BIODIVERSITY CONSERVATION IN THE TROPICS:

GAPS IN HABITAT PROTECTION AND FUNDING PRIORITIES

Authors: M.G. Murray, M.J.B. Green, G.C. Bunting and J.R. Paine

Department for International Development Project R6190

December 1996

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EXECUTIVE SUMMARY

This study makes use of several extensive GIS datasets, not previously available, to provide for the first time a comprehensive assessment of the conservation status of biodiversity throughout the tropics. Using the classification system of ecofloristic zones developed by the Centre National de la Recherche Scientifique (University of Toulouse, France) and that of closed moist forests developed by WCMC and IUCN - The World Conservation Union, the protected area coverage of tropical terrestrial habitats is examined and gaps identified in five regions: tropical Africa, South and South-East Asia, Insular South-East Asia, tropical South America, and Central America and the Caribbean.

Globally, 7.7% of tropical regions and 12.2% of moist tropical forests are conserved within protected areas. Protected area coverage of ecofloristic zones is shown to be uneven, with better protection of moist zones and forests compared with dry ones. It is suggested that future conservation actions should focus on improving the management of existing protected areas in moist zones, and on expanding protected area networks in drier zones. Regarding moist forest types, over 20% of sub-montane and montane forest types are protected but only 5% of inland swamp forest is protected. Some 12.4% of lowland rain forest occurs within protected areas.

The lowest regional level of representation in protected areas (3.6%) is in South and South-East Asia. Tropical South America has the highest level of protection (9.8%). Protection of the other regions is intermediate, some zones being poorly represented and others well represented in protected areas. Moist forests are least protected in Africa, where 7.6% of all moist forests are under protection and only 6.9% in the case of lowland rain forest. Tropical South America has the highest level of regional protection, with 15.1% of all moist forests and 14.4% of lowland rain forest within protected areas.

At the national level, countries with major proportions of particular ecofloristic zones and forest types within their jurisdiction are identified, and those providing low levels of protection are highlighted for priority conservation action. Thirteen countries contain entire ecofloristic zones within their territories and, therefore, are solely responsible for their protection. Countries with a low level of protection of ecofloristic zones and forest types are also identified. Seven ecofloristic zones receive no protection in any country.

A separate analysis of national and foreign investments in protected areas is presented for 25 tropical countries prioritised by the British Government for aid under its Renewable Natural Resources Strategies. Countries with a high diversity of ecofloristic zones tend to invest less in their protected areas. Foreign aid interventions do not adequately compensate for this disparity.

It is recommended that governments be guided by the findings in this report, particularly with respect to major gaps in the protection of tropical habitats. It is also recommended that the present study be supplemented by a quantitative assessment of the representation of centres of species diversity, speciation and endemism within tropical protected area networks.

In the longer term, it is suggested that a tripartite information system on (1) representation of tropical habitats and species hot spots within protected areas, (2) effectiveness of protected areas management, and (3) national and foreign investments in protected areas would enable cost effective strategies for conserving biodiversity in the tropics to be developed and monitored.

ACKNOWLEDGEMENTS

This is the final report on Research Project R6190 - *Investments in Conservation Areas in the Tropics*, funded by the Department for International Development, UK under its Renewable Natural Resources Research Strategy. In particular, WCMC thanks Howard Wright and Anne Bradley of the Forestry Research Programme, Oxford Forestry Institute which manages the Forestry Research Strategy for the UK Government. A summary of that part of this report relating to the conservation status of ecofloristic zones has been published in the *WCMC Biodiversity Bulletin* No. 1.

The research reported here is the product of several major projects previously carried out by WCMC, notably the compilation of an atlas of the world's tropical forests in collaboration with IUCN - The World Conservation Union (funded principally by British Petroleum p.l.c.), an assessment of the conservation status of tropical managed areas as a contribution to the FAO Forest Resources Assessment 1990 (funded by the former Overseas Development Administration, UK), and a review of financial investments in biodiversity conservation (funded by the European Commission). It has also benefited from an ongoing review of the Indo-Malayan protected areas system, funded by the World Bank and executed by Dr John MacKinnon, Asian Bureau for Conservation in close association with WCMC. Massimiliano Lorenzini and George Muammar, FAO Forest Resources Assessment 1990 Project kindly prepared in digital format the ecofloristic zones classification system, first developed by F. Blasco and P. Legris and subsequently applied by M. K. Sharma, F. Lavenu and others to tropical regions.

The project was first conceived by Dr Mark Collins, Director of WCMC, whose support throughout its duration has been appreciated. The authors are very grateful to Victoria Freeman for her considerable secretarial assistance. Christine Carey-Noble and Mary Edwards also contributed to this study. Jeffrey McNeely and Dr Timothy Whitmore provided helpful comments in an earlier version (October 1995) of this report.

1. INTRODUCTION

1.1 OBJECTIVES

The aims of this study are twofold:

- to examine the adequacy of conservation area networks in tropical regions for protection of the full range of terrestrial ecosystems, and

- to quantify investments and identify shortfalls in national protected area networks, focusing on those countries prioritised by the British Government for development assistance under its Renewable Natural Resources Strategies.

The first objective is addressed in two complimentary ways by examining the extent to which (a) potential vegetation and (b) forest types are represented within protected areas. Potential vegetation is based on an ecofloristic zone (EFZ) classification system developed by the Centre National de la Recherche Scientifique (University of Toulouse, France). A classification developed by WCMC and IUCN - The World Conservation Union is used for closed moist forest types.

In examining protected area networks, the study identifies those EFZs and forest types with little or no protected areas coverage. It also distinguishes between countries with *de facto* sole responsibility for conservation of an EFZ, by virtue of their near exclusive territorial jurisdiction of that EFZ, and those with shared responsibility.

The second objective is addressed by assessing levels of national and foreign investment in protected areas in those tropical countries prioritised for aid by the British Government under its Renewable Natural Resources Strategies[1]. Information on investments in protected areas is related to that on richness of biodiversity, enabling gaps in financial support for biodiversity conservation to be identified.

1.2 HOW TO USE THIS DOCUMENT

1.2.1 Guide to contents

The methodology is described in Section 2, including background information on the EFZ and forest classification systems used in this study. The results of the analysis of the conservation status of EFZs and forest types are presented for each tropical region in Section 3. Investments in protected areas are assessed in Section 4. The report concludes with recommendations for future research required for policy development (Section 5).

Keys to the EFZ and forest classification systems are given in Tables 1 and 2, respectively. They should be used in conjunction with the maps which show the distribution of EFZs and forests in relation to protected areas.

[1] These strategies cover agriculture, biodiversity, forestry, aquatic resources and livestock/wildlife.

The raw data from the results of the analyses of the conservation status of EFZs and forest types are given for each region in the annexes. These data are presented in two ways:

- by EFZ or forest type, by country, and
- by country, by EFZ or forest type.

The first way enables the distribution and conservation status of a particular EFZ or forest type within its range countries to be readily looked up. The second provides a profile of the EFZs or forest types within a country and the extent to which they are protected.

The raw data are summarised in a series of complementary tables. In the case of the EFZ analysis, the data are also presented in a series of plots (Figures 1-4) which highlight priorities for conservation action, based on the extent of an EFZ within a country and the extent to which it is protected, as explained in Section 2.2.

Steps to quickly look up an EFZ or forest type, a country with respect to its EFZs or forest types, or the level of investments in a country's protected areas network are outlined below.

1.2.2 To look up the conservation status of an EFZ or forest type

1. Use the maps, in combination with the key in Table 3, to identify the relevant EFZ and its major zone.

   [e.g. Major Zone 2, EFZ 1 in tropical Africa: Guinea-Congolian lowland rain forest.]

2. Refer to Table 4, 9, 14, 19 or 24 to identify its approximate extent within protected areas, and those countries accounting for more than 25% of its total area.

   [i.e. 5-10% protected; Zaire is the only country with >25% of EFZ 1.]

3. If required, refer to Annex 1, 5, 9, 13 or 17 for full details of its distribution and extent of protection within range countries.

   [i.e. EFZ 1 is distributed among six countries. Zaire, for example, has 78.2% of the total extent, of which 5.9% lies within protected areas. Of the total extent, 4.6% is protected in Zaire.]

4. Refer to the relevant plot in Figures 1-4 to identify priorities for national conservation action. The results are discussed for the different regions in Sections 3.1.1, 3.2.1, 3.3.1, 3.4.1 and 3.5.1, respectively.

   [i.e. Figure 1b for Major Zone 2 shows that the highest priority for the conservation of EFZ 1 is in Zaire, plotted in bottom right quadrant, which is the only country having more than 10% of this ecofloristic zone and less than 10% of it protected.]

A similar procedure should be followed for a forest type, beginning with the relevant forest map and key in Table 2. Relevant tables are 6, 11, 16, 21 or 26, and annexes are 3, 7, 11, 15 and 19. Note that the results are not plotted, but they are discussed for each of the regions in Sections 3.1.2, 3.2.2, 3.3.2, 3.4.2 and 3.5.2.

1.2.3 To look up the conservation status of a country's EFZs or forest types

1. Use the maps, in combination with the key in Table 1, to identify the relevant EFZ.

   [e.g. Paraguay comprises EFZs 6 (evergreen forest), 11 (swamp grassland), 12 (semi-evergreen forest), 16 (dry semi-deciduous forest) and 19 (cerrados).]

2. Refer to Table 5, 10, 15, 20 or 25 to identify the importance of the country for each EFZ and the extent of its protection.

   [i.e. Over 50% of each of three EFZs is distributed within Paraguay, but none is exclusive to the country. Semi-evergreen forest (EFZ 12), for example, covers 19,383,934ha, of which 374,448ha are protected.]

3. If required, refer to Annex 2, 6, 10, 14 or 18 for full details about the distribution and extent of protection of EFZs within the country.

   [i.e. Of the five EFZs found in Paraguay, semi-evergreen forest (EFZ 12), for example, is the most extensive and 1.7% is protected.]

A similar procedure should be followed for a forest type, beginning with the relevant forest map and key in Table 2. Relevant tables are 7, 12, 17, 22 and 27, and annexes are 4, 8, 12, 16 and 20.

1.2.4 To look up investments in a country's protected area network

This part of the study is restricted to 25 countries prioritised by the British Government for aid under its Renewable Natural Resources Strategies. Data are not available for all of these countries.

1. Refer to Table 30 for expenditure by national protected area agencies expressed per unit area protected. These data are plotted in Figure 7.

   [e.g. Among the highest level of national investment is in Sri Lanka, with US$ 150 per sq.km protected.]

2. The impact of Official Development Assistance (ODA) on national investments in protected areas is shown in Figure 10, based on data in Table 30.

   [i.e. ODA accounts for an additional US$ 67 per sq.km protected in Sri Lanka.]

3. If required, refer to Annex 21 for a summary of the raw data for ODA projects concerned with protected areas.

   [i.e. There is one ODA project, funded by GEF, concerned with protected areas in Sri Lanka.]

2. METHODS

2.1 BACKGROUND TO CLASSIFICATION SYSTEMS

A variety of classification systems have been developed to comprehend better the global distributions of plants and animals (WCMC, 1992a). These systems, which attempt to classify the natural environment into discrete, discontinuous units, are inevitably imperfect since in reality nature takes the form of a highly variable continuum responsive both to spatial variations in climate, soils and topography, and to historical processes influencing species' distributions. These latter have left behind their own unique pattern in species richness and degree of endemism which frequently cuts across otherwise uniform habitats. Despite these difficulties, biogeographic classification of the natural environment has been attempted, not least because of the fundamental importance of providing a rational basis for the management and conservation of biodiversity.

The classification system of ecofloristic zones (EFZs) was developed by F. Blasco and P. Legris (CNRS, University of Toulouse, France) in order to standardise existing vegetation classifications of tropical Asia and the Pacific (Sharma, 1986; FAO, 1989). Subsequently, it was applied to the vegetation of Africa (Sharma, 1988) and South America (Lavenu, Bellan and Meste, 1988). The classification is based on four criteria:

- climate (mean annual precipitation, length of dry season, temperature and relative humidity);
- physiognomy and structure of vegetation using interpretation of satellite imagery;
- edaphic factors (soil and physical environment); and
- dominant or characteristic forest species of indigenous flora.

Thus, this system shares the principal features of other global habitat classification schemes in that it describes generalised habitat types in conjunction with a climatic or topographic descriptor (e.g. dry savanna steppe and thickets, or lowland rain forest <300m), and also recognises biogeographical boundaries in flora and fauna between regions which are otherwise similar in their climate and vegetation (e.g. transition forests of Madagascar, 800-1,800m; transition forests of southern Africa, 800-1,500m). However, it should be recognised that the analysis of protected areas coverage at this large scale inevitably disregards important localised variation in habitats. For example, the nature of the underlying substrate is not included in the criteria used to define EFZs, although different substrates often give rise to different assemblages of species within the same eco-climatic zone (IUCN, 1996).

The EFZ classification system is summarised for the different tropical regions in Table 3. Thirteen major zones are distinguished, each represented by one or more EFZs in the different regions. Whereas major zones are common to all regions (except the Mediterranean which occurs only in tropical Africa), EFZs are characteristic of particular regions.

A classification of moist forests was developed by WCMC and IUCN to integrate national datasets and produce a pantropical forest map. This is shown in Table 2. The system is currently limited to closed moist forest, except in Latin America where closed dry forest and pine forest is

also recognised. Open forest/woodland and savanna woodland have not been included. Datasets are mostly from the late 1980s but some are earlier than this (IUCN, 1991, 1992, 1996).

2.2 ECOFLORISTIC ZONES AND FOREST TYPES

The countries included in this study are those covered in the 1990 FAO Managed Areas Assessment (WCMC, 1992b) with the addition of South Africa (Tables 3, 8, 13, 18, 23). Digital data on EFZs, forest types and protected areas were processed at a regional level using geographical information system (GIS) technology. The regions chosen correspond with the EFZ coverages compiled by FAO. These are as follows:

- Tropical Africa
- South and South-East Asia
- Insular South-East Asia (including New Guinea)
- Tropical South America
    - Central America and the Caribbean.

The EFZs were digitised by FAO, as part of its Forest Resources Assessment 1990 Project, and the data provided to WCMC for the purpose of this study. The Solomon Islands were included in the moist forest coverage, but not the EFZ coverage, of Insular South-East Asia. The other data layers were extracted from WCMC's Biodiversity Map Library, as follows:

- Biological Reporting Units,
- tropical forests, and
    - protected areas.

The WCMC Biodiversity Map Library is continuously expanding and being updated. For example, an ongoing review of the protected areas system in the Indomalayan realm contributed significantly to this study in terms of updating the protected areas coverage for this realm.

All classes of forest listed in the *Conservation Atlas of Tropical Forests* were included in the analysis (IUCN, 1991, 1992, 1996). IUCN Protected Area Management Categories I-VIII (old system[2]) were included; Categories I-III were then differentiated from the rest in order to distinguish between totally and partially protected areas. Protected areas not assigned to an IUCN Category were excluded from the analysis. Similarly, some Category VIII protected areas for which geographical coordinates are not yet available were excluded.

The GIS analysis was carried out using the overlay functions provided by ARC/INFO (Version 7). For each tropical region, data layers were combined to form one vector coverage, each polygon having a spatial area as well as a code for its forest type, EFZ, country and protection status. Once the vector coverage had been compiled, it was transformed from its original geographic coordinates system to a suitable equal area projection[3] to enable the sizes of polygons to be exported to a FoxPro database. This was used to generate the statistics of Annexes 1-20. Analysis of these statistics is presented in Tables 1-29 and Figures 1-4. Each

[2] For descriptions of the old system of categories see *Categories, Objectives and Criteria for Protected Areas* , IUCN (1978). The new IUCN classification system of six categories has yet to be applied. For a full description of this new system see *Guidelines for Protected Area Management Categories*, IUCN (1994).

[3] The projection chosen was Lambert Azimuthal with the radius of the sphere of influence set to the default value of 6,370km (the approximate radius of the Earth). The following central meridians were used: Africa 20° East, Central America 90° West, South America 60° West, South-East Asia 85° East, and Insular Asia 125° East. The latitude of the projection's origin was taken to be the Equator (0°) for each coverage.

figure shows the percentage of an EFZ within a country plotted against its protection within that country. Countries with no protection of an EFZ are included in the presentation of log-transformed data by adding 0.01 to the score of their protected area coverage. The figures are divided into four quadrants with the following conservation implications, as shown below:

The arrow indicates the direction of increasing priority for conservation action. Thus, for example, a data point labelled with the appropriate country ISO code in the bottom right of a plot, indicates that most of the EFZ lies within the territory of that country, where little of it is protected.

Throughout this report, adequate protection refers to EFZs or forest types for which at least 10% falls within protected areas (IUCN Categories I-VIII). This minimum of 10% is based on that agreed at the III World Congress on National Parks and Protected Areas to be an appropriate and practical target for each of the world's biogeographic provinces (McNeely and Miller, 1984). This target was applied to Biomes at the IV World Congress (IUCN, 1993).

2.2.1 Data limitations

Protected areas less than 1,000ha were excluded from the analysis, as this eliminates about 45% of sites at a loss of only some 0.2% of total area protected. Protected areas were held as polygons if boundary data were available or as point locations if only single coordinates were available. Both forms were included in the analysis. For point locations, circles were generated round each point proportional to the area of the site.

A few EFZs extend beyond the regions considered in this analysis. Statistics concerning protected area coverage refer to the areas within the countries indicated in Tables 3, 8, 13, 18 and 23.

2.3 INVESTMENTS IN PROTECTED AREAS

National investments in protected areas can be measured in several ways including the total area allocated for conservation, financial inputs, and staffing levels. The percentage of the total area of a country under protection is an indication of a nation's commitment to biodiversity conservation, but this may be relatively independent of its economic and human resources available to conserve biodiversity. Ultimately, it reveals little about the quality of management in protected areas. Financial investments in protected areas indicates the overall level of national expenditure on *in situ* conservation activities, but data are seldom readily available to differentiate between expenditure on actually managing protected areas and other operations. Thus, it cannot be used by itself to indicate the effectiveness of conservation efforts on the ground. In this respect, a comparison of staffing levels might provide a more direct indicator of what countries actually achieve in managing protected areas. However, staffing level by itself ignores the institutional context of a country, and its ability to deliver effective training programmes and to adequately support staff in the field (James *et al*., in press). Thus, all three indicators of national investment were utilised in this study.

Data on national investments and on foreign aid for protected areas were compiled for 25 of the 26 countries prioritised for development assistance by the United Kingdom under its Renewable Natural Resources Strategies. China was omitted because it falls outside tropical Asia with respect to the EFZ classification developed by FAO (1989). These data are summarised in Annex 21.

Data on national investments in 1992 were obtained from a worldwide survey of 600 protected area management agencies that was part of an earlier study funded by the European Commission (James *et al*., in press). Agency budgets overstate the investment in actually managing protected areas for the reasons discussed above. Where data were not obtained from all the agencies responsible for protected areas in a given country, the investments of those agencies which responded are taken as representative of that country's overall conservation effort. National investment data are expressed per unit area protected to provide a comparative measure of the intensity of conservation effort.

Data on foreign aid were also taken from the above-mentioned study funded by the European Commission (WCMC, 1995), part of which included a survey of Official Development Assistance (ODA) channelled through bilateral and multilateral aid agencies. The survey did not routinely include assistance from foreign NGOs, private foundations or the corporate sector, unless such data were available from the UNDP Development Corporation Reports which were systematically scanned for information on biodiversity conservation projects.

A number of criteria were applied in selecting investments for the present study:

- aid had to be specifically for projects devoted to biodiversity conservation;
- biodiversity conservation projects had to include a protected areas component; and

- the project had to be ongoing during 1992.

Thus, for the purposes of this study, foreign aid for biodiversity conservation is defined narrowly in terms of ODA directed towards protected areas in 1992. Projects which were aimed primarily at improving the management of natural resources for commercial utilisation rather than conserving biodiversity *per se* were excluded, as were projects which supported *ex situ* conservation. Projects concerned with buffer zone development on the periphery of protected areas were also excluded. For purposes of the analysis, both the total commitment of all projects active in 1992, and the proportion of the total commitment allocated for 1992, were used to assess a country's receipt of foreign aid. The former provides a fuller picture of the scale of support received by countries, the latter is more directly comparable with the data on national investments in 1992.

3. PROTECTION OF ECOFLORISTIC ZONES AND FOREST TYPES

3.1 TROPICAL AFRICA

The 41 countries of tropical Africa included in this analysis are listed in Table 3. The largest countries, Sudan and Zaire each cover about 10% of the region. They are some 100-200 times greater in size than the smallest countries, Burundi, Djibouti, Equatorial Guinea, Gambia, and Rwanda.

3.1.1 Ecofloristic zones

A key to the EFZs of tropical Africa is provided in Table 1. The *Code* refers to the classification found in Map 1 and Annexes 1 and 2. The *Class* indexes the habitat descriptions of Sharma (1988). The *Major Zone* indicates to which of 12 eco-climatic zones, common to all tropical regions, each EFZ belongs, with an additional zone (13) for temperate forests in South Africa (Table 1).

The extent of protection of each EFZ in tropical Africa is illustrated in Map 1 and detailed in Annex 1 which contains a breakdown of each EFZ by country. For example, EFZ Code 1 (Guinea-Congolian lowland rain forests) is found in six countries, but 78% is found in Zaire. Some 5.9% of the EFZ is protected overall, but only 4.7% in protected areas of Categories I-III. Some 4.6% of this EFZ is protected by protected areas (I-VIII) in Zaire.

Annex 2 provides an alternative breakdown of the protection of EFZs. In this case countries are listed alphabetically and classified by EFZ. For example, Angola has nine EFZs but two of them (13 Wetter Zambezian miombo woodlands and dry evergreen forests; 19 Drier Zambezian miombo, mopane woodlands, dry deciduous forests) make up over 60% of the area of the country. Overall 4.9% of Angola is protected, but only 0.6% of the country by protected areas in Categories I-III. EFZs 5, 18 and 56 have no protection in Angola. The majority (84.3%) of EFZ 18 (wooded grassland with *Adansonia digitata*) falls within Angola (Annex 1).

The EFZs of tropical Africa vary in size from a tiny fragment of lowland rain forest on the east coast of Madagascar (EFZ 2) to a large belt of dry evergreen rain forest in west and central Africa (EFZ 5), some 15,000 times greater in area (Map 1). Of the 53 EFZs in tropical Africa, only 14 have more than 10% of their area protected within conservation areas, 10 have less than 1% protected and two (EFZs 2 and 18) have no protection (Table 4).

The diversity of EFZs within countries is shown in Table 3: six countries have 10 or more EFZs within their territory. Countries with a high proportion of at least one EFZ within their territory are indicated in Table 5: 13 countries hold 50% or more of at least one EFZ within their boundaries; three of these countries (Kenya, Madagascar and South Africa) have sole responsibility for one or more EFZs, in that the entire zone falls within their territory. The special responsibilities of Madagascar and South Africa for the conservation of unique habitats is emphasised by the number of EFZs (9 and 10, respectively) that are found exclusively within their boundaries.

Within the framework of the EFZ approach, there are compelling arguments for national conservation action where a country has a high proportion of an EFZ and little of it is currently protected by that country, as shown in Figure 1. Priorities for national conservation action are identified below.

Major Zone 1 (lowland wet) is composed of a single EFZ (4: swamp forests, mangrove and edaphic grasslands, see Table 1) which occupies two discontinuous coastal strips, one in west Africa and the other in Nigeria and Cameroon. This study indicates the need for greater protection of this EFZ in Liberia, Sierra Leone and Nigeria (Figure 1a).

Major Zone 2 (lowland very moist) consists of several areas of lowland rain forest in central Africa and along the northern and eastern coasts of Madagascar (described by EFZs 1, 2, 3 and 6). Some of these EFZs include centres of endemism and species diversity which may not be evident from the GIS analysis. Thus, the central African belt stretches from the western areas of high endemism and diversity in Cameroon and Equatorial Guinea, to eastern Zaire, which is a second focal centre of endemism and diversity. The moist forests of Madagascar are also exceptionally rich in endemic species. The urgent need for further protection of three of the four EFZs in Madagascar is highlighted in Figure 1b.

Major Zone 3 (lowland moist with short dry season) is a large discontinuous area of semi-evergreen forest in west and central Africa and along the eastern coast of Africa (described by EFZs 5, 7 and 8). These EFZs do not distinguish between the forest refugia of Upper Guinea and Cameroon or between the centres of endemism of the eastern coastal forests. This study indicates the need for better protection of EFZ 7 in Mozambique and Tanzania and further protection of EFZ 8 in South Africa (Figure 1c).

Major Zone 4 (lowland moist with long dry season) consists of deciduous woodlands and semi-evergreen forests (described by EFZs 9-13). This zone is distributed across Africa in a wide sub-Sahelian belt, a second broad belt to the south in Angola, Zambia, Mozambique, S.E. Zaire and Tanzania, and also in Madagascar. There are several centres of endemism in western Angola, Zambia, Mozambique, Tanzania and Madagascar which are not distinguished by the EFZs. Figure 1d highlights the need for protection of EFZ 9 in Guinea-Bissau, increased protection in Guinea, and for increased protection of EFZ 12 in Madagascar.

Major Zone 5 (lowland sub-dry) consists of deciduous woodlands and savannas with a wide distribution across the continent (described by EFZs 14-19, 22). It contains many important sites for large mammal populations, and several centres of endemism, including western Angola, southern Zambia, southern Mozambique, Natal and northern Tanzania, which are not distinguished by the EFZs. Figure 1e highlights the need for increased protection in many countries, but especially of EFZ 18 in Angola and EFZ 15 in Mozambique.

Major Zone 6 (lowland very dry/sub-arid) consists of dry savanna, shrub and bushland which includes a Sahelian band, a fragmented area of eastern Africa, a wide band in southern Africa, and a section along the southern coast of Madagascar. The zone is described by EFZs 20, 21, 23, and 32-35. It contains centres of endemism and diversity in western Angola and the Cape Province of South Africa, Tanzania, Ethiopia and Somalia that are not distinguished by the EFZs. Figure 1f highlights the need for increased protection in many countries, including EFZ 34 in Madagascar, EFZ 21 and 33 in Somalia, and EFZ 32 in Niger and Sudan.

Major Zone 7 (lowland arid/desertic) consists of shrub pseudo-steppe and steppe in the regions of the Namib, Afar, Ogaden and Sahara deserts. The zone is described by EFZs 36-38. It contains centres of endemism along the western margins of Angola, Namibia and South Africa, and in Somalia which are not distinguished by the EFZs. Figure 1g indicates the urgent need for protection of EFZ 37 in Somalia.

Major Zone 8 (premontane moist) consists of transition forests and woodlands between 1,000m-3,000m with a discontinuous and widespread distribution in Guinea, Cameroon, eastern and south-central Africa and Madagascar. The zone is described by EFZs 39-45. It includes or partially includes several centres of endemism in Cameroon, eastern Zaire, Ethiopia and Tanzania. Figure 1h highlights the need for protection of EFZ 39 in Tanzania, EFZ 40 in Cameroon, EFZ 42 in Angola and Zaire, and EFZ 45 in Madagascar.

Major Zone 9 (premontane dry) consists of grassland, shrubland and evergreen forests from 1,500m to 3,000m, with a fragmented distribution in eastern Africa and in South Africa. The zone is described by EFZs 49-54. It passes through a number of centres of endemism in eastern Africa and one endemic bird area in South Africa. Figure 1i highlights the need for protection of EFZ 54 in Somalia and Sudan, and increased protection of EFZs 49 and 50 in South Africa, and EFZ 53 in Kenya.

Major Zone 10 (montane moist) consists of montane evergreen bushland, thicket and forest from 1,500m to 3,000m with a fragmented distribution in eastern Africa, South Africa and Madagascar. The zone is described by EFZs 56-58 and 61. It is associated with a number of areas of high endemism and species richness in eastern Africa. Figure 1j shows that the zone is moderately well protected, but highlights the need for increased protection of EFZ 61 in Ethiopia.

Major Zone 11 (montane dry) consists of montane evergreen scrubs from 1,500m to 2,900m in South Africa (described by EFZ 62). It includes part of the Drakensberg Alpine Region, a centre of plant diversity and part of an endemic bird area. Figure 1k indicates that this zone is inadequately protected.

Major Zone 12 (alpine) consists of alpine scrub above 2,900m in small fragmented localities in eastern Africa and South Africa. It is described by EFZs 64 and 65. It includes parts of several centres of endemism. Figure 1l indicates that this zone is adequately protected.

Major Zone 13 (Mediterranean and temperate) consists of fynbos and temperate forests in South Africa (described by EFZs 25, 27, 29 and 30). It includes the Cape regional centre of endemism with two centres of plant diversity and endemism: the Western Cape Domain and the Cape Floristic Region. Figure 1m emphasises the sole responsibility of South Africa to conserve this zone.

3.1.2 Moist forests

A key to the moist forest types of the tropical regions of the world, including Africa, is provided in Table 2. The code refers to the classification found in Map 2 and Annexes 3 and 4.

Annex 3 provides information on the protection of moist forests in tropical Africa, with a breakdown of countries for each type of forest. For example, mangrove (Forest Code 111) is found in 16 countries of tropical Africa, but 48% of it occurs in just two countries, Nigeria and Gabon. Only 2.0% of mangrove is protected overall and only one tenth of this is in protected areas of Categories I-III. Some 5.8% of mangrove in Gabon is protected (Categories I-VIII) but only 0.2% in the case of Nigeria.

Annex 4 provides information on the protection of moist forests within each African country. For example, Cameroon has four types of forest, one of which (lowland rain forest) comprises 31.6% of the country. Some 65.9% of the country is not forested. Inland swamp forest (Forest Code 113) has no protection in Cameroon, but only a minority of this forest type is found in Cameroon (Annex 3).

When considered broadly, it can be seen from Table 6 that montane rain forest is well represented in protected areas in Africa, but that mangrove, inland swamp forests and lowland rain forests require greater protection.

Countries with a high proportion of the various moist forest types within their territories are indicated in Table 7. Zaire contains more than 50% of three types of forest: inland swamp, lowland rain forest and montane rain forest, the former two categories being poorly represented in protected areas. Congo, Ethiopia and Nigeria have extensive inland swamp forest, montane rain forest and mangrove, respectively. Inland swamp forest is not protected in Congo and very little of Nigeria's mangrove is protected; montane rain forest is well represented in protected areas of Ethiopia. The majority of other countries contain only small proportions of these forest types.

3.2 SOUTH AND SOUTH-EAST ASIA

The 12 countries of South and South-East Asia included in this analysis are listed in Table 8. India is much the largest country covering almost 50% of the region's land area. It is almost four

times larger than Pakistan, the next largest country, and over 60 times larger than Bhutan, the smallest country of the region.

3.2.1 Ecofloristic zones

A key to the EFZs of South and South-East Asia is provided in Table 1. The *Code* refers to the classification found in Map 3 and Annexes 5 and 6. The *Class* indexes the habitat descriptions of Sharma (1986). The *Major Zone* indicates which of 12 eco-climatic zones common to all tropical regions are associated with the EFZs of this region.

The extent of protection of each EFZ in South and South-East Asia is illustrated in Map 3 and detailed in Annex 5 which contains a breakdown of each EFZ by country. An alternative arrangement of the data is found in Annex 6, which lists countries alphabetically and provides a breakdown of the EFZs in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.1.

The EFZs of South and South-East Asia vary in size from a small patch of hill forest in Sri Lanka (EFZ 36) to a large area of dry deciduous forest in India (EFZ 18) which is some 5,100 times greater in area (Map 3). Of the 39 EFZs in the region, only five have more than 10% of their area protected by conservation areas, 11 have less than 1% of their area protected, including four with no protection at all (Table 9).

The diversity of EFZs within countries is shown in Table 8. India is much the most diverse country with 26 EFZs represented. Countries with a high proportion of at least one EFZ within their territory are indicated in Table 10. Seven countries in the region (Cambodia, India, West Malaysia, Myanmar, Pakistan, Sri Lanka and Vietnam) each contain entire EFZs within their territories and, therefore, are solely responsible for their protection. India contains over 50% of 15 EFZs, and four of these are found nowhere else, emphasising the regional importance of this country for habitat conservation.

Within the framework of the EFZ approach, there are compelling arguments for national conservation action where a country has a high proportion of an EFZ and little of it is currently protected by that country, as shown in Figure 2. Priorities for national conservation action are identified below.

Major Zone 2 (lowland very moist) consists of lowland evergreen rain forest in the Western Ghats of India, in Sri Lanka, in a belt extending from the Himalayas to Malaysia, and in parts of Indo-China. It is described by six EFZs (3-6, 14 and 15). The major zone includes numerous centres of diversity and endemism. This study indicates the need for increased protection of EFZ 14 in Vietnam, EFZs 4 and 5 in Myanmar and EFZs 5 and 15 in India (Figure 2a).

Major Zone 4 (lowland moist with long dry season) consists of moist deciduous forests which form a transition between rain forests and drier areas across the region, and is also found in the foothills of the Himalayas. It is described by EFZs 24-29. The need for increased protection of

EFZ 29 in Cambodia, EFZ 28 in Bangladesh, EFZ 26 in India and EFZ 24 in Myanmar is illustrated in Figure 2b.

Major Zone 5 (lowland sub-dry) consists of a large area of dry deciduous forest covering much of India, and large areas of Cambodia, Lao PDR, Myanmar, Pakistan, Sri Lanka, Thailand and Vietnam. It is described by EFZs 7-9 and 16-19. The need for increased protection of EFZ 7 in Vietnam, EFZ 17 in Myanmar and EFZs 8, 9, 18 and 19 in India is demonstrated in Figure 2c.

Major Zone 6 (lowland very dry/sub-arid) consists of thorn forest and pseudo-steppe in north-west India and Pakistan. It is described by a single EFZ (22) in this region. The need for increased protection of this EFZ in both India and Pakistan is illustrated in Figure 2d.

Major Zone 7 (lowland arid/desertic) consists of pseudo-steppe vegetation in Pakistan and north-west India. It is described by a single EFZ (30) in this region. The zone includes part of the Indus valley. The need for increased protection of EFZ 30 in Pakistan is shown in Figure 2e.

Major Zone 8 (premontane moist) consists of hill and montane forests in the foothills and mountains of the Himalayas, extending south into Myanmar, Lao PDR and Thailand, and scattered across other high country. The zone is described by EFZs 32-39. It incorporates many centres of endemism and diversity. The need for increased protection of EFZ 36 in Sri Lanka, EFZs 34 and 35 in Myanmar, EFZs 37 and 38 in India and EFZ 38 in Pakistan is shown in Figure 2f.

Major Zone 9 (premontane dry) consists of dry evergreen forest and pseudo-steppe in hill country and in the foothills of the Himalayas in Pakistan and northern India. It is described by EFZs 20 and 21. The need for increased protection of EFZ 21 in Pakistan and EFZ 20 in India is illustrated in Figure 2g.

Major Zone 10 (montane moist) consists of moist montane temperate forests stretching from the Western to Eastern Himalayas. It is described by EFZs 10-13. The major zone incorporates several centres of endemism and diversity. The need for increased protection of EFZs 10 and 11 in Myanmar, EFZs 10 and 12 in India, EFZ 12 in Nepal and EFZ 13 in Pakistan is shown in Figure 2h.

Major Zone 11 (montane dry) consists of Himalayan dry temperate forests, principally in north-west Pakistan. It is described by a single EFZ (23). The need for increased protection of EFZ 23 in Pakistan is shown in Figure 2i.

Major Zone 12 (alpine) consists of alpine steppe and scrub in the western and eastern Himalayas. It is described by EFZs 31, 40 and 41. The need for increased protection of EFZs 31 and 41 in Pakistan and EFZs 40 and 41 in India is shown in Figure 2j.

3.2.2 Moist forests

A key to the moist forest types of the tropical regions of the world, including South and South-East Asia, is provided in Table 2. The code refers to the classification found in Map 4 and Annexes 7 and 8.

Annex 7 provides information on the protection of moist forests in South and South-East Asia, with a breakdown of countries for each type of forest. An alternative arrangement of the data is

found in Annex 8, which lists countries alphabetically and provides a breakdown of moist forests in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.2.

The majority of moist forest in South and South-East Asia consists of lowland rain forest (Forest Code 122) and lowland monsoon forest (Forest Code 220), which occur in all countries included in the analysis with the exception of Pakistan. Also a negligible amount of lowland rain forest occurs in Bhutan (Annex 7). It can be seen from Table 11 that inland swamp, lowland rain forest and montane monsoon forest are well represented in protected areas in South and South-East Asia, but that mangrove, montane rain forest and lowland monsoon forest are less adequately protected.

Countries with a high proportion of moist forest types within their territories are indicated in Table 12. Myanmar contains over 50% of montane rain forest but none of it is protected; it also contains large areas of lowland rain forest with virtually none protected. Large areas of mangrove are found in Bangladesh and Thailand with little protection. India has large areas of lowland and monsoon rain forest with relatively small amounts protected. West Malaysia has large areas of inland swamp forest with little protection.

3.3 INSULAR SOUTH-EAST ASIA

The six countries of Insular South-East Asia included in this analysis are listed in Table 13. The Solomon Islands are omitted from the section on EFZs. Indonesia is by far the largest country incorporating almost two thirds of the region's land area. It is over four times larger than Papua New Guinea, the next largest country, and over 300 times larger than Brunei, the smallest country in the region.

3.3.1 Ecofloristic zones

A key to the EFZs of Insular South-East Asia is provided in Table 1. The *Code* refers to the classification found in Map 3 and Annexes 9 and 10. The *Class* indexes the habitat descriptions of FAO (1989). The *Major Zone* indicates which of 12 eco-climatic zones common to all tropical regions are associated with the EFZs of this region.

The extent of protection of each EFZ in Insular South-East Asia is illustrated in Map 3 and detailed in Annex 9 which contains a breakdown of each EFZ by country. An alternative arrangement of the data is found in Annex 10, which lists countries alphabetically and provides a breakdown of the EFZs in each country. Examples which assist in the interpretation of Annexes are given in Section 3.1.1.

The EFZs of Insular South-East Asia vary in size from a small patch of evergreen forest on Sumba (EFZ 6) to a large area of lowland evergreen forest west of Wallace's line (EFZ 1), which is some 475 times greater in area (Map 3). Of the 17 EFZs in the region, eight have greater than 10% of their area protected by conservation areas and only one (EFZ 12) has less than 1% under protection (Table 14).

The diversity of EFZs within countries is shown in Table 13. Indonesia is much the most diverse country with all 17 EFZs represented. Countries with a high proportion of at least one EFZ within their territory are indicated in Table 15: Indonesia, Papua New Guinea and the Philippines each include 50% or more of some EFZs. Five EFZs are found exclusively within

Indonesia, emphasising the regional importance of this country for conservation of unique habitats.

Within the framework of the EFZ approach, there are compelling arguments for national conservation action where a country has a high proportion of an EFZ and little of it is currently protected by that country, as shown in Figure 3. Priorities for national conservation action are identified below.

Major Zone 2 (lowland very moist) consists of large areas of lowland rain forest which cover the greater part of this region (Map 3) and which are described by EFZs 1-6. The area contains

numerous centres of endemism and diversity which are not distinguished by the GIS analysis of EFZs. The need to improve protection of EFZ 4 in Papua New Guinea is shown in Figure 3a.

Major Zone 3 (lowland moist with short dry season) consists of moist semi-deciduous forests which are scattered across the region. It is described by EFZs 7 and 8. These EFZs include centres of endemism and species richness in the Philippines, Sulawesi, Java, Flores, Sumba, Timor, Tanimbar and southern New Guinea. The need for increased protection of EFZ 7 in Indonesia is shown in Figure 3b.

Major Zone 4 (lowland moist with long dry season) consists of dry deciduous forest in parts of Philippines, Java, Flores, Sumba and Timor. It is described by EFZs 9 and 10. As with the previous zone, the EFZs incorporate several centres of endemism and species richness. The need for increased protection of EFZ 10 in Indonesia is shown in Figure 3c.

Major Zone 5 (lowland sub-dry) consists of dry deciduous forests and thickets in southern New Guinea and the Lesser Sunda islands. It is described by EFZs 11 and 12, both containing important centres of endemism and diversity. The need for increased protection of EFZ 12 in Indonesia is shown in Figure 3d.

Major Zone 8 (premontane moist) consists of montane evergreen forests scattered across the region. It is described by EFZs 13 and 14, indicating the biogeographical divide of Wallace's line. The zone contains several centres of endemism and diversity. The need for increased protection of EFZ 14 in Papua New Guinea is shown in Figure 3e.

Major Zone 10 (montane moist) consists of montane forest and thickets in Malaysia, Indonesia and Papua New Guinea. It is described by EFZs 15 and 16, indicating the biogeographical divide of Wallace's line. The need for increased protection of EFZ 16 in Papua new Guinea is shown in Figure 3f.

Major Zone 12 (alpine) consists of alpine grasslands and low scrub in the highlands of New Guinea. It is described by a single EFZ (17). The need for protection of EFZ 17 in Papua New Guinea is shown in Figure 3g.

3.3.2 Moist forests

A key to the moist forest types of the tropical regions of the world, including Insular South-East Asia, is provided in Table 2. The code refers to the classification found in Map 4 and Annexes 11 and 12.

Annex 11 provides information on the protection of moist forests in Insular South-East Asia, with a breakdown of countries for each type of forest. An alternative arrangement of the data is found in Annex 12 which lists countries alphabetically and provides a breakdown of moist forests in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.2.

The majority of moist forest in Insular South-East Asia consists of lowland rain forest (Forest Code 122) which occurs in all countries included in the analysis (Annex 11). It can be seen from Table 16 that mangrove, montane rain forest and montane monsoon forest are well represented in protected areas in Insular South-East Asia, but that inland swamp, lowland rain forest and lowland monsoon forest are less adequately protected.

Countries with a high proportion of moist forest types within their territories are indicated in Table 17. Indonesia contains over 50% of five types of forest: mangrove, inland swamp, lowland rain forest, lowland monsoon forest and montane rain forest, three of these being less than adequately protected (above). The Philippines has over 50% of montane monsoon forest, over half of which is protected. Papua New Guinea has large areas of montane rain forest which are poorly protected.

3.4 TROPICAL SOUTH AMERICA

The 10 countries of South America included in this analysis are listed in Table 18. Brazil is by far the largest country. Covering almost 60% of the region, it is over six times larger than Peru, the next largest country, and over 90 times larger than French Guiana, the smallest country in the region.

3.4.1 Ecofloristic zones

A key to the EFZs of tropical South America is provided in Table 1. The *Code* refers to the classification found in Map 5 and Annexes 13 and 14. The *Class* indexes the habitat descriptions of Lavenu, Bellan and Meste (1988). The *Major Zone* indicates within which of 12 eco-climatic zones common to all tropical regions each EFZ lies.

The extent of protection of each EFZ in tropical South America is illustrated in Map 5 and detailed in Annex 13 which contains a breakdown of each EFZ by country. An alternative arrangement of the data is found in Annex 14 which lists countries alphabetically and provides a breakdown of the EFZs in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.1.

The EFZs of tropical South America vary in size from a small patch of evergreen forest in Columbia and Venezuela (EFZ 3) to a large belt of moist forest extending across the Amazon basin and foothills of the Andes (EFZ 2), some 180 times greater in area (Map 5). Of the 31 EFZS in tropical South America, 13 have more than 10% of their area protected by conservation areas, five have less than 1% of their area protected and one (EFZ 8) has no protection (Table 19).

The diversity of EFZs within countries is shown in Table 18. Six of the 10 countries in this region have 13 or more EFZs within their territory. Countries with a high proportion of at least one EFZ within their territory are indicated in Table 20: seven of the 10 countries incorporate 50% or more of at least one EFZ within their boundaries; two (Brazil and Peru) of these have sole responsibility for one or more EFZ, in that the entire zone falls within their jurisdiction. Five EFZs are found exclusively within Brazil, emphasising the regional importance of this country for conservation of unique habitats.

Within the framework of the EFZ approach, there are compelling arguments for national conservation action where a country has a high proportion of an EFZ and little of it is currently protected by that country, as shown in Figure 4. Priorities for national conservation action are identified below.

Major Zone 1 (lowland wet) is composed of a single EFZ (Forêt ombrophile, 0 mois secs), which occurs in the upper Amazon basin and a coastal strip of Columbia and Ecuador. Several

centres of diversity and endemism are found within this EFZ, both east and west of the Andes. This study indicates that this EFZ is adequately protected (Figure 4a).

Major Zone 2 (lowland very moist) consists of large areas of lowland rain forest in the Amazon basin and the foothills of the Andes. It is described by a single EFZ (2) which includes several centres of diversity and endemism in Amazonia and the Guayana Highlands. This zone is adequately protected (Figure 4b).

Major Zone 3 (lowland moist with short dry season) is a large discontinuous area of evergreen forest (described by EFZs 3, 4, 5 and 6). It forms a transition between Amazonian forest and cerrados in the south and east, and also occurs south of the Orinoco and on the Atlantic and Pacific coasts. This study suggests that there is a need for more protection of EFZs 5 and 6 in Brazil.

Major Zone 4 (lowland moist with long dry season) consists of deciduous forest, tree savanna and prairie occurring in a southern belt across central Brazil and northern Bolivia, and in Paraguay, and in a northern belt across Columbia, Venezuela, Guyana and Surinam. It comprises EFZs 8-12. The need for protection of EFZ 7 in Peru, EFZ 9 in Colombia, EFZs 11 and 12 in Brazil, and EFZ 12 in Paraguay is shown in Figure 4d.

Major Zone 5 (lowland sub-dry) consists of deciduous and dry forest widely spread across the region and described by EFZs 13-16. It includes the Caatinga of northeastern Brazil, the Gran Chaco in Bolivia and Paraguay, and the Guajiran lowlands of Columbia and Venezuela - all sites of high diversity and endemism. The need for increased protection of EFZ 13 in Ecuador and Bolivia, EFZ 14 in Brazil and EFZ 16 in Bolivia is shown in Figure 4e.

Major Zone 6 (lowland very dry/sub-arid) consists of dry forest and scrub stretching in a narrow coastal or near coastal band from Ecuador in the north to Chili, and also occurring in Venezuela. It is described by EFZ 17. It includes the centres of diversity associated with the Lomas Formations of Peru and the coastal Cordillera of Venezuela. The need for increased protection of this EFZ in Peru is shown in Figure 4f.

Major Zone 7 (lowland arid/desertic) consists of prairie in an arid coastal strip of Peru described by EFZ 18. It includes the centre of diversity associated with the Lomas Formations. The need for increased protection of this zone in Peru is shown in Figure 4g.

Major Zone 8 (premontane moist) consists of sub-montane forests in southern Brazil, fringing the Andes, and on the highlands of southern Venezuela, western Guyana and northern Brazil. The zone is described by EFZs 19, 20, and 29-33. The need for further protection of EFZs 19, 20 and 31 in Brazil, EFZ 29 in Peru and EFZ 30 in Guyana is shown in Figure 4h.

Major Zone 9 (premontane dry) consists of deciduous, sub-montane forests fringing the Andes in Venezuela, Colombia and Peru. It is described by a single EFZ (34). The need for increased protection in both Peru and Colombia is shown in Figure 4i.

Major Zone 10 (montane moist) consists of montane moist forest situated along the Andes, from Venezuela in the north to Bolivia. It is described by EFZs 35-37. The area includes centres of species richness and endemism in the central and eastern Andes. This major zone is relatively well represented in protected areas, but there needs to be further protection of EFZ 37 in Peru (Figure 4j).

Major Zone 11 (montane dry) consists of montane dry forest situated along the western, central and eastern Andes in Colombia, Bolivia and Peru. It is described by a single EFZ (38). As with the previous zone, the area is associated with several centres of diversity and endemism. The need for improved protection of this zone in Bolivia and Peru is shown in Figure 4k.

Major Zone 12 (alpine) consists of alpine scrub and herbaceous communities covering a large area of the central Andes in Ecuador, Peru and Bolivia and smaller fragmented areas of Colombia and Venezuela. It is described by a single EFZ (39) and is associated with centres of endemism and diversity in Peru and Ecuador. The need for further protection in Peru is shown in Figure 4l.

3.4.2 Moist forests

A key to the moist forest types of the tropical regions of the world, including South America, is provided in Table 2. The code refers to the classification found in Map 6 and Annexes 15 and 16.

Annex 15 provides information on the protection of moist forests in tropical South America with a breakdown of countries for each type of forest. An alternative arrangement of the data is found in Annex 16 which lists countries alphabetically and provides a breakdown of moist forests in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.2.

The majority of moist forest in tropical South America consists of lowland rain forest which occurs in all countries included in the analysis (Annex 15). It can be seen from Table 21 that

mangrove, lowland, sub-montane and montane forests are well represented in protected areas in South America, but that inland swamp, dry, and especially pine forests are less adequately protected.

Countries with a high proportion of moist forest types within their territories are indicated in Table 22. Brazil contains over 50% of four types of forest: mangrove, lowland rain forest, dry forest and pine forest, two of these being less than adequately protected in the region (above). Peru has large areas of inland swamp forest, sub-montane and montane rain forests, one of these being less than adequately protected (above). Bolivia and Venezuela have large areas of montane and sub-montane rain forests, respectively, both of which are well represented in protected areas.

3.5 CENTRAL AMERICA AND THE CARIBBEAN

The 30 countries of Central America and the Caribbean included in this analysis are listed in Table 23. Mexico is much the largest country, covering almost 50% of the region's land area. It is over 10 times larger than Nicaragua, the next largest country, and over 10,000 times larger than the smallest Caribbean island states of Montserrat and the British Virgin Islands.

3.5.1 Ecofloristic zones

EFZs of Central America and the Caribbean were not available at the time of this study. However, a map of Major Zones has been prepared by FAO from a combination of 77 Holdridge Life Zones (FAO pers. comm.). The Major Zones indicate the geographical boundaries of 12 eco-climatic zones which are common to all tropical regions (Table 1).

The extent of protection of each Major Zone in Central America and the Caribbean is illustrated in Map 5 and detailed in Annex 17, which contains a breakdown of each zone by country. An alternative arrangement of the data is found in Annex 18, which lists countries alphabetically and provides a breakdown of the zones in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.1.

The Major Zones of Central America and the Caribbean vary in size from the relatively small patches of moist terrain in Mexico, Guatemala and Costa Rica (Major Zone 10) to a large area, classified as *premontane dry*, covering much of Central America and parts of the larger islands of the West Indies (Major Zone 9). This latter zone is some 90 times larger than the former (Map 5, Table 24). Of the 10 Major Zones represented in the region, three have more than 10% of their area protected by conservation areas and three have less than 1% under protection (Table 24).

The diversity of Major Zones within countries is shown in Table 23. Mexico is much the most diverse country with nine of the 10 Major Zones represented. Countries with a high proportion of at least one Major Zone within their territory are indicated in Table 25. Only seven countries in the region contain over 10% of a Major Zone within their territory, and only three countries (Mexico, Nicaragua and Panama) contain over 25% of a Major Zone. Mexico contains over 50% of six Major Zones, and one of these (Major Zone 11) is found nowhere else, emphasising the regional importance of this country for conservation of unique habitats.

Although the analysis of conservation at the level of Major Zones is at a very large scale, it does suggest the need for increased protection of the *Premontane Dry* (Major Zone 9), *Montane Dry*

(Major Zone 11), *Lowland Sub-Dry* (Major Zone 5) and the *Lowland Very Dry/Sub-Arid* (Major Zone 6) in Mexico and, to a lesser degree, the *Lowland Moist with Long Dry Season* (Major Zone 4) in Cuba and Mexico.

3.5.2 Moist forests

A key to the moist forest types of the tropical regions of the world, including Central America and the Caribbean, is provided in Table 2. The code refers to the classification found in Map 6 and Annexes 19 and 20.

Annex 19 provides information on the protection of moist forests in Central America and the Caribbean, with a breakdown of countries for each type of forest. An alternative arrangement of the data is found in Annex 20 which lists countries alphabetically and provides a breakdown of moist forests in each country. Examples which assist in the interpretation of these annexes are given in Section 3.1.2.

The majority of moist forest in Central America and the Caribbean consists of lowland rain forest in countries of Central America and Cuba, and dry forest and pine forest in Central America, particularly Mexico, Honduras and Nicaragua (Annex 19). It can be seen from Table 26 that most moist forest types are well represented in protected areas in the region. However, pine forest is less adequately protected, particularly in Mexico and Guatemala, and dry forest is poorly protected, especially in Mexico which contains over 98% of this forest type.

Countries with a high proportion of moist forest types within their territories are indicated in Table 27. Cuba contains over 50% of mangrove and protects a little over 5%; Guatemala contains over 25% of inland swamp forest, of which almost 30% is protected, and over 25% of montane rain forest, of which only 2% is protected; Honduras also has over 25% of montane rain forest with 4% protected; Jamaica includes over 25% of sub-montane rain forest, of which 19% is protected; Martinique protects a high proportion of its lowland and montane rain forest; Mexico contains over 25% of lowland rain forest, of which 8% protected, over 98% of dry forest, of which only 0.3% is protected, and over 85% of pine forest, of which less than 2% is protected; and Nicaragua contains over 25% of inland swamp, of which 19% is protected.

3.6 DISCUSSION

In examining the adequacy of conservation area networks in tropical regions for protection of the full range of ecosystems, it is clear that this analysis of EFZs and moist forest types provides only a partial picture. A principal weakness is that neither classification recognises sufficiently the many centres of species diversity and endemism in the tropics, or numerous biogeographical boundaries and zones of convergence. Nevertheless, the analysis does provide an overview of the extent to which national protected area networks conserve a wide range of ecosystems, and this is elaborated further in the next section. The analysis also assists in the identification of priorities for conservation interventions at national and regional levels. In this regard, it has been shown that a number of EFZs fall exclusively within the territory of single countries, highlighting their sole responsibility for conservation: in Africa - Kenya, Madagascar and South Africa; in South and South-East Asia - Cambodia, India, Malaysia, Myanmar, Pakistan, Sri Lanka and Vietnam; in Insular South-East Asia - Indonesia; in tropical South America - Brazil and Peru; in Central America and the Caribbean - Mexico. It has also been shown that the level of protection of EFZs varies widely and that some have no part of their area currently protected. This is true of two EFZs in Africa (EFZ 2 lowland rain forest and EFZ 18 wooded grassland

with baobabs), four EFZs in South and South-East Asia (EFZ 14 evergreen and semi-evergreen forest, EFZ 19 deciduous and mixed forest, EFZ 31 temperate and alpine forest and scrub and EFZ 36 sub-tropical hill forest) and one EFZ in tropical South America (EFZ 8 cerrados).

3.6.1 Pantropical overview

An overview of protection of major EFZs and moist forest types in tropical regions of the world is provided in Tables 28 and 29, respectively. Some 7.7% of the tropics is protected (Table 28) and 12.2% of moist tropical forests are protected (Table 29). The more extensive protection of moist tropical forests suggests that the strategy to protect high biodiversity habitats is proving to be successful. However, the rapid rate of clearance of moist forests outside of protected areas will tend to artificially inflate the figure for protected area coverage (IUCN, 1992). Furthermore, a positive association between rate of forest clearance and species richness of tropical forests indicates that many forests rich in endemic species still receive little effective protection (Balmford and Long, 1994).

With respect to conservation of major EFZs, it is evident that the moist zones are better represented in protected areas than dry zones. Thus, lowland wet, lowland very moist, premontane moist and montane moist zones have 22%, 9%, 6% and 12% of their respective areas protected, whilst lowland very dry/sub-arid, lowland arid/desertic, premontane dry and montane dry zones have 7%, 5%, 3% and 2%, respectively protected (Table 28). Whilst, the priority given to moist zones may be justifiable in terms of biodiversity conservation, this study demonstrates the need to increase protected area coverage in drier zones. Also, it is widely recognised that future interventions in moist zones should begin to focus more on improving management of existing protected areas, particularly where protected areas coverage is considered to be adequate.

Regarding conservation of forest types, it can be seen that the two drier types (dry forest and pine forest) are poorly protected, with 4% and 2% coverage, respectively (Table 29). Of the moister forest types, sub-montane and montane rain forests and montane monsoon forest are particularly well protected, with 26%, 20% and 21% coverage, respectively, but inland swamp forest is comparatively poorly protected with only 5% coverage. Some 12% of lowland rain forest, which has been targeted as a pantropical habitat of exceptional biological richness, is currently protected.

3.6.2 Regional comparisons

The summary data in Tables 28 and 29 provides a framework in which to review regional protected area networks. At the regional level, South and South-East Asia is least well protected, with 3.6% of the region designated for conservation (Table 28). This is reflected in a relatively low protection status in all major zones. Conversely, the highest overall protection is found in South America with 9.8% of the region protected. In this case, however, some major zones, notably lowland sub-dry (5) and lowland arid desertic (7) are poorly protected. Central America and the Caribbean also have a comparatively low regional percentage protection. However, some zones in this region are relatively well protected, particularly lowland very moist (2) and lowland arid/desertic (7). Overall, protection in Africa is close to the global average but there is a tendency for moist African zones to be relatively poorly protected and for dry African zones, excepting (11) montane dry, to be relatively well protected. Protection in Insular South-East Asia is above average, especially in montane zones (8, 10 and 12).

The lowest overall percentage protection by area of moist forests is found in Africa with 7.3% of forest cover protected (Table 29). Mangrove, inland swamp and lowland rain forest are all relatively poorly protected, the latter being well below the level of protection found in every other region. This is a matter of some concern, given the importance of this forest type for biodiversity. However, on a more positive note, it can be seen that some 20% of montane rain forest is protected in Africa. The same caveats referred to above, concerning the rate of deforestation and the distribution of biological richness within tropical forests, apply here.

South America, which has much the largest area of moist forests, has the highest regional protection (15.1%), and this is reflected in above average protection of all forest types. Protection of moist forests in South and South-East Asia (10.7%) is second only to that in South America but still below the global average. Its small area of inland swamp forest is well protected, but mangrove, montane rain forest and montane monsoon forest are relatively under-represented in protected areas. Protection of moist forests in Insular South-East Asia (10.4%) is below average. Some 50% of the small area of lowland monsoon forest is protected, but relatively little (9%) of the large area of lowland rain forest is protected. The overall protection of moist forests in Central America and the Caribbean (8.7%) is well below average. However, the low level of protection of dry forest and pine forest in the region masks the elevated protection status of the moister forest types. Significantly, some 20% of lowland rain forest is protected in the region.

It is apparent from Tables 28 and 29 that the ordering of regions by level of protection differs depending on whether the classification is of EFZs or moist forest types. This is partly because the classification of moist forest types excludes arid habitats. It is also partly the result of differences in classification of vegetation. For instance, some areas of Cambodia, Vietnam, Lao PDR and Thailand are classified as lowland rain forest in the moist forest analysis but as deciduous forest in the EFZ analysis. More importantly, the analysis of EFZs is concerned with potential vegetation formations whilst that of moist forest is concerned with actual forest cover. The former provides a national or regional overview of the spread of protected areas across potential habitats, the latter provides quantitative information on the level of protection of intact forest habitats.

4. INVESTMENTS IN PROTECTED AREAS

4.1 INDICATORS OF BIODIVERSITY

Before examining the pattern of investments in biodiversity conservation, it is useful to briefly examine two independently derived measures of biological diversity at the national level. In studying the extent to which EFZs and moist forest types are represented in protected areas, information has been provided on the number of EFZs occurring within each tropical country (Tables 3, 8, 13 and 18). These data provide an index of biological richness at the ecosystem level which may be compared with the National Biodiversity Index (NBI) developed by WCMC (1992c). The NBI is a measure of biological diversity at the species level, derived from information on numbers of species and endemics for higher plants and four classes of vertebrates. It rates every country on a scale of 0.00 to 1.00, based on the number of species known to exist, or potentially exist, in the country.

These two indexes of richness appear to be closely related, although the relationship clearly is not linear (Figure 5). The number of EFZs is a decelerating positive function of the NBI, such that countries with a very high NBI, (e.g. South Africa, Indonesia and Brazil) have only slightly higher numbers of EFZs than countries with a considerably lower NBI. An exception to this trend is India which has markedly more EFZs in relation to its NBI. It is possible that the eco-climatic variation found within India has been more finely classified into EFZs than for other tropical regions. It can also be seen in Figure 5 that the distribution of countries on the NBI scale

is more heavily weighted towards the low end than is the distribution on the EFZ scale. While this study focuses on biodiversity at the ecosystem level and, therefore, utilises the EFZ index to identify gaps in investments in biodiversity conservation, it is also useful to employ the NBI as an additional, independent means of validation.

4.2 NATIONAL INVESTMENTS

The effect of biodiversity richness on the percentage of a country under protection is illustrated in Figure 6. No strong trend is apparent, but it can be seen that the four countries which are richest in biodiversity at both ecosystem and species levels (Brazil, India, Indonesia, and South Africa) have less than 10% of their territory protected. This indicates the need for greater development of protected area networks in countries richest in biodiversity. Many countries which are rich in biodiversity still possess significant portions of unconverted, natural land. They have the potential to establish representative networks of protected areas at a relatively early stage in their development, whilst population pressures on land do not pose immediate threats (James *et al*., in press). This is true of countries such as Brazil, Cameroon and Indonesia, and perhaps to a lesser extent, South Africa.

Information on the level of national investment and staffing in protected areas is currently available for only 15 and 13 of the 25 UK priority countries, respectively (Table 30). In 1992, South Africa had much the largest financial investment and also the largest staff commitment, albeit by a smaller margin. However, these two indicators of investment in conservation are not closely related when examined across other countries. For instance, Namibia invested US$ 147.3 per sq. km and 5.0 staff per 1,000 sq. km, while Pakistan invested less financially (US$6.2 per sq. km) but more staff (102.4 per 1,000 sq. km), as shown in Table 30.

Excluding South Africa which has a comparatively well-developed economy, it can be seen that countries with a high diversity of EFZs tend to invest less in protected areas (Figure 7). In a worldwide analysis of protected area investments, a negative relationship between species diversity (as measured by NBI) and national investment in protected areas was also described, and this was attributed to the lesser wealth available for investment in biologically rich countries (James *et al*., in press). In the present study, the negative trend is revealed amongst developing countries *per se*, suggesting that additional factors must play a role. Certain countries, such as Bolivia and Tanzania, which are rich in biodiversity and invest relatively little in protected areas, have nevertheless established extensive networks of protected areas. Assistance in establishing effective training programmes and institutional structures would be particularly valuable in these cases.

4.3 ODA

Official Development Assistance (ODA) for biodiversity conservation in protected areas was received by 17 of 25 countries in 1992 (Table 30). Grants[4] were the most common form of aid, but for small amounts. Concessionary loans[5] were uncommon but for much larger amounts (Table 31). Loans are more appropriate in funding projects from which a commercial return is anticipated, such as in the forestry and fisheries sectors.

[4] A grant is the provision of funds by a donor that do not require reimbursement from the recipient government.

[5] A concessionary loan is the provision of funds by a donor as a loan which comprises a minimum of 25% grant element, thus qualifying as an ODA transaction.

Levels of foreign aid commitments for protected area conservation are positively, if weakly, related to the EFZ index and NBI (Figure 8). The relationship is clearer in the case of the NBI (Figure 8b), although this is partly due to the absence of a data point for Mexico (highly diverse with nine Major Zones) in the EFZ plot (Figure 8a). This indicates that donors have tended to appraise the biological richness of a country in the process of allocating aid for conservation. The five countries receiving the highest amount of ODA for biodiversity conservation in protected areas are listed in Table 32. Each of these countries has a high NBI and/or a high number of EFZs. On the other hand, eight of the 25 countries received no aid for protected areas in 1992, and four of them are relatively rich in biodiversity (Table 33). Similar findings emerged from a global review of aid for biodiversity conservation in 1992 (WCMC, 1995). Differences between the amounts of aid reported in the two studies derive from the stricter criteria adopted in this study, which excludes large grants and concessionary loans for development in the forestry and fisheries sectors. These large aid interventions dwarf most of the smaller scale projects focused directly on biodiversity conservation. A similar positive association between biodiversity investment per unit area and number of restricted-range bird species has been reported by Balmford and Long (1995).

4.4 NATIONAL INVESTMENTS AND ODA

Previous work shows no evidence of aid substituting for national investments in protected areas, rather there is a weak tendency for countries with higher national investments to attract more ODA (WCMC, 1995). In the present study, which expresses both national investments and ODA per unit area protected, no such positive relationship is revealed (Figure 9). The distribution of ODA allocated in 1992 is patchy, making a substantial difference to the total investment in conservation in approximately one-third of countries (Table 30). Furthermore, it has little effect on the direction of a relationship in which the overall investment in protected areas is higher in countries with fewer EFZs (Figure 10).

Recent political developments are partly responsible for the absence of ODA for biodiversity conservation in some countries. For example, Eritrea achieved independence in May 1993, and a multi-racial parliament was elected in South Africa in April 1994. Also, this study underestimates the overall extent of foreign investments in protected areas due to the absence of data for the NGO, corporate and private sectors. More detailed studies at national levels are required to generate such data. Nevertheless, the study emphasises the modest and ephemeral contribution of ODA towards protected area conservation. Moreover, major donor-funded conservation projects with a protected areas component are frequently of limited duration, providing insufficient time in which to establish management regimes that can be sustained subsequently by national protected area agencies.

5. CONCLUSIONS AND RECOMMENDATIONS

This study illustrates the strategic importance of using GIS datasets to quantify the adequacy of protected area networks in tropical countries. Foreign donors should be guided by the finding that protected area coverage varies between moist and dry habitats, between different types of moist forests, and between different tropical regions of the world. At the national level, donors should be guided by the priorities elaborated here regarding the sole responsibility of some countries for conservation of EFZs, and the lack of representation of some EFZs within protected area networks.

It is recommended that the present study is supplemented by a quantitative assessment of the representation of centres of species diversity, speciation and endemism within tropical protected area networks. Preliminary evidence suggests that many, possibly the majority, of endemic bird areas and centres of plant diversity are inadequately protected in some regions.

This study also highlights the need to procure data on the effectiveness of conservation within protected areas to better guide aid interventions. Countries with a high diversity of EFZs tend to invest less in protected areas conservation, and aid interventions do not adequately compensate for this disparity. The IUCN Commission on National Parks and Protected Areas is currently developing a system of monitoring and evaluating management effectiveness within protected areas. A tripartite information system on (1) representation of tropical ecosystems, habitats and species hot spots within protected areas, (2) effectiveness of protected area management, and (3) national and foreign investments in protected areas conservation would enable cost-effective strategies for conserving biodiversity in the tropics to be developed and monitored.

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