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Wildlife Diversity and Conservation in Tropical America

Gerardo Ceballos and Oscar Sánchez

1. INTRODUCTION

One of the most remarkable characteristics of the tropics is their astonishing biological diversity. Although there is no general agreement about the number of species on earth, recent estimates show that the figure varies from five to 50 million (Wilson 1988). Tropical forests cover only seven per cent of the earth's land surface, but they contain up to 60-70 per cent of all living species (Myers 1988; Wilson 1988).

Tropical America may harbour between 300,000 and 1,000,000 plant and animal species. Indeed, the world's largest unspoiled tropical forests, covering approximately five million km^2, are found in the Amazon and Orinoco basins. Unfortunately, long-term conservation of such tremendous biological heritage is threatened by many factors. Hunting, deforestation, introduction of exotic species, and pollution are some of the factors promoting the demise of biodiversity in the American tropics. If the present trend of destruction continues in the coming decades, thousands of species will become extinct and several ecosystems will vanish.

In this chapter an analysis of the biological diversity of Tropical America and the problems for its long-term conservation are presented. In the first section Tropical America is defined and a brief summary of its biogeographical history presented. In the second section, the patterns of diversity of the main vertebrate groups are described. The last section is devoted to a discussion of conservation problems faced by Tropical American countries.

2. REGIONALISATION OF TROPICAL AMERICA

2.1. What is Tropical America?

The simplest method to define Tropical America is to rely on the climatic types in which tropical vegetation is known to occur. Three main types of Köppen's climatic classification systems are closely related with tropical ecosystems, namely the tropical rainy (Am-Af), tropical seasonally rainy (mostly Aw) and semi-arid tropical (Aw-Bs) climates. The differences among these climates reflect the variance of monthly temperatures, the yearly amount of rainfall and the patterns of monthly precipitation.

Based on these climatic criteria, Tropical America comprises a large area along both American coasts, from the Tropic of Cancer southward, including to the east the extensive Amazonian Basin south to the Tropic of Capricorn; to the west, it includes from Sinaloa, México, to the north-eastern portion of the Pacific coast of South America, approximately to the Gulf of Guayaquil in Ecuador (Fig. 1). Thus defined, it would exclude the high altitudes of Mexico, the Andean Cordilleras, the Chilean desert and the remainder of South America south of 23° 27' of South latitude. The Greater and Lesser Antilles are also tropical, but because of peculiarities of their insular nature, they will not be treated in detail in this chapter.

2.2. Biogeographic regionalisation of Tropical America

The most widely accepted biogeographic scheme to divide the American continent includes two great regions: 1) the Northern or Nearctic Region, which includes most of North America extending to portions of Central Mexico, and 2) the Southern or Neotropical Region, covering from the above mentioned boundary southward to South America. The term 'Neotropical' is sometimes misused through the inclusion of a considerable portion of South America that is not of a tropical nature; it seems likely to see quite a few changes of the biogeographical division of America, or at least of nomenclature, in the future (e.g., Müller 1973, 1974).

Some of the problems of geographic division seem to have arisen from a long-term tradition in the usage of certain names, but another factor has been the paucity of detailed information on certain critical areas of the New World. This reflects the need for more complete inventories of wildlife in these regions (Pine 1982; Mares and Genoways 1982).

In addition, the judgment of faunal or floral affinities has tended to be somewhat subjective in the past, until more precise numerical methods started to be applied to biogeography (Udvardy 1969; Cheetham and Hazel 1969). These methods are still undergoing further refinement (Baroni-Urbani and Buser 1976; Sánchez and López 1988), and are expected to allow for a more appropriate description of cases such as the complex mosaic of wildlife in the American tropics.

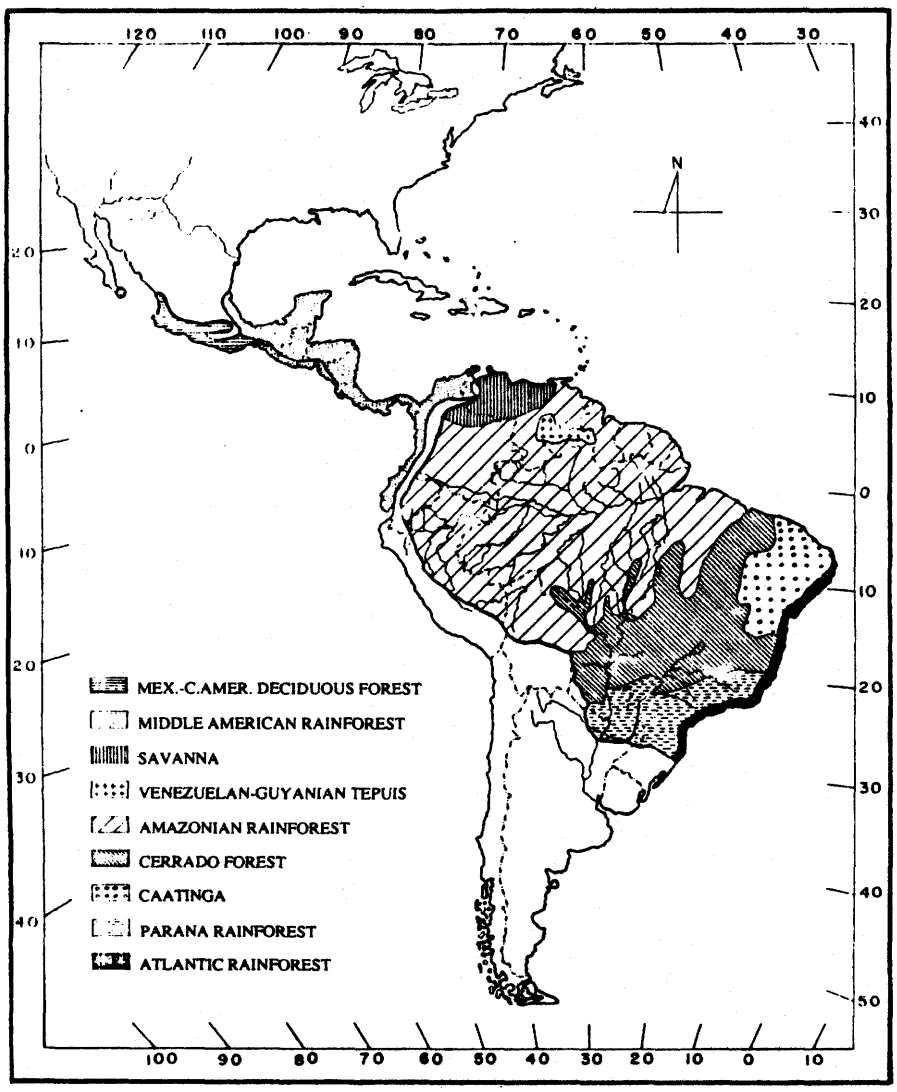

Figure 1. Vegetational types of Tropical America. Note that the Atlantic Rain forest was a thin track of vegetation; urban growth has reduced it to only 2 per cent of its former area. The apparently extensive and uninterrupted Amazon Forest has started to be traversed by the bald scars of the first roads of a huge projected network. While social needs cannot be ignored, the fragmentation of this area might give rise to more severe problems than it is expected to solve. An important center of plant and animal endemism is the Mexican-Central American Deciduous Forest, partly due to its relative isolation from other tropical areas of the continent. The Tepuis are also unique because of a high endemism despite their small size and juxtaposition with the Amazon Forest.

3. HISTORIC BIOGEOGRAPHY OF TROPICAL AMERICA

The overwhelming diversity of wildlife throughout tropical America has a long and complex history, beginning some 110 million years ago, when Gondwanaland (the southern portion of the primeval supercontinent Pangaea) had already at least 15 million years of being in the process of breaking up into the land masses that constitute present-day South America and Africa (Kurtén 1976; Hallam 1976; Smith and Briden 1977). Fossil records indicate that by that time insects had been present for a long time and all major vertebrate groups had already appeared; fish had been on the scene for at least 400 million years, the first mammals had appeared some 90 million years before, and flowering plants were new evolutionary achievements, as young as about 20 million years.

However, not all vertebrate groups were equally developed when South America started to separate from Africa and Antarctica; major orders and families of fish, amphibians, reptiles and at least the primitive birds were already established and were comparatively diversified, while mammals were still in early stages of radiation. Indications of these asynchronisms are the presence of fishes such as the Characidae of tropical areas both in Africa (*Hydrocyon*, "waterdogs") and in South America (*Serrasalmus*, "piranha"), amphibians such as the primitive frogs of the family Pipidae (*Xenopus* in Africa and *Pipa* in South America) (Dietz and Holden 1976; Hallam 1976). In comparison, the present terrestrial mammal genera had not yet appeared at that time and thus it is not surprising that only three genera of South American mammals are shared with Africa; these are cosmopolitan vespertilionid and molossid bats, widely known as strong fliers, that have colonised these areas (either way) rather recently. Considering the comparatively late diversification of mammals, the effect of this ancient break-up is clearly important for the evolution of endemic groups of mammals in South America, having increased the diversity of South American wildlife, long back.

Another determinant of the present-day richness of tropical American wildlife has to deal with the recurrent separation and connection of South America with North America. Both areas were first united about the Upper Jurassic (ca. 150 million y.b.p.); then they became separated and a series of volcanic island masses (what are now the Greater Antilles) were created and drifted to the East. In the Eocene (ca. 50 million years ago), North America was separated again from South America by the Bolivar Trench. During the Pliocene (about four million years ago), the Panamanian bridge appeared due both to the emergence of land and the lowering of the sea level.

This story is correlated with arrivals and/or returns (with different degrees of success) of plant and animal groups from North to South

America. These movements included some Asian invaders such as the crotalid snakes (Brattstrom 1964) as well as all-American taxa that further increased the floral and faunal richness of Tropical America. In fact, and just as an example of the effects of that interchange, according to fossil evidence, between 4.5 and 3.5 million years ago, the number of land mammal families in both areas were more or less equitable (nine for North America and 10 for South America) as compared to the number during the last one million years (North America 29 and South America 85). In addition to the evolution of the vast number of endemic organisms known from South America, the important role of the Panamanian bridge in furthering the biotic richness of tropical America is evident (Hallam 1976).

In more recent times, during the glacial and interglacial periods of the Pleistocene, profound climatic alterations took place in the tropical areas of America. These resulted in palaeoecological events such as fragmentation, retraction, and spread of vegetational communities. Such events of alternating reduction and increase, or even shifting, of the areas occupied by autochtonous and immigrant plant and animal taxa in the American tropics promoted speciation via vicariance and other mechanisms (Müller 1973; Haffer 1969; Vanzolini and Williams 1970; Prance 1973).

4. MAIN VEGETATIONAL COMMUNITIES OF TROPICAL AMERICA

The presence and distribution of types of vegetation depends more or less directly on the physical conditions imposed by climate, topography and soil. As the distribution of animals is usually closely related to the structure of the vegetational environment, the distributional patterns of tropical vegetation can be used as convenient guides for the discussion of wildlife in general.

Tropical America can therefore be divided into several main vegetational types (Figs. 2–5). Following the basic scheme of Cabrera and Willink (1980) and Hershkovitz (1972), Tropical America is divided into nine vegetation types. At such a large scale, it is unavoidable that some minor well-defined vegetational types result combined within the most similar major biomes.

4.1. Mexican-Central American dry deciduous forest

The Mexican-Central American dry deciduous forest is found along the Pacific coast, from southern Sinaloa, Mexico, to northern Panama (Fig. 1). This type of vegetation occurs in areas of high seasonality and yearly rainfall less than 1000 mm; with precipitation peaks between June and October. The remaining months of the year are very dry, and this severe drought reaches a maximum during April-March. During this period, almost all trees

Figure 2. The Venezuelan-Guyanian Tepuis, tall table-top mountains with high endemism of savanna plants and dense, humid forest in the gorges (Photo: G. Ceballos).

shed their leaves and the forest acquires a greyish, seemingly dead appearance, which changes rapidly with the onset of the next rainy season (Ceballos in press).

It is one of the most distinctive American tropical biomes, particularly because of its extremely high number of endemic plants and animals; for instance, in an inland extension of the coastal lowlands, north of the Mexican State of Guerrero and about 40,000 km² in size, the copal tree genus *Bursera* (Burseraceae) is estimated to include as many as 50 species, as compared to 30, 14, 10 and five in neighboring areas (Rzedowski 1978).

The height of the forest is from six to 18 m depending on the soil and plant species present. Although many tree genera may occur, dominant and conspicuous ones are *Ceiba* (Bombacaceae), *Lysiloma* and *Erythrina* (Leguminosae), *Spondias* and *Pseudosmodingium* (Anacardiaceae), and *Guazuma* (Sterculiaceae).

4.2. Middle American rain forest

This biome is found from southern Mexico, Guatemala and Belize to

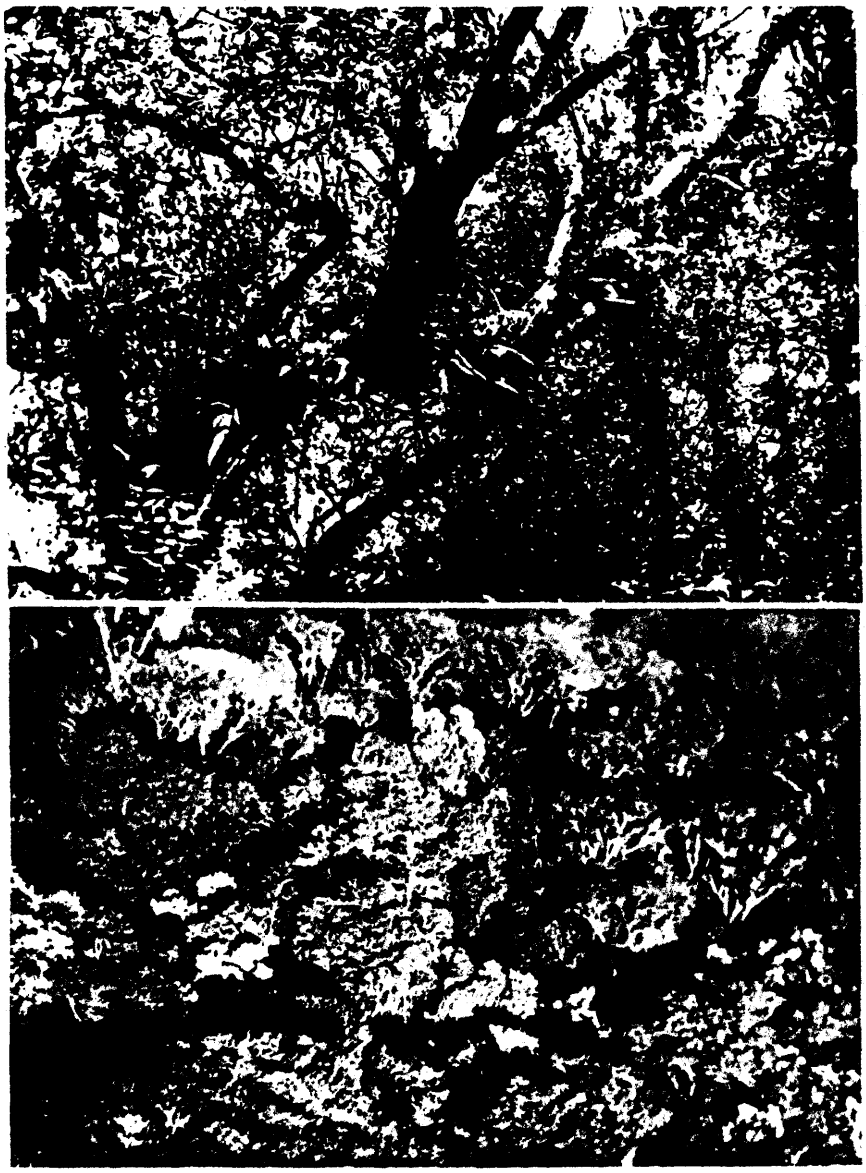

Figure 3a. The Atlantic forest is characterised by the high occurrence of epiphytic plants. **Figure 3b.** The Amazonian rain forest, is still the greatest single portion of tropical forest in the world. A thick mat of vegetation is seen which harbours an amazing diversity of life forms, most of which are unstudied (Photos: G. Ceballos).

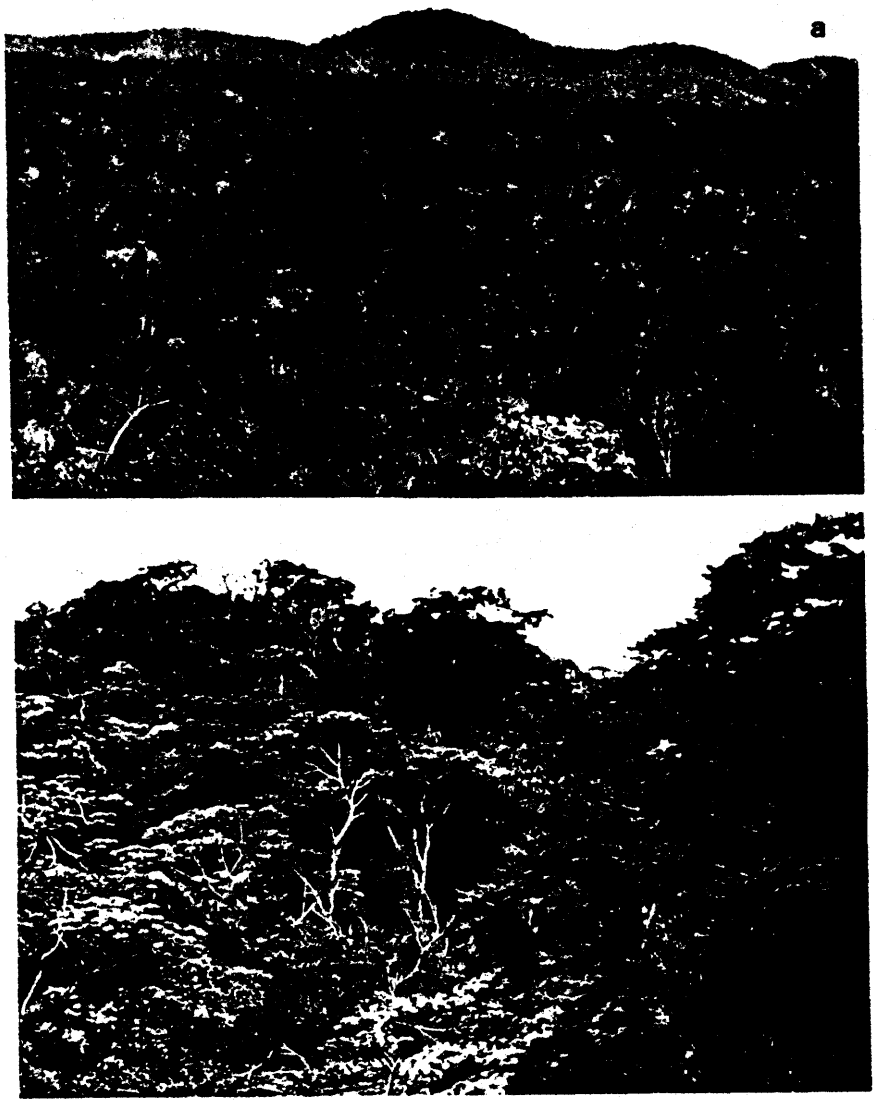

Figure 4a. The Mexican-Central American dry deciduous forest is the result of an early invasion of tropical life which has remained somewhat isolated. As a consequence of that process, parts of Central America, especially of western México, have a rich array of endemic species both of plants and animals.

Figure 4b. The Middle American rain forest; a recent derivative of tropical communities found in the Amazon Basin that has reached to the Tropic of Cancer in eastern North America (Photos: G. Ceballos).

Figure 5. The Paraná rain forest is spectacular because flat extensions are often interrupted by waterfalls and accidents of the landscape (Photo: G. Ceballos).

northern Panama (Fig. 1). It is a relatively humid lowland forest, found in areas with high annual precipitation (> 1500 mm) and relatively high and stable temperatures. It is somewhat similar in structure and overall composition of tree species to the rain forest of the Amazonian Basin (Cabrera and Willink 1980). In coastal areas of Central America and northern South America, this forest gives way to mangrove-dominated communities towards the shore.

The Middle American rain forest is characterised by the abundance of tree species, and it includes about 110 tree genera, with prevalence of Leguminosae, and over 20 palm-tree genera (Cabrera and Willink 1980). Dominant tree genera commonly include *Nectandra* (Lauraceae), *Manilkara* (Sapotaceae) and *Brosimum* (Moraceae). The height of the canopy varies from 30 to 50 metres. The Middle American rain forest is relatively poor in endemic plants (Rzedowski 1978), as compared to other South American rain forests. The low level of endemic species supports the hypothesis that this vegetation invaded Middle America, most probably from the Amazonian Basin, after the end of the last glacial period (Rzedowski 1978).

4.3. Savanna

This vegetational type is mostly found in northern South America, primarily

in Colombia and Venezuela (Fig. 1). Locally known as "Los Llanos", it occurs in seasonally flooded areas with four or five months of heavy rainfall alternating with seven or eight months of drought. Structurally, open grassland alternates with patches of trees or shrubs, with prevalence of Leguminosae (e.g., *Cassia, Mimosa*, and *Phaseolus*) and palms. Natural and induced fires keep this community as an open landscape, one which has been widely exploited for cattle and other farming activities.

4.4. Venezuelan-Guyanian Tepuis

These variegated savanna-like communities, found in Venezuela and Guyana (Fig. 1), are unique in their biotic composition, mostly because they grow in relative isolation on high tablelands called Tepuis (for example those of the Roraima Range; Cabrera and Willink 1980). These tableland communities tower up to 2000 m from the low Amazonian Basin forests and are separated, one from the next, by monumental gorges with almost vertical walls. A diverse flora, of about 8000 species, with high endemism (over half of the species) is found in this area; one example is the virtually endemic bromeliad genus *Navia* with 54 species. Biologically, the Venezuelan-Guyanan Tepuis are still poorly known.

4.5. Amazonian rain forest

This forest is found in the Orinoco and Amazon basins, mostly in Brazil, Peru, Bolivia, Ecuador, Guyana, Venezuela and Colombia (Fig. 1). In its pristine state, this vegetational type constituted the single most extensive mat of tropical rain forest in the world, occupying an area larger than India. Its distributional limits coincide well with those of the rubber tree *Hevea brasiliensis* (Cabrera and Willink 1980). Yearly thermal oscillation is minimal in the areas where this forest occurs, annual precipitation is from 2,000 to 4,500 mm, and humidity is high with little variation, although there is a definite increase in rainfall during a three-to-four month period.

Average canopy trees are about 30-40 metres high, although individual trees can grow up to 50 m or even more; dominance on the part of any plant species is negligible and this is also true for animal taxa. The low, undulating profile of the bottom of the Amazon Basin, situated only a few meters above sea level, determines that some areas are subject to seasonal flooding. In areas that flood, a Varzea forest develops, characterised by a more open appearance and understory composed of different species.

The fauna of the Amazon Basin has long been the paradigm of species richness. The high species diversity is due both to occurrence of many widespread taxa and substantial number of endemics. This makes the description of the Amazonian fauna quite difficult.

4.6. Cerrado forest

Almost confined to South-eastern Brazil, the Cerrado occupies an area roughly that of Mexico (2 million km²) and occurs in moderate heights, about 500 to 1,000 m above sea level (Fig. 1). Seasonality and the presence of a highly developed scrubby stratum with alternating open grassland are the outstanding features of this kind of vegetation. At least 25 species of trees may dispute dominance. A few Cactaceae and Bromeliaceae are found in the Cerrado. Although the arboreal stratum (up to 15 m in height) tends to be patchy, the Cerrado is very hard to traverse because of the thickness of the scrubby layer, responsible for its vernacular name (closed forest).

4.7. Caatinga

One of the more perplexing features of South America is the occurrence of definitely xerophytic vegetation in Brazil (Fig. 1), almost side by side with the rich and humid Atlantic rain forest. The Caatinga is narrowly separated from the moist forests of coastal eastern Brazil by mountains of moderate elevation, and is characteristically inhabited by medium-sized trees (e.g., *Bursera, Erythrina, Tabebuia* and *Spondias*). These are well known for their tolerance of long periodical droughts. There are a number of cacti, mostly of the chandelier type (e.g., *Cereus* and *Cephalocereus*) and also some others of the "Indian fig" type (*Opuntia*).

The Caatinga may become flooded in exceptionally rainy years while most of the time it suffers a prolonged drought which may last from early May to late September; when rain does occur, the nature of the soil (poorly developed and similar to the soils of some North African deserts), despite its potential fertility, will let most of the water pass, and, consequently, shortly after a downpour, the landscape will teem with life only to resume its usual and sometimes dramatic aridity in a few weeks.

4.8. Atlantic rain forest

The Atlantic rain forest occurs on the coastal slopes of the mountains of extreme eastern Brazil, where yearly rainfall may exceed 3500 mm (Fig. 1). This moist forest has thick, tall trees (e.g., *Sideroxylon, Pouteria, Cedrela* and *Tabebuia*) about 30-40 m in height. It differs from the Amazonian rain forest by its characteristically high occurrence of epiphytic plants, including bromeliads, orchids and ferns, which actually enhance the massive appearance of the vegetation (Cabrera and Willink 1980).

The high and nearly aseasonal occurrence of rainfall in this part of Brazil is caused chiefly by easterly winds related to warm oceanic currents such as the Brazilian Current and the South Atlantic Equatorial Anti-current.

When these warm, humid winds rise across the mountains of coastal Brazil, they cool and liberate most of their water. Having lost most of their moisture, the winds pass over the mountains. This phenomenon, known as orographic shadow, is partly responsible for the aridity of the nearby Caatinga.

4.9. Paraná rain forest

This is a complex of tropical to subtropical evergreen forests occurring in south-eastern Brazil, Paraguay and northern Argentina (Fig. 1), in areas where the annual amount of rain approaches 2000 mm. The maximum height of trees is about 30 m and these include the genera *Nectandra, Tabebuia, Halocalyx*, and *Cedrela* among others. There is no definite trend towards dominance of any given species. The understorey is usually dominated by bamboo (mainly of the genus *Chusquea*) and several species of tree-like ferns.

4.10. Chaco dry forest

The Chaco dry forest is an enormous mosaic of grasslands and woodlands that covers approximately one million square kilometers in southern Brazil, Bolivia, Paraguay, and Argentina. It grades into wetter forests to the north and desert scrub to the south. The climate is characterised by strong seasonality, with a well defined 4–5 month rainy season and a long drought. Most trees shed their leaves during the dry season, giving a very peculiar appearance to this forest. The Chaco dry forest has a high number of endemic species of plants and vertebrates. Unfortunately, large forest tracts have been severely disturbed by logging and cattle raising (Ceballos, in press).

5. BIOLOGICAL DIVERSITY

5.1. General trends in biodiversity

The American tropics have at least 1,100 species of mammals, 3,000 species of birds, 1,400 species of reptiles, 1000 species of amphibians, and thousands of species of freshwater fishes. A few countries that include Mexico, Colombia, Ecuador, Peru, and Brazil are consistently among the most biodiverse nations in the world (Tables 1 and 2; Figs. 6–9).

5.2. Diversity of mammals

The 1,100 or so mammal species in Tropical America comprise 25 per cent of the mammals in the world. Four countries in this region are among the

10 with the highest number of mammal species in the world (Table 1). Within Tropical America, the country with the highest number of species is Mexico (453), followed by Brazil (428), and Peru (410) (McNeely et al. 1990). The mammalian orders with the highest number of species are bats, rodents, edentates and carnivores (Table 2).

Table 1. Countries with the highest number of species of selected organisms (Modified from McNeely et al. 1990). Note that in all groups considered in the table, between 40 and 60 per cent of the top 10 countries are from Tropical America, and that Brazil, Mexico, and Colombia are consistently among the most biodiverse countries in the world.

	MAMMALS	BIRDS	AMPHIBIANS
1)	Indonesia (515)	Colombia (1721)	Brazil (516)
2)	Mexico (456)	Peru (1701)	Colombia (407)
3)	Brazil (428)	Brazil (1622)	Ecuador (358)
4)	Peru (410)	Indonesia (1519)	Mexico (282)
5)	Zaire (409)	Ecuador (1447)	Indonesia (270)
6)	China (394)	Venezuela (1275)	China (265)
7)	Colombia (359)	Bolivia (1250)	Peru (251)
8)	India (350)	India (1200)	Zaire (216)
9)	Uganda (311)	Malaysia (1200)	USA (205)
10)	Tanzania (310)	China (1195)	Venezuela (197)
	REPTILES	**ANGIOSPERMS**	
1)	Mexico (717)	Brazil (55,000)	
2)	Australia (686)	Colombia (45,000)	
3)	Indonesia (600)	China (27,000)	
4)	Brazil (467)	Mexico (25,000)	
5)	India (453)	Australia (23,000)	
6)	Colombia (383)	South Africa (21,000)	
7)	Ecuador (365)	Indonesia (20,000)	
8)	Peru (297)	Venezuela (20,000)	
9)	Malaysia (294)	Peru (20,000)	
10)	Thailand (282)	Former USSR (20,000)	

Table 2. Overall composition of the vertebrate fauna of Tropical America by major taxa, and differential contributions to their degree of endemicity. Those families whose occurrence outside tropical America is marginal are considered as "virtually endemic". Insular families endemic to the West Indies are included in this summary. In Odontoceti, only freshwater families are considered.

Class Order	Families	Endemic Families	% Endemics
AMPHIBIA			
Caudata	1	0	0
Salientia	12	7	58
Gymnophiona	3	1	33
Total	16	8	50
REPTILIA			
Chelonia	7	2	28
Crocodylia	2	0	0

Table 2. (Continued)

Class / Order	Families	Endemic Families	% Endemics
Amphisbaenia	1	0	0
Sauria	8	3	37
Serpentes	8	1	12
Total	26	6	23
AVES			
Tinamiformes	1	1	100
Rheiformes	1	1	100
Podicipediformes	1	0	0
Procellariiformes	1	0	0
Pelecaniformes	6	0	0
Ciconiiformes	5	1	20
Anseriformes	2	1	50
Falconiformes	4	0	0
Galliformes	4	3	75
Gruiformes	6	4	66
Charadriiformes	6	0	0
Columbiformes	1	0	0
Psittaciformes	1	0	0
Cuculiformes	1	0	0
Strigiformes	2	0	0
Caprimulgiformes	3	2	66
Apodiformes	2	1	50
Trogoniformes	1	0	0
Coraciiformes	3	2	66
Piciformes	5	3	60
Passeriformes	25	14	56
Total	81	33	40
MAMMALIA			
Marsupialia	3	2	66
Insectivora	2	1	50
Chiroptera	9	6	66
Primates	2	1	50
Xenarthra	4	4	100
Lagomorpha	1	0	0
Rodentia	17	13	76
Odontoceti	2	2	100
Carnivora	5	0	0
Sirenia	1	0	0
Perissodactyla	1	0	0
Artiodactyla	3	1	33
Total	50	30	60
GRAND TOTAL	173	77	44

Sources: Goin et al. (1978); Van Tyne and Berger (1976); Anderson and Jones (1984).

Figure 6a. The tapiro (*Tapirus bairdii*) is heavily hunted for hides and even for sport, because its meat is desirable only for some forest people.
Figure 6b. The river crocodile (*Crocodylus acutus*) attains a length of up to six metres, and its skin and meat are highly priced as are those of other allied species (Photos: G. Ceballos).

Figure 7a. The macaws (*Ara* spp.) started to be fancied as a pet after 1800 and gave rise to a flourishing market that has brought them to the verge of extinction.
Figure 7b. Notwithstanding their peculiar aspect, several species of iguanas, such as this *Ctenosaura pectinata*, are traditionally used as food by local people. The skin is also valued and even the eggs are eaten, with the consequence that, with fewer young being born, the species have become more endangered (Photos: G. Ceballos).

Figure 8a. The majestic jaguar (*Panthera onca*) is no more king of the jungles because of competition, hunting and devastation of land by Man (Photo: Fuluio Eccardi).
Figure 8b. Originally hunted by the local people with bow and arrow, the peccaries *Tayassu tajacu* have started to decline due to the widespread introduction of firearms in tropical countries (Photo: G. Ceballos).

Figure 9a. Thousands of boas (*Boa constrictor*) are collected every year in Tropical America, only to become luxury belts, ladies' shoes or wallets; others are sold to pet lovers around the world. A wise management of the species, including captive breeding, might help reduce the negative impacts on natural populations.

Figure 9b. Monkeys are plentiful in pristine forests of Tropical America. At least 13 species coexist in a small portion of the Caquetá River Valley in southern Colombia (Eisenberg 1989). Beside deforestation, hunting and trade have decimated some species such as the frugivorous spider monkey (*Ateles geoffroyi*) (Photos: G. Ceballos).

5.3. Birds

Perhaps one of the most interesting characteristics of the wildlife in Tropical America is the extraordinary diversity and beauty of its birds. Approximately 3,000 species of birds (30 per cent of the world's total) are found in the region. Colombia has the highest number (1,721) of birds in the world; indeed, six countries from Tropical America are among the 10 with the highest number of birds in the world (Table 1). Within the region, Colombia is followed in number of species by Perú (1,701), Brazil (1,622), Ecuador (1,447) and Venezuela (1,275).

5.4. Reptiles and amphibians

The herpetological fauna of Tropical America is not well known. There are vast regions that have hardly been surveyed, and many species new to science are described every year. Notwithstanding this, the herpetofauna of Tropical America is among the species-richest of the world. Nearly 4,000 species of amphibians are known throughout the world, and about 1,000 inhabit Tropical America, representing 25 per cent of the total (Cochran 1961).

Reptiles are a diversified group, particularly lizards and snakes. The world's species of both squamate groups has been estimated at nearly 6,500 (Schmidt and Inger 1957). From these, approximately 1,400 are native to tropical America (Peters et al. 1986) and represent 23.3 per cent of the world's total.

Mexico and Brazil have the highest number of reptile and amphibian species in the world, respectively. Five countries in terms of reptiles and six in terms of amphibians in Tropical America are among the 10 countries with the highest number of species of those groups in the world (Table 1).

6. DIVERSITY AT RISK: CONSERVATION PROBLEMS

6.1. Classifying species at risk

The impacts of human activities in the last few centuries has led to severe changes in natural ecosystems that have resulted in the extinction of many plant and animal species and threatened many more (Dorst 1972; Ehrlich and Ehrlich 1981). A major step in establishing conservation priorities in any region or country is to determine the conservation status of species.

An appropriate way to determine the conservation status of a species is by learning either its population size or the number of reproductive

individuals (i.e., its effective population size; Frankel and Soule 1981). Unfortunately, to get enough data to cover high numbers of species and large geographic areas is usually extremely expensive and time-consuming. To partially overcome these problems, conservation agencies have developed models and classification systems that include criteria that measure the biological vulnerability to extinction and the impacts of human activities on natural populations.

Several international conservation agencies compile data-bases about species at risk on a worldwide scale, including the International Union for Conservation of Nature and Natural Resources (IUCN), the US Fish and Wildlife Service, and the International Council for Bird Preservation. The classification method most widely used was developed by IUCN, utilising the population size or trends in other factors associated with the vulnerability to extinction. It classifies species in the following categories: Extinct, Endangered, Threatened or Vulnerable, Rare, and Indeterminate (Thomback and Jenkins 1982). Extinct species are taxa that have not been reported or recorded within the last 50 years or where there have been thorough surveys that have shown no individuals of the species. Endangered species are those taxa in danger of extinction, unlikely to survive if the factors causing their decline continue to operate. Threatened species are taxa likely to become endangered in the near future if the causal factors continue to depress their population. Fragile species are taxa with small populations, not endangered or threatened but at risk. Finally, indeterminate species are taxa known to belong to any of the above-mentioned categories but lacking enough information to assign them an appropriate conservation category.

6.2. Extinct and endangered species

In the last four centuries, approximately 226 species of vertebrates have become extinct throughout the world (Allen 1942; Dorst 1972). Unfortunately, the rate of extinction has increased dramatically in this century and it is likely that this trend will continue, at least for the next two or three decades. How such great losses of biotic diversity will affect the ecology and evolution of the earth's biota is unknown, but the result could be rather profound and catastrophic (Ceballos and Navarro in press; Ehrlich and Ehrlich 1981; Wilson 1988).

Problems of extinction of species and conservation of natural resources are most critical in tropical regions and developing countries. This is not only because such areas harbour most species on earth but also because they face tremendous social, economic, and political problems (e.g., Mares 1986; Wilson 1985). Although there is no general agreement about the rates of deforestation and species extinction in the tropical ecosystems throughout

the world, estimates of deforestation rates by the year 2000 fluctuate between 10 and 50 per cent. This could mean the loss of between 220,000 and 1,000,000 species (Ehrlich and Ehrlich 1981; Lugo 1988; Myers 1988). The American tropics are no exception. Hundreds of thousands of species are facing long-term conservation problems. Although estimates of the number of species that will become extinct by the year 2000 in this region vary greatly, they fluctuate between 100,000 and 500,000.

Information about the number, identity, and distribution of the species at risk in Tropical America is scanty. There are, however, regional conservation organisation compiling endangered species lists in many countries, including Mexico, Guatemala, Costa Rica, Panama, Colombia, Ecuador, Venezuela, Brazil and Peru (Coimbra-Filho 1972; Ceballos 1985; Ceballos and Navarro in press). Endangered species lists are available for most of the countries in Tropical America, but such lists are unconsciously biased towards the larger, better studied, and more appealing species. Smaller species such as invertebrates, rodents, and reptiles are usually ignored (Ceballos and Navarro in press; McNeely et al. 1990).

The number of threatened or endangered species has been growing almost exponentially during the last four decades. Although there is no general checklist including the majority of the species facing conservation problems in Tropical America, the information available gives a good idea of the problem.

Several species have become extinct in the Neotropics since the arrival of the Spanish "conquistadores" in the 16th century. The general causes of the demise of these and other species will be discussed in the following section. The precise number of the extinct species is not known, but at least 21 mammal species and 30 bird species have disappeared in historic times from Tropical America. The groups that have probably suffered most extinction are birds and rodents.

Few extinctions have been documented in continental ecosystems. Most mammalian extinctions occurred in the islands of the West Indies. For example, at least 19 species of small insectivores and rodents, including the Jamaican rice rat (*Oryzomys antillarum*), a solenodont (*Solenodon marcanoi*), and a hutia (*Geocapromys thoracatus*), disappeared within the last 100 years from some West Indies islands, probably because of competition with introduced rats and predation from introduced mongooses (Morgan and Woods 1986). Other larger mammals disappeared for different reasons. The Caribbean monk seal (*Monachus tropicalis*) was common in the Caribbean Sea until the last century, but it was heavily hunted for its meat and oil; very few survived by 1930, and the last was seen in 1953.

Several island bird species such as the Cuban military macaw (*Ara tricolor*), the Socorro dove (*Zenaida graysoni*) and the Jamaican nighthawk

(*Siphonorhis americanus*) became extinct in historic times. They disappeared after the establishment of permanent or temporal human settlements. For example, the Cuban military macaw was abundant in the Zapata swamp last century, but disappeared because of hunting and the destruction of its habitat. The last bird was seen in 1885 (Dorst 1972).

6.3. Causes of extinction

Modern extinctions associated with human activities are caused by many different factors; however, such factors can be ultimately classified as direct or indirect (Diamond 1984; Ceballos and Navarro, in press). The degree and scale of the perturbations caused by direct and indirect factors are quite different. Direct factors comprise all activities such as hunting and poisoning, specifically focused to capture or kill either a particular species or a set of similar species, with valuable or undesirable characteristics. Such activities usually have a devastating effect on the target species. In contrast, indirect factors such as pollution and habitat destruction are not specifically targeted at any species, but affect structural and functional characteristics of the environment. These usually have an impact on several species simultaneously (Ceballos and Navarro in press; Diamond 1984).

6.4. Direct factors: hunting and trade

Although information is scanty for the Neotropics, it is evident that direct factors such as commercial and subsistence hunting, trapping, trade of animals or their products, and destruction of predators and other "pest" species, have caused the decline of many vertebrate species. The wildlife trade, a multi-million dollar industry, is one of the principal industries in South America (Mares 1986). Capturing animal species for their skin, meat, or for trading them alive is a major threat. The number of animals captured each year to supply the trade is astonishing. For example, 5.4 million vertebrates of 25 species are legally exported annually from Argentina (Mares and Ojeda 1984). Trade has been particularly important in depleting populations of many species of monkeys, desyproctid rodents, deer, spotted cats, peccaries, tapirs, otters, macaws, Amazon parrots, song birds, crocodiles, iguanas and turtles.

The skin trade has particularly adverse effects on fur-bearing mammals and some reptiles, specially spotted cats, deer, otters, peccaries, turtles, crocodiles and snakes. The ocelot (*Felis pardalis*), the collared peccary (*Tayassu tajacu*) and the giant otter (*Pteronura brasiliensis*) are the most prominent mammals in the skin trade. From 1950 to 1965, more than 100,000 mammal skins were legally exported anually from Brazil including approximately 11,000 jaguar skins (Ojasti 1984). In Mexico, 1,280 jaguar

and 15,481 ocelot and margay skins were legally exported to the United States between 1968 and 1970. Over two million and one million hides of the collared peccary (*Tayassu tajacu*) and the white-lipped peccary (*Tayassu peccari*), respectively, were exported from Peru in 20 years. The impact of such high quotas on the distribution and population densities of the exploited species is tremendous. Many of the targeted species have already disappeared from regions where they were still common twenty years ago and several are on the brink of extinction (Robinson and Redford 1991).

Millions of crocodile, turtle, and snake skins or other products have been exported from Tropical America in this century. Many species have been hunted nearly to extinction throughout their geographic range. The caiman or yacare is the second most commonly exported reptile in the Neotropics. It is estimated that more than one million skins are exported annually just from Brazil, Bolivia, and Paraguay; major importing countries are the USA, Italy, Germany, Switzerland and Japan (Luxmoore et al. 1988). From 1976 to 1984, 146,000 yacare skins were exported from Argentina, a country where the distribution of this species is marginal (Cajal 1986). Hundreds of thousands of skins are still exported from countries in Central America, such as Guatemala and Honduras, where the species is almost extinct. Unfortunately, most trade in yacare is illegal, promoted by the high prices offered to the skins. Finished products are very expensive; wallets sell for $60-180, shoes for $475-600, and handbags for $375-1,000 (Luxmoore et al. 1988).

Trade in live animals is particularly bad for monkeys, birds such as macaws and Amazon parrots, and some reptiles. Between 1964 and 1974, an average 90,000 monkeys were legally exported from Colombia, Brazil, and Peru to the United States for biomedical research (Ojasti 1984). Millions of birds are annually exported to the United States, Europe, and Japan, including macaws, parrots, parakeets, seed-eaters, orioles, toucans, quetzals, jays, tanagers and raptors. It is estimated that Japan and the USA import two and one million wild birds, respectively, every year. The impact of trade on the populations of the exploited species is magnified by the fact that often only about 10 per cent of the mammals and birds captured in the wild arrive alive at their final destination. If we consider that legal trade is generally a minor percentage of the illegal trade, these numbers become even more dramatic. Although illegal trade has declined since the international ban on trade in endangered species, it is still a major problem in Latin America (Mares 1986; Mares and Ojeda 1984).

Hunting is a persistent problem affecting the long-term conservation of Neotropical species. The jaguar, white-lipped peccary, collared peccary, tapirs (*Tapirus bairdii* and *Tapirus terrestris*), curassows (*Crax* spp.), and other species have been locally depleted by commercial and subsistence

hunting (Table 3). Unfortunately, several critically endangered species are still legally hunted in many countries. In Mexico, hunting jaguars and other big game is illegal. However, illegal hunter guides may get up to U$10,000 for a jaguar hunt; similar situations occur in other countries such as Guatemala, Colombia, Brazil, Peru, and Argentina.

Table 3. Principal large mammals (> 5kg) hunted for meat in Neotropical forests according to their contribution in local diets, market price, number sold and consumer preference (Modified from Ojasti 1984). Highest rank is one and lowest is five.

	RANK (1 to 5)			
	Local diet	Market price	Amount consumed	Consumer preference
White-lipped peccary (*Tayassu tajacu*)	1	1	4	4
South American tapir (*Tapirus terrestris*)	4	5	5	3
Collared peccary (*Tayassu tajacu*)	3	2	1	5
Brocket deer (*Mazama americana*)	5	4	3	2
Agouti (*Agouti paca*)	2	3	2	1

Rural and Indian populations in Latin America rely heavily on the meat of wild animals to complement their diets; indeed, in many regions, wild animals are the only source of animal protein (Meggers 1976; Ojasti 1984). Intensive hunting pressures have caused the decline and local extirpation of many populations of mammals and birds (Robinson and Redford 1991).

6.5. Indirect factors: habitat modifications

Changes in the physical and biological characteristics of the environment are now by far the leading cause of extinctions throughout the world. The factors of habitat disturbance are habitat destruction, introduction of exotic species, pollution, and secondary extinctions as a result of other extinctions (Diamond 1984; Ceballos and Navarro in press).

The high rates of habitat modification and destruction in Tropical America are mainly related to agriculture, cattle raising and forestry. Many regions have been subject to intensive land-use, promoted as a goal of the agricultural policies in Latin America. Unfortunately, such practices have produced massive changes in the natural ecosystems, and in many cases,

without the economic benefits expected (Toledo et al. 1989). Although there is no general agreement about the rates of deforestation in tropical regions of the world, it is clear that tropical ecosystems face tremendous pressures. In general, 40 per cent of the land that used to support tropical forests throughout the world now lacks them (Wilson 1988). Estimates of deforestation rates in the Neotropics range from 17 to 67 per cent between 1980 and 2000; a deforestation rate of approximately one per cent per year in the best scenario and a three per cent per year in the worst case.

There is a general awareness of the deforestation problems of the tropical rain forest, specially in the Amazon and Orinoco basins where large tracks of virgin forest are destroyed every year. For example, in the state of Rondonia (southern Brazil) the population increased from 110,000 to 1,000,000 between 1975 and 1986. In the same period, the deforested area increased from 1,250 km^2 to 17,000 km^2. Large-scale deforestation of the rain forests also occurs in Peru, Ecuador, Colombia, and Venezuela; in Central America, tropical rain forests have disappeared from much of its area of distribution. Presently, the only large track relatively unspoiled is found in southern Mexico, Guatemala and Belize.

Unfortunately, other less extensive habitats face more severe deforestation problems, perhaps total destruction. Best examples are the Atlantic forest in eastern Brazil, the western forest of Ecuador, and the tropical deciduous forest in Central America, where 99, 95, and 98 per cent, respectively, of the pristine vegetation has already disappeared (Janzen 1988; Myers 1988; Wilson 1988).

6.6. Indirect factors: pollution

A major problem affecting the environment in Tropical America is the extensive and intensive use of many kinds of fertilisers and pesticides such as DDT and compound 1080, prohibited in developed countries. Extensive areas and thousands of rivers, streams, and lakes have been polluted by detergents, pesticides and industrial (e.g., lead, mercury) and urban wastes. A dramatic example of the effects of pollutants in the natural ecosystems has been the disappearance of raptor birds, predators and insectivore bats in the last 25 years (e.g., Geluso et al. 1976).

6.7. Indirect effects: introduction of exotic species

Man has also had an important negative effect on tropical American wildlife because of the introduction of foreign animals and plants. Many species of mammals such as cats, pigs, goats, and commensal rats and mice that have been accidentally or deliberately introduced in islands and other ecosystems, now pose a major threat for the survival of native species. It is clear that

introduced animals were one of the major causes of extinctions until recent decades.

7. CONSERVATION OF WILDLIFE IN TROPICAL AMERICA

"South America's problems regarding the use of natural resources are a result of historical, sociological, economic, and scientific factors. Most countries in South America have done a great deal to encourage conservation efforts, but the magnitude of the problem is well beyond their limited economic means to solve" (Mares 1986).

7.1. Social and economic factors

The conservation of the biological resources of Tropical America is extremely complex and is highly dependent on a profound scientific knowledge and a realistic understanding of the social and economical needs of its heterogeneous human inhabitants. Unfortunately, the exploitation and management of natural resources in Tropical American countries is usually based on political decisions rather than on scientific data.

The economies of all countries in Tropical America are burdened by huge external and internal debts. For example, Brazil and Mexico have the largest external debts in the world, owing other countries the staggering amounts of $100 and $80 billion, respectively. With the predominantly high interest rates in the world market, Mexico paid $80 billion between 1986 and 1989 to service its debt; however, its external debt did not decrease but increased. It is unlikely that any country will under such circumstances devote much financial resources for conservation. Any real hope of conservation of biodiversity in Tropical America must rest on changes in the global economy.

One of the reasons for the weakness of the economies of these so-called Third World countries is that they are based on exports of raw materials, and many of the determinants of the events which threaten the long-term preservation of their biological resources are to be found well beyond the boundaries of Tropical America. Most countries in Tropical America face high foreign-consumer pressures for the export of forest products. This doubly affects the region because there is no significant profit for local workers, hunters and the like. This, coupled with the increasing destructive capabilities of man because of readily available heavy machinery and new building techniques, designed to cope with industrial needs and the increasing demand for electrical power or road communications among other services, has caused tremendous negative impacts on the regional natural resources.

7.2. Political factors

Internally, conservation problems in Tropical America are strongly related to bad administration and increased demands for services associated with high population growth rates. It is not infrequent that some catastrophic experiences of man-induced habitat alteration have been raised by political action, taken to provide hungry or angry sectors with land. In many cases, large areas have been cleared and granted without consideration for the quality of land; tropical forests usually grow on poor soils, ill-suited for agricultural purposes. The future cost of political improvisation can be extremely high.

On the other hand, many governments in Tropical American countries are still plagued with corruption and lack of democracy. Fortunately, in the last few years there has been a trend towards more democratic governments throughout the region.

7.3. Education and scientific knowledge

A basic problem in the conservation of Tropical America's natural resources is the lack of education at all social levels and the small size of local scientific communities. In order to have a strong positive impact on the preservation of the regional biodiversity, it is necessary to implement national conservation plans that teach people from all social classes the importance of conservation and their responsibility towards their natural heritage. However, even under the best of circumstances, education for the preservation of biological diversity will not be possible with the limited financial resources of these countries. That responsibility should involve national and international efforts (Mares 1986).

On the other hand, there should be both national and international efforts to promote and encourage scientific studies of the natural resources of the area, to provide alternative ways of using them rationally. Not much time is left, but there is no way to success without strong scientific knowledge. Conservation-oriented research should evolve action plans on studies on taxonomy, biogeography, ecology and other scientific disciplines in relation to the social and economic problems of the area and people. The political environment in which specific conservation problems are to be treated and conservation measure implimented should also be stable.

7.4. Legislation, national parks, and reserves

Legislation to protect and regulate wildlife exploitation is adequate in most countries in Tropical America, but law enforcement is difficult, mainly because of lack of funds, trained personnel, and educational programmes.

Tropical American countries have done a great deal to encourage conservation, and 260 parks and reserves, covering approximately 500,000 km² (around three per cent of the continental land) have been established. This represents three times as much land protected as in the USA (Mares 1986). However, most protected areas have problems of land ownership, agriculture, cattle grazing, hunting, deforestation, fires, and illegal trade in fauna and flora.

Protected areas, even those free of the problems mentioned above, are not sufficient to preserve most endangered species, mainly because of size constraints. In this respect, a key point for conservation is to rationally manage disturbed (i.e. exploited) habitats to ensure their conservation and regeneration, to prevent protected areas from becoming isolated.

7.5. Conclusion

As we have seen in this chapter, conservation of wildlife in Tropical America is not a simple task. Coordinated work by biologists, planners, businessmen, politicians and the public is required to ensure a lasting result.

No sustainable economic and social development is possible through depletion of the natural resources of a given region, not to say the world. We need to be aware that man is the only species of mammal that has invaded almost every part of the globe in just a few thousand years; and that thereafter its technological power has increased dramatically in the last 200 years. The question is: How long can he continue to ask from the earth more than it can offer? The abuse of wildlife is a painful lesson which has to be learned—the sooner the better.

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