A report on the status of the herpetofauna of the Commonwealth of Dominica, West Indies

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Abstract. We review the status of the herpetofauna of the Commonwealth of Dominica, which is often cited as having the most complete extant herpetofauna of all the Lesser Antillean islands, a region which has suffered much historical extinction. Recent years have seen a number of threats of grave concern to island and regional endemic species, the chief of these being the arrival of chytridiomycosis on this island with negative effects on the mountain chicken *Leptodactylus fallax*, and the establishment of a non-native Greater Antillean anole, *Anolis cristatellus*, which has succeeded in displacing the native endemic *Anolis oculatus* from a part of the island in less than a decade.

Key words: *Anolis cristatellus*; *Anolis oculatus*; chytridiomycosis; habitat loss; *Iguana delicatissima*; invasive species; *Leptodactylus fallax*; Lesser Antilles; mountain chicken.

Introduction: General Ecology of Dominica

Dominica is one of the largest of the eastern Caribbean islands. However, by most standards it is a small island, being only 48 km long and 24 km at its widest point. It has a maximum altitude of 1447 m (Morne Diablotin) and several peaks over 1000 m distributed from the extreme northern to the southern tip (fig. 1). It receives an extremely high rainfall (in excess of 10,000 mm on the highest peaks). The spatial and temporal variation in the distribution of rainfall determines the distribution of varying habitats on the island (Lang, 1967). Reptiles form a significant part of its fauna, and it is one of the few Lesser Antillean islands that appears to have retained its original reptile and amphibian fauna over the last 200 years.

Xerophytic (or xeric) woodland (often misleadingly referred to as dry scrub woodland) occurs in areas of low rainfall (<2000 mm) with a pronounced dry season, predominantly on the Caribbean (leeward) coast. The vegetation is characterised by deciduous species, which shed their leaves during the dry season (February to May). There are few epiphytes (except in localised areas where a moister

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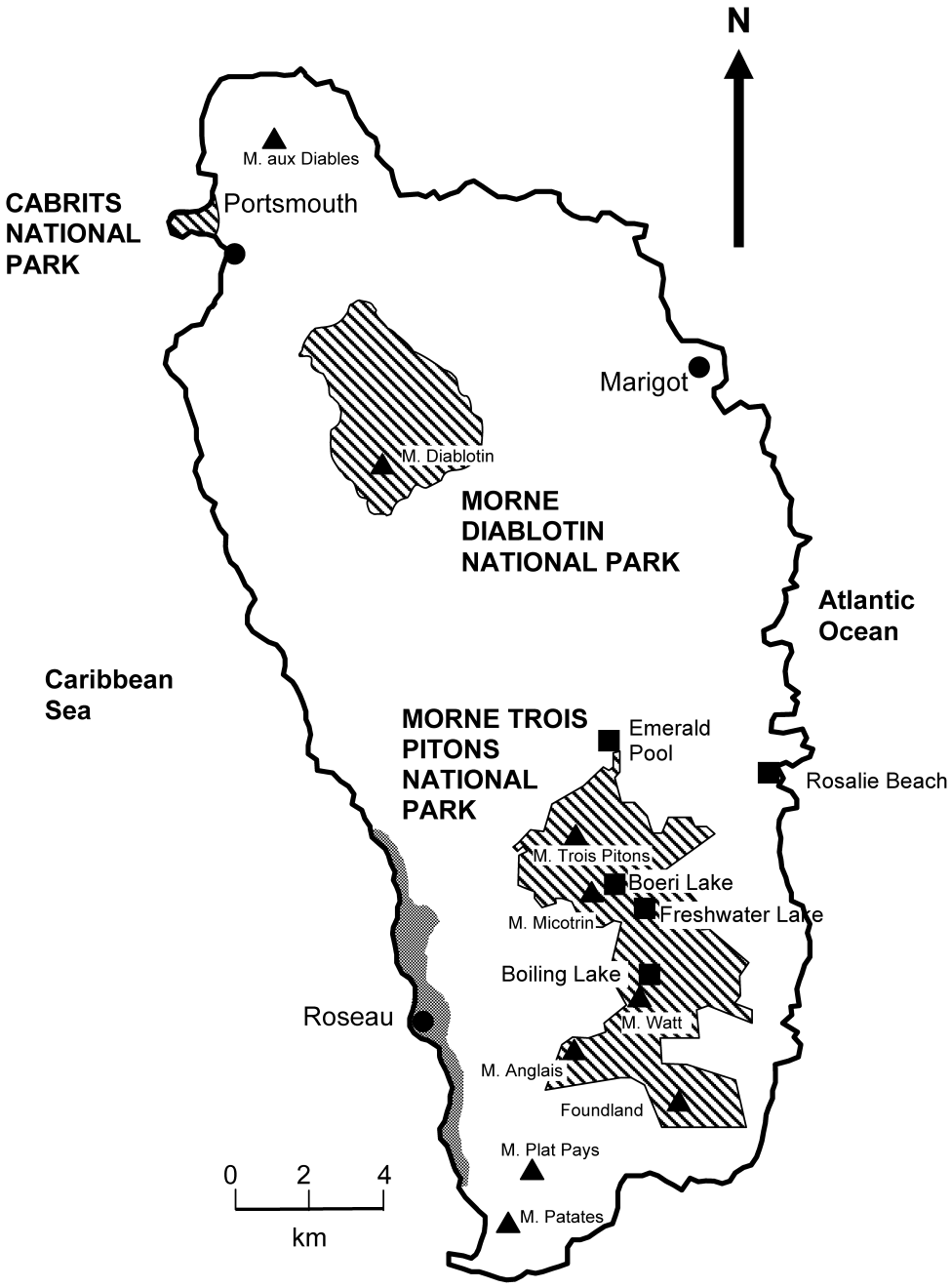

Figure 1. Map of Dominica, showing significant peaks (triangles), protected areas, the three main population centres and other points of interest including those mentioned in the text (squares). The range of the invading *Anolis cristatellus* as of February 2006 is shown by stippling. Within this range, the native *Anolis oculatus* is presently absent or very rare.

microclimate may occur) and the trees, which are generally unbuttressed, may reach a height of 12-15 m. The canopy is fairly complete, and little sunlight reaches the forest floor except during the dry season. Almost all this vegetation type, throughout the Caribbean, has been disturbed at some time, and it is unclear how closely it resembles the original vegetation. There are certainly a large number of introduced species that now flourish. Significant tree species (with their local names) include *Lonchocarpus latifolius* (savonnèt), *Tabebuia heterophylla* (white cedar or pòwyé), *Pimenta racemosa* (bwa denn or bay) and *Bursera simaruba* (gommier wouj, also known as birch gum, naked indian or turpentine tree). Strangling fig *Ficus citrifolia* (figuier) is mainly restricted to ruins (e.g. at Cabrits). Shrubby species include croton, *Zanthoxylum spinosum* or *caribaeum* (lépini), *Leucida leucocephala* and *Morinda citrifolia* (kòwòsòl dyab). Another characteristic feature of xeric woodland is the presence of thorny species, e.g. the introduced logwood *Haematoxylon campechianum* (kampèch), and shrubs including *Acacia* and *Lantana* species. On slopes nearest the sea, the effects of wind and sea spray during occasional storms modify the vegetation somewhat. Species here include white cedar, Indian almond (*Terminalia catappa*) sea grape (*Cocoloba uvifera*), seaside mahoe (*Thespesia populnea*), and manchineel (*Hippomane mancinella*), although the latter occurs rarely in Dominica (Carrington, 1998).

Littoral woodland is a distinct type of vegetation that is found on the exposed eastern or windward (Atlantic) coast of the island, although it contains species that may be found in both xerophytic woodland and rainforest. Much of it has been cleared for agriculture and good examples of this vegetation type only remain in a few locations such as Eden, Pointe Baptiste, and Rosalie Point. The soil on this coast is typically highly weathered and infertile, with poor water penetration. The littoral woodland has a very dense canopy and thus ground vegetation is sparse as are epiphytes and lianas. Most of the species present are hard-leaved evergreens adapted to physiological drought (caused by the drying effects of the sea wind). There is a transition from a hedge-like growth (dense, matted and distorted by the wind, with an almost complete canopy) close to the sea to relatively tall (up to 20 m) evergreen woodland behind. Species present include *Coccoloba uvifera*, white cedar *T. pallida*, galba *Callophylum calaba*, *Pimenta racemosa*, the overtop palm (locally known as kokoyé and yattahou) *Syagrus amara*. A species of *Clusia* also occurs rarely in the littoral hedge most exposed to the effects of the sea.

Substantial parts of the island are covered by rainforest. Over 60 species exceeding 10 cm girth at breast height (gbh) have been recorded per 1000 m^2 in Dominican rainforests (Lack et al., 1997). *Dacryodes excelsea* (gommier) is typically the dominant tree species, along with three species of *Sloanea* (chataignier), although the dominants vary from place to place according to exposure, depth of soil, drainage and other aspects of the site. Other notable tree species here include *Amanoa caribaea* (karapit), *Sterculia caribaea* (maho kochon), *Licania ternatensis* (bwa dyab) and *Tapura antillana* (bwa kòt). *Cephaelis schwartzii*, with waxy blue bracts surrounding small white flowers, is a common ground-layer shrub. Filmy ferns are

abundant and tree ferns are also present. Terrestrial and arboreal orchids, lianas, climbers (chiefly aroids) and a variety of epiphytes (e.g. large-leafed anthuriums, *Clusia* sp.) are abundant. In montane rainforest, the canopy is lower and thinner and the forest less stratified with correspondingly more luxuriant ground vegetation. Common trees in this zone are *Sterculia caribaea* (Maho kochon), *Hibiscus tuliparifolius* (Gombo moutayn), *Prestoea acuminata* (Palmist moutany) and *Podocarpus coriaceus* (wézinyé moutany), the latter being the only native conifer on the island. The air is extremely humid, with moisture often condensing directly out of the air onto the vegetation. There is usually an abundant layer of vegetation on the ground, and mosses and filmy ferns adorn every available surface. There are many bromeliads growing on (or close to) the ground, and these form important breeding sites for the native *Eleutherodactylus* frog species.

The final major vegetational zone found in Dominica is elfin woodland, found on the most exposed ridges and highest peaks of the island. Sometimes referred to as "dwarf cloud forest", it is not stratified and the canopy is very low (3-6 m) and thicket-like, with a mass of gnarled, entwined branches. The ground vegetation here often occurs as epiphytes in lower elevation forest. Especially on exposed ridges, the canopy is characteristically shaped by the wind, giving it a "combed" appearance. This vegetation type occurs from about 1000 m (depending on aspect and exposure) up to the summits. The dominant species is *Clusia mangle* (kaklen), often forming 50% of the trees present and sometimes occurring in pure patches. Another species present in the canopy is the palm *Prestoea acuminata*, while in the understorey mosses occur in large mats and festoons. Although this vegetation type is not very significant for reptiles as conditions are too cool and cloudy for much of the year (although *Anolis occulatus*, *Liophis juliae*, and *Sphaerodactylus vincenti* have been found at the interface between this and upper montane rainforest), it forms a substantial part of the range of the endemic *Eleutherodactylus amplinympha*.

The Herpetofauna

Amphibia

The mountain chicken *Leptodactylus fallax* is a large frog (females reach 17 cm SVL), which is frequently used for food, and its name derives from the fact that its meat tastes rather like chicken. It is a ground nester, laying twenty or so eggs in a foam nest in burrow half metre long, which is guarded by the female (Lescure, 1979). It has only recently been discovered that the female provisions her young by laying additional unfertilized eggs in the nest over the course of their development (Gibson and Buley, 2004). Prior to 2002, it was widely used as a novelty food by Dominicans and tourists (with annual harvests estimated as between 8,000 to 36,000 individuals). This harvest has been banned since 2002 after the population was confirmed as being infected with chytridiomycosis (see Conservation Issues, below). While the species is also found on Montserrat, it has been severely affected

by the volcanic activity occurring on that island since 1995. On Dominica its natural distribution is from sea level to a maximum of 400 m altitude only on the western side of the island, in natural forest and agricultural areas (Kaiser, 1994). However, introduced populations have been recorded from the east coast (e.g., Governor Estate near Melville Hall, Petite Savanne, La Plaine and Rosalie). It has suffered a large and catastrophic decline since 2002 over all of this former range and is now listed as critically endangered on the IUCN Red List.

The smaller whistling frogs, which do not seem to have been affected by chytridiomycosis, include three species of *Eleutherodactylus* (*E. martinicensis*, *E. johnstonei* and *E. amplinympha*). The latter is the only Dominican endemic (Kaiser et al., 1994). It is most abundant in the transition zone between montane rainforest and elfin woodland, but it co-exists over a broad range of altitudes with the more widespread *E. martinicensis*. It is listed as endangered in the IUCN Red list, because of its restricted range and probable decline in the extent of its habitat. Kaiser et al. (1994) suggested that *E. martinicensis* itself might have been introduced by Amerindian or French settlers, as its present distribution in the Lesser Antilles correlates well with the former French colonies. If this is the case, it is possible that the distribution of *E. amplinympha* may have shrunk in the last few hundred years through competition with this introduced species. However, *E. martinicensis* is itself listed as Near Threatened on the IUCN Red List as it generally appears to be declining across its very localised range. This may be related to the presence of a competitor, *E. johnstonei*, which has become widespread throughout the Lesser Antilles (Corke, 1992). Kaiser and Wagenseil (1995) confirmed the presence of *E. johnstonei* as a relatively recent introduction on Dominica, and recorded its distribution as restricted to the narrow strip on the sea side of the coast road from Fond Colet to Mahaut, and along the edge of the Imperial Road up the Antrim Valley as far as Springfield. It appears to be able to displace *E. martinicensis* only in open disturbed habitat.

Reptilia

Testudines. All marine turtles are on CITES Appendix I. Of these, the leatherback turtle (*Dermochelys coriacea*), have been recorded nesting on Dominica, with recent activity concentrated on the south-east coast beaches, particularly beaches at Rosalie and La Plaine. Loggerhead turtles (*Caretta caretta*) are also reported (CCA, 1991) from Dominican waters, but not recorded nesting. Green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*), are regularly encountered in Dominican waters and they also nest on the island. Although it is locally known that these turtles nest on beaches on both leeward and windward coasts of the island, efforts are currently being made to document the full extent of the distribution of nesting activity. Anecdotal reports from divers, reinforced by the personal experience of A.M. and R.S.T., suggest that the latter two turtle species are encountered more frequently in recent years. This may be due to the creation of the Soufriere-Scott's Head Marine Reserve, since spear fishermen will take juvenile turtles, or it may be

due to extraneous factors. In recent years, sea turtle protection has seen an upsurge in local interest, with beach patrols and tourist excursions being organised.

Geochelone carbonaria, the red-footed tortoise, is known from Dominica but rarely seen in the wild. It is probable that it represents an introduced species, perhaps established as long ago as Amerindian settlement of the island but more likely to be relatively recent.

Sauria. There are two endemic lizard species, *Amieva fuscata* (Teiidae) and *Anolis oculatus* (Iguanidae). As described by Malhotra and Thorpe (1992a), *A. fuscata* occurs primarily at lower elevations, and is restricted to coastal woodlands and associated cultivated areas below 300 m elevation. It may be lower in abundance in cultivated areas, but on the other hand it is also spreading to higher altitudes than it would have naturally occupied in areas of rainforest that have been opened up by agriculture. *Anolis oculatus* is very morphologically variable and was formerly considered to contain four subspecies (Lazell, 1972). However, morphological (Malhotra and Thorpe, 1991a, 1997a, 1997b) and molecular studies (Malhotra and Thorpe, 2000; Stenson et al., 2004) re-examined this variation and concluded that there was no evidence of interruptions to gene flow between the morphologically distinct populations, rather they represented clinal variation in response to selection for geographically varying environmental conditions (Malhotra and Thorpe, 1991b; Thorpe et al., 2005). The last published review of the distribution of this species (Malhotra and Thorpe, 1992b) indicated that they were present in all parts of the island up to c. 900 m elevation, at varying densities. However, recent years have shown a worrying trend towards the extirpation of the species from the southwestern quadrant of the island, which is associated with the establishment of an invasive species of anole from Puerto Rico (*Anolis cristatellus*) between 1997 and 2002. This invasion is described more fully below. However, there have also been declines noted in recent years in other areas for less obvious reasons, e.g., at Cabrits National Park, where some of the highest densities on the island were recorded in 1991 (Malhotra and Thorpe, 1991b). These declines may be temporary, as recent visits to the Cabrits in January 2007 suggest that the population is returning to its former abundance.

The Lesser Antillean iguana is perhaps the lizard species of highest current conservation concern, being listed as Vulnerable by the IUCN Red data book and on CITES Appendix II. The Dominican population of *Iguana delicatissima* is the largest and most secure of the remaining populations of this species (Day et al., 2000), being one of the few major islands on which the species occurs where its larger congener and competitor *I. iguana* does not also occur. Until recently thought to be an introduction into the Lesser Antilles, possibly deliberately dispersed as a food source by the first Amerindian settlers, recent genetic studies have suggested that some Lesser Antillean *Iguana iguana* populations, such as the nearly extinct population on St. Lucia (Alberts, 1999), are genetically distinct from those of the mainland and may therefore be native to some islands. It appears to be able to outcompete *I. delicatissima* and may also affect it by genetic introgression (Breuil,

2002). *Iguana delicatissima* still appears to be common in Dominica, and there are some sites where they are especially abundant (e.g. Canefield, Batalie Valley, Rosalie, Morne Raquette, Hampstead, Woodford Hill). While most abundant and frequently seen in coastal areas, they have been observed in some rainforest areas in fine weather, such as in the Picard Gorge opposite the parrot viewing point on the Syndicate Nature Trail.

Geckos include two species of litter or dwarf gecko *Sphaerodactylus fantasticus* and *S. vincenti*. Recent evidence suggests that *Sphaerodactylus fantasticus* is a relatively recent colonizer. Currently found at a few scattered localities along the dry western coast of Dominica, it is also found on the neighbouring islands of Guadeloupe, the Saintes, Marie Galante and Montserrat (Jones, 1999). The Dominican population appears very similar morphologically to the populations from the vicinity of the capital Basse Terre in Guadeloupe, although they were placed in their own subspecies (*S. f. fuga*) by Thomas (1964). However, molecular studies have shown that they are genetically close to the morphologically similar subspecies from Guadeloupe (R.S. Thorpe and Y. Surget-Groba, unpublished data), suggesting that they are relatively recent colonists of Dominica. *Sphaerodactylus vincenti* is also found on three islands south of Dominica, although molecular work in progress may lead to nomenclatural changes (R.S. Thorpe and Y. Surget-Groba, unpublished data). It is restricted to rainforest localities, and has been recorded in several parts of the island including Belles, Freshwater Lake, Palmiste Ridge, Syndicate and D'leau Gommier (Schwartz and Henderson, 1991; personal observations). Other gekkonid species whose presence is a result of recent introductions include *Thecadactylus rapicauda* and the house gecko *Hemidactylus mabioua*. The former is widespread in Dominica, most abundant in dry forest but also found in relatively pristine rainforest (Bullock and Evans, 1990), and also frequently found in the crevices and roof spaces of houses. The latter is largely restricted to the vicinity of human habitation, and is much less abundant in Dominica.

The skink present on Dominica, *Mabuya mabouya*, was formerly thought to be widespread throughout the Neotropics, but following recent taxonomic revision (Miralles, 2005) *M. mabouya* sensu stricto is now thought to be a regional endemic, restricted to Dominica, Guadeloupe, Martinique and St. Lucia. This species is now very rare in the Lesser Antilles, except in Dominica, and has probably vanished from Martinique (Cork, 1992). In Dominica, it is still widespread in coastal regions of the island, and may reach relatively high elevations in cultivated areas where it is often found under the corrugated iron roofs of agricultural sheds. It is often confused with the microteiid lizard *Gymnophthalmus pleei*, which although only officially recorded from Cabrits and Botanic Gardens in Roseau (Brooks, 1983), is almost certainly more widespread. However, there may be more than one species of *Gymnophthalmus* present (see below), thus the exact distribution of these similar species requires further work.

Serpentes. The largest snake on Dominica, reaching a length of 4 m, is *Boa constrictor*. While other subspecies of *B. constrictor* are listed on CITES Appendix II, due to the substantial trade in live animals and leather of this species, the Dominican subspecies is apparently not considered very attractive and does not feature in the international trade to any extent. It is widely distributed in Dominica in a variety of undisturbed and disturbed forest and agricultural land, though apparently confined to wet ravines in the dryer parts of the island (Lazell, 1964). It can still be considered fairly common in Dominica, although it is possible that larger individuals are becoming less commonly seen. It is vulnerable to persecution and hunting for its fat that is converted into snake oil, a locally prized remedy for low libido and rheumatic pains, as well as accidental killing by vehicles on roads. The species has not been systematically studied since Lazell (1964) described it as a subspecies *B. c. nebulosa*. Its genetic distinctness from the other Lesser Antillean population in St. Lucia (*B. c. orophias*), and from mainland populations, needs to be investigated.

There are also two medium sized colubrid snakes, *Liophis juliae* and *Alsophis antillensis* belonging to endemic subspecies, with additional subspecies being found on other Lesser Antillean islands. However, many of these other populations (such as those on the main islands of the Guadeloupean archipelago, Grande Terre and Basse Terre) are extremely scarce (Breuil, 2002), possibly because of the presence of mongoose on these other islands but not on Dominica (Henderson, 1992). The two colubrid species overlap in their distribution on Dominica to a large extent and either species may be found anywhere on the island except at the highest elevations, but *L. juliae* is more common at more mesic localities and higher elevations, while *A. antillensis* reaches highest densities in xeric woodland on the west coast. Both snakes are persecuted out of an innate fear of snakes, though as lizard and amphibian feeders they pose no risk to humans or their animals. Finally, the blind snake *Typhlops dominicana*, is endemic to Dominica, although some consider *T. guadeloupensis* to be a subspecies of this species (Schwartz and Henderson, 1991).

Erroneous and doubtful records

Several checklists of the reptiles of Dominica include two species whose presence on Dominica is unlikely or erroneous. One of these, usually referred to as *Clelia clelia* (but now shown in fact to represent a different species *C. errabunda*) is a colubrid that reaches extremely large size (c. 2 m) and is a specialist reptile feeder known from one other Lesser Antillean island, St. Lucia, where it is now extinct. However, Underwood (1993) conclusively demonstrated that the record from Dominica was due to a cataloguing error. Occasional reports of large "black" snakes by foresters are likely to be melanic boas, and even so, juveniles of most *Clelia* species are not black but reddish with a conspicuous yellow collar. As juveniles will be far more abundant than adults, the total lack of sightings of anything corresponding to this description should be a clear indication that this snake is not present on Dominica.

The other species whose presence on Dominica is in doubt is *Sphaerodactylus microlepis*. The main range of this species is in St. Lucia, and the record for Dominica rests on a single specimen with no precise locality in the Natural History Museum, London. However, it was catalogued together with some specimens that are clearly from Dominica (G. Underwood, personal comm.) so it cannot be clearly attributed to an error. Its presence in Dominica, however, remains to be verified.

Finally, while it has been known for some years that a microteid *Gymnophthalmus* species is present, the original specimens are very variable (Brooks, 1983) and it is not clear whether more than one species is present. While only the species *G. pleii* has been officially recorded for Dominica, the taxonomy of *Gymnophthalmus* species is a matter that requires resolving (Murphy, 1997), so the number of species present on Dominica, and their identity, requires further study.

Conservation Issues

Threats to the survival of reptile and amphibian species in the Lesser Antilles include habitat loss, disturbance, unintentional killing, intentional killing, introduced species, disease and natural disasters. These vary greatly in importance.

Habitat loss

Dominica has a long history of human habitation, with several waves of pre-Columbian Indian colonisers preceding the Carib Indians whose descendants still inhabit the island. It was given its present name by Columbus himself, who encountered it on his second voyage across the Atlantic. However, the resident Caribs and the rugged terrain deterred both him and subsequent waves of European settlers, and Dominica did not suffer the extensive loss of habitat during the colonial period that other islands experienced. A small population size (71,727 estimated in the 2000 population census) has meant that extensive development and urbanisation has been restricted largely to the south-west coast around the capital Roseau, and other small pockets, especially in the vicinity of the larger settlements of Portsmouth (north-west coast) and Marigot (north-east coast). At least semi-natural vegetation still covers c. 66% of the land surface (Evans, 1986). However, some habitat types have been disproportionately affected by agricultural activities. For example, extensive clearing and associated habitat degradation (e.g. by subsequent erosion) for commercial monocrop agriculture (especially bananas) after the 1940s has left only remnants of littoral woodland. Tropical lowland rainforest, montane rainforest and transitional forest have also been substantially reduced. Relatively little damage has occurred due to commercial wood harvesting. The relatively inaccessible cloud forests do not appear to be perturbed by agriculture but may be vulnerable to natural catastrophes (see below). They have also been affected in some parts of the island, such as Freshwater Lake, by hydro-electric projects which have decreased overall habitat area available by raising water levels in the lake and subsequent

erosion and landslides along the pipeline route. Change in agricultural practices may also be having an effect e.g. an increase in spraying in banana and other tree crop plantations may extirpate populations of reptiles and amphibians that might otherwise have survived quite well in plantation environments. Species that may be especially vulnerable to such changes and to habitat alteration and fragmentation in general include *Iguana delicatissima* and *Ameiva fuscata*.

Disturbance and predation by human commensals

Some species (e.g. marine turtles) are extremely susceptible to an increase in tourism development along, and increasingly heavy use of beaches, which may prevent them from nesting. However, recently formed conservation groups now control access to known turtle nesting beaches. Other ground nesters, such as iguanas, may also be readily disturbed and the increase in density of potential predators of juveniles such as cats and dogs may also be detrimental. The increased tidiness of grounds that are maintained for tourists, where leaf litter is raked away on a regular basis, may rapidly extirpate even initially dense populations of litter-living dwarf geckos, as has been observed by several of the authors at one site near Batali Beach.

Accidental killing

Increase in pollution may kill amphibians and reptiles directly as well as destroying their food or habitat. Discarded plastic trash floating in the sea may be mistaken for jellyfish by turtles, with generally fatal results. The amount of trash dumped directly into the sea has declined substantially in the last couple of decades after a garbage collection service was initiated, but unauthorized dump sites can still be seen from the sea. An increase in road traffic may also be affecting some species (e.g., boas, female iguanas crossing coastal roads to find nesting sites, juvenile iguanas dispersing from the nests). It is difficult to assess the impact of road kills. It does not appear to be a major threat but may be locally significant at particular times.

Intentional killing

This occurs for food, saleable products, “pest” control, and also out of innate fear of snakes. Species that are harvested for local consumption in Dominica include leatherback, green and hawksbill turtles, iguanas (*I. delicatissima*) and their eggs, and mountain chickens (*L. fallax*). This may cause local overexploitation of certain populations. Until recently, there was a specialised market for tourists who wanted to sample exotic local specialties such as mountain chicken. This apparently raised the demand to the point that a consignment of frog’s legs were imported into Dominica to meet it, and this is being investigated as a possible source of introduction of disease (see later). Boas are also harvested for their fat bodies, from

which "snake oil" is extracted and sold as a local remedy for arthritic pain, and other afflictions, and frequently killed when they are caught raiding chicken coops. While any amphibian or reptile may be casually killed without good reason, snakes are particularly subject to this through the apparent innate fear of snakes in humans, even though all species present in Dominica are harmless.

Introduced species

These may have had a devastating effect throughout the Lesser Antilles. Introduced animals may prey on, or compete with, naturally occurring species. More insidiously, they may hybridize with them and irreversibly compromise the purity of their gene pool. Dominica has escaped the introduction of the cane toad and the mongoose, which have been implicated in the extinction of ground-living amphibians and reptiles on other West Indian islands (Henderson, 1992), possibly because the cultivation of sugar cane has never been very important on the island. However, other introductions such as goats, cats and dogs have also been implicated in the decline of iguanas in other islands (Henderson, 1992), but may not be a significant factor in Dominica because of the large amount of remaining relatively unaffected habitat. With the recent increase in attention being given to the mountain chicken, several incidents of domestic cats catching and killing juvenile mountain chickens have been reported. Common iguanas (*Iguana iguana*) may replace the endemic *I. delicatissima* or pollute the gene pool by hybridisation as has occurred in Les Saintes (Day and Thorpe, 1996). Although the green iguana has never been recorded in Dominica, it is common on neighbouring islands and the possibility of a future introduction cannot be discounted, especially as it has been shown to be capable of rafting between islands (Censky et al., 1998). Given the importance of the Dominican population, vigilance should be maintained to prevent such an introduction being successful.

The whistling frog *E. johnstonei* has been widely introduced within the Lesser Antilles beyond its presumed natural range e.g., into Anguilla (Censky, 1989) and the Grenadines (Henderson et al., 1992) and may represent a serious conservation threat to the other whistling frogs by competitive replacement (Kaiser and Henderson, 1994). Although it may outcompete naturally occurring species (in Guadeloupe and perhaps Martinique) there is also evidence to suggest that in many cases it is limited to disturbed habitats and is not replacing the local species from undisturbed habitat (e.g., in Grenada and St. Vincent). Nevertheless, ongoing habitat disturbance may facilitate the spread of this frog at the expense of local species. No evidence exists on whether hybridisation between species poses a potential problem.

The most recent introduction of concern is that of a Greater Antillean anole *Anolis cristatellus*, which has established itself in Dominica between 1997 (when an island-wide survey of anoles by A.M. and R.S.T. did not detect it) and 2002 (when Forestry officers' reports of a non-native anole in the Canefield area of Dominica were followed up by an identification of the species by R.S.T. as *A. cristatellus* from Puerto Rico and the Virgin Islands). As a medium-sized solitary generalist,

the native Dominican anole is unlikely to be able to co-exist with a similar sized congener, particularly when the competitor is already very well adapted to withstand competition as it comes from a multi-species assemblage in the Greater Antilles. *Anolis cristatellus* has also been introduced to Florida and the Dominican Republic and on the latter, it tends to replace the native *A. cybotes*. This represents a potentially serious conservation issue, not just to Dominica, but also to the other Lesser Antillean endemics if it spreads further.

A preliminary survey carried out July/August 2002 across 67 localities found very dense populations of *A. cristatellus* around Canefield and parts of Morne Daniel (i.e., Canefield Pool). However, it did not reveal any *A. cristatellus* outside the southwestern coast area. A more detailed survey of the SW coast and Antrim Valley that same year involving an additional 23 localities showed that *A. cristatellus* was distributed from north of the Belfast River (near the prawn farm at Jimmit) south to Roseau, and up to 150 m elevation along the Imperial road (Interestingly this distribution coincides almost exactly with the distribution of another invasive species, *E. johnstonei*). Thus, the site of original invasion from which they have spread appears to be Canefield (adjacent to the Airport) and Deep Water Harbour (adjacent to the port) and implies that they may have been introduced accidentally via imported goods. Further surveys in 2003 and subsequently every year (with the latest in February 2006) has shown that the range of the invader has advanced on all fronts, but this advance is relatively slight, ranging from just 100 m further inland along the Imperial road, less than 1 km northwards to Rodney's Rock, and c. 1.5 km southwards to Anse Bateaux.

In the longer-term, the prognosis is that the native anole will be eradicated from large areas of the island, even under the best scenario where environmental conditions in some parts of the island give an advantage to *A. oculatus* over *A. cristatellus*. In its native Puerto Rico, *A. cristatellus* has a widespread distribution including montane habitats, but at higher altitudes it tends to be restricted to more open areas. Therefore, except where hurricanes and agriculture open up the montane rainforest, these areas may not be so vulnerable to invasion. A detailed study of morphological and genetic variation is being carried out by J. Eales and R.S. Thorpe as the presence of appreciable morphological and genetic variation within the invading species has implications for its further spread on the island. It may have the capacity for rapid adaptation to allow it to colonise habitats from which it may otherwise be excluded. The worse case scenario is therefore that it will effectively eradicate *A. oculatus* across the island (perhaps leaving behind just small surviving pockets) and also spread from the Canefield/Deep Water Harbour area to the docks of other Lesser Antillean islands where it will eradicate other endemic anoles. The situation is being closely monitored and studied.

Natural disasters

Dominica is subject to several natural catastrophic processes, including hurricanes, storm surges, landslides, earthquakes and volcanic eruptions. Hurricanes can do a

great deal of damage, and while these are naturally occurring, they may prove to be the final deciding factor once other factors have produced a critical situation (e.g., by allowing an introduced species to move into disturbed habitat). Volcanic eruptions have also occurred throughout the geological history of Dominica with some massive eruptions recorded from the geologically recent past. For example, a massive eruption occurred in Dominica c. 28,000 years ago, with the resulting ash deposited on the sea floor up to 150 km to the east, and pyroclastic flows extending 300 km to the south (Sigurdson and Carey, 1981). The signature of these major events has been detected in the patterns of genetic diversity of the native anole, although it has clearly survived these cataclysmic events. Presently, Dominica has eight Pleistocene-Recent volcanic centres concentrated in the southern half of the island. It is widely considered to be one of the most volcanically hazardous countries in the world and the possibility of significant eruptions in the near future is high. It is estimated that there is a 20% chance of a volcanic eruption occurring in the next decade, and that it is extremely likely that a significant eruption will take place in southern Dominica within the current century (UWI, 2000), leading to widespread destruction of habitat and local extinctions putting further pressure on endemic or near-endemic species.

Disease

On the 3rd December 2002, the outbreak of the fungal disease chytridiomcycosis was first reported in the village of Gallion, in southwest Dominica. Other reports came in rapidly thereafter and dead mountain chickens have since been reported from La Haut, Elmshall, Bagatelle, Coulibistrie, Soufriere, Dublanc valley, Fab, Milton Estate, Tarrou Valley and Carholm (i.e., across the full range of the species). Subsequent surveys (Magin, 2004) indicated the frogs were no longer present at many sites where it was thought that they had previously been common and it was estimated that the population declined by as much as 70% by February 2004. The population size may now (in 2007) be as low as 8,000 individuals and the species is in a critically endangered state. However, the disease does not seem to be affecting *Eleutherodactylus* species to the same extent, possibly because they do not tend to breed on the ground, but this is continuing to be monitored.

Conservation Legislation and Initiatives

Dominica has a strong legal basis for supporting the proper management of its forest and wildlife resources. The government agency responsible for wildlife management and protection in Dominica is the Forestry, Wildlife and Parks Division of the Ministry of Agriculture, Fisheries and Environment, with the primary relevant legislation being the Forestry and Wildlife Act (1976), which makes provision for the protection and management of wild fauna and the management of their forest habitat. For example, this allows for a closed hunting season, which between 1976

and 1999 extended from 1 March through August 31 each year (CCA, 1991). Since 2000, the closed season has been extended to nine months (i.e., from January to the end of September). Further legislation in 2003 gave full protection to *Leptodactylus* and banned the import of frogs legs and other amphibian products into Dominica. The National Parks and Protected Areas Act (1975) provides for the establishment of national parks and a protected area system. In 1994, Dominica signed the Convention on Biological Diversity and has prepared and adopted a Biodiversity Strategy and Action Plan. The Pesticide Control Act controls the importation and use of pesticides, and public education has been undertaken in reference to this act. The UN Convention to Combat Desertification was ratified by Dominica on 28th November 1997.

Protected areas

Over 20% of Dominica is under protective legislation. The reptile and amphibian communities of the island are protected within three National Parks (fig. 1), the newest of which, the Morne Diablotin National Park, was only gazetted in 2000. The smallest, the Cabrits National Park (531 ha), is situated on a small headland in the northwest of the island, including an area of xeric woodland (which however has only developed in the last 100 years, as the headland was virtually treeless during the 18th and 19th century when it was the location of the British-built Fort Shirley) with an adjacent 35 ha wetland, one of the most significant wetlands in Dominica. Despite its small size, the Cabrits supports some of the highest densities of reptiles ever recorded (Bullock and Evans, 1990; Malhotra and Thorpe, 1991b), including populations of most of the reptile species present on the island. There are also low densities of *Eleutherodactylus martinicensis* (although these may be present in higher numbers in and adjacent to the parts of the wetland that are more protected from salt spray). Only a minority of species (i.e. those that are only found at higher elevations, including *Sphaerodactylus vincenti*, *Eleutherodactylus amplinympha*, *Leptodactylus fallax*) are not found within the boundaries of the Cabrits National Park. However, the Cabrits is unlikely to sustain viable populations of some of the larger or less common reptiles (e.g., *Iguana delicatissima*, which are not common in any of the currently designated National Parks).

The higher altitude forests and communities are protected within the Morne Diablotin National Park (8,242 ha) and the Morne Trois Pitons National Park (6,857 ha). The latter, the first National Park established in Dominica, was designated under the National Parks and Protected Areas Act No. 16 of 1975, and added to the World Heritage List in 1997. Although these two parks encompass a relatively large area and contain a variety of habitats (including forest edge habitats that harbour species not normally expected at high altitudes such as the heliothermic skinks and ground lizards), they are vulnerable to external influences such as increasingly regular occurrence of hurricanes and invasion of disease and alien species. Finally, there are two forest reserves that form an integral element of the country's natural resource

management; the Central Forest Reserve, established in 1952 (410 ha), and the Northern Forest Reserve, legally established in 1977 (8,903 ha).

Ironically it is one of the species that is currently of greatest conservation concern, *Leptodactylus fallax*, which is not found in any of these protected areas, as its natural range is restricted to intermediate elevations. The full range of genetic diversity within some variable species such as *Anolis oculatus* is also not adequately protected by the existing protected area system.

Conservation Programs

Captive breeding

On 1st April 2005, a three-year collaborative project, funded by the Darwin Initiative, was started to protect Dominica's amphibians from the threat of fungal disease, involving the Forestry and Wildlife Division and the Veterinary Services Division of the Dominican Ministry of Agriculture and Environment, the Zoological Society of London and other international conservation organisations. Captive populations of *Leptodactylus fallax* (not of Dominican origin) are located in Jersey, Chester and London Zoos in the UK, and one of Dominican origin in St. Louis in the US. There are plans to establish a Dominican mountain chicken population in UK zoos in 2007 and a captive breeding centre in Dominica itself. Captive individuals of *Iguana delicatissima* from Dominica are currently established at the Jersey Zoo, UK and in San Diego and Memphis Zoos, USA, but have had rather limited breeding success to date, with only nine young having been produced, (one in 1997 and eight in 2000) by Jersey Zoo's captive pair, eight years after breeding trials had begun (Gibson, 2001).

Education

No hunting of *Leptodactylus fallax* on Dominica has been allowed since 2003, and posters and leaflets, targeted at both Dominicans and tourists, have been produced outlining the disease threat and the ways in which people can help (e.g., by obeying the laws which now protect the species and by avoiding touching or moving frogs on the island to reduce chances of inadvertently spreading the disease). A website on the issue was also developed by the Zoological Society of London. A surveillance network is also being created with assistance from the general public and Dominican Hunters Association, inviting all sightings of the species (whether sick, dead or healthy animals) on the island to be reported. A good response was received to this program, with many reports from the public about the location of calling frogs being made by members of the public in 2006. A public education program aimed at reducing turtle poaching has also been undertaken through the Rosalie Sea Turtle Initiative (RoSTI). While some publicity has also taken place about the invading anole, the difficulty of distinguishing the invading species from the native has precluded more active participation of the general public in a monitoring program.

Monitoring

The Darwin funded project has also led to the establishment of molecular diagnostic facilities in Dominica (completed in November 2005 and officially commissioned in 2006) and the training of local personnel in amphibian survey and diagnostic technology, to facilitate the continued monitoring of the spread of chytridiomycosis in Dominica. The expertise developed within Dominica will be made accessible to other Caribbean islands at risk, and a Management Plan will be produced to minimise the risk of spread of the disease. The spread of the invading anole *Anolis cristatellus* and its interaction with the native endemic species is also being studied by the University of Wales Bangor, in collaboration with the Forestry, Wildlife and Parks Division.

Recommendations

Although *Anolis oculatus* is not yet at risk of extinction, the extent of genetic variation on the island has probably already been greatly affected, since the area affected corresponds to almost the entire range of the South Caribbean ecotype (Malhotra and Thorpe, 2000). It should therefore be a priority to set up captive breeding colonies of this ecotype to preserve as much of the existing genetic diversity of the species as possible. The protected areas of Dominica are generally above the maximum known elevation of *Leptodactylus fallax* (400 m) and contain few, if any, animals. This species is clearly of high priority for continuing conservation action. However, the effect of the fungus on the endemic *Eleutherodactylus* species is not entirely known and should be a priority for further study. The danger to currently healthy populations from future introductions should not be underestimated, and vigilance should be exercised so that any such introductions (e.g. of the green iguana) can be caught at an early stage. This could usefully include training of port officials and workers, as they have already assisted in the apprehension of non-native species of frog *Osteopilus septentrionalis* (native to Cuba) and dwarf gecko *Gonatodes vittatus* (possibly from Northern Venezuela) in separate incidents at Woodbridge Bay Port in 2006. Genetic studies on the uniqueness of the island's snakes, currently considered subspecies of more widespread species, should also be encouraged. Finally, further studies on the status and distribution especially of island and regional endemics, and those with restricted or patchy distributions on the island, should be carried out.

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