The Conservation of Brazilian Reptiles: Challenges for a Megadiverse Country

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Abstract: *About 650 species—330 snakes, 230 lizards, 50 amphisbaenids, 6 caimans, and 35 turtles—comprise the known reptile fauna of Brazil. Only 20 are considered threatened. Except for the marine and freshwater turtles, which suffer from overexploitation and habitat destruction, they are threatened because of their rarity and extremely restricted ranges. Despite its richness and diversity, research on Brazil's reptile fauna is still largely restricted to alpha taxonomy. Surveys, an electronic database of all herpetological collections, and phylogeographic studies based on molecular genetic techniques are needed to improve our understanding of the biogeography of this group and to delineate effective conservation strategies to preserve the evolutionary potential of existing lineages. Autecological, population, and community studies that monitor effects of habitat degradation, fragmentation, and loss, pollution, and exploitation are needed for a better understanding of the effects of the widespread and ever-worsening degradation of Brazil's natural ecosystems.*

La Conservación de Reptiles Brasileños: Retos para un País Megadiverso

Resumen: *La fauna conocida de reptiles en Brasil comprende cerca de 650 especies—330 serpientes, 230 lagartijas, 50 anfisbaénidos, 6 caimanes y 35 tortugas. Solo 20 son consideradas amenazadas. Excepto por las tortugas marinas y dulcecuícolas, están amenazadas debido a su rareza y distribución extremadamente restringida. A pesar de su riqueza y diversidad, la investigación sobre la fauna reptiliana de Brasil esta restringida principalmente a la taxonomía alfa. Se requieren prospecciones, una base de datos electrónica de todas las colecciones herpetológicas y estudios filogeográficos basados en técnicas de genética molecular para delinear estrategias de conservación efectivas para preservar el potencial evolutivo de los linajes existentes. Se requieren estudios de contaminación, explotación, autoecológicos, de poblaciones y comunidades para monitorear efectos de la degradación, fragmentación y pérdida de hábitat para un mejor entendimiento de los efectos de la extensiva y cada vez peor degradación de los ecosistemas naturales de Brasil.*

Taxonomy and Conservation

Brazil has the richest fauna and flora of all of South and Central America, but most information on reptiles is still preliminary. Today about 650 reptile species are recognized as occurring in Brazil: 610 Squamata (330 snakes, 230 lizards, 50 amphisbaenids), 6 caimans, and 35 turtles. These numbers are from a personal checklist, but the Brazilian Herpetological Society (SBH) is working on a consensus list, following a workshop in 2004 that assessed the taxonomy and geography of the Brazilian reptile fauna. Although unfinished, the result was a slightly lower figure of 629 species. The full list will be available on the society's Web site in 2005 (SBH 2004).

Amazonia has the most lizards and amphisbaenids (109 species). The Cerrado and the Atlantic Forest have 70 and 67 recorded species, respectively. Numbers are lower in the Caatinga (45 species) and transitional areas such as the Pantanal of Mato Grosso and high-elevation moorland or *campo rupestre* (each with 12 species). If humid forest enclaves in the Caatinga (the *brejos* of northeastern Brazil) are included, its number of species jumps to

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73, comparable to the Cerrado and the Atlantic Forest. Amazonia also has the highest diversity of snakes (138 species), followed by the Atlantic Forest (with 134), the Cerrado (117), and the Caatinga (45). Caatinga remains in last place even when the brejos are included (the number rises to 78). The numbers of snake species in the Amazon Forest, the Cerrado, and the Atlantic Forest are similar if one includes savannas in the count of Amazonian species, remnant patches of Amazonian forests in the count of Cerrado species, and open formations (savannas and campo rupestre) in the count for the Atlantic Forest. This similarity is explicable by the changes in the location and extent of forests and savanna in the Pleistocene and early Holocene (Haffer 2001; Wang et al. 2004). Patterns of endemism among these biomes can best be assessed with lizards because many snakes and all amphisbaenids are secretive, fossorial, and little known. Amazonia has 81 endemic lizards, the Atlantic Forest 40, the Caatinga 25, and the Cerrado 16. A further 16 lizards are endemic to other formations, including sand dunes, *restinga* (sandy coastal scrub and forest), campo rupestre, and dry forests.

Although these numbers give an idea of the faunistic differences between these major biomes, they are not directly comparable because some complex groups tend to be more prevalent in one or another ecosystem, and some have received modern and thorough (if not exhaustive) taxonomic revisions. A revision of the genus *Tropidurus*, for example, increased the diversity of species typical of open areas (Rodrigues 1987; Frost et al. 2001). The same will happen when other genera, such as *Cnemidophorus*, are revised, further increasing open-formation numbers and endemism. Likewise, differences in the extent to which different regions and biomes have been inventoried are still large enough to bias the numbers.

Except for possibly the Crocodylia, the size of the Brazilian reptile fauna is still underestimated because of insufficient inventories and too few taxonomists. The five largest reptile collections in the country—the Museum of Zoology (University of São Paulo); the Emílio Goeldi Museum, Belém; the National Museum, Rio de Janeiro; the snake collection of the Instituto Butantan, São Paulo; and the herpetological collection of the University of Brasília—have yet to be fully entered into electronic databases. Even when combined, they fail to represent many key areas and ecosystems: gaps that persist when all of the country's zoological collections are considered. The geographical representation needed for exhaustive systematic revisions for most genera is lacking, and, therefore, any certainty that current taxonomic arrangements provide a true picture of the diversity.

Inventories in new areas frequently reveal new species. I recently described two genera of gymnophthalmid lizards from the Atlantic Forest (Rodrigues et al. 2005) and have just collected a third, as-yet-unknown genus. Besides the poorly resolved taxonomies of the more complex groups, numerous new species sit in laboratories awaiting description. A reptile fauna endemic to an area of sand dunes in the Caatinga, along the middle stretches of the Rio São Francisco, was discovered as recently as the 1990s (Rodrigues 1996, 2003). This discovery resulted in the description of five new genera, increased the number of Brazilian Squamata by 25 species, and revealed some extraordinary biological adaptations previously unknown for South America (Rodrigues & Juncá 2002). Although the reptile fauna of the Caatinga was considered well researched (Vanzolini et al. 1980), such unexpected discoveries suggest how little we know of the patterns and processes responsible for the evolution and differentiation of our fauna. We are still in the exploratory phase in terms of our understanding of Brazil's biological diversity, and no area should be regarded as having low biological importance without exhaustive inventories and field surveys.

Phylogenetic studies using molecular techniques have contributed greatly to our understanding of lineages within species or species groups. They have allowed for revisions of taxonomically complex groups, frequently revealing unrecognized taxa and facilitating the reconstruction of historic affiliations, contacts, and isolation events among populations and between species: important for the recognition of isolated or distinct lineages. They have also been key in developing conservation strategies, especially in patchy or isolated environments such as open habitats in Amazonia (e.g., savannas and white sand scrub or *campina*), isolated forest patches in the Caatinga, and high-altitude moorland in the Atlantic Forest. Studies of a gekkonid, *Gymnodactylus darwinii*, of the coastal Atlantic Forest between Rio Grande do Norte and São Paulo, for example, have demonstrated an accentuated genetic variation resulting in a split into two species and the recognition that larger rivers are separating genetically differentiated populations (Pellegrino et al. 2005).

Molecular systematics provides information on the genetics of wide-ranging species or species groups in continuous habitat. Comparisons of the divergence patterns of populations currently isolated in, for example, forest patches in the Cerrado, with those of populations that were restricted and isolated in the past but are widespread today (i.e., those that differentiated in Tertiary or Quaternary forest refuges in the Amazon and the Atlantic Forest) are of great interest for setting priorities for protected areas. When supplemented with more refined autecological and metapopulation studies, these tools are indispensable for a better understanding of the dynamics of highly fragmented landscapes.

The Squamata, in general, are quite resistant to habitat fragmentation. For a time, recently isolated forest fragments maintain their high diversity, independent of their size (Freire 2001). Reptile communities in remnant forests in northeastern Brazil, however, isolated in the Holocene, show stochastic alterations in species abundance and composition (Vanzolini 1981). Similar cases have been documented for the Cerrado (Colli et al. 2003).

Carnaval (2002) showed that amphibian populations in isolated forests in the Caatinga are little differentiated and that marked differentiation may exist among populations in large areas of continuous forest. Understanding the degree to which this may occur in other species is important in developing conservation strategies, and research on this is under way with arboreal *Enyalius* lizards, *Coleodactylus* geckos, and spectacled lizards (*Leposoma*). If similar patterns are found, remnant forests in the Caatinga will continue to be a conservation priority, but the goal will be to understand differentiation rather than to maintain what one would have supposed to be genetically differentiated populations. There are no extensive phylogeographic studies of Brazilian crocodiles and turtles (indispensable for complex groups as that of Geoffroy's side-necked turtle [*Phrynops geoffroanus*]).

Nearly all known Brazilian reptiles probably occur in one or more protected areas, but the mere maintenance of a single population is obviously insufficient to protect the genetic variability in the species' component populations. To improve representation, we need a better understanding of their distributions—strategic field surveys and complete electronic databases of museum collections are indispensable (Graham et al. 2004).

Principal Threats

Habitat destruction is the principal threat. The impacts on lizards and snakes are more easily perceived because they are terrestrial. Forest species are more vulnerable because they are unable to withstand the high temperatures of open formations. Savanna and open-formation species are more resistant, but many will disappear when their habitats are totally eliminated (for example, by soybean plantations in the Cerrado). Because they are subterranean and poorly known, we know little of the impacts of surface habitat degradation or loss on amphisbaenids. Because people fear or dislike snakes and amphisbaenids, they tend to be killed whenever they are seen.

Crocodiles and turtles are persecuted for their meat and eggs. Policing and patrolling, environmental awareness, improved formal education in rural communities, and activities generating alternative revenue have been and are important components of conservation strategies for these commercially important species. Numerous government projects for both marine turtles (coordinated by the National Center for Conservation and Management of Marine Turtles [TAMAR project]; IBAMA-TAMAR 2004) and freshwater turtles (formerly coordinated by the National Centre for Conservation and Management of Amazonian Turtles (CENAQUA), and policing and patrolling for the illegal poaching for crocodile skins have slowed population declines, which were precipitous in the 1970s. River destruction, prevalent in the south and southeast and increasingly so in Central Brazil and the southern and eastern Amazon, also a major threat. Habitat destruction of rivers comes from the loss of gallery forest (loss of shading and nutrient input and increased bank erosion), siltation, and pollution and poisoning through domestic and industrial waste and agrochemicals. Siltation and erosion destroy and modify the riverbanks, beaches, and thermal niches where crocodiles nest. These are pervasive and poorly perceived threats that can gradually decimate populations of both crocodiles and turtles. Because the sex of crocodile and turtle offspring is determined by incubation temperature, changes in the thermal conditions around nests from habitat degradation can result in biased sex ratios, a threat in itself.

Sex determination by incubation temperature has also been recorded for some lizards. A recent study of spectacled lizards, *Leposoma*, revealed heavily male-biased sex ratios (Rodrigues et al. 2002). There is no known chromosomal mechanism of sex determination in *Leposoma*, and it is possible that this results from increased incubation temperatures in forests with broken canopies, such as is often found in *cabruca*—canopy-shaded cacao plantations (Rodrigues et al. 2002).

Hydroelectric dams are apparently a localized threat: habitat in the area of the reservoir is lost entirely. While animals flee, large numbers are rescued and dumped in nearby forest, even though the impacts on the ecology and biology of the surrounding populations are largely unknown (Pavan 2002). The long-term consequences of altering the natural flood cycles and water flow downstream, which in turn modify sediment deposition, nutrient input, and vegetation succession, are unknown. For shallow rivers with extensive alluvial floodplains and distinct cycles of inundation, these changes can be highly significant. Brazil's rivers, notably in the north, have enormous and untapped hydroelectric potential. Given this potential, and the fact that gallery forests were key refuges during dry periods in the Quaternary, dams are likely to have enormous potential impacts on the reproductive biology of the turtle and crocodile populations downstream and on the population structure of lizards, snakes, and amphisbaenids. These impacts may not be immediately evident.

The smaller forest reptiles are very susceptible to microclimate changes, and logging results in drier understorys (to the extent of rendering the forest floor highly susceptible to fires; Barlow & Peres 2004). Hunting is difficult to control and is deleterious to reptile communities over the mid term (Jerozolimski & Peres 2003). Mining alters water quality and water balances, besides destroying and degrading the physical integrity of streams and rivers. Dredging river beds for gold or precious stones, or to make them navigable for large ships, wrecks the natural fluvial sediment dynamics and destroys turtle and crocodile nesting sites, particularly affecting turtles of

Table 1. Reptiles on the Brazilian Official List of Species Threatened with Extinction (IBAMA 2003) that are critically endangered (CR), endangered (EN), or vulnerable (VU) according to the World Conservation Union (IUCN) categories and criteria (Version 3.1, IUCN 2001).

Taxon	*States recorded**	*IUCN category*	*IUCN criteria*
Lacertilia *Liolaemus lutzae*	RJ	CR	A1c, B1, B2c
Serpentes *Bothrops alcatraz*	SP	CR	B1ab(iii)
Serpentes *Bothrops insularis*	SP	CR	B1ab(iii)
Serpentes *Corallus cropanii*	SP	CR	A4b
Serpentes *Dipsas albifrons cavalheiroi*	SP	CR	B1ab(iii)
Testudines *Dermochelys coriacea*	marine	CR	D
Lacertilia *Placosoma cipoense*	MG	EN	B1, B2b
Serpentes *Bothrops pirajai*	BA	EN	B1ab(iii)
Testudines *Eretmochelys imbricata*	marine	EN	D
Testudines *Lepidochelys olivacea*	marine	EN	D
Testudines *Phrynops hogei*	RJ, MG, ES	EN	B1ab(iii)
Lacertilia *Anisolepis undulatus*	RS	VU	B1, B2c
Lacertilia *Cnemidophorus abaetensis*	BA	VU	B1, B2b
Lacertilia *Cnemidophorus littoralis*	RJ	VU	B1, B2b
Lacertilia *Cnemidophorus nativo*	BA, ES	VU	B1, B2b
Lacertilia *Cnemidophorus vacariensis*	RS, PR	VU	B1a, B2a
Lacertilia *Heterodactylus lundii*	MG	VU	B1, B2b
Lacertilia *Liolaemus occipitalis*	RS, SC	VU	B1, B2bc
Testudines *Caretta caretta*	marine	VU	C1
Testudines *Chelonia mydas*	marine	VU	C1

**States: BA, Bahia; ES, Espírito Santo; MG, Minas Gerais; PR, Paraná; RJ, Rio de Janeiro; RS, Rio Grande do Sul; SC, Santa Catarina; Sp, São Paulo.*

the genus *Podocnemis* (Haller 2002; Moretti 2004). Agrochemicals are another major threat and may be especially serious in small protected areas surrounded by agricultural land. Long-term effects are unknown and need to be understood in order to delineate appropriate conservation strategies. Monitoring of reptile populations is essential in situations such as these.

Threatened Species

Despite the widespread destruction of Brazil's natural vegetation and landscapes, only 20 reptiles are on the Brazilian threatened species list (IBAMA 2003). The tree boa (*Corallus cropani* [Boidae]), Alcatraz's lancehead (*Bothrops alcatraz*), the golden lancehead (*Bothrops insularis* [Viperidae]), and *Dipsas albifrons cavalheiroi* (Colubridae), the last two endemic to the Ilha Queimada off the coast of São Paulo, are critically endangered, as are the tropidurid lizard, *Liolaemus lutzae* (Tropiduridae) and the leatherback turtle (*Dermochelys coriacea* [Dermochelydae]) (Table 1). The principal threats to these species are their extreme rarity (*Corallus cropani*) or highly restricted ranges (the others). The spectacled lizard (*Placosoma cipoense* [Gymnophthalmidae]), Piraja's lancehead (*Bothrops pirajai* [Viperidae]), Hoge's sideneck turtle (*Phrynops hogei* [Chelidae]), the hawksbill turtle (*Eretmochelys imbricata*), and the olive Ridley (*Lepidochelys olivacea* [Cheloniidae]) are endangered. The turtles are threatened from overexploitation and numerous other threats, such as long-line fishing. The forested range of Piraja's lancehead is very restricted and is being destroyed. *Placosoma cipoense* is rare and extremely poorly known. Seven lizards and the loggerhead and green turtles are listed as vulnerable. Again the turtles are listed largely because of overexploitation or the potential of it, and the lizards have very restricted ranges and threatened habitats. Four other species, two snakes and two turtles, are considered near threatened, and 16 taxa are data deficient (Table 2).

Many of Brazil's southern and southeastern states, where the majority of the endangered species occur, have compiled threatened species lists and enacted state legislation for their protection. The lists are published as red data books with species profiles, analyses, and recommendations for conservation measures. Paraná's was the first in 1995; those for Minas Gerais, São Paulo, and Rio de Janeiro were published in 1998 (see Rylands 1998) and Rio Grande do Sul in 2002 (Fontana et al. 2003). Paraná recently carried out a revision of its threatened species list (Mikich & Bérnils 2004).

In 2001 IBAMA established the Center for the Conservation and Management of Reptiles and Amphibians (RAN; Edict 058, 24 April 2001), absorbing CENAQUA, which formerly dealt specifically with freshwater turtles. RAN's mission focuses on research on and conservation measures for threatened and commercially important amphibians and reptiles (IBAMA-RAN 2004).

Discussion

Protected areas are the key strategy for the conservation of Brazil's reptiles: state, federal, and indigenous areas

Table 2. Reptiles considered by the Brazilian Institute for the Environment (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis [IBAMA]) as near threatened (NT) or data deficient (DD) (IBAMA 2003), according to the World Conservation Union (IUCN) categories and criteria (version 3.1, IUCN 2001).

Taxon	*States recorded**	*IUCN category*
Serpentes *Bothrops fonsecai*	SP, RJ, MG	NT
Serpentes *Clelia montana*	SP, RJ, MG	NT
Testudines *Acanthochelys radiolata*	SP, RJ, MG, ES, BA, SE, AL	NT
Testudines *Hydromedusa maximiliani*	SP, RJ, ES, MG	NT
Lacertilia *Cercosaura ocellata petersi*	RS	DD
Lacertilia *Colobosauroides cearensis*	CE	DD
Lacertilia *Leposoma baturitensis*	CE	DD
Lacertilia *Stenocercus azureus*	RS	DD
Lacertilia *Stenocercus dumerilii*	PA	DD
Serpentes *Bothrops cotiara*	PR, SC, RS	DD
Serpentes *Bothrops muriciensis*	AL	DD
Serpentes *Calamodontophis paucidens*	RS, SC, PR	DD
Serpentes *Ditaxodon taeniatus*	RS, PR, SP, MS	DD
Serpentes *Echinanthera cephalomaculata*	AL	DD
Serpentes *Lachesis muta rhombeata*	Southeast (except SP) and Northeast (except MA and PI)	DD
Serpentes *Philodryas arnaldoi*	PR, SC, RS	DD
Serpentes *Philodryas oligolepis*	MG	DD
Serpentes *Xenodon guentheri*	PR, SC	DD
Testudines *Phrynops vanderhaegei*	SP, GO, DF	DD
Testudines *Trachemys adiutrix*	MA	DD

**States: AL, Alagoas; BA, Bahia; CE, Ceará; DF, Federal District; ES, Espírito Santo; GO, Goiás; MA, Maranhão; MG, Minas Gerais; MS, Mato Grosso do Sul; PA, Pará; PR, Paraná; PI, Piauí; RJ, Rio de Janeiro; RN, Rio Grande do Norte; RS, Rio Grande do Sul; SC, Santa Catarina; SE, Sergipe; Sp, São Paulo.*

cover nearly 23% of the country's land surface (Rylands & Brandon 2005 [this issue]). Although they secure prima facie the preservation of the species within them, they are subject to fires and to threats that are difficult to perceive. Depending on their size and location, the extinction of at least a fair proportion of their species is inevitable.

Geomorphologic and paleoclimatogical factors need to be considered both in developing conservation strategies and in the tenets of conservation biology. The biological communities of areas that are today forested but were dominated by open formations during the Quaternary are quite possibly condemned, even though they represent a unique piece of Brazil's evolutionary heritage. It is necessary to define and integrate short-, mid- and long-term conservation objectives to ensure that, over time, at least some of the existing protected areas can be more than just field laboratories; instead, they can become nuclei of biological diversity, maintaining their capacity for anagenesis and cladogenesis.

Results of phylogeographic studies carried out in Australia (Schneider et al. 1998; Schneider & Moritz 1999) show that areas occupied by forests today were dominated by open formations during the last glacial maximum. In Brazil we also know that the dominant natural landscapes and climate patterns were entirely different during the last glacial maximum (20,000–15,000 years ago) and the peak of the climatic optimum (Haffer & Prance 2001; Wang et al. 2004). Incorporating climate change considerations into conservation strategies, based on a profound understanding of past changes, is vital and urgent, especially given the growing evidence that the changes will occur more rapidly than imagined previously.

The myriad archipelagos of tiny isolated fragments of natural vegetation now prevalent over enormous areas of the Cerrado, the Caatinga, and the Amazon and Atlantic forests, and the innumerable habitats created through their destruction and degradation, would seem to sustain reptile faunas that are still quite similar to their original communities. Gaining an understanding of diversity patterns, monitoring the genetic variability of populations in these fragments, and comparing them to populations isolated at different times in the past would be invaluable contributions to conservation in Brazil.

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