

PRIORITIES FOR CONSERVATION OF THE BIODIVERSITY
IN THE COLOMBIAN ANDES

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PREFACE

The present paper is written for the 1991 IUBS-Tropical Mountain Ecosystems seminar, to be held from the 9th till the 15th of December 1991 at the Universidad de Cauca and the Fundación Universitaria de Popayán, in Popayán, Colombia. The international seminar on "Tropical Mountain Ecosystem Functioning in America and Africa in Relation to Biodiversity and Global Change" will be a meeting point for experts dealing with African and Latin American mountain ecosystems, especially on the subjects of biodiversity, ecological processes, global change and wise land management. The seminar is within the scope of the IUBS "Decade of the Tropics" programme (Solbrig and Golley, 1983) and the International Program of Research on Tropical Mountain Ecology (Monasterio *et al.*, 1987).

This paper, the conclusions and recommendations it contains, need to be discussed further, *e.g.* by the specialists gathered at the IUBS-TME seminar. To guide or initiate this discussion, the conclusions and recommendations of this study might be interpreted as a draft motion addressed to the Colombian government, which aims at informing the Colombian authorities to make additional and substantial conservation efforts in the Andes. Further discussion could possibly take place in the IVth World Congress on National Parks and Protected Areas, scheduled for February 1992 in Caracas, Venezuela. This congress will review the whole question of the role of parks and other conservation areas in conserving global biological diversity. An indication of the 'scope' of the congress is given by the shift during the last years from the traditional protected area approach towards the wider context of multi-purpose land management. This recent approach sees the conservation of biological diversity as one of the most important general objectives of such management of rural areas. The "Biosphere Reserve" concept of UNESCO's Man and the Biosphere Programme (MAB)

seems to fit into this approach, and might be a useful concept for implementation of priority areas for conservation in the context of the present study.

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The information in this paper is not based on the author's own observations and research, but is gathered from available literature. The conclusions and recommendations, however, are the author's opinions.

H.P. van Velzen, November 1991.



FOREWORD

*The Museum of Natural History of the Universidad del Cauca is pleased to present this special issue of **Novedades Colombianas**; its content was given as working material to the participants of the "International Seminar on Tropical Mountain Ecosystem Functioning in America and Africa in relation to Biodiversity and Global Change" held in Popayán in December of 1991.*

The document, prepared by Dr. H. P. Van Velzen, is a significant and timely contribution to the conservation of the biological megadiversity of the Colombian Andes, whose process of human intervention is highly distressing. Most of the original vegetal cover has all but disappeared from the mountains of the country, only to give way to agro-pastoral programs that do not take into consideration wild flora and fauna. Certain types of natural vegetation, such as subandean forest and xerophytic enclaves, have been dramatically intervened; unfortunately, there are no protected areas to guarantee the survival of the species typical to those ecosystems.

It is necessary and urgent to carry out research in order to know better the natural resources of the andean region; so that the lines of development can be traced from a scientific basis, compromising the benefit and conservation of those resources.

The bilingual edition of this document has been made possible by the financial support of the Dutch Embassy. It is aimed to contribute to an awareness of the importance of conserving the existing Biodiversity, one of the most valuable assets of the country.

Comments and contributions to the document are welcomed.

INTRODUCTION

The severe threats to the tropical mountain ecosystems in general and that of the northern Andes in particular, necessitate action to achieve the conservation of these vulnerable areas. This study will deal with the subject of nature and biodiversity conservation, i.e. the protection of species and habitat in the Colombian Andes. The central problem to be assessed here is: why establish conservation areas in the region? Other problems are: where and how to establish these conservation areas? What ecological criteria need to be fulfilled to get recognition for the proposals, first by the Colombian authorities and second by the international organizations?

The first aim of this study is to provide (preliminary) general clues for the rationalization and implementation of a necessary conservation action plan for the Colombian Andes region. This will be done by providing recent insights on the subjects of nature conservation and the selection of priority areas for conservation, as agreed upon by the International Union for Conservation of Nature and Natural Resources (IUCN), the world's leading conservation organization. Examples of different floral and faunal groups subject to such selection are given. Special attention will be paid to endemic species, threatened species and habitats and centres of speciation. The information on all these subjects will be synthesized, and preliminary priority areas will be prepared.

I. THE COLOMBIAN ANDES

Topography and orogenesis

The Colombian Andes forms part of the northern Andes, i.e. north of the Huanca-bamba Depression in southern Ecuador and northern Peru, where the Andes drops beneath the 2000 m alt. contour. This mountain depression separates the northern Andean phytogeographical province with páramo vegetation at high altitudes, from the

southern Andean phytogeographical province with puna vegetation.

The Colombian Andes is constituted by three Cordilleras, which diverge toward the north and are separated by deep valleys (fig. 1). Two of them, the Cordillera Central and Occidental, are prolongations of the Ecuadorian Andes. The Cordillera Oriental divides northward into the Sierra de Perijá and the Cordillera de Mérida (the former on the Venezuelan border and the latter completely on Venezuelan territory). Finally, there is an isolated part in the north, the Sierra Nevada de Santa Marta, reaching 5775 m, separated from the Sierra de Perijá by the Cesar Depression.

While some 15 million years ago (during the Miocene) hills or mountains up to 2000 m alt. may already have existed, the principal upheaval of the northern Andes to its present elevations took place during the Pliocene, from about 5 million to 3 million years ago (Van der Hammen *et al.*, 1973; Van der Hammen and Cleef, 1986; Van der Hammen, 1989, 1991; Kroonenberg *et al.*, 1990). It created a new environment on the isolated South American continent. About 4-3 million years ago, North and South America were joined by the Isthmus of Panama and a great interchange of plants and animals began, profoundly altering the biota of the Americas (Stehli and Webb, 1985).

The main northern Andean range is the Cordillera Oriental, which is extremely large and complicated. It extends about 1200 km from the Nudo de los Pastos to the northern part of the Sierra de Perijá, and reaches a width of 200 km. It has an extensive range of páramo areas above 3000 m up to 4200 m alt., and even much higher massifs such as the Sierra Nevada del Cocuy (5493 m) and the Nevado de Sumapaz (4560 m). The main part of the Cordillera Oriental from the low and narrow northern extremes, south of the Sierra de Perijá, to Páramo de Tamá and from there to Páramo de Sumapaz, is about 570 km long. From about 3.7°N south to 2°N there are no páramos. The eastern slopes of the Cordillera Oriental pass into

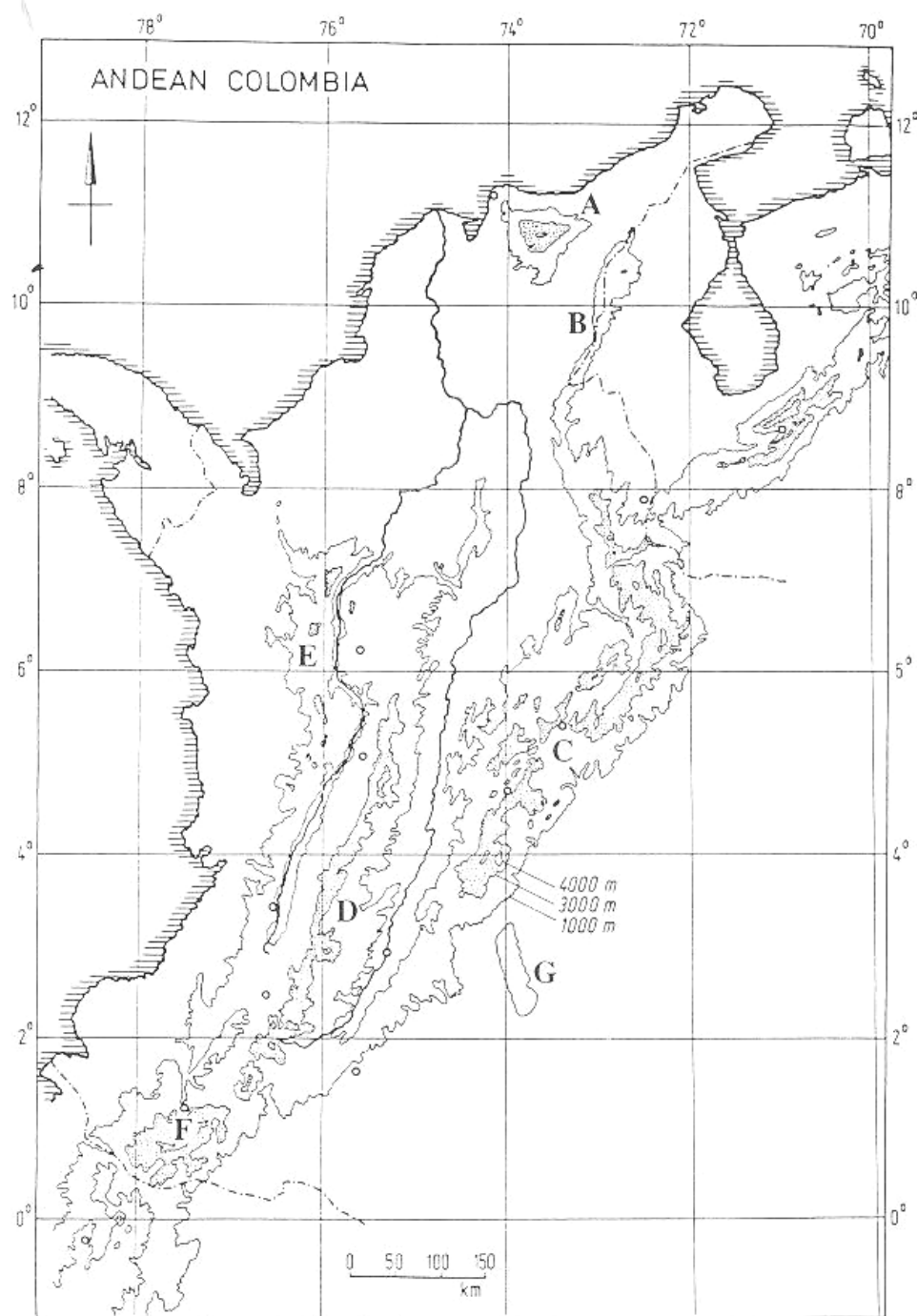


Fig. 1. Major elevational features in Colombia. A. Sierra Nevada de Santa Marta; B. Sierra de Perijá; C. Cordillera Oriental; D. Cordillera Central; E. Cordillera Occidental; F. Nudo de los Pastos; G. Serranía de la Macarena.

the lowland areas of the Llanos, north of the Serranía de la Macarena, and into the Upper Amazonian lowlands, south of La Macarena.

The area where the Cordillera Oriental meets the Cordillera Central is somewhat below 2°N. It is the region of the Páramo de las Papas or the "Macizo Colombiano". The Cordillera Central is a huge area, 750 km long from the Nudo de los Pastos and about 100 km in width. It is above 3000 m in altitude and includes several of the highest mountains of Colombia: Nevado del Huila, 5750 m; Rufz, 5300 m; Tolima, 5215 m; Quindío, 5150 m; Santa Isabel, 5100 m; Puracé, 4800 m. During the Pliocene and the Pleistocene, volcanic activity was a factor of considerable importance in the Cordillera Central. The Cordilleras Central and Oriental are separated by the valley of Río Magdalena.

The so-called Troncal-Sur of the Central Cordillera, or the Nudo de los Pastos, continues from the Páramo de las Papas southward across the volcanic region of Pasto, Cumbal (4764 m), Tulcán, and Chiles of southern Colombia and northern Ecuador south to the Páramos del Angel to about 0°30'N.

The Cordillera Occidental is separated from the Cordillera Central by the valleys of Río Cauca and Río Patía. Volcanic activities in the past have formed bridges between both Cordilleras. It extends for about 650 km northward from the Nudo de los Pastos and is very narrow (less than 50 km). Although it has some very high peaks (Tatamá, 3950 m; Frontino, 4083 m; Paramillo, 3960 m), there are only some scattered páramo patches, i.e. in the the Nudo de Paramillo, the northern extremity of the Cordillera Occidental. The western slopes of the Cordillera Occidental pass into the Chocó lowland biogeographic region.

Vegetation zonation

In the northern Andes the following vegetation zones can be distinguished as based on the initial subdivision of

Cuatrecasas (1934, 1958; Van der Hammen *et al.*, 1983, 1984, 1989; Van der Hammen and Cleef, 1986; Rangel, 1991): lowland tropical forest (0-1000 m alt.); Subandean (lower montane) tropical forest (1000-2300 m alt.); Andean (upper montane) tropical forest (2300-3200/3600 m alt.); high Andean forest (3000/3500-3500/3900 m alt.); páramo (above 3200/3900 m alt.). The limits of the vegetation zones may differ considerably (as indicated), according to a difference in local conditions (temperature, humidity, wind protection). The transition of the Subandean to the Andean forest zone corresponds approximately with the lowermost boundary of (occasional) night frost occurrence. The upper forest limit fluctuates between 3000 and 4000 m alt., but the uppermost trees, determined primarily by temperature, may occur up to 4300 m alt. Normally, the forest limits on the relatively humid slopes are slightly higher than on the relatively dry inter-Andean slopes.

The páramo is estimated to cover about 2% of the surface area in Colombia. In general it can be differentiated in three zones (Cuatrecasas, 1958; Cleef, 1981; Sturm and Rangel, 1985; Van der Hammen and Cleef, 1986; Rangel, 1991): subpáramo (forest limit-3400/3900 m alt.), grass páramo (3400/3900-4200/4500 m alt.), and superpáramo (4200/4500-nival belt about 4800/5000 m alt.). Climatically humid páramos are rich in bamboos (*Chusquea* spp.) and bogs, while climatically dry páramos are more frequently dominated by bunch grasses (*Calamagrostis* spp.).

During the Pleistocene glacial-interglacial cycles, the different vegetation zones shifted considerably (Van der Hammen, 1974, 1989; Van der Hammen and Cleef, 1986; Hooghiemstra, 1984, 1989; Hooghiemstra and Sarmiento, 1991). During the glacial phases, when temperature dropped about 8°C high in the Andean mountains, the upper forest line descended 1200 m or more, and consequently the lowermost part of the páramo belt became located at an altitude of less than 2000 m (in the tropical lowlands temperatures dropped possibly only some 4

(± 2)°C, but evidence is not conclusive; Van der Hammen, *pers. comm.*). Accordingly, the altitudinal vegetation zones were compressed and moved downward. During interglacial periods the forest extended slope upward again, reducing the area of páramo vegetation. The Pliocene orogenetic processes, the evolving landbridge in the Late Pliocene between the North and South American continents and the Pleistocene glacial-interglacial cycles, had serious consequences for the Andean floral and faunal composition, species distribution patterns, evolution, speciation and diversity.

II. CRITERIA FOR SELECTION OF CONSERVATION AREAS

Introductory remarks

To be able to point out the location of potential new reserves in the Colombian Andes, we need to find a set of objectives or criteria against which these choices can be measured and judged or evaluated. An important objective of the International Union for Conservation of Nature and Natural Resources (IUCN), is to catalyze and coordinate conservation of species and genetic diversity throughout the world. The principal focus is on those species whose survival is threatened or which are of special ecological or economic importance. The establishment and management of protected areas, in this respect, is seen as a means for conserving samples of the world's ecological diversity.

However, the protection of biological diversity does imply more than just the establishment of a protected areas system. It also requires sustainable use of natural resources and an integrated approach of land management in areas which are already under human influence. It still remains very important to deal separately with the specific subject of protected areas establishment. Although there is at least some international agreement to preserve and protect the world's genetic resources and biological di-

versity (e.g. the World Charter for Nature), there is no generally accepted scheme for establishing priorities for the conservation of biological diversity. This entirely depends on the perspectives, values, and goals of the individuals, organization, institution or nations involved in biodiversity protection, and the resources at their disposal for dealing with conservation priorities.

Yet there are at least the following criteria for setting biodiversity conservation priorities (e.g. Saavedra and Freese, draft manuscript, 1985; Reid and Miller, 1989; McNeely *et al.*, 1990): (1) diversity of species and habitats; (2) species endemism (taxonomic distinctiveness) and habitat uniqueness; (3) level of threat (severity and imminence of disturbance); (4) utility. These criteria need further examination for the purpose of rational conservation planning.

Species and habitat diversity

It seems obvious that the best conservation policy is to conserve areas of maximum biological diversity. These are the areas with the relatively greatest total number of different species. Even though the total number of species present may not be known with great accuracy, protection areas have to be established in evidently species-rich areas (McNeely *et al.*, 1990: p.102). The criterion of species diversity per se does not take into consideration evenness and information on rarity and commonness (species abundance). All species are treated as taxonomically equivalent and as equal units for conservation purposes.

Strictly connected with species diversity is habitat diversity. The latter is the number of intact habitats which forms the abiotic environment of the populations of different species in a single geographic region. Species diversity differs between different habitats. Habitats with a more complex or differentiated structure or physiognomy (stratification) contain more species than do 'simpler' habitats. Furthermore, each particular species tends to occur only in certain habitats, because each species must occupy

a distinct niche. This niche specialization causes species diversity to increase with niche or resource diversity, and thus with habitat diversity (Diamond, 1988).

In general, species diversity tends to decrease along an altitudinal gradient, e.g. from the tropical lowland rainforest towards the perpetual snowcap on the summit of a high Andean mountain. At least three important factors contribute to this phenomenon (Diamond, *op cit.*): (1) decrease in habitat structural complexity (physiognomy) and consequently in habitat diversity; (2) decrease in productivity (from medium-low elevations upwards), reinforcing the effect of the first component; (3) continuous decrease in area on conical mountains with altitude, causing less available space and habitat for less species. Some parts of the Andes though have a more trapezoidal shape, with a broad plateau at high elevations (Altiplano), so that the area actually increases and species diversity is relatively great. These general considerations need to be kept in mind when the species diversity of different floral and faunal taxa along the altitudinal gradient in the Colombian Andes is reviewed (Chapters IV and V).

Species and habitat distinctiveness

Besides maintaining the highest number of habitats and species, the more distinctive elements of biodiversity should receive high priority. This implicates that the taxonomic position of a particular species also needs to be taken into consideration. For instance a monotypic species, or a species that is the only representative of a higher taxon (genus, family, order), deserves more protection than a subspecies of a polymorph and widespread species. Especially endemic species, being species restricted to a relatively small geographic region, deserve our full attention. This is because areas with high endemism often have single populations of the particular endemic species. Thus, the protection of a community with many endemic species is a greater contribution to the conservation of biodiversity than

the protection of a community with many widespread species. Similarly, habitats that are unique, rare or that contain numerous endemic species deserve higher priority than habitats which are widespread or contain species that are common elsewhere.

Taxonomic distinctiveness can best be measured by cladistic methods. Vane-Wright *et al.* (*in press*) discuss the idea that meaningful measurements of diversity of taxa can be developed, in which both taxonomic rank as well as species number (the first criterion) are taken into account, and that these measurements can be applied to the assessment of conservation priorities. They state that by applying the taxic weighting procedure, the emphasis on endemics (species restricted to just one of the sample areas) can be removed, while still employing what they call "taxonomic complementarity". This is the procedure in which, after an area of high endemism is set aside, the species included in that area are not weighted any more, and the next area is chosen basically on the remaining fauna ("taxonomic or reduced complement") with the highest number of endemics, and all additional non-endemics contained in that area. This procedure is repeated until the total complement is reached.

The problems inherent in their approach are that a single species concept among taxonomists does not exist, that many taxa, especially in the tropics are insufficiently known, that their classification is uncertain, and that relatively very little is known on the biogeography of species. These factors make selection of potential protection areas in the tropics, by taxic weighting very hard to justify. Vane-Wright *et al.* (*ibid.*) themselves pointed out that the 'primary analysis' involving the identification of priority areas on a global scale, needs to be based on those species groups of flora and fauna which are relatively well-known, or which can easily be studied.

A relatively easy and probably reliable approach is that centres of endemism seem to coincide with centres of species richness. Although it is not a priori certain that high

concentrations of endemism coincide with areas of exceptionally high diversity, for Terborgh and Winter (1983) this question seems irrelevant, "for it is the distinctive character of the faunas of centres of endemism that is of interest, not diversity per se". Diamond (1985) examined the distribution patterns of forest birds in tropical Africa, and concluded that to a large degree, centres of species richness and of endemism do coincide. Brown (1982), however, revealed that regional endemism and species diversity are principally very different phenomena as far as the butterflies *Heliconiini* and *Ithomiinae* are concerned. Species diversity in these Lepidoptera is strongly correlated with present ecological conditions and tends to reach maximum not in the centres of endemism but in isolated points near the peripheries of the endemic centres. On the other hand there is a correlation of centres of endemism with paleoecology, i.e. phytogeographical studies revealed that centres of endemism (and species diversity) coincide in general with postulated Pleistocene forest refugia. Cracraft (1985) suggests that the concept of areas of endemism is more general than the Pleistocene forest refuge concept: most, if not all, refugia are areas of endemism, but not all areas of endemism are forest refugia.

Despite the possible objections to the concept, the location of the postulated Pleistocene forest refugia might be a useful concept in selecting priority areas for conservation. Refuge areas that may be rich in endemic species resulted from climatic changes during the Pleistocene, when climatically cool and dry glacial periods alternated with warmer and more humid interglacial periods. The refugia areas remained forested during the arid phases of the ice ages, and were thus periodically reduced to 'islands' surrounded by savanna vegetation (Prance, 1982). During the dry glacial periods, while the forests retreated, the páramo vegetation extended some 1000 m downward or even more. In contrast, during the interglacials while the forest vegetation was expanding again, the páramos were reduced

to isolated patches (páramo refugia) on the highest altitudes (Van der Hammen and Cleef, 1986; Van der Hammen, 1989). Both forest refugia during the glacial stages and páramo refugia during the interglacial stages are responsible for the isolation of populations. This enabled the occurrence of genetic differentiation of the separated populations and to allopatric speciation.

Barrett (1980) provided a map of the proposed locations of the Pleistocene forest refugia in Amazonia, based on the distribution patterns of various faunal and floral species, i.e. birds, lizards, plants and butterflies. Some of these forest refugia also occur in the "hot spots" (sensu Myers, 1988), which are areas of endemism common to a number of different groups. Many forest refugia however, don't seem to overlap completely, and the climatic refugium concept does not always provide a straightforward explanation for the centres of species diversity and endemism. Moreover, while the refugia are selected only on the criteria of highest endemism and species diversity, and the compilation of refugia is often based on species distributions, crucial to this selection is the individual species concept (Prance, 1982). As mentioned before, it is hard to obtain a similar species concept among taxonomists.

Despite the probable shortcomings, the recognition of centres of species diversity, areas of endemism, or 'critical faunas and floras' for particular taxonomic groups and Pleistocene refugia might be a useful tool to determine the priority areas for conservation, in a first large-scale inventory.

Species and habitat threat

The most threatened species, ecosystems and habitats need protection first. The threat to biological diversity is influenced by how widespread species are (i.e. the level of endemism of the species), how common they are in their habitat(s) (i.e. the abundance of the species) and by how intense the human caused disturbance in a particular area is (e.g. deforestation, land conversion, soil

degradation, erosion, environmental pollution).

The WWF-US (World Wildlife Fund) distinguishes between the severity and the imminence of disturbance. Severity indicates the rate of modification of species populations and ecological processes. Imminence indicates how soon a particular area will be affected by human intervention. High priority will be given to areas which are intact but at imminent threat to human disturbance (Saavedra and Freese, draft manuscript, 1985). Furthermore, it seems very reasonable to concentrate conservation efforts on the few remaining undisturbed 'wilderness' areas, which probably encompass no more than 5-10% of the former (sub)Andean forests (according to Henderson *et al.*, 1991).

The status of threat to the different species is generally expressed as one of the IUCN threatened species categories: Extinct, Endangered, Vulnerable, Rare, Indeterminate or Insufficiently Known. Because of limited resources it is necessary to define priorities based on solid inventories of organisms which may be endangered, vulnerable or rare. Because the urgency to identify the sites for protection is great, the task will have to be based on the few relatively well-known groups of organisms, e.g. birds (see Chapter V).

Utility

Utility or usefulness is a criterion which certainly plays a role in setting priorities for conservation, although it is very hard to decide what is useful for local and global communities, for current and future generations. Furthermore, decisions based on utility will almost certainly reflect implicit value judgments.

The fact that a particular site contains an important gene pool of plants of (potential) value to man will undoubtedly play an important stimulating role in the selection of areas for conservation purposes.

The use of safeguarding areas of montane forests in the Colombian Andes is clear. The

protection of ecosystems that play an important or even critical role as the watershed for agricultural grounds, villages, or irrigation projects is easier to justify than the conservation of ecosystems that provide only indirect services to humanity. Priority should be given to the wettest Andean slopes, which are more susceptible to degradation, i.e. erosion due to human activities. This is specifically the case at the altitudes between 800 and 1800 m in western and eastern Colombia.

Furthermore the potential for scientific, educational, recreational and tourism activities are criteria which certainly need to be considered for the evaluation of each conservation area. Priority could also be given to candidate national parks with potential to serve as demonstration sites of the values and functions of conservation areas (Barrett, 1980).

Rational conservation planning

The planning and implementation of protection sites need to incorporate the criteria of species richness, taxonomic distinctiveness, habitat diversity and uniqueness, rate of threat (including the availability of undisturbed areas), and utility, as described above. These criteria need to be merged in a process of rational conservation planning. Such a conservation strategy is described by Burley (1988) as the "gap analysis concept". This process evolves along a number of stages. The first stage is the identification and classification of the various elements of biological diversity. The second stage is the examination of the existing and proposed systems of protected areas and other land management units that help conserve biological diversity. Finally, the determination of the unrepresented or poorly represented elements (e.g. major ecosystems, vegetation types, habitat types, endemic species) in the existing system of conservation areas.

The underlying concept of the gap analysis process is that it is assumed that much or most of the biological diversity will be protected if it is assured that all vegetation types

are well represented in a system of conservation areas, though Burley states that in addition to this process of conservation planning, special efforts must be made to ensure that particularly critical species and ecosystem types get protection, i.e. the remaining still undisturbed but vastly threatened 'wilderness' areas.

III. STATE OF THE COLOMBIAN NATURAL HABITAT, WITH SPECIAL REFERENCE TO THE ANDES

Biodiversity and species threat

Colombia is called a "megadiversity country". With an area of 1,138,914 sq. km, or 0.77% of the emerged continental masses, Colombia has about 10% of the total flora and fauna of the planet. Megadiversity countries, a concept developed by Mittermeier (1988), which have the highest species diversity in the world, are thus critical to the survival of the majority of the world's biological diversity, and at the same time have a very high portion of threatened species. Mittermeier states that approximately 50 to 80% of the world's total bio-

logical diversity will be found in some 6 to 12 tropical countries. The first six of these countries he mentions, emerging from preliminary analysis, are Brazil, Colombia, Mexico, Zaire, Madagascar, and Indonesia. The number of species for selected organisms, as well as the number of threatened species in Colombia is outlined in **table 1**.

Nature destruction

Colombia is undergoing a continued loss of natural vegetation. Agricultural expansion in general and coffee production in particular, combined with rapid population growth centred in the Andes, have led to substantial rates of deforestation in the montane vegetation. Due to great human pressures there are a whole series of interdependent and mutually reinforcing problems in the mountainous zones: degradation of the páramos due to overgrazing and excessive burning; elimination of the montane forests; habitat destruction; degradation of the river basins; diminished water resources during the dry season; soil erosion; floods in valleys and cities; pressures on the system of protected areas, etc. (see e.g. Monasterio *et al.*, 1987).

Table 1. Species diversity in Colombia and position compared to species diversities over other countries of the world (acc. to IUCN, 1990b). Threatened species belong to one of the following IUCN categories: Extinct, Endangered, Vulnerable, Rare or Indeterminate (IUCN, 1990a).

Faunal and floral species groups	Total No. of species	No. threatened species	Position on world rank list
Mammals	367	25	7
Birds	1742 *	28 (105) **	1
Reptiles	383	24	6
Amphibians	375	?	2
Swallowtail Butterflies	59	?	6
Angiosperms	45-50,000	?	2
Bryophytes	1500	?	?

* For birds the number of species are acc. to Negret and Fernández (*pers. comm.*), and include 7 new species for isla Gorgona, described by Orúz (1990).

** The number of Insufficiently Known categories of threat, plus numbers of near-threatened species (acc. to Collar and Andrew, 1988) are given in parentheses. The number of threatened bird species is probably much higher (187 spp. according to Negret and Fernández, *pers. comm.*).

Terborgh and Winter (1983) produced what they called a 'state-of-the-habitat map' for Colombia (and Ecuador) based upon visual inspection of high-resolution satellite images. The map only provides a general indication of the intensity of use of the landscape during the early 1980's. In fact more exact, up-dated and detailed satellite monitoring is needed in the short term. At any rate, the map indicates that the Andean region, i.e. the entire Andean plateau and the many intermontane valleys, constituting 20-25% of the Colombian land surface, is densely settled and largely to almost completely deforested. The foothill region at the eastern base of the mountains has been less systematically exploited, but since the 1980's it is rapidly being colonised. Large sections of the montane forest belt of the eastern slopes between 1000 and 3000 m alt., were still intact in 1983. The Colombian western slopes are perhaps the most devastated in the entire tropical Andes (Saavedra and Freese, draft manuscript, 1985).

Furthermore, as far as the adjacent Colombian lowlands are concerned, nearly all of the forested lowland plain of the Amazon basin was still intact in 1983, although Myers' report (Myers, 1980) states that since the mid-1960's, some 16,000 km² of these lowland forests in the Caquetá and Putamayo territories have been converted to agricultural and cattle grounds, and a further 45,000 km² were in the process of being cleared or were scheduled for clearing. The Colombian llanos (Llanos Orientales) are subject to cattle grazing and periodic burning. The whole area of the lower Río Cauca and Río Magdalena valleys in northern Colombia supports a dense human population and is under intensive use.

The most recent information on the forest resources and deforestation in Colombia is provided by the IUCN (1990b). The total forest and woodland area was 51,507,000 ha in 1985-87, which means a 5.5% decrease since 1975-77. The average annual deforestation of Colombian closed forests is 11,000 ha. During the 1980's a total area of

890,000 ha of closed and open forests has been deforested.

In summary, the most heavily affected areas in Colombia are the Andean mountains. The level of threat to the uplands of western Amazonia is very high. In Colombia almost the entire montane zone has been deforested, up to 10,000 km² (Myers, 1988). Because the level of human pressure in Colombia is far more severe on the mountain environments than on the tropical lowlands, it seems reasonable to concentrate conservation efforts on these environments.

Furthermore, the diverse, threatened flora of the northern Andean region as a whole (i.e. the Andes in northern Peru, Ecuador, Colombia and Venezuela), attracts disproportionately little interest from biologists and conservationists. For its size, the northern Andes is the most diverse region in the Neotropics, while being highly deforested and faced with immediate threat of destruction (Henderson *et al.*, 1991). The northern Andes, with a surface area of 'only' 383,000 km², has an estimated total of some 40,000 vascular plant species, while the Amazon Basin has a surface area of 7 million km² and an estimated total of some 30,000 vascular plant species (Gentry, 1982). Furthermore, only 8-11% of the Amazon Basin is deforested, while 90-95% of forests in the northern Andes have already been cleared. Last but not least, the Andes, i.e. the (sub)Andean forests, are vital to the hydrology of the Amazon Basin.

National Parks system

Protected areas are necessary elements of nature conservation. Firstly, they maintain essential ecological processes and life support systems (e.g. the government of Colombia has expanded its protected areas in the Andean watersheds to ensure the maintenance of water supplies on which major industrial and residential development depend). In the second place, protection areas preserve species diversity and the genetic variation within them. Thirdly, they

maintain the productive capacities of ecosystems and safeguard habitats critical for the sustainable use of species. Finally, protected sites provide opportunities for scientific research, education, training, as well as recreation and tourism (Lucas, 1984).

As part of the policy seeking to preserve ecological processes and genetic diversity, Colombia has created 42 conservation areas under the National Parks system (IUCN, 1985;INDERENA, 1989). These units are distributed into three main categories, according to the IUCN categories of protected areas: 2 Reserves (Category I), 34 National Parks (Category II), 6 Sanctuaries for Flora and Fauna (Category IV). The total area covered by these conservation units is 9,301,690 ha (8.2% of the total area of Colombia), 9,254,260 ha of which are totally protected areas (categories I and II), with no extraction use, and 47,410 ha are partially protected areas (category IV), with local sustainable extractive use.

Furthermore Colombia has three Biosphere Reserves (Category IX), according to the Man and the Biosphere programme of UNESCO (MAB), with a total area of 2,514,375 ha: El Tuparro Nature Reserve (928,125 ha), Cinturón Andino Cluster Biosphere Reserve (855,000 ha), and the Sierra Nevada de Santa Marta including Tayrona National Park (731,250 ha).

Colombia became party to the World Heritage Convention on May 24th 1983. There is one cultural World Heritage Site (Category X) initiated in Colombia, namely Cartagena, an ancient city, but no natural World Heritage Site.

The conservation units or protected areas are distributed over different biogeographic units. The most widely used biogeographic classification is the one developed by Udvardy. He identified eight biogeographic realms, which he subdivided into 193 provinces. His system is used in IUCN's global inventory of protected areas (IUCN, 1985) and by UNESCO-MAB. According to the IUCN system, Colombia falls within six biogeographic provinces, which are all

represented in the Natural Parks system of Colombia.

The most important mountain systems are represented in the Colombian Parks system (INDERENA, *op cit.*): (a) the Cordillera Oriental from the Páramo de Las Papas to the Guajira Peninsula (Guácharos, Picachos, Sumapaz, Chingaza, Iguaque, Pisba, Cocuy, Tamá and Estoraques National Parks); (b) the Cordillera Central (Nevado del Huila, Hermosas, Nevados); (c) the Cordillera Occidental and the Nudo de Paramillo (Orquídeas, Farallones, Munchique, Tatamá and Paramillo reserves); (d) the Nudo de los Pastos (Puracé reserve); (e) the Nariño highlands (Galeras and Corota reserves); (f) the Sierra Nevada de Santa Marta (S.N. de Santa Marta); (g) the Serranía del Darién (Katíos); (h) the Serranía del Baudó (Utria); (i) the Serranía de La Macarena (La Macarena). The Cocuy National Park in the Cordillera Oriental and the Sierra Nevada de Santa Marta presents all altitudinal belts, from the warm tropical zone to the perpetual snow peaks.

Several areas have been preselected as possible protection sites in Colombia. Some fifteen years ago the 'Instituto Nacional de los Recursos Naturales Renovables' (INDERENA) identified some 115 areas as possible reserves, national parks and sanctuaries for flora and fauna (INDERENA, 1976). It seems obvious that the base of the western Andes (Chocó), and the Cordilleras Central and Oriental have more national parks than the Cordillera Occidental and the Nudo de los Pastos. Of the areas marked on the 1976 INDERENA planning map, some of the protection sites have been realised, especially in Amazonian lowland (INDERENA, 1989). The planned protection sites in the area of the Nudo de los Pastos near the border with Ecuador (around Pasto) have hardly been realised.

To delineate the areas where new protective areas should be located in Colombia in general and the Colombian Andes in particular, it is necessary to provide an overview of the critical species and priority areas, based on different floral and faunal groups of

species. The ecological criteria of species and habitat diversity, distinctiveness and threat (Chapter II) will play a decisive role in the analysis. These criteria should be kept in mind, because these will play a role in the planning of new protective sites, i.e. National Parks.

IV. PRIORITY AREAS FOR CONSERVATION OF DIFFERENT FLORAL TAXA

Plant species diversity

Of the estimated total of 90,000 species of flowering plants in the Neotropics, some 40,000 species (almost 50%) are proposed to occur in the northern Andean region. Gentry (1982) sampled a data set of 8,117 Neotropical monographed vascular plant species, of which 1,454 species (18%) were present in the northern Andean region, of these species 819 species were endemic, equivalent to 56% endemism. The Andes may be considered to be an important centre of speciation in the Neotropics. The origin of this enormous regional species diversity is analysed by Gentry (*ibid.*). The Neotropical flora is essentially composed of two distinct floras: the lowland flora of basic Gondwanan origin and the montane flora of basic Laurasian origin. The Gondwanan taxa are present in the Neotropics with over 10 times as many species as the Laurasian taxa. Within these Gondwanaland-derived groups two phytogeographic patterns can be distinguished: Amazonian centred taxa, dominated by trees and lianas, and Andean (mainly northern Andean) centred taxa, dominated by epiphytes, shrubs and palmettos. Almost half of all Neotropical plant species appear to belong to these Andean-centred habit groups. The overwhelming plant species diversity in the Neotropics in general, and in the northern Andean region in particular, is due to the Pliocene upheaval of the Andes, and the subsequent explosive speciation of these epiphytes, shrubs and palmettos. This speciation is most evident in

the Andean foothills and Subandean forests. The present Andean (upper montane) forests at higher altitudes in the northern Andean region are ecologically dominated by a few Laurasian taxa (e.g. Fagaceae), which arrived in the Andes by migration after the closing of the Panamanian landbridge (4-3 million years ago) and have undergone little speciation since then. The number of Laurasian taxa decreases vastly southward (e.g. *Quercus* spp. dominate most of the Colombian Subandean forests, but is absent in Ecuador).

According to Van der Hammen (1991) Subandean lower montane environments already existed during the Miocene (or even in the Lower Tertiary) in isolated patches. This might explain the high rate of endemism in the present Subandean forests and foothills. From the Miocene period on this very rich Subandean flora developed, i.e. in some 15 million years. The Andean and páramo floras evolved in a threefold shorter period of some 5 million years, since the Pliocene upheaval of the Andes (Van der Hammen and Cleef, 1986).

Extremely local endemism (i.e. distributions naturally restricted to a few hundred km², sometimes even to 5-10 km²) is a characteristic of many cloud forests in the Neotropics. Probably 20-25% of the montane forest angiosperm species in isolated cloud forests in western South America are strictly endemic (Gentry, 1986). Myers (1988) supposes that the level of endemism for plant species in western Amazonia from southern Colombia to Peru (around 20,000 plant species) could well be 25 % or more. This very high percentage of local endemism is responsible for the fact that the regional species diversity is very high, even though the diversity of individual Andean forests is relatively low (Gentry, *in prep.*, see below).

The Serranía de la Macarena is expected to contain a vast quantity of floristic diversity. It is in fact the continuation of a chain of very old plateaus in the Guiana region. Along the Serranía de la Macarena three biogeographic regions come together: the northern Andean region, the Orinocan re-

gion and the Amazonian region. Recently, the area was appointed as an ecologically important study area by the 1992 Tropenbos programme for Colombia (Tropenbos, 1991).

Vascular plant species

The world's largest local concentration of tree species and woody lianas, both with a diameter ≥ 10 cm dbh. (diameter at breast height) can be found in the relatively moist and fertile forests near the base of the Andes, a conclusion derived from a study on species diversity in the upper Amazon lowland tropical forests between 140 and 400 m alt. on different locations in Amazonian Peru and one location on the Venezuela-Brazil border (Gentry, 1988b). The diversity of tree species ≥ 10 cm dbh. in 6 Peruvian 1-hectare plots varied between 165 and 300. This makes the upper Amazonian forests the world's richest in tree species.

Along an altitudinal gradient in the tropical Andes from about 1,500 m alt. to above 3,000 m alt., near the upper limit of the forest, there is a sharp decrease in diversity of tree and woody liana species (≥ 2.5 cm dbh., in 11 montane Neotropical 0.1-ha samples, 6 sites of which are located in the Colombian Andes). This decrease is essentially linear, so there is no indication of a "mid-elevation bulge" in diversity, as far as these habit groups (trees and woody lianas) are concerned (Gentry, 1988a). Above 2000 m alt. familial diversity decreases less sharply with altitude than does species diversity (Gentry, *in prep.*). For a series of 26 Andean 0.1-ha forest sample plots of woody plants >2.5 cm dbh., an average of 135 species were found in sites between 1500-1700 m alt.; 128 spp. between 1700-2000 m alt.; 101 spp. between 2000-2400 m alt.; 68 spp. between 2400-3000 m alt. and 35 spp. above 3000 m alt. (Gentry, *ibid.*). Along different altitudinal transects from tropical lowland forests up to superpáramo, Rangel (1991) found greatest species diversity in the Subandean zone (± 1000 -2300 m alt.) in

both Sierra Nevada de Santa Marta and in the Cordillera Central (Parque Nacional los Nevados and Parque Nacional Puracé).

The epiphytic vascular flora changes in both diversity and composition along the altitudinal gradient. Greatest epiphytic diversity as well as density is found at intermediate elevation cloud forests. The peak in epiphytic species diversity appears to be between 1,000 and 2,000 m alt. Epiphyte density (number of individuals) tends to be greatest around 2,000-2,500 m alt. (Gentry and Dodson, 1987). According to Gentry and Dodson (*ibid.*) 10% of all vascular plants are epiphytes, of which 60% belong to the single family of Orchidaceae. This means that of the total number of 45-50,000 vascular plant species in Colombia, 4500 to 5000 species are epiphytes, of which 2700-3000 are orchids. It is estimated that the total number of orchids in Colombia is higher and approximates 3500 species.

Of the Pteridophyte taxa, 29 of the total 33 families, 120 of the total 300 genera and about 2,100 of the total 10,000 species occur in the Americas. Most of these taxa are present in the tropical rain forest, especially in the montane rain forests and cloud forests. Genera and species that grow only outside the rain forest are mostly those which grow at high altitudes on tropical mountains, such as *Jamesonia* and species of *Lycopodium* in the páramo (Tryon, 1989).

Of the total number of 510 species of tree ferns (Cyatheaceae), 197 species are present in the Neotropics, of which 196 species are endemics, and 110 are local endemics with a range of about 500 km or less. There are 75 species which occur in the Andes from northern Argentina to Venezuela, with 57 (76%) endemics, and 25 (33.3%) local endemics (Tryon and Gastony, 1975). Among the 40 American species of the genus *Cyathea*, 19 do occur in Colombia (Tryon, 1989). Most species are present at altitudes of 500 to 2500 m, with a decline in species at lower altitudes and higher elevations (Tryon and Gastony, *op cit.*). Two Andean species of *Cyathea* grow at 4200 m alt.,

which is the highest altitude reported for tree ferns.

Vascular páramo vegetation

The páramo areas above 3300-3800 m alt. probably contain some 3000 to 4000 species of flowering plants, with up to 60% endemics (Luteyn, *in prep.*, cited by Van der Hammen, 1991). There are over 300 genera of vascular plants in the páramos of the northern Andes (Cleef, 1979, 1981). The páramos of the Cordillera Oriental probably contain some 700 species, of which about 250 are endemic (which is over 35%) (Van der Hammen and Cleef, 1986). The vascular flora of these páramos (at a generic level) is made up of almost 50% tropical elements (41% of which are neotropical elements, including 7% endemic (páramo) elements) and for the other 50% of temperate elements (Cleef, 1979, *in press*). Endemism appears to be less in the páramo flora of the Tatamá massif in the Cordillera Occidental with about 4% endemic elements, and 35% neotropical elements (Cleef and Chaverri, *in press*).

Comparison of different major páramo areas reveals that some great differences in diversity (i.e. species diversity) exists between these areas. There are 260 genera in the páramo flora of the Cordillera Oriental, 145 genera occur in the isolated páramo of the Sierra Nevada de Santa Marta (Buritaca), and 114 genera in the Tatamá massif in the Cordillera Occidental (Cleef and Chaverri, *in press*). Along a transect from the Andean forest zone up to the páramos of the Parque los Nevados in the Cordillera Central (2940-4500 m alt.), there are 472 species, belonging to 223 genera and 93 families (Rangel *et al.*, 1983). Thus the number of genera and species in the páramo region alone of the Cordillera Oriental is greater than the total number of genera and species in the páramo region plus the Andean and High Andean vegetation zones in the Cordillera Central. This might partly be explained by the periodic extinctions in the Cordillera Central due to volcanic eruptions (Salamanca, 1991).

The difference (in diversity) between the páramos of the three Cordilleras is further illustrated by the number of species of the genus *Espeletia* s.s. The genus has 55 species in the páramos of Ecuador, Colombia and Venezuela). Of these, 36 species (36 endemics) occur in the Cordillera Oriental, 4 (3) species in the Cordillera Central, and 3 (2) species in the Cordillera Occidental (Cuatrecasas, 1986). This pattern of distribution is paralleled by the genus *Diplostephium*, which has 31 species (25 endemics) in the páramos of the Cordillera Oriental (including the Sierra de Perijá), 17 (9) species in the páramos of the Cordillera Central, and 6 (2) species in the páramos of the Cordillera Occidental. The genus *Espeletiopsis* is only present in the Cordillera Oriental (including the Sierra de Perijá) with 17 species, which are all endemic. The Cordillera Oriental is a major centre of radiation (speciation and distribution) in the northern Andes, i.e. of the genera *Espeletia*, *Espeletiopsis* and *Diplostephium* (Cuatrecasas, 1986; fig. 2).

For this reason the Sierra Nevada de Cocuy and the Páramo de Sumapaz in the Cordillera Oriental are identified as "Centres of Plant Diversity" (IUCN, *in prep.*). The IUCN-Centres of Plant Diversity Project identifies areas around the world, which are of major importance to the conservation of plant species, namely those sites where species diversity and/or endemism is particularly high, irrespective of the levels of threat of those sites, and irrespective of their actual protective status. The world-wide project will include 150-200 priority sites of global importance. The candidate sites for South America were selected at the 'Workshop on South American Centres of Plant Diversity' (Quito, Ecuador, June 10-14, 1991).

Bryophytes

Colombia is one of the richest countries in bryophytes of the Neotropics, with about 1500 species in 300 genera (Gradstein *et al.*, 1989). Endemism is low among the

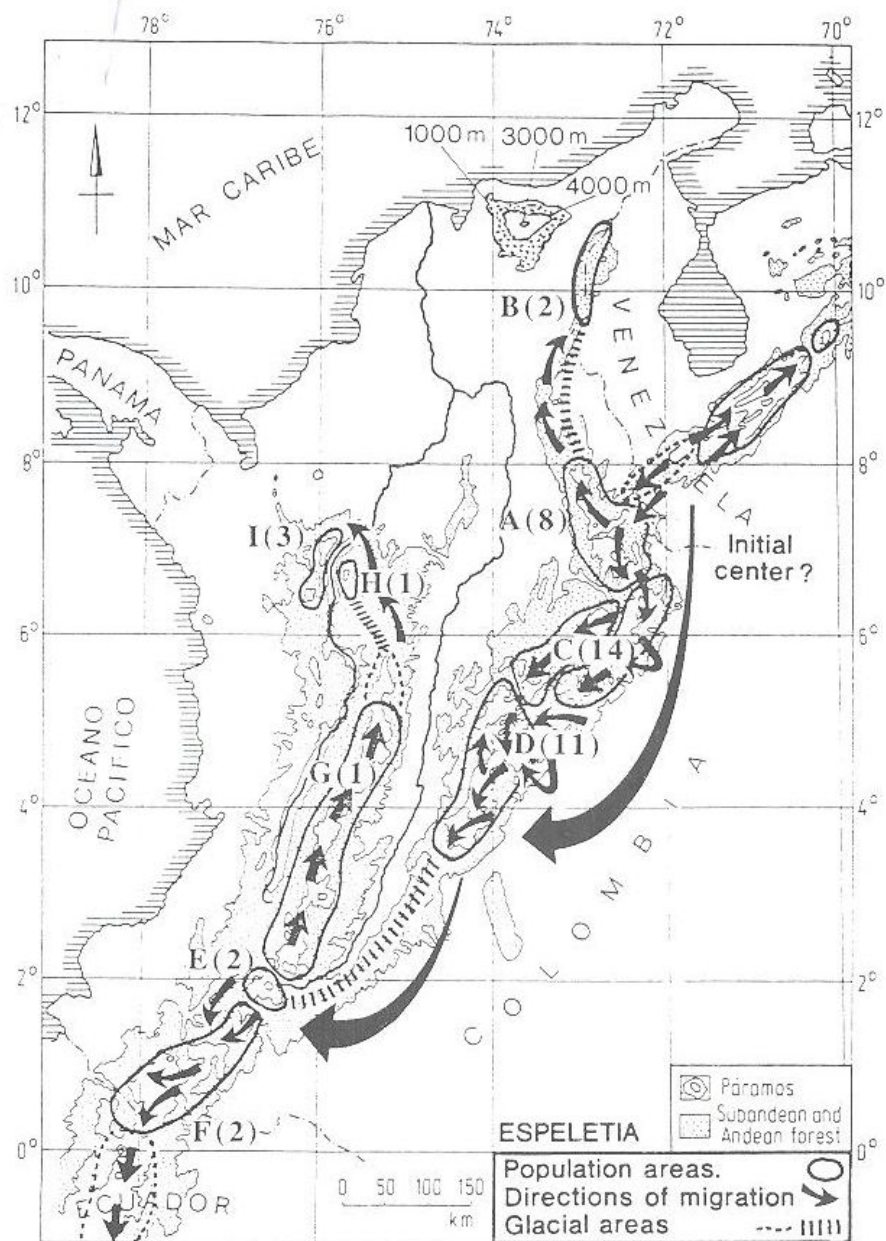


Fig. 2. Present Colombian areas of distribution and directions of migration and radiation in *Espeletia* spp.: A, Tamá-Santander and Norte de Santander; B, Sierra de Perijá; C, páramos of Boyacá; D, páramos of Cundinamara; E, main Cordillera Central; F, Macizo Colombiano nucleus; G, Nudo de los Pastos; H & I, northern parts of Cordillera Central and Occidental (Chaquiro-Frontino páramos). Number of different species in parentheses (Adapted from: Cuatrecasas, 1986).

bryophytes, although somewhat more common among liverworts (Hepaticae) than mosses (Musci). The total known diversity of mosses (Musci) in Colombia presently is 895 species distributed among 240 genera and 67 families (Churchill, 1991). About 11% of the moss species are endemics (some 100 species), and approximately 93% of the Colombian moss species are restricted to the Andean region. Of the liverwort species approximately 80% occur in the Andean region. The lowland forests are species poor.

Based on analysis of the bryophyte flora along an altitudinal transect in the Cordillera Central (Parque de los Nevados) (Gradstein *et al.*, *op cit.*), it appears that the largest number of species are present between 1200 and 3800 m alt., with a maximum in the upper montane (Andean) forest zone. The number of liverworts seems to be greater than mosses in this zone. Relatively few bryophyte species are present below or above these altitudes. The number of mosses seems to be greater than liverworts in the lowland forests or the páramo. The general increase of bryophytes from lowland up to the páramo is essentially due to two climatic factors: increase of humidity (clouds and fog), decrease in temperature (bryophytes lack high temperature tolerance) (Gradstein and Pócs, 1989).

A vast majority of the Andean bryophyte species are of tropical origin. In the Subandean and Andean forests 80% or more of the entire bryophyte flora are neotropical or wide tropical elements. These elements probably arrived from lower altitudes during the upheaval of the Andes, some 5 million years ago. Above 3000 m alt. these elements decrease to 50% or less and Andean and endemic elements become more common (30-45%). Temperate species appear at higher altitudes, and attain about 20% in the páramo. These elements arrived after the formation of the Panamanian landbridge, at about the same time (3 million years ago) as the upheaval.

As for bryophytes in general, mosses accordingly increase in species number and

cover with elevation at least to the treeline. Maximum species richness is reached in the upper montane tropical forest, in particular near the transition zone to the (sub)páramo (Churchill, 1991).

As far as the epiphytic hepatics are concerned, in the transition zone between the Subandean and Andean forest belt on the western slope of the Central Cordillera in Colombia, around 2400 m alt., there is a marked increase in their number, compared to lower altitudes. Both the mosses and the foliose lichens have an optimum in number of species at about 2130 m alt. (Wolf, 1989). A clear maximum of approximately 100 taxa/altitudinal interval (of approx. 200 m) of epiphytic liverworts is found at mid-elevational altitudes (2550-3190 m). The distribution patterns of individual taxa reveal that the belt of greatest liverwort richness coincides with the contact transition zone (Wolf, *pers. comm.*). So while there is no 'mid elevation bulge' for trees and lianas (Gentry, 1988a), there seems to be one for liverworts and lichens.

Lichens

There are no numbers available for lichen species diversity in the northern Andes or Colombia. On a transect from 600 to 4600 m alt. over the Colombian Cordillera Central (Parque de los Nevados) about 295 taxa were found, of which some 235 species have been identified. According to Sipman (1989) there are probably 600-900 species. Along this transect lichens become more common with increasing elevation, with an optimum around 3000-4000 m alt. (Sipman, 1989). Extreme climatic conditions in the páramo belt decrease the ecological possibilities for most vascular plants, while the possibilities for lichens increase (Hofstede, *pers. comm.*). In the superpáramo zone the number of lichen species decrease. Below ca. 2000 m alt. crustose lichen species dominate. Above this altitude foliose lichens dominate. Fruticose lichens are nearly absent below 2000 m alt., and increase gradually in number until ca. 4000 m alt. Local

(neotropical and northern Andean) elements are most frequent between ca. 2000 and 3500 m alt. (25-35%). The northern Andean element has its optimum in the superpáramo, where it rises to over 10%. The temperate and arctic-alpine elements are represented only at the higher elevations. In the superpáramo they constitute 36% of the known lichen flora.

Habitat diversity

An indication of the habitat diversity in the Colombian Andes is provided by the number of zonal and azonal communities in the different Cordilleras. Zonal vegetation is mainly influenced and determined by the prevailing climate in a particular region, while for azonal vegetation the peculiarities of the soil type (including water) are of main influence (Cleef, 1981). For the páramo region of the Sierra Nevada de Cocuy (Cordillera Oriental), a total of 121 communities (28 zonal and 93 azonal communities) were distinguished (Cleef, *ibid.*). Along the transect in Parque los Nevados (Cordillera Central) 22 zonal and 29 azonal communities (total of 51 communities) were distinguished (Cleef *et al.*, 1983).

The extreme species richness of vascular plants in the Cordillera Oriental has certainly to do with its great habitat diversity, especially in the páramo region, according to the great number of (a)zonal communities.

V. PRIORITY AREAS FOR CONSERVATION OF DIFFERENT FAUNAL TAXA

Mammals

The total number of mammalian species in Colombia is reported to be 367 species which have been collected in the country, plus an other 85 species which have not been collected in Colombia, but whose presence are very probable due to their occurrence in adjacent countries (Cuervo *et al.*, 1986). Accordingly, there might be over

450 mammalian species on Colombian territory.

Eisenberg (1989) describes the following 12 species as characteristic, endemic, non-volant, terrestrial species of the Andean region, which all occur in Colombia: *Marmosa dryas* (Mouse Opossum), *Cryptotis thomasi* (Shrew), *Nasuella olivacea* (Mountain Coati), *Sciurus pucherani* (Tree Squirrel), *Oryzomys minutus* (Rice Rat), *Aepeomys lugens* (Climbing Rat), *Thomasomys aureus* (Climbing Rat), *Chilomys instans* (Colombian Forest Mouse), *Echinoprocta rufescens* (Short-tailed Porcupine), *Agouti taczanowski* (Mountain Paca), *Tremarctos ornatus* (Spectacled Bear) and *Pudu mephistophiles* (Northern Pudu). Based on mammalian species descriptions by Eisenberg (*ibid.*), the author counted over 40 species (excluding Primates and Chiroptera), more or less restricted to one or more of the Colombian Cordilleras above 1000 m alt. Of these species 33 occur in the Cordillera Oriental (of which 12 species are endemic to this Cordillera or are shared with the Venezuelan Andes); 24 species occur in the Cordillera Central (2 endemic species); 22 species occur in the Cordillera Occidental (3 endemic); 13 species occur in the Nudo de los Pastos (no endemics).

Over 50% of these Colombian Andean species (22 species) belong to the Rodentia. Relative species diversity concerning the total South American mammals is greatest in rodents (43.2% of the total number of mammalian species present in the South American fauna, or over 410 species in 95 genera). Relative species diversity in the other South American taxa are: Chiroptera 22.4%; Primates 9.6%; Marsupialia 9.4%; Fissipedia 6.8%; Edentata 4.2%; Artiodactyla 2.3%; other taxa 2.1%.

The páramos of the northern Andean region contain 27 species of rodents (13 (or almost 50%) of which are endemic species), belonging to 15 (sub)genera and 4 families: Cricetidae (24 species, 10 genera), Caviidae (1 spp.), Agoutidae (1 spp.), Sciuridae (1 spp.). As far as the family with the greatest

number of species is concerned (the Cricetidae), according to Reig (1986), the northern Andes is the "area of original differentiation" of its tribe Oryzomyini. This indicates that the Oryzomyini experienced the main differentiation (cladogenesis) of its genera within the area of the northern Andes. The taxon is well represented in the páramo region, with 14 genera, 5 of which are endemic (36%). The differentiation of the Orozomyini was probably triggered by the increase of the montane habitat diversity, due to the Pliocene upheaval of the Andes.

The Andes chain and the different Cordilleras have been important dispersal routes for tropical and temperate-adapted species from South America to the north and vice versa (Stehli and Webb, 1985) and the Andean corridors have been important for those species adapted to higher elevations. The Subandean forest refugia along the eastern slopes of the Andes, i.e. in Ecuador and Peru, have been forested nearly continuously throughout the Plio-Pleistocene climatic cycles. These forest refugia have been important centres of speciation during the glacial periods and they have been reservoirs for interglacial dispersal (Eisenberg, 1989).

Of the mammals living in Colombia, 29 species are reported to be threatened species and are included in the IUCN red data book (Thornback and Jenkins, 1982; IUCN, 1990a). According to Eisenberg two of these species are not present in the country any more or possibly never were, i.e. *Cacajao calvus* (Red and White Uakari) and *Ateles geoffroyi* (Black-handed Spider Monkey). The typical high altitude species *Tremarctos ornatus* and *Pudu mephistophiles* as well as *Tapirus pinchaque* (Mountain Tapir) are included in the Red Data list, but there are some other threatened mammalian species that possibly occur in mountain environments or at lower elevations in Colombia (table 2).

Non-human primates

Colombia has the world's sixth greatest primate diversity, preceded by Brazil (52 primate species), Indonesia (33-35), Zaire (29-32), Cameroon (28-29) and Madagascar (28). Colombia contains more than one-third of all neotropical primates (27 species, from 12 different genera). Peru has the same number of species and genera. Colombia's

Table 2. Threatened mammalian species in the Colombian Andes, and their categories of threat. l: lowland tropical forest zone, s: Subandean forest zone, a: Andean forest zone, h: high Andean forest zone, p: páramo zone. (Sources: Thornback and Jenkins, 1982; Eisenberg, 1989; IUCN, 1990a). Threatened species belong to one of the following IUCN categories: Extinct, Endangered, Vulnerable, Rare or Indeterminate (IUCN, 1990a).

Species	English name	Alt. distr.	Cat. of threat
<i>Saguinus leucopus</i>	White-handed Pinché	l + s	E
<i>Saguinus oedipus</i>	Cotton-topped Tamarin	l + s	E
<i>Lagothrix lagothricha</i>	Woolly Monkey	l + s + a	V
<i>Ateles paniscus</i>	Black Spider Monkey	l + s + a	V
<i>Myrmecophaga tridactyla</i>	Giant Anteter	l + s	V
<i>Dinomys branickii</i>	Branick's Giant Rat	l + s	E
<i>Speothos venaticus</i>	Bush Dog	l + s	V
<i>Tremarctos ornatus</i>	Spectacled Bear	h + p	V
<i>Felis pardalis</i>	Ocelot	l + s	V
<i>Felis tigrina</i>	Little Spotted Cat	l + s	V
<i>Felis wiedii</i>	Margay Cat	l + s	V
<i>Tapirus pinchaque</i>	Mountain Tapir	h + p	V
<i>Pudu mephistophiles</i>	Northern Pudu	h + p	I

primate species contain 11% endemic species (0% endemic genera), and ranks fourth in the world where primate endemics are concerned, preceded by Madagascar (93% endemic species; 92% endemic genera), Indonesia (44-50% endemic species; 12.5% endemic genera), and Brazil (35% endemic species; 12.5% endemic genera) (Mittermeier, 1988).

Hernandez and Defler (1985) distinguished between 22 different primate species in Colombia, and described their distribution over the country. The number of species decreases with altitude: 10 species were considered to be typical lowland species, and were present only to the base of the Eastern Andes, up to the 500 m alt. limit (the average elevation at which the steep slopes of the Andes begin), 5 species have a distribution up to 1500 m alt., two up to 2000-2100 m alt., one species up to 2500 m alt. (although this species *Ateles paniscus* is subdivided into *A. paniscus* (Black Spider Monkey), *A. belzebuth* (Long-haired Spider Monkey) and *A. fusciceps* (Brown-headed Spider Monkey) by other authors). Finally 4 species occur up to above 2800 m alt., of which 2 species occur up to 3200 m alt.: *Aotus lemurinus* (Night Monkey) and *Alouetta seniculus* (Red Howler Monkey) (table 3).

Hernandez and Defler (*op cit.*) constructed a map showing the regional densities of the primate species (fig. 3). On the basis of this distribution map and the actual status of the forest habitats in the country, they pointed out the immediate need for at least the following three reserves: (1) southwest part of Putamayo on the upper Guamues river. This area contains the highest primate diversity in Colombia (13 species). It probably forms part of a Pleistocene forest refugium ("Putamayo") in that area (according to Brown, 1982); (2) on the lower Apaporis river in the transitional zone between the Amazon valley and the Guyana shield; (3) on the upper Apaporis river (on the border between the Departments of Caquetá and Guaviare, including the Sierra de Chiribiquete).

All three areas are supposed to be areas of high endemism, in fauna as well as flora. In 1989 the third area was safeguarded by the creation of the largest National Park of Colombia, i.e. the Serranía de Chiribiquete (1,280,000 ha). The first two areas still need to become reserves according to both authors. The southwestern part of Putamayo is the most interesting area, with respect to the present study.

Table 3. Primate species with (potential) distributions up in the (sub) Andean forest zone of the Colombian Andes (Source: Hernandez and Defler, 1985). For categories of threat see legend table 2.

Primates	English name	Range up to (m alt.)	Cat. of threat	Protection
<i>Saguinus leucopus</i>	White-handed Pinché	1500	E	no
<i>Saguinus oedipus</i>	Cotton-topped Tamarin	1500	E	?
<i>Saimiri sciureus</i>	Squirrel Monkey	1500		yes
<i>Aotus lemurinus</i>	Night Monkey	3200		yes
<i>Aotus brumbacki</i>	Night Monkey	1543		no
<i>Alouetta palliata</i>	Mantled Howler Monkey	1400		yes
<i>Alouetta seniculus</i>	Red Howler Monkey	3200		yes
<i>Cebus albifrons</i>	Brown Pale-fronted Capuchin	2000		yes
<i>Cebus capucinus</i>	White-throated Capuchin	2100		yes
<i>Cebus apella</i>	Brown Capuchin	2800		yes
<i>Lagothrix lagotricha</i>	Woolly Monkey	3000	V	yes
<i>Ateles paniscus</i>	Black Spider Monkey	2500	V	yes



Fig. 3. Map showing regional densities of primate species in Colombia. Number indicate species within area outlined. The dashed area is the Andean zone without sampling data or without occurrence of primate species. (Adapted from: Hernandez and Deffler, 1985).

Avifauna

Within the Andean zone (only 1.3% of the world's land surface), 17% of all the world's species of birds are present. In the montane forest of the tropical Andean region (which cover only 0.2% of the world's land surface), 70% of the 2,900 non-marine birds of South America, or 6.3% of the world's bird species have been recorded (Fjelds  and Krabbe, 1990). In short, Colombia is the world's richest country in bird species, with 1665 species.

In the high Andean biomes (p ramo and puna), with a surface of 185,000 km², 166 bird species are present in total, belonging to 84 genera and 32 families. The p ramo area of the northern Andes (25,000 km²) has 62 bird species (Vuilleumier, 1986), of which some 29 species strictly occur in the p ramo, and do not or only rarely go down below the upper Andean forest limit. In the Cordillera Oriental the number of species per island of p ramo, 5 of which were sampled, varies between 8 and 27 (or 5-14 for restricted p ramo birds); in the Cordillera Central, where two p ramos were sampled, the number of species was 24 and 29 (or 13 and 14 for restricted p ramo species); in Paramillo (Cordillera Occidental) 7 species (3 restricted) were found (Vuilleumier and Simberloff, 1980). There are especially many endemic forms in the Cordilleras Oriental and Central (Fjelds  and Krabbe, 1990).

Cracraft (1985) provided an elaborate overview of the probable areas of endemism concerning the South American endemic avifauna, i.e. taxa that are 'restricted' to a particular area. His areas of endemism are not necessarily equivalent to the Pleistocene forest refuges. In Cracraft's opinion many of the areas of endemism are considerably older than the Pleistocene refugia and the patterns of endemism were established prior to that epoch. In Colombia, the following areas of endemism are present: Choc , Nech , Magdalena, Santa Marta, Guajira, Perij , North Andean, and North Amazon (Napo) Centre. The division of the Andes

(North Andean Centre) into three ranges, and the consequent isolation of montane bird populations makes Colombia the richest of all South American countries in bird species. Because of the complex topography and elevational-ecological zonation of the Andes, species distribution patterns in the Andes are complex and defining areas of endemism in the Andes is particularly difficult.

A more fine-tuned picture of species distributions in the Colombian Andes is elaborated by Terborgh and Winter (1982, 1983). They concentrate on the endemic birds, being species with small ranges, arbitrarily defined by the authors, as any distribution encompassing less than 50,000 km². In Colombia over 100 bird species are endemics according to this criterion. Terborgh and Winter (1982) examined the geographical distribution of all (155) endemic species in Colombia and Ecuador. In the Andean region the following distributions occurred: western slopes (Cordillera Occidental), 29 spp.; Andean plateaus (p ramo regions), 23 spp.; intermontane slopes (R o Magdalena and R o Cauca valleys, Cordillera Central), 22 spp.; eastern slopes (Cordillera Oriental), 3 spp. The total number of 77 endemic species in the Andean region represents 50% of the total number of endemics. The other half is made up of lowland endemics (25%), and endemics occurring in isolated pockets of habitat (25%).

Data about threatened birds have been compiled in the IUCN/ICBP (International Council for Bird Preservation) red data books. A considerable proportion of the threatened birds of South America belongs to the Andean zone. Of the near-threatened or potentially endangered species of Colombia (Appendix 2 in Collar and Andrew, 1988), nearly 50% occur primarily in the lower montane belt (9% of the land surface) and 20% in the upper montane zone (6% of the land surface) (Fjelds  and Krabbe, *ibid.*).

Terborgh and Winter (1982, 1983) distillate the optimum locations for future reserves in the areas of most concentrated endemism, i.e. where the greatest spatial

overlap of endemics exists. These critical areas and centres of avian endemism in Colombia are, in descending order of importance (fig. 4): (A) the western base of the Nudo de los Pastos on the border between Colombia and Ecuador; (B) at the western base of the Cordillera Occidental (Chocó) in Valle; (C) in the western slope of the Cordillera Occidental themselves in Cauca, Valle and Caldas; (D) the middle elevations of the Sierra Nevada de Santa Marta; (E) in the Serranía de Baudó; (F) at the northern end of the Cordillera Central and in the adjacent humid lowlands of northern and north-eastern Antioquia. The seventh endemic concentration centre is the Napo refugium in eastern Ecuador, and, although not mentioned by Terborgh and Winter, both slopes of the Cordillera Central and the eastern slope of the Cordillera Oriental are two other critical areas for conservation of birds (Orejuela, 1985).

In conclusion, the Cordilleras Occidental and Central are especially rich in endemic species, as far as the slopes are concerned. The páramo regions of the Cordilleras Central and Oriental are the richest in bird species, which almost certainly has to do with the very small páramo area in the Cordillera Occidental (i.e. Paramillo) and the abundant páramo areas of the Cordilleras Central and Oriental.

Herpetofauna

The Andes have the richest herpetofauna of South America; of the 2210 South American species, one-third (727 species) occur in the Andes, of which 462 species are amphibians and 265 reptiles. The distribution patterns and origins of the different taxa of herpetofauna in the Andes are discussed by Duellman (1979) and Lynch (1986). Of the Andean herpetofauna more than 50% (415 species) occur in the northern Andes (table 4). The rate of endemism is very high in this region: 83% or 345 species, and 7 endemic genera. Of the 415 northern Andean species, nearly two-thirds are frog species (262 species, 225 of which are

endemic). In the Colombian Andes, the Cordillera Central has the highest percentage of endemism (54%), except for the Sierra Nevada de Santa Marta with 76% endemic species. The number of species is greatest in the Cordillera Oriental (103 species). If only those species that do not occur below 2500 m alt (i.e. upper Andean forest species) are considered, 100% of the species in the Cordillera Occidental (2 species) are endemic, although the greatest number of endemic species (13 species or 81%) occur in the Cordillera Oriental, followed by the Cordillera Central (13 species or 72%). The Nudo de los Pastos has only 1 endemic upper Andean species (20%).

Of the 301 genera and 3,533 species of Anura (frogs and toads) in the world, 107 genera (36%) and 1,545 species (44%) occur in the Neotropics. There are 96 genera which are endemic to the Neotropics (Duellman, 1988). Greatest species richness and highest percentage of endemism in the northern Andes is amongst the frogs. Frogs form 60% of the entire Andean herpetofauna, and even 65% of the northern Andes herpetofauna (Duellman, 1979). Of the 14 dominant frog genera, 9 occur essentially in the northern Andes (Lynch, 1986). Along an altitudinal gradient from lowland tropical forest up to the páramo in Colombia, among other northern Andean countries, species diversity decreases and reproductive strategy changes (Duellman, 1988). Greatest species diversity is found in the equatorial region of the upper Amazon basin. The tropical lowland sites near the base of the Andes do not only have the highest species diversity, but also the greatest diversity of reproductive modes, although the generalized reproductive mode (eggs and tadpoles in lentic water) is characteristic of all lowland sites. In the Andean forest, where ponds are scarce, other reproductive modes prevail: forest modes (aerial aquatic habitats, i.e. in Bromeliacca species) and terrestrial eggs and/or larvae that are dependent on the high humidity of the air (over 75%), or stream-breeding (over 35%).

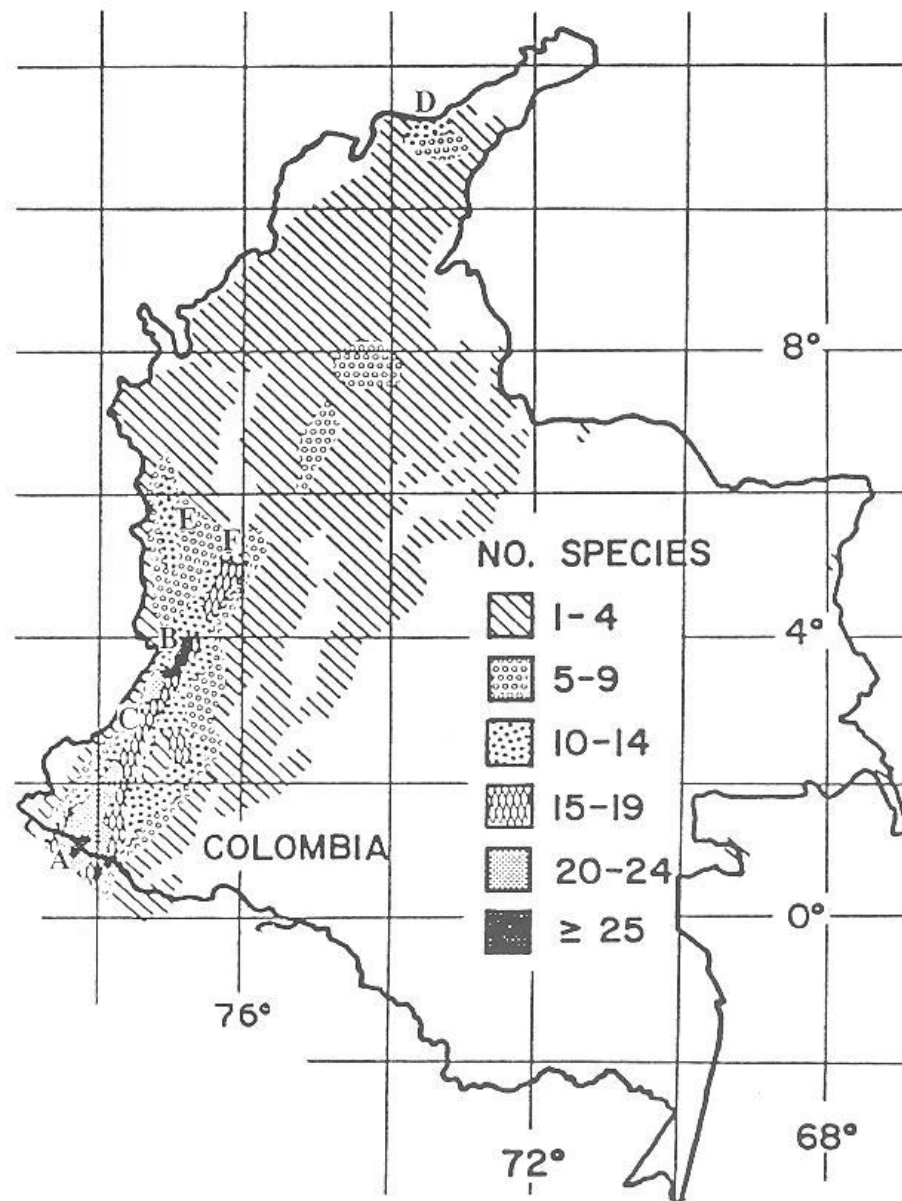


Fig. 4. Areas of concentration of endemic bird species in Colombia. A, western base of the Nudo de los Pastos; B, western base of the Cordillera Occidental; C, western slope of the Cordillera Occidental; D, Sierra Nevada de Santa Marta; E, Serranía de Baudó; F, northern end of the Cordillera Central. (Adapted from: Terborg and Winter, 1982, 1983).

Table 4. Genera and species of Amphibians and Reptiles in Colombia and the different parts of the Andes. Number of endemics in parentheses (Source: Duellman, 1979).

Geographic area	Amphibians	Reptiles	Herpetofauna		
	Species	Species	Genera	Species	Spp. > 2500m
Northern Andes	288 (248)	127 (97)	(7)	415 (345)	73 (72)
Cordillera Oriental	62	41	30	103 (36)	16 (13)
Cordillera Central	58	20	34	78 (42)	18 (13)
Cordillera Occidental	44	22	27	66 (29)	2 (2)
Nudo de Pasto	17	6	11	23 (1)	5 (1)
SN de Santa Marta	16	5	13	21 (16)	-
Colombia	375	383		758	

Fishes

As far as the fresh-water fish fauna of the northern Andes is concerned, only very scarce information is available on the species occurring in this region and their distributions. According to Nijssen (*pers. comm.*) the species of the genus *Chaetostomus* (family Loricariidae, loricarid catfishes) are endemic and adapted to the specific conditions in fast running water of high Andean streams. Eigenmann (1924) describes this genus as confined to the mountain streams of northwestern South America, with Río Madre de Dios in southern Peru as the southernmost locality. The 18 species are characterized by the narrow naked area about the snout, which is free from tentacles, and the wide mouth, the mandible being about equal to the interorbital. They adhere to pebbles and stones in the fast running streams with their mouths. Five species of this genus are described which occur in the Colombian Andes streams.

According to Dahl (1971) two genera of the family Trichomycteridae, *Astroblepus* and *Pigidium* (for both genera 10 spp. described for northern Colombia) are characteristic for the Andean mountain streams in northern Colombia. These genera have a high number of endemic species, although there are no numbers available for these genera in particular, nor for the fish-fauna in general.

Invertebrates

The northern Andean region appears not to be a dispersal centre of butterfly species, but is rather a cluster of scattered areas (Descimon, 1986). Only the Satiridae have 1 or 2 highly endemic species in the northern Andes. As far as the Heliconiini and Ithomiinae are concerned, centres of endemism of these species groups show good correlation with paleoecological forest refuges (Brown, 1982). The Andean forest refuges of Santa Marta, Catatumbo (Parijá), Villavicencio (eastern slopes of the Cordillera Oriental near Macarena) and Putamayo (in the Nudo de los Pastos) have a high probability (80-100%), while Nechí, Cauca and Magdalena have a probability of 60%.

The Andean Brown Butterflies (family Satyridae, tribe Pronophilini) are described as 'Rare' taxon in the IUCN invertebrate red data book (Wells *et al.*, 1983). They show high diversity and endemism (table 5). While the overall species richness in the high Andes is very low (Descimon, *op cit.*), the Pronophilini are especially richly represented in the high altitude cloud forests of the tropical Andes. In the area they occur between 1100 and 4000 m alt. or above. Above 2,500 m alt. they are the most diverse group of butterflies. Their maximum diversity is found in the Andean forest zone (2500-2700 m alt.) of the northern Andes. These data are confirmed by the elevational

Table 5. Distribution of Satiridae (Andean Brown Butterflies) in Colombia (Source: Wells *et al.*, 1983).

Geographic Area	No. of species	No. of endemics
Cordillera Oriental	92	27
Cordillera Central	80	11
Cordillera Occidental	57	4
Serranía de Perijá	35	11
S. N. de Santa Marta	22	12

species distributions found by Fassl (1911, cited and tabulated by Descimon, 1986), where the Satiridae showed greatest species diversity (over 20 species) between 2000 and 3000 m alt. The overall highest Lepidopteran species diversity occurred in the Subandean forest zone. Between 1000 and 2000 m alt. species diversity was over 96 species.

The conservation measures proposed in the IUCN red data book are that representative areas of cloud forest and páramo from 1500 to 4000 m alt. in each Cordillera should be set aside as protected areas, although the exact locations of these areas are not outlined.

In the Parque los Nevados (Cordillera Central), soil macrofauna and mesofauna were collected along a transect on both sides of the Cordillera (Van der Hammen and Beglinger, 1989). Earthworm biomass reached maximum values (up to 180 cc per m² or 1.8 ton per ha) in both western and eastern parts of the transect between 2600 and 3400 m alt. in the Andean forest zone. Between 2100 and 2600 m alt. very low values were found. As far as the total mesofauna is concerned, there is an increase of number of individuals along the altitudinal gradient. In the higher tropical and Subandean zones the average number of individuals is 100-250 per litre (2500-6000 per m²), in the Andean zone 400-1000 per litre (10,000-25,000 per m²), and in the páramo zone 1100-1500 per litre (27,000-37,000 per m²). The most numerous species groups are the Acari (mites) followed by the Collembola (springtails). Formicidae (ants) are almost exclusively found below 2700 m

alt.; they decrease between 2100 and 2700 m alt., while the individuals of mites, springtails, beetles (Coleoptera) and larvae increase between these altitudes. Chelonethii (Pseudo-scorpionidae) are only present below the páramo zone.

The increase in humidity (due to mist), increased accumulation of humus and related decrease in soil-pH along the altitudinal gradient up the upper montane cloud forest belt are probably the most important factors which cause the change in earthworm biomass and number of individuals of mesofauna. In this respect it is useful to recall one of the determinants of species diversity along altitudinal gradients (Diamond, 1988): decrease in productivity, probably determined by these factors.

VI. SYNTHESIS

Myers' "hotspot" areas

Myers (1988) identified ten priority areas in the tropics that deserve immediate conservation in the light of the criteria aforementioned (Chapter II). These areas feature exceptional concentrations of species, exceptional levels of endemism, and exceptional degrees of threat. They are key localities of biotic richness under acute threat, and are called "hot spots". As far as Colombia is concerned, the Chocó region and the uplands of western Amazonia are two out of the ten hot spot areas. (The other "hotspot" areas are Madagascar, Atlantic Coast Brazil, western Ecuador, eastern Himalayas, peninsular Malaysia, northern Borneo, the

Philippines and New Caledonia). According to Myers, the area of western Amazonia as a whole, i.e. the lowlands as well as the uplands are "surely the richest biotic zone on Earth (with) a higher level of endemism in the uplands than in the lowlands", with special reference to the species concentrations of vascular plants and birds in the area.

The uplands of western Amazonia include the upland sectors between 500 and 1500 m alt. of the eastern Andean slopes that border western Amazonia (Cordillera Oriental). It extends about 2200 km from the southern part of Colombian Amazonia, through Ecuador, and right along the Amazonian fringe of Peru (fig. 5). It comprises a belt mainly 50 km wide, sometimes only 25 km. Thus it encompasses no more than 100,000 km². Some 65,000 km² (65 %) of

the area's forest has already been cleared or otherwise converted

Multidisciplinary approach

The Third World Parks Congress, in Bali, Indonesia, in October 1982, concluded its sessions with the recommendation, among others, that "special attention should be given to the conservation of the particularly vulnerable forest systems in (...) the eastern Andean slopes." (McNeely and Miller, 1984: p.766), which are the Cordillera Oriental and the Nudo de los Pastos in Colombia. Based on literature reviews, questionnaires and specialist meetings in May and December 1985, the WWF-US (World Wildlife Fund-U.S.) produced two draft manuscripts on the biological

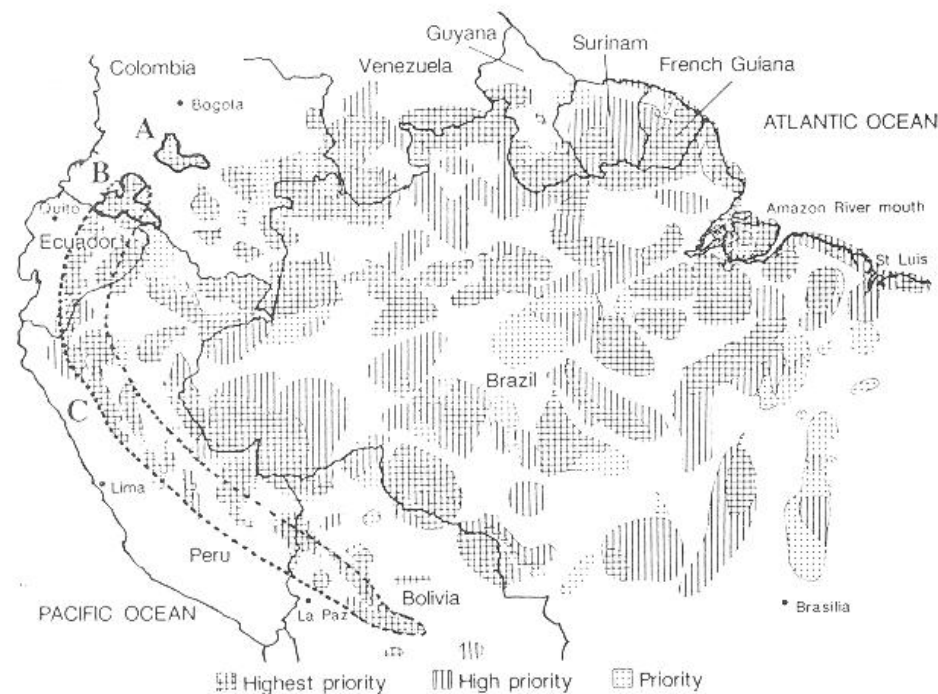


Fig. 5. Areas of biological priority for conservation in Amazonia, graded into three levels (from: Prance, 1990). A. upper Río Guayabero area; B. western part of Putumayo and eastern part of Nariño; C. uplands of western Amazonia, a "hot spot" area sensu Myers (1988)

priorities for conservation in the tropical Andes (Saavedra and Freese, draft manuscript, 1985) and in the Chocó biogeographic region in Colombia (Kirkbride, draft manuscript, 1986). The areas are selected because they deserve special attention to ensure effective management and protection, based on their biological importance and the operational feasibility of protection, according to a multidisciplinary team of (local) specialists.

On the preliminary list of priority protected and unprotected sites most areas are located in the Cordillera Occidental, and are upward extensions of the adjacent Chocó lowland rainforest region. From north to south these areas are: the Pavarando-Pavardocito-Mutató region, including Paramillo NP; Las Orquídeas NP; Río Beberá; Watershed of Río Andágueda; Cerro Tatamá and Cerro Torrá; Farallones de Cali NP. In the Nudo de los Pastos: Munchique NP (especially its needed eastward enlargement); Río Telembi; Cumbal-Chiles Volcanoes, including La Planada NR. The only priority area appointed in the Cordillera Oriental is the Cordillera de Los Picachos NP. As a northward extension of the Cordillera Central, the Serranía de San Lucas is appointed as priority area. This area extends along the postulated Nechí Pleistocene forest refuge. Furthermore the area where the departments of Santander, Norte de Santander and César meet was also appointed as priority unprotected area. This area belongs to the postulated Catatumbo refugium. Finally the Sierra Nevada de Santa Marta is included as special priority protected area.

Recently some 100 biologists, physical scientists and conservation planners agreed on the areas of biological priority for conservation in Amazonia (Workshop 1990: Priority Areas for Conservation in Amazonia, Manaus, January 1990, see: Prance, 1990). The scientists worked in specialist groups (plant systematics, plant ecology, mammals, ornithology, herpetology, ichthyology, entomology, geomorphology (fragility of soils) and climate, and units of

conservation). Each specialist group produced a map to justify their selection of priority areas. Finally, all maps were fused, and areas with the maximum overlap between the disciplines were given the highest priority. Two other categories of priority were distinguished: high priority and priority areas.

Of special interest for the purpose of our study are the two 'highest priority' areas in the Colombian sector of the western Amazonian uplands and the adjacent Amazonian lowlands: the Upper Río Guayabero area (1), in the western part of Meta, up to the eastern Andes and the western part of Putumayo and the Nariño highlands (2) on the border with Ecuador (fig. 5).

CONCLUSION

The northern Andes is an important area of species diversity, from the Andean foothills adjacent to the Amazonian uplands (i.e. tree and liana species), along the slopes (vascular epiphytes, pteridophytes, e.g. *Cyathea* spp., bryophytes, soil macro- and mesofauna, and Lepidopteran species), up to the páramo regions (with high species diversity in vascular plants and lichens). Furthermore, there are great numbers of endemic species groups in different altitudinal ranges, e.g. bird species along the western base of the Andes, *Chaetostomus* spp. fishes and Satiridae (Andean Brown Butterflies) at mid-elevations, and species of *Espeletia* in the different páramo regions. It thus seems reasonable to plead for the protection of Andean biomes from the tropical lowlands, along the Andean slopes, up to the superpáramo, in order to maximize biological diversity (species as well as habitats) inside the protected areas. In the long term this will be the only way to safeguard the continuation of evolutionary processes.

Although being an important area of species diversity and endemism, the Andean mountains are at the same time among the most heavily threatened areas in Colombia, although detailed satellite monitoring in the

short term has yet to reveal the actual most recent state of nature destruction, land use and management in the Andean region. Beforehand, the greatest conservation efforts should concentrate on these vulnerable environments. All such efforts should encompass examination of the criteria for setting biodiversity conservation priorities, agreed upon by IUCN, i.e. species abundance and diversity and habitat diversity; species endemism or taxonomic distinctiveness and habitat uniqueness; severity and imminence of threat; utility. Rational conservation planning becomes possible when all criteria are dealt with, although choices can be made on different grounds (utility criterion). The most threatened species, habitats, ecosystems and areas need protection first. The immediate task of identifying sites for protection can be based on the few relatively well-known groups of organisms (e.g. birds). The centres of species diversity, the proposed Pleistocene forest refugia and areas of endemism, seems to be useful tools to determine the priority areas for conservation of different species groups.

A synthesis of all available data on priorities for conservation discussed thus far cannot be more than a preliminary effort. A multidisciplinary approach concerning the Amazon region (fig. 5), needs to be elaborated for the Andean region too. But when concentrating on the ecological arguments

for conservation priorities described in the previous chapters, some judgments can be made.

Comparison of the different Andean Cordilleras reveals that the Cordillera Oriental has relatively the greatest species diversity concerning vascular páramo vegetation, *Espeletia* spp., páramo birds, mammalian fauna, herpetofauna, as well as Satiridae (table 6). The base of the Cordillera Oriental and the Amazonian uplands bordering the Nudo de los Pastos have the greatest numbers of woody species (trees and lianas). This makes the Cordillera Oriental evidently a priority area for conservation.

The number of endemic bird species is greatest in the Cordillera Occidental and the Nudo de los Pastos. Furthermore, the area of avian endemism on the border between Colombia and Ecuador, is adjacent to the "highest priority" area of the interdisciplinary workshop (fig. 5). The latter area coincides with the highest primate density (fig. 3) and forms part of the western Amazonian uplands "hotspot" sensu Myers, especially rich in plant species (fig. 5). This makes the area along the transect from the Nariño highlands to the eastern slopes of the Andes in the Nudo de los Pastos a candidate priority area for conservation. This will probably be affirmed by further ecological transect studies in this area.

Table 6. Summary of comparisons between the Colombian Cordilleras, concerning the different floral and faunal species groups. Where possible, the Cordilleras are ranked from 1 (relatively highest species diversity) to 4 (relatively lowest species diversity).

	Cordillera Oriental	Cordillera Central	Cordillera Occidental	Nudo de los Pastos
Trees&lianas	1			1
Vascular páramo vegetation	1			
<i>Espeletia</i> spp.	1	2	3	
Mammals	1	2	3	4
Primates				1
Endemic birds	4	3	2	1
Páramo birds	1	2	3	
Herpetofauna	1	2	3	4
Satiridae	1	2	3	

In comparing the different Colombian Cordilleras and ranking them as priority areas for conservation, ecological motives are not the only concern. There are many other factors to deal with, e.g. criteria and principles concerning the planning of conservation areas. The severity of threat due to human pressures, involvement of local peasants in conservation and buffering of protection cores are essential factors, which need to be evaluated and dealt with in conservation planning.

In the light of the aforesaid, some conclusions can be drawn point by point:

- a. Given that centres of endemism, Pleistocene forest refugia and centres of species diversity are important criteria for the appointment of areas requiring protective status;
- b. Concluding that the Cordillera Oriental is a very high priority area for conservation, based on the facts that it has relatively the highest species diversity concerning vascular páramo vegetation, *Espeletia* spp., páramo birds, mammalian fauna, herpetofauna, Andean Brown Butterflies, as well as woody species (together with the Andean foothills bordering the Amazonian uplands in the Nudo de los Pastos);
- c. Concluding that the border area with Ecuador, from the Nariño highlands to the uplands of western Putamayo on the eastern slopes of the Colombian Massif, is another priority area for conservation, based on the facts that this area has a very high degree of avian endemism, is adjacent to the "highest priority" area of the interdisciplinary workshop on conservation in Amazonia, which has the highest primate density in Colombia, and forms part of the western Amazonian uplands "hotspot" sensu Myers;
- d. Assuming that areas appointed as protected areas of IUCN Category II (National Parks) are accordingly well protected and managed by the Instituto

Nacional de los Recursos Naturales Renovables' (INDERENA);

- e. Assuming that further examination reveals that these areas can be adopted as high priority conservation area by the authorities and that it is possible to realize one or more of the previously (in 1977) planned sites in the area by INDERENA;
- f. Concluding that the protection of Andean biomes from the tropical lowlands, along the Andean slopes, up to the superpáramo, is necessary along a continuous transect, in order to maximize biological diversity (species as well as habitats) inside the protected areas;

The following recommendations can be made:

1. Concentrate on conservation of the Andean habitats in general and that of the Cordillera Oriental and the Colombian-Ecuadorian border zone in particular;
2. Maintain and strengthen the existing protective sites (i.e. National Parks) in the Andean region in general and the Cordillera Oriental in particular, i.e. by enforcing and/or initiating measures to avoid disturbing influences inside or adjacent to the park borders;
3. Pay special attention to the Andean region on the border with Ecuador in the appointment, establishment and management of protective sites, i.e. National Parks;
4. Expand the existing National Parks and Reserves to such an extent that they encompass the whole continuous area along the Andean slopes from the lowland areas up to the superpáramo and the nival belt;
5. Protect all or most of the remaining 'wilderness' areas in view of the probably very small percentage of still intact (sub)montane forests;
6. Initiate additional ecological studies for conservation purposes in the Colombian Andes, i.e. transect studies, especially in the Nudo de los Pastos and the

Cordillera Oriental, along both eastern and western slopes, from the lowlands up to the superpáramo.

It probably becomes clear that there is a necessity to make additional substantial conservation efforts in the Andes. For this reason, discussion on priorities for conservation in the area cannot come to a standstill.

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