Anolis wattsi**	

(Pritchard, 1984). The current figure is about 6000 females annually (Eckert, 2006), making the nesting population the largest in the insular Caribbean and perhaps the second largest in the World (Fournillier and Eckert, 2009). A total of 5642 nesting events by 3757 females were recorded at monitored beaches in 2009; 2176 at Grande Riviere, 2212 at Matura, 761 at Fishing Pond, and the remainder in Tobago (Turtle Village Trust, unpubl. data). Large numbers of leatherbacks also nest on the more remote beaches west of Grande Riviere, especially Paria, Madamas, and Tacarib (fig. 2a; Livingstone, 2006). The leatherback is said to be unpalatable and of little commercial value, although the forelimb muscles may be eaten (Fisheries Division Data Collector at Guayaguayare, pers. comm., 12 March 2004). There was widespread slaughter of leatherbacks on north and east coast beaches in the 1960s (Bacon, 1970), apparently due to vandalism; most of the carcasses were left or only used as shark fishing bait (Gaskin and Shephard, 1994; Lambie, 2005). The species has since been effectively protected in Trinidad on the three main nesting beaches, but is subject to poaching and harassment on unprotected beaches. There is a small nesting population on the west coast of Tobago, subjected to persistent poaching; Bacon (1981) and Nathai-Gyan et al. (1987) estimated the population to number in the dozens. Since then the population has increased, the most important nesting beaches being Turtle Beach and Grafton Beach (Fournillier and Eckert, 1998). Substantial slaughter of leatherbacks at Black Rock in 1999 led to the formation of Save Our Sea Turtles Tobago, which has monitored turtle beaches since 2000 (Clovis, 2004); 378 leatherback nests were recorded in 2008, and 421 in 2009 (Lalsingh, 2008, 2009). Egg poaching (of any sea turtle) is known in both islands but is not as common as slaughter of females on the beach and is not considered a major problem.

***Caretta caretta*.** The major breeding areas of the loggerhead in the Atlantic are on the south-east coast of the USA. Loggerheads undertake transoceanic journeys as juveniles, travelling in the Gulf Stream to the eastern Atlantic and back in the Northern Equatorial Current, passing north of Trinidad (Gavilan, 2001). Local data are consistent with this pattern; loggerheads rarely nest in Trinidad (Bacon, 1981), and are only occasionally caught by fishermen off the north coast (Gaskin and Shephard, 1994). There is no evidence of nesting or foraging in Tobago (Fournillier and Eckert, 1998).

***Chelonia mydas*.** The green turtle is a resident foraging species in Trinidad, also occasionally nesting on the north-east, west and south coasts (Pritchard, 1984), and is a principal target of the turtle fishery (in which it is known as the greenback). In Tobago the seagrass meadow foraging habitat is concentrated around the south-west (Fournillier and Eckert, 1998). Sightings of green turtles have been made all around the island (fig. 2b, sites 1-3, 5, 9, 10, 12-15, 17; M. Cazabon-Mannette, unpubl. data). Six nesting green turtles were observed in Tobago from 2000-2004 (Clovis, 2004).

***Eretmochelys imbricata*.** The hawksbill nests on the north and east coasts of Trinidad (Pritchard, 1984) and in Tobago (Lalsingh, 2008, 2009). Livingstone (2006) reported about 675 nests of hawksbills on the north coast of Trinidad each year from 2000-2004. The extent of hawksbill foraging habitat is probably greater in Tobago than in Trinidad. Cazabon-Mannette (unpubl. data) found hawksbills to be distributed on reefs between Cove and Crown Pt. on the south-west of the island (fig. 2b, sites 13-16), along the north coast (sites 3-8), and throughout Speyside. The hawksbill was formerly utilized by the turtle fishery in Trinidad and Tobago for the carapace, used as a source of tortoiseshell, as well as for meat. Chu Cheong (1995) reported the value of carapace to be several times that of meat. The export of hawksbill shell is now illegal (Gaskin and Shephard, 1994).

***Lepidochelys olivacea*.** The olive ridley (or batali in Trinidad) is probably the most abundant sea turtle worldwide, found in all tropical and subtropical ocean basins, but is the least abundant species in the western Atlantic (Marcovaldi, 2001). It is rare in Trinidad (Bacon, 1981), but possibly nests on the west (Pritchard, 1984; Godley et al., 1993) and north (Livingstone, 2005) coasts, and has been reported in offshore nets. Sightings are very infrequent in Tobago; confusion in reporting is possible because batali refers to the leatherback in Tobago (Fournillier and Eckert, 1998).

Conservation status

Nine species of the terrestrial and freshwater herpetofauna are listed by CITES (tables 1 and 2), all of them on Appendix II (CITES, 2010). *Caiman*, *Iguana* and *Tupinambis* are hunted locally, but there is no export trade — movement of wild meat is generally in the opposite direction with imports (often illegal) from South America, though reptiles have not featured in this trade to date. Apart from the colubrid *Clelia*, the other species on CITES Appendix II are all part of blanket international restrictions on trade in boas and tortoises. *Podocnemis* species, that are probably at least a transient part of the Trinidad herpetofauna, are also on Appendix II. All sea turtles are listed on Appendix I of CITES, with commercial international trade prohibited.

Table 3 summarizes the IUCN Red List (IUCN, 2010) categories and criteria for the 15 species listed as Vulnerable, Endangered, or Critically Endangered; these are all amphibians or chelonians. The criteria are based on declining population size (A), limited geographic range (B), or small population size (D), with a clear distinction between the two taxa in the causes of endangerment.

The threatened amphibians generally owe their status to restricted geographic range (B1), due to a small number of locations (a) or declining area (b_{iii}), or because the small range makes populations vulnerable to disturbance or stochastic events (D2); one of these factors applies in all but one case. The exception is *P. urichi*, the threat status of which is solely due to a substantial reduction in population size (A2), and which is categorized as Endangered. Additional factors which lead to

Table 3. IUCN Red List categories[1] and criteria[2] for threatened herpetofauna in Trinidad and Tobago. *Species in which the genus has changed since Murphy (1997).

	Category	A1				A2					B1			B2		D2
		a	b	c	d	a	b	c	d	e	a	$b_{(iii)}$	$b_{(v)}$	a	$b_{(iii)}$	
Hyalinobatrachium orientale	VU 2001	–	–	–	–	–	–	–	–	–	●	●	–	–	–	–
Mannophryne olmonae	CR 2001	–	–	–	–	●	–	–	–	●	●	–	●	–	–	–
Mannophryne trinitatis	VU 2001	–	–	–	–	–	–	–	–	–	●	●	–	–	–	–
Flectonotus fitzgeraldi	EN 2001	–	–	–	–	–	–	–	–	–	●	●	–	–	–	–
*Phytotriades auratus**	CR 2001	–	–	–	–	–	–	–	–	–	●	●	–	●	●	–
*Pristimantis charlottevillensis**	VU 2001	–	–	–	–	–	–	–	–	–	–	–	–	–	–	●
*Pristimantis turpinorum**	VU 2001	–	–	–	–	–	–	–	–	–	–	–	–	–	–	●
*Pristimantis urichi**	EN 2001	–	–	–	–	●	–	–	–	●	–	–	–	–	–	–
Leptodactylus nesiotus	VU 2001	–	–	–	–	–	–	–	–	–	–	–	–	–	–	●
Dermochelys coriacea	CR 1994	●	●	–	●	–	–	–	–	–	–	–	–	–	–	–
Caretta caretta	EN 1994	●	●	–	●	–	–	–	–	–	–	–	–	–	–	–
Chelonia mydas	EN 2001	–	–	–	–	–	●	–	●	–	–	–	–	–	–	–
Eretmochelys imbricata	CR 2001	–	–	–	–	–	●	–	●	–	–	–	–	–	–	–
Lepidochelys olivacea	VU 2001	–	–	–	–	–	●	–	●	–	–	–	–	–	–	–
*Chelonoidis denticulata**	VU 1994	–	–	●	●	–	–	●	●	–	–	–	–	–	–	–

[1] Red List categories are: CR = Critically Endangered; EN = Endangered; VU = Vulnerable, based on 1994 (version 2.3) or 2001 (version 3.1) categories and criteria (IUCN, 2010).

[2] Criteria may be briefly summarized as follows, for the 2001 version unless specified; details of thresholds (population declines, areas, population sizes) differ among categories, being more severe for higher (CR) and less severe for lower (VU) categories. Criterion A is a decline in population size over 10 years or three generations, whichever is the longer. Criterion A1 specifies a more severe decline than A2, but the latter is exacerbated by being ongoing, irreversible, or not understood. Factors on which the decline is based are (a) direct observation of numbers, (b) an index of abundance, (c) the area of occupancy, (d) exploitation, (e) effects of pathogens, introduced taxa etc. In the 1994 version A1 is an observed past decline while A2 is a projected decline over the next 10 years or three generations. Criterion B is limited geographic range, in terms of total range (B1, extent of occurrence) or area of habitats utilized within that range (B2, area of occupancy). Factors involved are (a) fragmentation or small number of locations, (b) continuing decline of range, based on (b_{iii}) area or quality of habitat, or (b_v) number of mature individuals. Criterion D is small population size, with D2 for Vulnerable species (only) being a small area of occupancy or number of locations making them prone to disturbance or stochastic events.

higher threat categories are a small area of utilized habitat (B2) in the case of *P. auratus*, and a substantial population size reduction in *M. olmonae*, both of which are Critically Endangered. In both cases of declining population size, the factors involved in this assessment are (a) direct evidence of decline, and (e) effects of pathogens. Both species are described as having declined within the last 5-10 years in protected forest areas, possibly due to the amphibian chytrid fungus (IUCN, 2010). The decline of *P. urichi* is reported only for Tobago, not Trinidad. Evidence for these population declines is, however, anecdotal. The taxonomic separation of *M. trinitatis* from populations in Venezuela greatly reduces the geographic range of the species. Together with the finding of the amphibian chytrid fungus in *M. trinitatis*, these factors are likely to lead to change in its Red List category, perhaps to Endangered.

In contrast to the amphibians, the threatened chelonians owe their status to declining population size (A1 and/or A2), determined either by direct observation of numbers (a) or through an index of abundance (b) in sea turtles, and by decline in habitat (c) of *C. denticulata*. The most threatened are *D. coriacea* and *E. imbricata*, which are Critically Endangered. The reason for declining population size is listed as exploitation (d) in all cases, rather than pathogens as in the amphibians.

Interactions with Humans

Environmental change in Trinidad and Tobago

Trinidad was first settled about 8000 years ago, from the Orinoco delta (Wilson, 2007). It was discovered by Europeans in 1498, by Columbus, who supposedly also sighted Tobago. The islands had been inhabited by a sequence of coastal Amerindian groups, who hunted sea turtles, lizards, tortoises, snakes, and caiman, in addition to mammals, birds and fish (Boomert, 2000; Steadman and Stokes, 2002). Trinidad and Tobago were still covered in forest when discovered by Europeans.

Sea turtles accounted for the largest number of identified specimens at two Amerinidian sites in Tobago (Steadman and Stokes, 2002). It is probable that effects on other herpetofauna were low, although small species seem to have been used to a greater extent in Tobago as larger game declined (Steadman and Jones, 2006). Thus, reptiles made up 46% of identified specimens at the earlier (2900 BP) site; 94% of those were sea turtles, with the rest being *Iguana*, *Boa*, and unidentified colubrid(s). At a later (1200-900 years old) site, reptiles made up 45% of identified specimens, but sea turtles only accounted for 42% of those, with *Iguana* (31%), and *Boa* (15%) being more frequent, along with smaller numbers of *Tupinambis*, *Ameiva*, *Polychrus*, *Rhinella marina*, unidentified colubrid snakes and small lizards (Steadman and Stokes, 2002).

Trinidad was part of the Spanish Empire until 1797 when it was captured by Britain. Tobago had a complex history involving several European countries, but was British from 1815. Economic development (Williams, 1942), population

growth, and probably effects on the herpetofauna were low at that time, perhaps with the exception of tortoises (morocoys). A 1595 Spanish source quoted by Boomert (2000) reported a "great store of tortoises" in Trinidad, some being received from Amerindians. The population of Trinidad was only 36,600 in 1838, while Jamaica (about twice the area) had a population ten times greater in 1844 (Watts, 1987). The early economy was based on sugar, with annual production of 4900 tons for Trinidad and 7000 tons for Tobago in 1800; Jamaica and the Lesser Antilles had both reached comparable production a full century earlier (Watts, 1987). Nevertheless, environmental damage was sufficient to spur protection of the Main Ridge of Tobago in 1776, the oldest legally protected forest reserve of its kind in the world. The aim was to "remove to Your Majesty a tract of Wood Land lying in the interior and most hilly parts of this island for the purpose of attracting frequent Showers of Rain upon which the Fertility of Lands in these Climates doth entirely depend" (as quoted by Environment Tobago, 2010).

Sugar production in Trinidad increased rapidly in the 19th Century, while it declined from the 1800 level in Tobago. Population size increased to 258,000 in 1901, which included immigration of indentured workers from India from 1845-1917. The 19th Century saw most of the suitable lowland areas being brought into cultivation, but because of the late start compared to other Caribbean islands, much of the highlands remained undisturbed (Watts, 1987). Trinidad and Tobago were joined administratively within the British Empire in 1889. Tobago previously had a local democratic assembly while Trinidad had Crown Colony status and was governed directly from London. A lasting consequence is that Tobago today has considerable local autonomy through the Tobago House of Assembly (THA), especially in environmental matters.

The 20th Century saw the continuing decline of sugar production in Tobago, the industry being closed in the 1930s; as a result Tobago was the most under-populated island in the British West Indies by 1946 (Library of Congress, 2006). Sugar production increased in Trinidad up to the 1960s, followed by decline; only a single sugar factory remained by the 1980s. The state sugar company closed in 2003, and the sugar factory in April 2010. Former cane areas have been neglected or developed for other purposes (e.g., housing). Thus although the population continued to increase, to about 1.3 million in 2000, the decline of the sugar industry reduced the pressure for destruction of natural habitats as former cane areas were utilized instead. Trinidad and Tobago has the lowest population growth rate of any of the territories considered in this series, at -0.87% per year (Wilson et al., 2006, 2011), due to emigration.

Apart from sugar, there has also been extensive cultivation of cacao at lower elevations in the Northern and Central Ranges, and in Tobago, for over 250 years. Cocoa was the main export between 1870 and 1930, and Trinidad and Tobago was the second largest producer in the world (Watts, 1987; Library of Congress, 2006). Many cacao estates were abandoned after 1930, and remain so today (Van den Eynden, 2007). Cacao is usually an understory crop and retains considerable herpeto-

fauna and other biodiversity (Faria et al., 2007), particularly when abandoned, and so is less environmentally damaging than sugar. Rice has been cultivated extensively around both the Caroni and the Nariva swamps, controversially in the case of the latter as swamp forest has been destroyed in the process. The Nariva Reforestation Project is being funded by the World Bank to reforest 1300 ha of illegal rice fields over the next 5 years.

Trinidad and Tobago became an independent nation in 1962, and a republic in 1976. The islands retain considerable extent and variety of wild habitats, and no ecosystem types have been lost (Kenny, 2008). About 51% of the land is forested, two thirds of which is utilized commercially, but only 5% is plantations (mostly teak and Caribbean pine; Chalmers, 2002). The rate of forest loss is about 0.8% per year. 15% of the land area is arable, and another 15% is built (MPUE, 2006). Economic development in the 20th century has largely been fuelled (metaphorically and literally) by the oil and gas industries; agriculture accounts for only about 6% of exports (Pemberton et al., 2002). Oil and gas production are associated with transport (pipeline) and refining activities, and "downstream" industries. As of 2002, Trinidad was the world's largest exporter of both ammonia and methanol (Encyclopedia of the Nations, 2010), and there are controversial plans for large scale aluminium smelting (Kenny, 2006). Tobago has a more typical Caribbean island economy largely based on tourism.

Conservation legislation

Biological conservation in the Republic of Trinidad and Tobago is the joint responsibility of two agencies. The Environmental Management Authority (EMA) drafts legislation (table 4a) and checks compliance with international treaty obligations (table 4b), following its National Environmental Policy (EMA, 2005). The Forestry Division regulates use of natural areas, and its Wildlife Section issues permits for hunting and collecting. Both agencies cover both Trinidad and Tobago, but the Department of Natural Resources and the Environment of the Tobago House of Assembly also has considerable powers. A permit has recently (2005) been introduced to licence all biodiversity studies in Tobago, after application and payment of a US$100 fee, a system expected to be adopted in Trinidad.

Currently only sea turtles (when on land) and some reptiles receive protection under the Conservation of Wild Life Act (CWLA) (table 4), which defines "animals" as any mammal, bird or reptile (thus excluding amphibians). Schedule 2 (game animals) includes caiman, iguana, and matte (*Tupinambis*), which may be hunted under licence from October to February (formerly to March). Schedule 3 (vermin) includes venomous snakes, specifically the mapipire balsin (*Bothrops*), mapipire zanana (*Lachesis*), and coral snakes (*Micrurus*), which may be destroyed by the landowner at any time. Other "animals" not listed on Schedules 2 or 3 are protected, but may be captured for scientific purposes under a Special Game Licence. Cooper (2008) illustrated lizards collected for a foreign museum, but confiscated in Trinidad for lacking this licence. Hunting requires an annual State Game Licence, issued by

Table 4. (a) National environmental legislation (and most recent amendment) and (b) international treaty obligations relevant to herpetofauna conservation in the Republic of Trinidad and Tobago (MLA, 2004; Bräutigam and Eckert, 2006).

National Legislation	Year	Chapter	Purpose
Environmental Management Act	2000	35:05	Establishes the EMA, to promote understanding and conservation of the environment and to develop a National Environmental Policy.
Environmentally Sensitive Species Rules	2001	Subsidiary LN 63	Prohibit taking, possession or trade of an organism or its parts, removal or export, or other activities likely to cause harm to the species.
Environmentally Sensitive Areas Rules	2001	Subsidiary LN 64	Protect a defined area, including prohibiting removal of or damage to all animals in the area.
Institute of Marine Affairs Act	1976, 1996	37:01	Establishes the IMA to advance marine scientific research and advise Government on marine matters.
Marine Areas (Preservation and Enhancement) Act	1970, 1996	37:02	Creation of restricted areas to protect flora and fauna, natural beauty, public enjoyment, or promote scientific study and research.
Forests Act	1915, 1999	66:01	Regulates use of forests and forest produce.
Forests (Prohibited Areas) Order	1953, 1990	Subsidiary	Restricts entry to Matura and Fishing Pond beaches.
	1997	GN 125	Restricts entry to Grande Riviere beach.
Conservation of Wild Life Act	1958, 1980	67:01	Regulates hunting and scientific collecting, export of animals, Game Sanctuaries.
Animals (Diseases and Importation) Act	1954, 1997	67:02	Regulates import of animals and requires notification of animal diseases.
Fisheries Act	1916, 1975	67:51	Regulates fishing methods and species, including sea turtles.
Mongoose Act	1918	67:55	Bans import or keeping, allows ordering destruction by landowners.

Table 4. (b).

International Treaty	Adoption in Trinidad and Tobago	Purpose
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	Entered into force 1984	Regulates import and export of wild life.
Convention on Wetlands of International Importance (Ramsar)	Entered into force 1993	Conservation of wetlands.
Convention on Biological Diversity (CBD)	Ratified 1996	Protection of biodiversity.
Cartagena Convention, Protocol Concerning Specially Protected Areas and Wildlife (SPAW)	Ratified 1999	Protection of marine biodiversity, including sea turtles.

the Wildlife Section at six centres in Trinidad (fig. 2a) and in Tobago, whereas the Special Game Licence for research is issued at the head office in St. Joseph. The State Game Licence is accompanied by up to five optional permits (TT$20 each; TT$6.3 = US$1) out of eight categories of game. The "alligator" permit allows capture of unlimited numbers of caiman, iguana, and matte; the number and total weight (in lbs) caught on each permit are later self-reported on an annual hunting return. Special Game Licences are also issued for amphibians, although this is only a legal requirement if specimens are to be exported under CITES regulations. A new Conservation of Wildlife Bill was drafted in 2003 (EMA, 2004, 2006), but this has not been enacted. Caiman, iguana and matte were on Schedule 1 (species requiring a harvesting licence), and the five sea turtles and the tortoise *C. denticulata* on Schedule 4 (protected species harvested only under a special licence, e.g., for scientific research). Consideration of the turtle fishery probably prevented enactment of this bill, as occurred with the second series of Environmentally Sensitive Species (below).

Sea turtles have an ambiguous legal status in Trinidad and Tobago. They are protected under the CWLA, but a legal harvest is permitted under the Fisheries Act, which defines "fish" to include turtles. In practice, turtles on land, their eggs, and female turtles within 1000 yards of the shore or within reefs, are absolutely protected by law. Outside these limits, all sea turtles may be legally caught and sold, apart from during a closed season from March to September. The three most important leatherback nesting beaches, a total of almost 20 km, have been declared as prohibited areas under the Forests (Prohibited Areas) Order (table 4). A permit from the Wildlife Section is required to visit these beaches, and permit holders must be accompanied by an accredited tour guide.

The legislation creating National Parks in Trinidad and Tobago has not been completed, so that although some exist on paper (such as Matura) they do not receive effective protection. There are also 13 Wildlife Sanctuaries and 35 Forest Reserves (MPUE, 2006) which are similarly ineffective (EMA, 2001). The inadequacy of legal protection of environment and biodiversity in Trinidad and Tobago led to the

Environmental Management Act of 1995 (re-enacted in 2000 due to a technicality) which established the EMA, and the Environmentally Sensitive Areas (ESA) and Environmentally Sensitive Species (ESS) Rules (table 4). The ESS Rules prohibit removal of an organism (except for scientific research approved by the relevant authority), disturbance of the habitat of the species or of the organisms themselves, pollution of the habitat, or any other activity likely to cause harm to the species. The ESA Notices (defining particular areas) define "animal" as any member of the animal kingdom, and prohibit removal of or damage to animals in the area. Amphibians living within an ESA are thus protected.

The first series of three ESSs (the manatee, Trinidad piping-guan, and sabrewing hummingbird) was selected internally by the EMA and designated in 2005. The second series selected comprised the five species of sea turtles, but their designation was rejected in Cabinet, apparently due to pressure from members concerned about closure of the turtle fishery. The third series was selected by the EMA after a consultation exercise, because there was a wide range of candidate species; the process is of interest as herpetofauna received substantial support, perhaps against expectation. External experts were invited to summarize the conservation problems of particular taxa at a stakeholder consultation in April 2006: plants, corals and molluscs, marine fish, amphibians and reptiles, birds, and mammals. The consultation was attended by invited representatives of community-based conservation groups, naturalists, eco-tour operators, hunting groups and others. Attendees scored three species in each taxonomic group for ten criteria: as a flagship, umbrella, biodiversity indicator, sentinel, or keystone species, and for endangerment, immediacy of threat, utility, uniqueness, and research potential. The top scoring seven species of each attendee were then awarded 1-7 ranking points. The top ranking six species overall were the ocelot (162 points), *Phytotriades auratus* (122), stony corals (94), silky anteater (90), *Mannophryne olmonae* (75), and orchids (57). After internal review, the ocelot and golden tree frog were selected by the EMA as the proposed third series of ESS, and the draft Notices are currently (April 2010) open for public comment before being considered by Government. It is notable that the golden tree frog was selected in preference to other species with a much greater local conservation profile such as the scarlet ibis.

Environmentally Sensitive Areas are in many cases the same as the National Parks, although the boundaries do not coincide exactly. The first three were Matura (fig. 2a), a forested area at the eastern end of the Northern Range (designated in 2004); Nariva Swamp (2005); and Aripo Savanna, an edaphic wet grassland with forest islands (2007). Several other ESAs have been proposed, including Caroni Swamp, Trinity Hills, Buccoo Reef, and Main Ridge Reserve (fig. 2b). The south-west peninsula of Trinidad and the north-east of Tobago, both of which are important for herpetological diversity (see distribution maps in Murphy, 1997) are the main regions where additional protected areas are needed to conserve amphibians and reptiles.

The Animals (Diseases and Importation) Act (table 4) defines "animal" as all animals of whatsoever kind, and so implicitly includes amphibians. Reptiles are explicitly included, with no bird, reptile or insect allowed to be imported except under licence. This Act thus potentially allows some control of species introductions, and also deals with notification of diseased animals and could be used in actions against chytridiomycosis. The Marine Areas (Preservation and Enhancement) Act enables the creation of restricted areas to protect flora and fauna, or to promote scientific study and research, and restricts entry except with permit, and could be used to protect areas important for sea turtles. The Institute of Marine Affairs Act established the IMA to advance marine scientific research and advise Government, and the IMA has been active in research and public education on sea turtles.

Hunting and utilization

There is much hunting for sport and food in Trinidad and Tobago, including of caiman, iguana (fig. 3) and *Tupinambis*. Caiman were also previously used in the curio trade (Kenny, 2008). The number of hunters in Trinidad and Tobago has increased from about 3500 in 1975 (Cooper and Bacon, 1981) to about 10,000 today (R. Sorrillo, pers. comm., 26 April 2010). Hunting is less prevalent in Tobago; only about 60 permits were issued per year in the late 1990s (EMA, 2001), compared to about 8000 in Trinidad. Van den Eynden (2007) and local assistants interviewed hunters living in and visiting the Matura National Park, and found that 21% of the rural population hunted, for an average of 38 days per year.

There has been no full analysis of hunting returns, most of which were recently contaminated in storage and have since been destroyed. Returns from Trinidad for the 2000/2001 season were digitized by the Department of Food Production of the University of the West Indies and are analysed here. These records show 5939 hunters, who purchased 8453 permits (1.42 permits per hunter). Only 387 permits were for "alligator"; 4.6% of all permits issued, to 6.5% of hunters. There was significant variation in the proportion of permits for "alligator" among the six offices (χ^2 test, $P < 0.001$), with a very low value at Rio Claro (0.8% of permits), the reason for which is obscure. 160 hunters submitted non-zero returns for the "alligator" permit, accounting for 1430 animals caught, a mean of 8.9 per hunter; there was no significant difference among the six offices (Kruskal-Wallis test, $P = 0.64$). Most returns were for 1-10 animals, but 16 hunters claimed more than 20 catches, the highest being 73 (fig. 4a). Van den Eynden (2007) recorded iguanas as the only reptiles hunted in the Matura National Park; their value was TT$60-100 each (compared to, e.g., TT$100-300 for agouti, the most popular quarry with permits taken out by 55% of hunters). It is probable that iguanas make up the large majority of catches under the "alligator" permit throughout Trinidad, the modal size of animal caught being 1-2 kg (fig. 4b); animals above 4 kg were probably *Caiman*. There was no significant difference in mean size of animals caught among the six offices (Kruskal-Wallis test, $P = 0.16$). Van den Eynden (2007) found that less than

Figure 3. Trinidadian hunter with a large *Iguana iguana* (total length c. 1.8 m, mass 3-4 kg). Photo by Kevin Mahabir, 2007 (Colour original — see www.ahailey.f9.co.uk/appliedherpetology/cariherp.htm).

half of hunters interviewed reported catches under permit to the Wildlife Section, and unlicensed hunting is also prevalent; perhaps particularly for iguanas, which are often taken opportunistically, including in suburban areas.

Hunting of mammals and birds is also likely to have some negative effects on herpetofauna, most directly through presence of hunters and their dogs in the forest, killing snakes. Snake bites are a regular risk to hunting dogs, which their owners treat using traditional remedies (Lans et al., 2001). Hunting dogs are valuable, and most hunters seem to take every opportunity to kill any snakes encountered, venomous or not (Van den Eynden, 2007). Persecution of venomous snakes is widespread in Trinidad, although fatal bites are infrequent. A recent case, of unknown species, was reported as the first in several years (John, 2009). This took place in a yard, not in the forest. There may also be indirect negative effects of hunting of other taxa on herpetofauna; Zimmerman and Bierregaard (1986) found

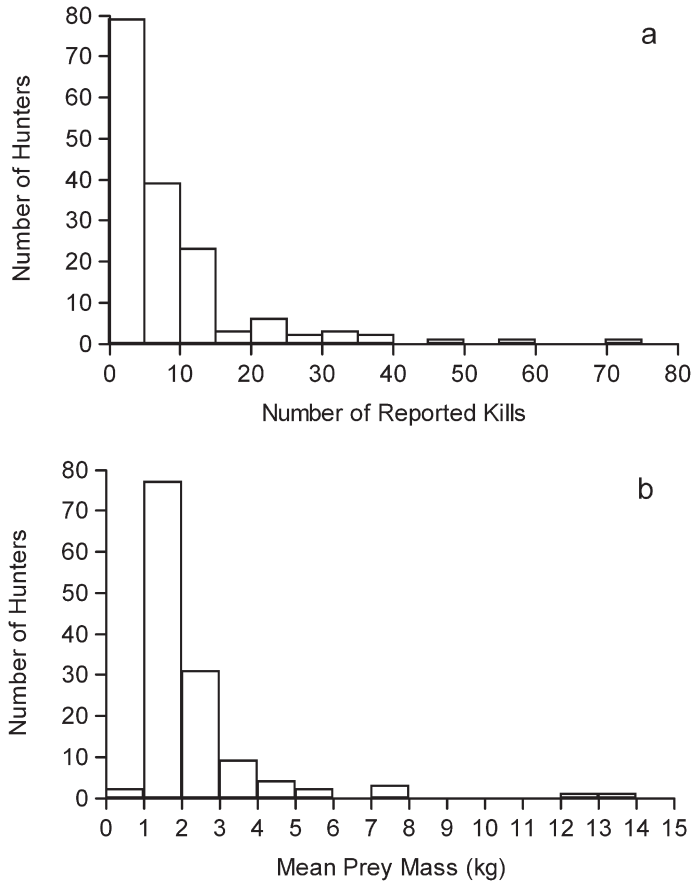


Figure 4. Results from Trinidadian hunters reporting on "alligator" permits (valid for *Iguana*, *Tupinambis* and *Caiman*). (a) Frequency distribution of number of animals caught (excluding zero returns), $n = 160$. (b) Frequency distribution of mean animal size (kg), $n = 130$.

that Amazonian frogs had declined in forest fragments without peccaries to provide breeding pools.

Tortoises were formerly hunted, being seen in markets up to the 1950s; *C. denticulata* was widespread and considered a delicacy, though it is now rarely seen (Kenny, 2008). There is evidence that it used to occur in Tobago, together with a large extinct edible frog, both possibly extirpated by hunting in Amerindian or early colonial times (Hardy, 1982). Cooper and Bacon (1981, Appendix II) used the name "mountain chicken" for the large frog *Leptodactylus bolivianus*, apparently by analogy with *L. fallax* of Dominica and Montserrat. The name is not used popularly, and there is no evidence of current utilization of *L. bolivianus*, which is a relatively uncommon forest-edge frog. As noted by J.S. Kenny (pers. comm., 17 October 2003), "no-one in Trinidad eats frogs". *Iguana* eggs, *Boa* fat, and whole young

Bothrops and *Lachesis* may be used in traditional medicine in Trinidad (Van den Eynden, 2007), and turtle eggs and organs are said to be used as aphrodisiacs.

There is a small artisanal turtle fishery in Trinidad and Tobago; historical data are given by Rebel (1974). The fishery is based on hard-shelled turtles (i.e., not leatherbacks), using nets of 15-30 cm mesh 30 m long (which may be joined in series), suspended from the surface to a depth of 2-3 m. Nets are set at known foraging areas of the turtles, and checked each morning and evening. Most turtles are caught at night. Harpoons may also be used, especially at Grande Riviere, Toco and Carenage (Lee Lum, 2003). The marine turtle fishery is principally of green turtles and hawksbills, making up 50% and 47.5% of the total in Trinidad (Chu Cheong, 1995), the remainder being loggerheads. The species composition of the catch depends on the area fished; green turtles in seagrass beds, and hawksbills in rocky areas and reefs.

Chu Cheong (1995) of the IMA surveyed 15 fishing depots in Trinidad from 1982-1983 and found turtle fishing at six depots. Only 1-4 persons were involved at each depot (a total of 12 persons), as a part-time activity. The same investigator (Lee Lum, 2003) surveyed 27 depots in 2001-2002 and found turtle fishing at eight depots, also with a total of 12 persons involved. Only four depots had turtle fisheries in both surveys (Matelot, Toco, Mayaro, and La Lune). The sea turtle fishery in Trinidad is thus small scale, with an admitted 4-10 turtles caught per week at each depot in 1982-1983. The changing incidence of turtle fishing at depots suggests that the fishery is opportunistic rather than traditional in any one location. Data are available for the weight and value of turtle meat sold up to 1980, but since then no data have been collected by the Fisheries Division, because the redesigned fish reporting form did not include turtles (Chu Cheong, 1995).

The IMA survey did not cover Tobago, but turtle fishery statistics from before 1980 (in Chu Cheong, 1995) show that quantities landed were only a small fraction of those at Trinidad depots (18-250 kg per depot per year, compared to, e.g., 5245 kg per year at Carenage). In a survey of 215 fishermen around Tobago in 2007 (Cazabon-Mannette, unpubl. data), 22 confirmed that they targeted turtles, and 14 considered turtles an important source of income. One who fished regularly during the open season reported catching 150 turtles per year. These 22 fishermen were interviewed at landing sites all around Tobago; turtle fishing activity was not restricted to the south-west as previously reported. The price of turtle meat was usually TT$25-30 per pound, about twice that obtained for fish.

Invasive competitors, predators and diseases

Invasive herpetofauna are likely to have little effect on native species as most are currently restricted to man-modified habitats, although *Hemidactylus mabouia* may have displaced *H. palaichthus* on the main islands. Among the introduced anoles, *A. wattsi* is the most ground-dwelling and would have the greatest effect on the native *A. chrysolepis* if it spreads into forested areas (White and Hailey, 2006). None of the introduced *Anolis* are likely to hybridize with *A*. (*Norops*) *chrysolepis*,

but hybridization occurs between *A. aeneus* and *A. trinitatis* and may be partly responsible for the decline of the latter species (Gorman et al., 1971; Hailey et al., 2009). *Eleutherodactylus johnstonei* has been implicated in declines of frogs in other islands (Henderson and Berg, 2006, 2011); the most likely native (and endemic) species to be affected is *Pristimantis* (formerly *Eleutherodactylus*) *urichi*. The nuisance of the loud calling of *E. johnstonei* has already been felt, which can only exacerbate the largely negative local opinions of herpetofauna. More importantly, there could be acoustic interference with other frogs (Hedges, 1993), whose calls have evolved in the absence of this species.

Invasive and introduced non-herpetofauna are more problematic. The small Indian mongoose was introduced at Santa Cruz in the Northern Range in 1875 (Lever, 1985), to control rats and/or snakes. It spread rapidly, already being considered a pest by 1902 when a bounty was introduced (Williams, 1918). The mongoose became common in agricultural and abandoned land, but not in natural forests. It is absent from Tobago (Nellis and Everard, 1983). The preferred habitat seems to be dry bush, as in other West Indian islands or in India; perhaps native mammal predators also exclude the mongoose from forest in Trinidad. Bounty records show that the mongoose declined after 1930, for an unknown reason; Nellis and Everard (1983) state that Trinidad was among the islands most heavily damaged, but is now the least affected, by the mongoose which is now at ecological equilibrium at low population density. Nevertheless, it is likely that the herpetofauna has been affected; Urich (1931) noted the scarcity of *Ameiva*, small ground snakes, *Rhinella* and *Leptodactylus* in areas with mongooses. Williams' (1918) study of stomach contents estimated that an individual would consume 17 lizards, 18 snakes, and 29 anurans in a 3-month period, with frogs being taken particularly in sugar cane fields, and snakes in cacao plantations.

The red imported fire ant *Solenopsis invicta* was observed near the Caroni Swamp in 2000 (Davis et al., 2001), and has spread to urban areas in Trinidad and to Tobago (J.K. Wetterer, pers. comm., 16 October 2004); it is particularly common in sugar cane areas (Wetterer and Davis, 2010). The fire ant is a threat to eggs, hatchlings, and adults of terrestrial reptiles (Wetterer and Moore, 2005), and to eggs and hatchling sea turtles (Wetterer et al., 2007). A synergistic action is possible between any beach loss from global warming and presence of the fire ant, since ants increase higher up the beach closer to dune vegetation. Beach replenishment which widens a beach thus reduces ant predation (Wetterer et al., 2007), but reduced beach width from sea level rise and erosion might increase exposure to ants.

Potentially the most damaging invasive species to the herpetofauna is the chytrid fungus *Batrachochytrium dendrobatidis*, which has been implicated in amphibian declines worldwide. The fungus was detected at high prevalence (25%) using DNA analysis of skin swabs of *Mannophryne olmonae* in Tobago in 2006 (Alemu et al. 2008). The fungus has also been detected using the same methods in Trinidad, with two positive results in 2007 and a further eight in 2009, all from two populations of *M. trinitatis*; those at highest altitude among 12 populations examined (J.B. Alemu

I et al., unpubl. data). *Mannophryne* species appear to be resistant carriers of the amphibian chytrid, and do not show symptoms of chytridiomycosis; other local species may not be so fortunate.

Incidental catch of sea turtles

The bycatch of sea turtles is a large problem in Trinidad and Tobago waters, causing more deaths of leatherbacks than all others causes combined (Eckert and Eckert, 2005). Leatherbacks are principally caught in gillnets set for kingfish and carite, when the turtles approach nesting beaches. Lee Lum (2006) estimated that more than 3,000 leatherbacks were caught by the gillnet fishery in Trinidad in 2000, mostly on the north and east coasts from January to August when turtles were arriving to nest. Hawksbill and green turtle incidental catches were reported to be rare, but these species are clandestinely eaten when captured, even in the closed season (Lee Lum, 2003). Pritchard (1984) noted that the incidental catch of the rare olive ridley turtle might be proportionately important, as this slow-swimming species is easily caught in trawls.

About 67% of leatherback turtles were released alive after incidental catch, usually requiring nets to be cut (Fournillier and Eckert, 1998; Lee Lum, 2006). A grant for net repairs was offered at one time under an UNEP-funded programme, but is no longer given. This compensation was effective in reducing turtle mortality as fishers were more amenable to cutting their nets to release turtles quickly (and alive). Incidental catches are associated with green multifilament nets, as these are used at night (when turtles approach nesting beaches) at the surface, and are strong enough to hold turtles. In contrast, nylon monofilament nets are set in the day, anchored to the sea floor, and rarely catch turtles, and are not sufficiently strong to hold leatherbacks if caught (Lee Lum, 2003). Incidental catches in gillnets are mostly within 5 km of the beach, although these nets are used up to 15 km offshore. Incidental capture was particularly a problem on the north coast, where turtles were described as “thick in the water” in the peak nesting season. Nevertheless, all fishers surveyed by Lee Lum (2003) knew of the regulations concerning sea turtles, and 65% agreed with them.

Turtles and tourism

A number of activities associated with the large amount of general tourism development in Tobago are detrimental to sea turtles. These include (Fournillier and Eckert, 1998): sand mining and beach erosion; hotel development (often unlicensed); release of sewage offshore; photopollution from beachfront lighting affecting adults and hatchlings; disturbance from tourists approaching nesting females; mechanized beach cleaning; presence of predatory feral dogs; retention of hatchlings by hotel management; boat mooring and diving on reefs; sedimentation of reefs and seagrass beds.

On the other hand, ecotourism is an increasing economic activity and factor in conservation in Trinidad and Tobago. The Main Ridge Rain Forest won awards as the World's Leading Ecotourism Destination annually from 2003-2006, and as the World's Leading Green Destination in 2007 and 2009 (WTA, 2010). Much of the current focus of local ecotourism is marine, including sea turtles. There are many community-based conservation and ecotourism groups, particularly on the north and east coasts of Trinidad (table 5); the most well-known is Nature Seekers at Matura. Ecotourism has been shown to positively affect local attitudes to turtles in Trinidad (Waylen et al., 2009). The Turtle Village Trust (TVT) was formed in 2006 as the umbrella organisation for local turtle conservation organisations, and aspires to foster partnerships among community groups, government and corporate entities "to place Trinidad and Tobago as the premier turtle tourism destination globally". Some 46,000 visits were recorded at beaches to watch turtles nest in 2009; about 30,000 at Grande Riviere and the balance at Matura (fig. 5a). Locals made up the majority of visitors, but over 13,000 were foreigners. TVT has increased and standardized survey efforts and coordinated tagging across important nesting beaches to improve population estimates, and installed signs in communities across north-east Trinidad (fig. 5b). Public awareness and capacity building are also areas of focus; TVT staff make presentations at schools and events, produce informative brochures and flyers, and are involved in training members of the communities.

The Future — Threats and Recommendations

Two additional threats to herpetofauna have not been studied in Trinidad and Tobago but are likely to have increasing impact. These are threats that will occur as a result of future development of the islands, and the local effects of global climate change.

The Government of the Republic of Trinidad and Tobago previously (to May 2010) had as its major policy the achievement of developed country status by 2020 (the Vision 2020 programme). Development will bring increasing threats of habitat loss and pollution from industrialization, urbanization, transport links, and quarrying (which is often illegal in Trinidad, and involves much environmental damage through siltation of rivers, in addition to the habitat removed). The current (June 2010) Government does not stress the development of industry to the same extent, but its focus on agriculture (which already uses large quantities of pesticides in Trinidad — Pemberton et al., 2002) also has potential for environmental damage. Indirect effects of pesticides on the herpetofauna (e.g., on prey populations) could also be important. Work on these threats in Trinidad and Tobago is in the early stages, e.g., finding a suitable local model for ecotoxicological studies (Hailey et al., 2006, 2007). Salinization from produced water from the oil industry is also a threat to amphibians. Currently 17 inland wells have total produced water discharge rates of 100,000 barrels per day, with a salinity of 8-33 ppt, 90% of which enters waterways (Elias-Samlalsingh and Agard, 2004). Seismic surveys for oil and gas are potentially a threat to sea turtles. Increased utilization of forest resources is

Table 5. Community-based and coordinating conservation groups in Trinidad and Tobago involved with sea turtles.

Group	Location	Associations
Blanchiseusse Environment and Art Trust (BEAT)	Blanchiseusse	
PAWI[1] Sports, Culture and Eco Club	Matelot	UNDP; Caribbean Forest Conservation Association; Wildlife Section; University of Glasgow (Livingstone and Downie, 2005).
Grande Riviere Nature Tour Guide Association (GRNTGA)[2]	Grande Riviere	Wildlife Section; Institute of Marine Affairs (Peters, 2004; Lee Lum, 2005).
Sans Souci Wildlife Tours	Sans Souci (Toco)	Toco Foundation.
Toco Foundation	Toco	Sans Souci Wildlife Tours.
Nature Seekers	Matura	Wildlife Section; WIDECAST, Duke University.
Fishing Pond Environmental Community Group (FPECG)	Fishing Pond	Wildlife Section.
Fishing Pond Turtle Conservation Group (FPTCG)	Fishing Pond	Wildlife Section.
Manatee Conservation Trust	Manzanilla	Wildlife Section.
Manzanilla Wildlife and Environmental Project (MWEP)	Manzanilla	
Nariva Environment Trust	Manzanilla	Wildlife Section.
Save Our Sea Turtles Tobago (SOSTobago)	Tobago	Department of Natural Resources and the Environment; Barbados Sea Turtle Project (Clovis, 2004).
Turtle Village Trust	Trinidad and Tobago	Wildlife Section; Department of Natural Resources and the Environment; Ministry of Tourism; BHP Billiton; Atlantic LNG; IFAW; Community groups.

[1] The local name of the Trinidad piping-guan, not an acronym.
[2] Formed in 2001 as the successor to the Grande Riviere Environmental Awareness Trust (GREAT).

Figure 5. (a) Turtle nesting tour at Matura (photo courtesy Nature Seekers) — the lamp has a red screen. This group is mostly local visitors. (b) Turtle Village Trust welcome sign at Grande Riviere, where there is also a visitor centre (Colour originals — see www.ahailey.f9.co.uk/appliedherpetology/cariherp.htm).

also probable. Local forestry practices have been shown to affect biodiversity of bats relatively little (Clarke et al., 2005); thermal and other possible effects on herpetofauna (e.g., Vitt et al., 1998) await study.

Global climate change is expected to have major effects on the economy and environment of Small Island Developing States (Mimura et al., 2007). Higher sea levels might reduce the size of sea turtle nesting beaches (Fish et al., 2005), increase the risk of erosion of nests (Lee Lum, 2005), and bring nests closer to dangers from invasive fire ants. Rising sea levels may also cause salinity increases in coastal fresh water, such as swamps, ditches and temporary pools used by breeding amphibians. Tropical herpetofauna experience stable climates, and may be unable to adapt to change even though temperature increases in the tropics are predicted to be smaller than those at high latitudes. Lowland tropical lizards are thus vulnerable as they

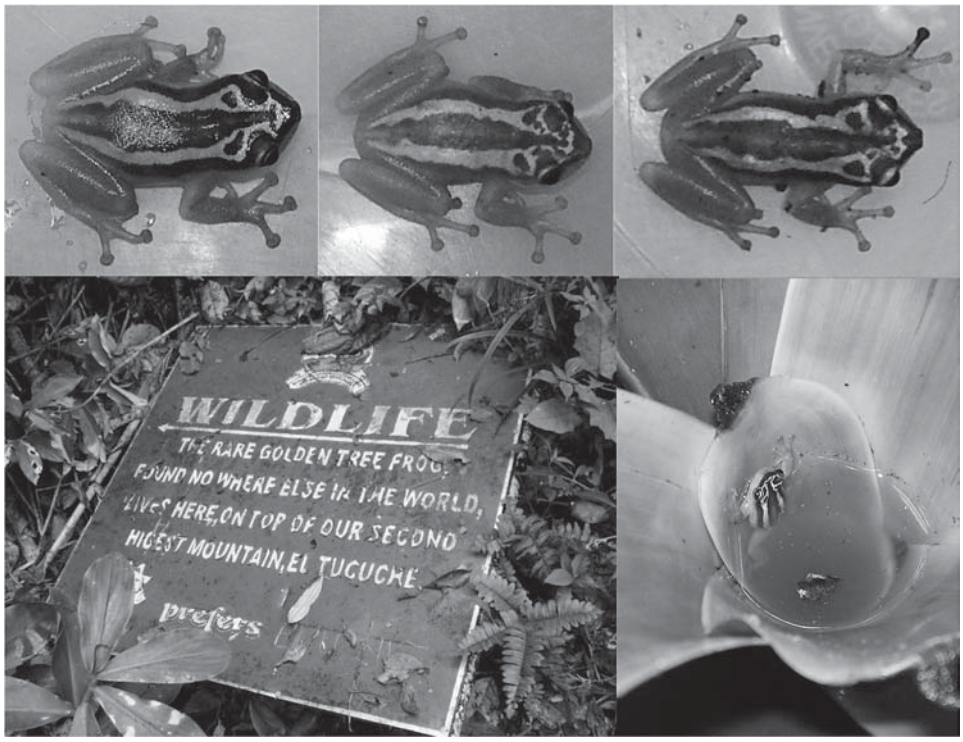


Figure 6. The golden tree frog *Phytotriades auratus*, a Critically Endangered Trinidad endemic. Captive frogs, showing variation in markings sufficient for individual recognition in captivity. Fallen conservation sign on El Tucuche, February 2010; these signs were placed high in the hills, where they were hard to maintain (and possibly less useful). Captive frog in tank of bromeliad, *Glomeropitcairnia erectiflora*. (Colour originals — see www.ahailey.f9.co.uk/appliedherpetology/cariherp.htm).

already exist close to their thermal maxima, and would be under physiological stress from even a small rise in temperature (Huey et al., 2009). The lowland herpetofauna of Trinidad and Tobago is perhaps of lesser conservation importance, as it is similar to the mainland fauna; endemic species in the highlands are of much greater concern. Many species may simply migrate upwards with increasing temperatures as competition from warm-adapted species increases from below, but this option is not available to species found only at high elevations, hence the importance of the golden tree frog in local conservation (fig. 6). Lena Dempewolf (pers. comm.) and others are currently assessing the geographic and exact elevation limits of the frog and the giant bromeliad. The generally accepted relation between temperature and elevation on mountains is a decrease of 1°C for an ascent of 150 m (MacArthur, 1972). If *P. auratus*, or its bromeliad, is sensitive to high temperatures, then their current elevation limit suggests that they will be vulnerable to any increase of mean temperature over 1°C. The target to limit global warming to 2°C would thus condemn *P. auratus* to extinction, even if practical and legal protection measures in progress are successful. Global warming may also increase the risk of

chytridiomycosis at montane tropical sites as the warmer climate becomes more suitable for the fungus (Pounds et al., 2006).

If global temperatures increase as predicted, the only option for protecting *P. auratus* would be ex-situ conservation, either in captivity or translocation to higher elevation habitats outside of Trinidad, e.g., to Venezuela where *G. erectiflora* also occurs (Clarke et al., 1995). There have been approaches from Chester and Paignton zoos (UK) to set up captive breeding populations of *P. auratus* (R. Gibson and M. Bungard, pers. comm., January 2010). Preliminary study of three captive individuals (A. Hailey, pers. obs.) has shown that both frogs and bromeliads may be maintained successfully, and their markings are sufficient for individual recognition in a small group (fig. 6). Locating frogs within bromeliads has proved difficult; two were later found in a 40-cm tall bromeliad examined carefully on El Tucuche and brought down for culture, and one hid in a 15-cm bromeliad moved between cages. Non-destructive searching of bromeliads is thus likely to underestimate wild populations. Collection and destructive examination of bromeliads unfortunately still occur, but would be prohibited if *P. auratus* becomes an ESS, with restrictions on disturbance of its habitat.

Recommendations

1. Specific legal protection for all endemic herpetofauna. The concept of the ESS is for a small number of flagship species, and is unlikely to be extended to other amphibians or reptiles. An updated version of the draft Conservation of Wildlife Bill should therefore include all endemic species on Schedule 4 (protected species harvested only under a special licence).
2. Recognition of amphibians as "animals" in the legislation replacing the CWLA, so that they receive the same protection as other non-game and non-vermin species. The ignoring of amphibians seems to be a general pattern in laws of the former British West Indies territories, presumably reflecting their similar legislative backgrounds. Attendees from several islands at a recent workshop on chytridiomycosis in the Caribbean (Dominica, March 2008) noted this pattern, with amphibians only being recognized in law in those territories with game species (mountain chickens, in Dominica and Montserrat).
3. Inventory the herpetofauna in all existing and proposed protected areas to show whether those are deficient for any threatened species, and if so to expand the network, e.g., in the south-west peninsula of Trinidad and north-east Tobago. In addition, the protection offered to non-game animals by Wildlife Sanctuaries and Forest Reserves should be increased.
4. Research on herpetofauna populations and species diversity in key habitats, and the effects of habitat degradation, forestry, pollution and environmental change on local herpetofauna species and communities.
5. Restrict the spread of the amphibian chytrid fungus using approved hygienic methods such as those discussed at the Dominica chytridiomycosis workshop

(Cunningham, 2006). Spread of this pathogen into, and then between, the high elevation areas occupied by the golden tree frog is particularly to be avoided.

6. Research on alternative conservation measures such as habitat creation or regeneration, for example of montane forests and bromeliads, and translocation of herpetofauna to form new populations. This may be the most effective short-term strategy to conserve the golden tree frog, though ineffective against global warming.
7. Development of captive populations of the golden tree frog, both in Trinidad and overseas, as an insurance against unsuitability of montane areas after global warming, and against chytridiomycosis in wild populations.
8. Improved data gathering on hunting of lizards and caiman, and on their population levels. At least half of all legal hunting is unreported, and there is in addition much poaching, including hunting in the closed season. There is currently no basis on which to determine whether hunting levels of reptiles (or any other game) are sustainable.
9. Full legal protection of sea turtles, and restriction of access at night to all important nesting beaches.
10. Practical protection of sea turtles at nesting beaches by additional funded patrols. Existing funded and voluntary turtle patrols (e.g., by students of the University of the West Indies Biological Society) cannot cover more than a small fraction of the total places and times required for effective protection of nesting turtles.
11. Increased use of international volunteer groups to patrol turtle nesting beaches, adding to successful programmes such as Earthwatch at Matura and the University of Glasgow on Trinidad north coast and Tobago index beaches.
12. Replacement of the turtle fishery by alternative income sources for fishers, such as their involvement on boats in the lucrative dive ecotourism sector (in Tobago; Trinidad waters are too opaque). Until this can be achieved, turtles should be added to the Fisheries Division fish reporting form so that the scale of the catch can be monitored.
13. Reduction of the incidental catch of leatherback turtles using fishery regulation, such as prohibited areas around the main nesting beaches in north-east Trinidad or restrictions on the depth at which nets are set, or practical turtle-repellent devices.
14. Increase local capacity through training and employment of herpetologists with environmental agencies, and increased availability and use of local information sources and reference collections in education to overcome negative local attitudes to herpetofauna.
15. Finally, it should be recognized that development has benefits as well as risks for conservation. Developed country status should be associated with high standards of wildlife protection and conservation, and compliance with international obligations.

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