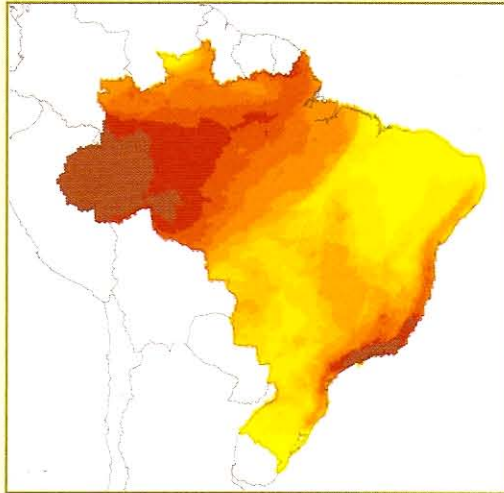
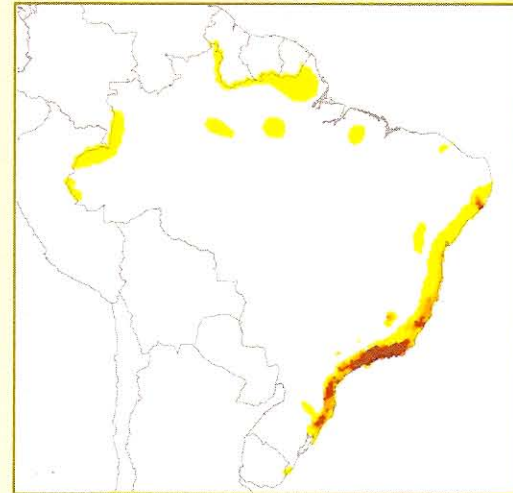


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**Figure 1.** Richness map of all amphibian species in Brazil, with dark red colours corresponding to regions of higher richness. Colour scale based on 10 quantile classes. Maximum richness equals 139 species.



**Figure 2.** Richness map of all threatened amphibian species in Brazil, with dark red colours corresponding to regions of higher richness. Colour scale based on five quantile classes. Maximum richness equals 24 species.

## ESSAY 9.5. A BRIEF OVERVIEW OF THE AMPHIBIANS OF COLOMBIA

The amphibian fauna of Colombia is among the largest and most diverse on the planet. According to the results of the Global Amphibian Assessment, nearly 700 recognized species of amphibians are known from, or expected to occur in, Colombia, and our current estimate stands at 732. The diversity of amphibians in Colombia is, to a certain degree, the fortuitous consequence of human politics – it is as if Colombia's borders were drawn with the specific intent of maximizing its amphibian diversity. That is, Colombia's amphibian diversity is a function not only of the area of this tropical country, but also its specific location. For example, the two countries with the greatest number of amphibian species are Brazil and Colombia (Ecuador is a distant third, with "only" 449 species). With 752 recognized species listed in the GAA, Brazil has a slightly larger amphibian fauna, but its area is over eight times greater than that of Colombia. Consequently, Brazil has  $8.8 \times 10^{-5}$  species per  $\text{km}^2$ , whereas Colombia has  $6.1 \times 10^{-4}$  species per  $\text{km}^2$  – a full order of magnitude more.

In occupying the north-western-most portion of South America, Colombia includes the rich amphibian fauna of the rain-soaked Pacific lowlands and adjacent Andean foothills, and this is augmented by capturing many species (e.g., the dendrobatid *Colostethus panamensis*, LC) and lineages (e.g., the brachycephalid genus *Craugastor*) that extend into Colombia from Central America. The eastern borders reach far into Amazonia, and further north the Llanos secure fauna associated with the Orinoco river drainage. Predominantly Venezuelan lineages, such as the aromobatid *Aromobates*, extend into Colombia in the Serranía de Perijá, and the isolated Sierra Nevada de Santa

Marta harbors an endemic fauna that includes such enigmatic species as the brachycephalid *Geobatrachus walkeri* (EN).

Nevertheless, although Colombia's regional span contributes greatly to the diversity of amphibians, it is the Andean backbone that is most significant (Lynch *et al.* 1997). Whereas to the south and north-east the Andes form comparatively simple systems, in Colombia they divide into three isolated ranges that radiate from the Nudo de Pasto, and these ranges harbor about two-thirds of Colombian amphibians. Among the Andean species, most occur in the cool, moist cloud forests between 1,200 and 2,500m asl, and many are confined to extremely small areas. Although experimental data are lacking, it is assumed that this isolation is due to the adaptation of species to specific environments and their inability to survive under even mildly different conditions. For example, although two adjacent mountains may share identical environmental conditions, the different environment (e.g., higher temperature and lower precipitation) of the intervening valley would serve as a barrier to dispersion and gene flow (Lynch and Duellman 1997).

The limited geographic distribution of most Colombian amphibians makes them extremely susceptible to habitat alteration and destruction. This poses a special challenge for Colombian policy makers because humans have targeted precisely the same elevations of the Andes for their development activities. For many Andean species, the removal of a single remaining patch of forest may mean the extinction of the species. For example, *Atopophrynus syntomopus* (CR) is the only species of its genus and is known from a single

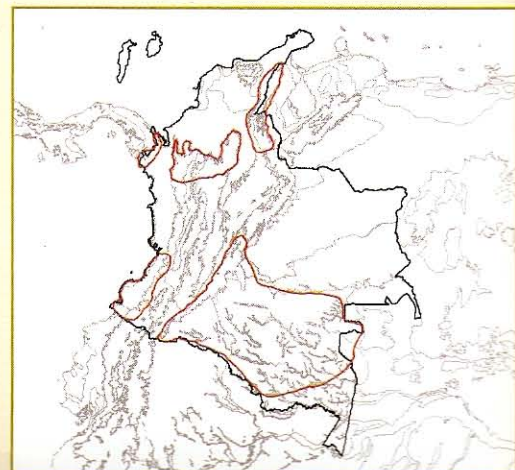
locality in the Cordillera Central of Antioquia in an area that has been subjected to extreme deforestation. In addition to the habitat alteration that accompanies human development, other actual or potential threats to Colombian amphibians include the introduction of exotic species (including the illicit introduction of the North American Bull frog, *Lithobates catesbeiana*, for commercial purposes), global climate change and increased exposure to ultraviolet radiation, and infectious disease – especially chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobatidis* (Rueda-Almonacid *et al.* 2004).

According to the IUCN Red List, just less than half (47%) of all Colombian amphibian species are classified as Least Concern. Of the remainder, 18% are Endangered or Critically Endangered, and another 18% are Near threatened or Vulnerable. Quantitative data derived from rigorous monitoring studies are lacking for all of those species, but data are so scant for an additional 17% of Colombian species that not even a rough estimate of their status could be made, and they are designated as Data Deficient.

Given the state of knowledge of Colombian amphibians, two areas of research are in urgent need of increased attention. First, taxonomic research – including the exploration of under-sampled areas and the production of revisionary, monographic studies of groups and regions – must be expanded to complete the identification of Colombian amphibians. Although few localities can be considered thoroughly sampled, Acosta-Galvis (2000) highlighted a number of high-priority regions, including mid- to high-elevations of the central



*Geobatrachus walkeri* (Endangered) is a frog known only from the north-western and western slopes of the Sierra Nevada de Santa Marta in northern Colombia. © Taran Grant



**Figure 1.** Priority regions for further inventory and survey work in Colombia.



and northern Cordillera Central and Cordillera Occidental, higher elevations along the length of the Serranía de Perijá, the páramos of the Cordillera Oriental in southern Cundinamarca and Tolima departments, the Serranía del Darién along the Colombo-Panamanian border, the southern Cordillera Occidental and adjacent lowlands in Cauca and Nariño departments, and the Cordillera Oriental and rainforests of Putumayo, Amazonas, Caquetá, Guaviare, Vaupés, and Guainía departments (Figure 1).

The discovery and identification of previously unknown species in all major groups of Colombian amphibians shows no sign of slowing in the foreseeable future. Indeed, as the expansion of institutional (e.g., natural history collections, molecular laboratories, GIS databases, parallel computing facilities) and human resources (e.g., active scientists and hyperactive students trained in amphibian systematics) continues, we anticipate that the current rate of discovery will continue or increase in the coming years. For example, although it once seemed that the Amazonian fauna was spatially quite uniform (albeit highly diverse), denser sampling, exploration of previously unstudied localities, and analysis of non-traditional data – especially

DNA sequences – are revealing much greater complexity, and what were believed to be widespread species are frequently found to involve numerous, even distantly related species of more modest distributions. As our appreciation of the diversity of Colombian species increases, so too does our understanding of their basic biology so crucial to implementing effective conservation strategies to ensure their survival.

A second critical area of research in need of attention is the establishment of long-term, reliably funded studies that monitor natural populations at key localities in both pristine and fragmented, or otherwise developing, areas. Such monitoring programs would allow researchers to track the spread of infectious diseases, understand the response of individual species to differing pressures, and distinguish natural and normal population fluctuations from extreme and abnormal declines, all of which is necessary to design and implement an efficient conservation strategy to ensure the survival of one of the world's most diverse and fascinating amphibian faunas.

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## ESSAY 9.6. THREATENED AMPHIBIANS OF THE WEST INDIES



*Eleutherodactylus orientalis* (Critically Endangered) from a small flat top mountain in eastern Cuba called El Yunque de Baracoa. The very small range and declining quality of habitat in the region are causes for concern. Adults are only 11mm long, only one millimetre longer than the smallest frog in the world, *E. iberia*, which also occurs in eastern Cuba. © S. Blair Hedges, Penn State

The West Indies is a complex assortment of islands and countries located between North and South America. In total land area (224,000km<sup>2</sup>) it is similar in size to Great Britain and includes three major island groups: a chain of four large and old islands (the Greater Antilles), a relatively flat limestone bank to the north (Bahamas and Turks and Caicos Islands), and a classical volcanic island-arc in the east (the Lesser Antilles). The Greater and Lesser Antilles are located within, or at the border of the Caribbean Sea, but the Bahamas Bank is within the Atlantic Ocean. From the standpoint of biodiversity, the West Indies – sometimes called the “Caribbean Islands” – includes the Cayman and Swan Islands, but usually excludes islands neighboring Central and South America (e.g., Aruba, Curaçao, Trinidad and Tobago, etc.), which have faunas that more closely resemble those on the continents (Figure 1).

The origin of the West Indian fauna has been debated for more than a century, and continues to be an area of active research. Because the Greater

Antilles were once connected, as a geological unit, with North and South America in the late Cretaceous (~60-70 million years ago), it has been suggested that the present fauna arose by “vicariance” – in other words, traveled with the islands as they broke away from the continents. But fossil and genetic research has failed to identify more than a few West Indian groups that fit this model, if any. Most, or all, groups probably arrived to the West Indies by flying, swimming, or floating on flotsam (mats of vegetation). The east to west direction of ocean currents means that the source for almost all flotsam in the West Indies is South America (or, more rarely, Africa), and this agrees with the evolutionary affinities of much of the non-flying land fauna (Hedges 2001, 2006).

With its 172 native species, the amphibian fauna of the West Indies is remarkably diverse for such a small land area. Yet it is also peculiar in that all the native amphibians are frogs – there are no salamanders or caecilians – and most (147 species) belong to a single genus of direct-developing leptodactylid frogs, *Eleutherodactylus* (Schwartz and Henderson 1991; Hedges 1999). West Indian amphibians range in adult size, from the smallest frog in the world, *Eleutherodactylus iberia* of eastern Cuba, at 10mm, to the giant ditch frog *Leptodactylus fallax* (the “Mountain Chicken”) of the Lesser Antilles, reaching 210mm.

Frogs of the genus *Eleutherodactylus* (see Essay 1.4) lay their eggs on land, bypassing the aquatic tadpole stage, which eventually hatch into miniatures of the adults. One species of *Eleutherodactylus* in Puerto Rico even gives birth to living froglets. Parental care is common among the species, and many guard their eggs during development. The sex of the egg-guarder follows evolutionary lines, with the father having this job in the Puerto Rican group of species, whereas in Jamaica the mother is usually the guarder (Townsend 1996). Individual species are adapted to a great many terrestrial niches, including underground burrows, rock caves, cliffs, salt marshes, waterfalls, bromeliads, tree holes, leaf litter, and vegetation of all types. The term “ecomorph” has been used with West Indian *Eleutherodactylus* to recognize the morphological and ecological convergence in species from different islands and their adaptations to these niches.

Other native amphibians include a modest radiation of toads (11 species, family Bufonidae) and an assortment of treefrogs (nine species, family Hylidae). With eight species, Cuba is the center of diversity for toads, whereas Jamaica and Hispaniola are hot spots of hylid frog diversity, with four species each. There are several species of aquatic ditch frogs (*Leptodactylus*) as well, including the Mountain Chicken that occurs on Montserrat and Dominica. A single species of dendrobatid frog occurs on Martinique. All but a few species of West Indian amphibians are endemic to a single island.

Many species occur in the lowlands, but a peak in species density occurs between 550 and 1,150m elevation, usually corresponding to cloud forest habitat. On average, species body size decreases by about one mm per 100m of increasing elevation, so a lowland species is typically twice as long

(~56mm) as one on a mountaintop at 2,500m (Hedges 1999). The number of sympatric (co-occurring) species varies among and within islands, with the highest number recorded being 24 species near the Haitian village of Castillon in the Massif de la Hotte of Hispaniola.

From a conservation standpoint, the West Indies is one of the hottest biodiversity hotspots (Smith *et al.* 2005). On average humans have destroyed more than 90% of the original native habitat in the West Indies and it is no surprise that these forest-dwelling species have been decimated. Clearing of land is often for subsistence farming, but trees are also sold for building materials or made into charcoal for cooking fuel. Charcoaling is practiced in Jamaica, Cuba, and Hispaniola and is one of the major sources of income in Haiti where the human population has soared to over eight million and where essentially no original forests remain (Hedges and Woods 1993; Young *et al.* 2004).

A recent assessment of the status of West Indian amphibians found that 84% of the species are threatened (Young *et al.* 2004), with 37% listed as Critically Endangered, 36% as Endangered, and 11% as Vulnerable. There is no other region of the world that has such a high proportion of threatened species. Among those 63 species listed as Critically Endangered, eight are considered to be “possibly extinct” because they have not been seen in many years (Hedges 1993, 1999; Young *et al.* 2004). These include the live-bearing species *Eleutherodactylus jasperi* of Puerto Rico, as well as several stream-dwelling species.

Besides the major threat from deforestation, a few species have disappeared from forested areas and the reason for this is unclear. Certainly, no forests in the West Indies are pristine because of introduced flora and fauna that impact the native biota. For example, Old World rats and mongooses can be encountered throughout forested areas high on mountains in the Greater Antilles and these species are known to prey on amphibians. Still, it remains to be established whether introduced predators, climate change, a chytrid fungus, another threat, or rather a combination of these factors is the primary cause for the presumed extinctions of these amphibians (Burrows *et al.* 2004).

Most countries have made some efforts to control deforestation, such as the designation of national parks and protected areas. These efforts are to be applauded, but unfortunately most have had limited or no success in slowing the destruction of habitat. This is especially true in the countries such as Haiti and the Dominican Republic, where clear-cutting and charcoaling continue within protected areas, mostly because budgets allocated to environmental protection are insufficient. Essentially no original forests remain in Haiti (Hedges and Woods 1993), and therefore many endemic species – including those not found in the Dominican Republic – will likely become extinct in the near future unless something is done soon. Species in other countries may not be far behind.

It is imperative that international agencies, both conservation-based and

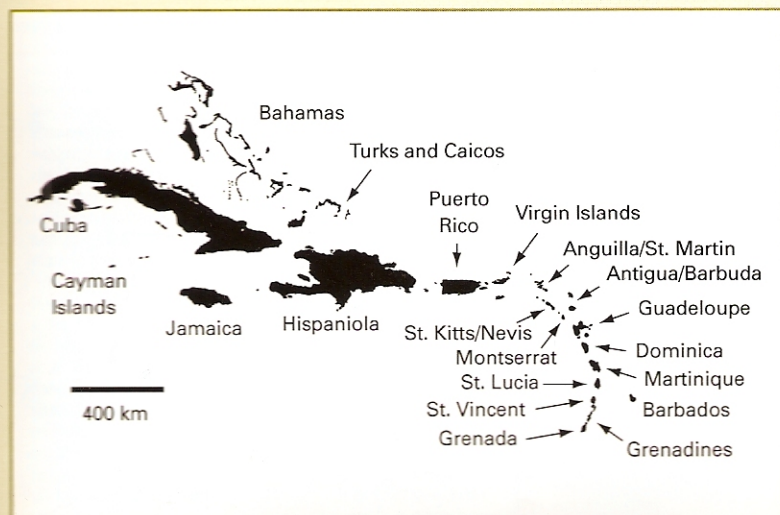


Figure 1. Map of the West Indies (Caribbean Islands).

*Eleutherodactylus glanduliferoides* (Critically Endangered) from the Massif de La Selle of Haiti. This species is only known from a few places on the northern slope of these mountains, just above the densely populated capital city of Port-au-Prince. The region is completely deforested and this species is possibly extinct. © S. Blair Hedges, Penn State

