

The Biodiversity Challenge: Expanded Hot-Spots Analysis

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Summary

This paper aims to throw light on the mass extinction that is overtaking Earth's species. Using an analytic methodology developed for an earlier partial assessment, it focuses on a series of 'hot-spot' areas, these being areas that (a) feature exceptional concentrations of species with high levels of endemism, and (b) face exceptional threats of destruction. The paper identifies another eight such areas, four of them in tropical forests and four in Mediterranean-type zones. The analysis reveals that the four tropical-forest areas contain at least 2,835 endemic plant species in 18,700 km², or 1.1 percent of Earth's plant species in 0.013 percent of Earth's land surface; and that the four Mediterranean-type areas contain 12,720 endemic plant species in 435,700 km², or 5.1 percent of Earth's plant species in 0.3 percent of the Earth's land surface. Taken together, these eight hot-spot areas contain 15,555 endemic plant species in 454,400 km², or 6.2 percent of Earth's plant species in 0.3 percent of Earth's land surface. This is to be compared with the earlier hot-spots analysis of 10 tropical-forest areas, with 34,400 endemic plant species in 292,000 km², or 13.8 percent of Earth's plant species in 0.2 percent of Earth's land surface.

Taking all 18 hot-spot areas together, we find they support 49,955 endemic plant species, or 20 percent of Earth's plant species, in 746,400 km²,

or 0.5 percent of Earth's land surface. This means that one fifth of Earth's plant species are confined to half of one percent of the Earth's land surface – and they occur in habitats that are mostly threatened with imminent destruction.

By concentrating on these hot-spot areas where needs are greatest and where the pay-off from safeguard measures would be greatest, conservationists can engage in a more systematised response to the challenge of large scale impending extinctions.

Introduction

This paper reviews the findings of an expanded analysis of 'hot-spot' areas, these being areas that (a) feature exceptional concentrations of species with high levels of endemism, and (b) face exceptional threats of destruction. This analytic approach can serve as a key contribution to conservation strategies.

To demonstrate the value of this approach, an earlier appraisal (Myers, 1988) examined the case of 10 areas in tropical forests, viz. Madagascar, the Atlantic coast of Brazil, western Ecuador, the Colombian Choco, the uplands of western Amazonia, eastern Himalayas, peninsular Malaysia, northern Borneo, the Philippines and New Caledonia. It found the areas' expanse of 292,000 km² comprised only 3.5 percent of primary tropical forests, yet these contained endemic plant species amounting to 27 percent of all tropical forests' plant species, together with a much greater proportion (albeit undocumented) of animal species. At a higher scale of calculation, it revealed that 0.2 percent of the Earth's land surface contains 13.8 percent of Earth's plant species, for an 'area/species index' of 69 (13.8 divided by 0.2). Moreover, all these 10 areas are

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Table 1 Tropical forests: additional hot-spot areas

Area (km ²)	Extent of forest (km ²)		Present plant species	Species endemic to area	(%)
	Original	Present (primary [*])			
Ivory Coast	160,000	4,000 ^{**}	2,770	200	(7)
Tanzania	31,000	6,000	1,600	535	(33)
Western Ghats in India	50,000	8,000	4,050	1,600	(40)
Southwestern Sri Lanka	16,000	700 ^{***}	1,000	500	(50)
Totals	257,000	18,700	9,420	2,835	(30)

In summary, almost 3.8 percent of Earth's plant species (30 percent of them endemic) occur in 0.013 percent of Earth's land surface.

* Some, though not many, primary forest species can survive in secondary forests.

** Of these 4,000 km² of remaining primary forest, 2,000 km² are in the Tai Forest National Park, supporting 870 plant species (31 percent of the total), 150 of them (17 percent) being endemic.

*** Of these 700 km² of remaining primary forest, 56 km² occur in the Sinharaja Forest Reserve, supporting 75 percent of Sri Lanka's endemic tree species.

Sources: numerous, as cited under the area reviews in the texts.

losing their forests so fast that it is unlikely they will retain as much as 10 percent of original tree cover by the year 2000. This means, according to the theory of island biogeography (for brief review, see Myers, 1988), they will then be unable to support more than 50 percent of their original species. So in these 10 areas we can expect the early demise of 17,000 plant species and at least 350,000 animal species (perhaps several times more animal species). This in itself would amount to a spasm of species extinctions unparalleled in human history.

Furthermore, since the hot-spots approach identifies key localities of biotic richness under acute threat, it enables conservationists to determine their priorities in a more informed and methodical manner than has often been the case to date. Of course, it is not the only 'silver bullet' strategy available; it should be viewed in complementary accord with the 'Megadiversity Countries Strategy' developed by Mittermeier (1988).

Analytic Approach

For each hot-spot area, the analysis depends on establishing three prime factors: 1) the number of plant species originally extant; 2) the number of species remaining today; and 3) the number of species likely to survive into the opening part of the next century.

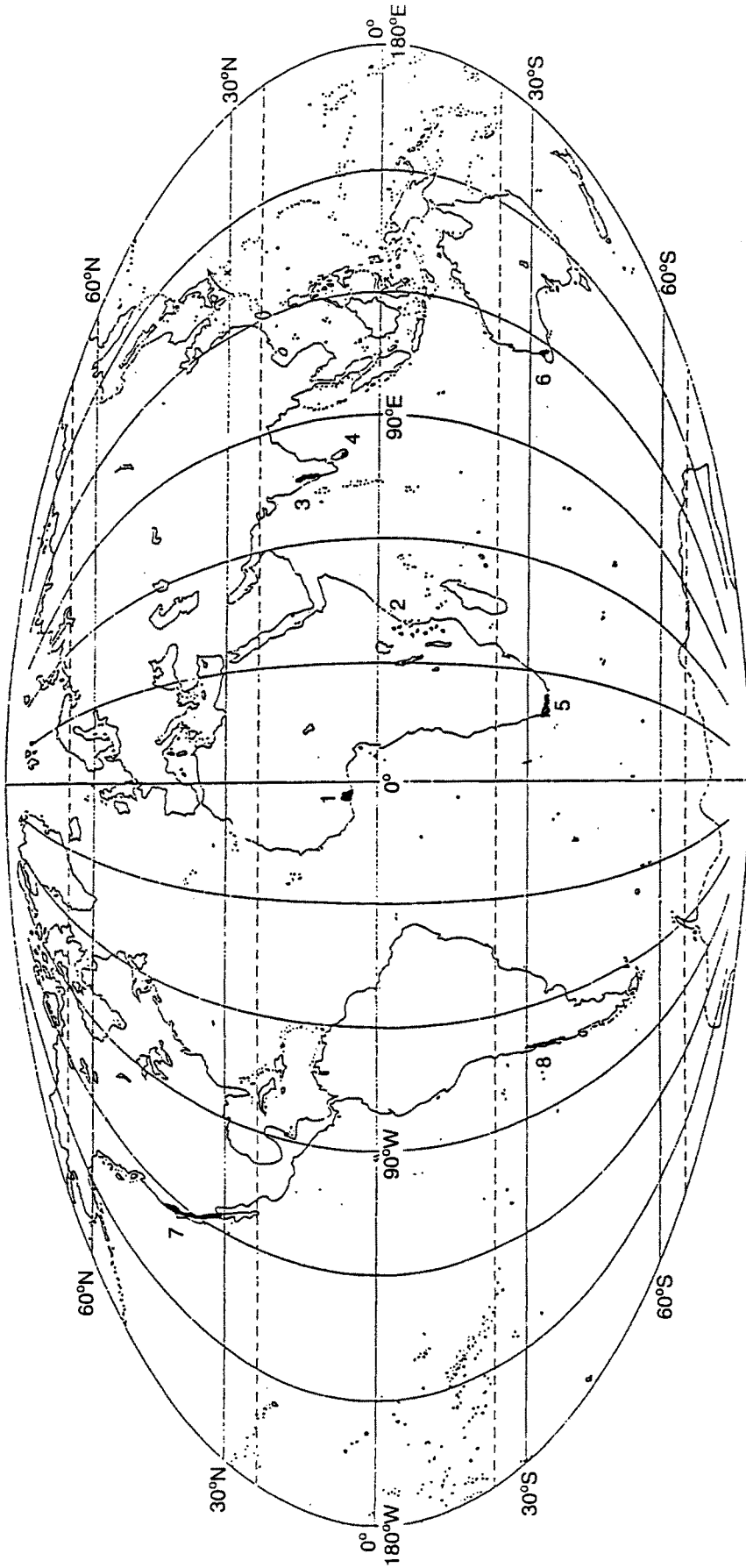
Plant species are chosen as an indicator category of species, rather than mammals, butterflies or some other taxon, because they are

the best known of any category with large number of species. We can be pretty sure the 250,000 species identified include virtually all plant species extant; it is estimated that only another 10,000 species are still to be discovered. We have a better idea of their distributions and ranges than is the case with other categories except for mammals and birds, which total only 13,000 species. In the main, we have also a clearer understanding of plants' conservation status – much clearer than for any other category except for mammals and birds.

That is not to say, of course, that other categories might not reveal different sets of hot-spots. One of the original 10 hot-spots, New Caledonia, contains relatively few mammals and other vertebrate species. But one can reasonably suppose, even though the situation is almost entirely undocumented, that the rich flora has led to the evolution of a similarly rich invertebrate fauna. Since invertebrates make up the great bulk of all animal species, and since the hot-spots analysis is concerned with the mass extinction overtaking Earth's biotas generally, it is considered that plant species serve as adequate indicator species, at least for the purpose of an exploratory appraisal. So the focus of this paper is confined to the best known category of organisms, vascular plants (or 'higher' plants – of which flowering plants comprise 88 percent), henceforth referred to simply as 'plant species'.

This is not to leave animal species entirely out of account. True, we know all too little about animal species in hot-spot areas. In tropical

EIGHT MORE HOT-SPOT AREAS



1. IVORY COAST
2. EASTERN ARC FORESTS OF TANZANIA
3. WESTERN GHATS
4. SRI LANKA
5. CAPE FLORISTIC PROVINCE
6. SOUTH WESTERN AUSTRALIA
7. CALIFORNIA FLORISTIC PROVINCE
8. CENTRAL CHILE

Fig. 1 Eight more hot spot areas.

◀ Fig.2 Tropical rainforest, Ivory Coast. (Photo. courtesy: of Prof U. Rahm and WWF).

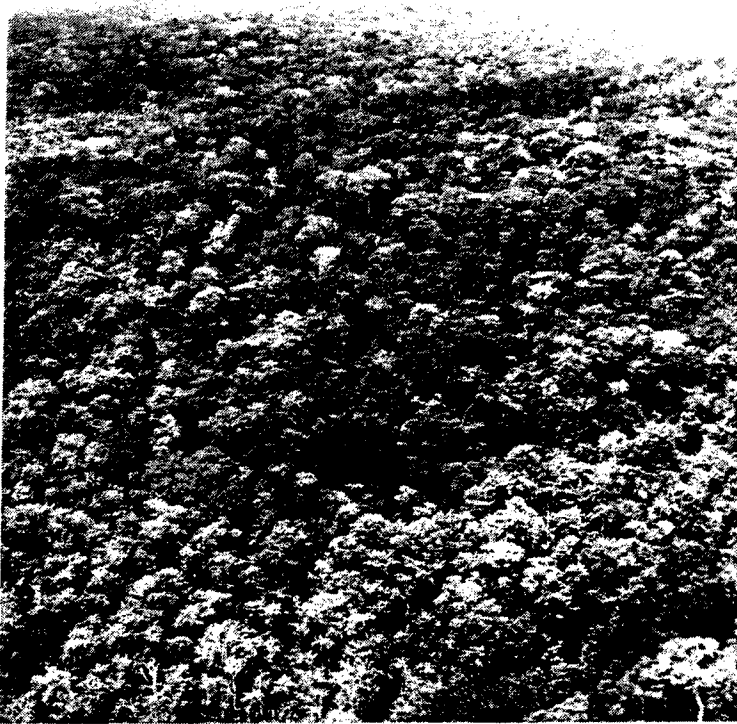


Fig.4 Partial clearing of tropical rainforest reveals stilt roots, Tai region, Ivory Coast. (Photo. courtesy: Prof U. Rahm and WWF). ▼





Fig. 3 Road clearing in tropical rainforest, Tai National Park, Ivory Coast. (Photo. courtesy: Dr Wilhelm Barthlott and WWF).



Fig. 5 Tropical forest in Usambara Mountains, Tanzania. (Photo courtesy: F.P. Jensen and WWF).

forests, for instance, there could well be 30 million, and conceivably as many as 80 million, insect species (Adis, 1990; Erwin, 1988; Stork, 1988). Yet to date we have identified little more than 0.5 million of all invertebrate species. We can assert, however, in light of species-area inventories in several sectors of the tropics, that there are at least 20 animal species for every one plant species – albeit a calculation based upon a minimum planetary total of 5 million species. This reflects the fact that terrestrial life depends ultimately for its existence on some 250,000 higher plant species, these being the great bulk of organisms capable of photosynthesis. These plant species contrast with the tens of millions of heterotrophic species. So the extinction of one of the photosynthetic species should lead, in a food-web or energetic sense alone, to an average of between 30 and 250 extinctions of other kinds of organisms (Raven, 1976). Obviously a rare herb would not affect as many other organisms, but the disappearance of a widespread tree could affect many times more. For the purposes of this paper, however, and in order to remain consistent with the earlier analysis (Myers, 1988), also to be

cautiously conservative, it will be assumed that one plant species is matched by only 20 animal species.

The data base: strengths and weaknesses

In many instances the statistical information is considered accurate to within 5 percent or better. In many others it is sufficiently accurate to rank as sound support for 'working estimates'. In some again, it is regarded as qualitatively correct, even though the quantitative data are sorely deficient: indicative information and best-judgement appraisals have their role to play in a paper such as this, provided their constraints are explicitly recognised. In a few further instances, which are identified as such, the information base is so poor that it is nothing better than an 'educated assessment', or a rough-and-ready estimate, albeit carefully conservative. The author believes this overall approach, uneven as it is, is justified in an analytical exercise that seeks to delineate the conservation challenge of a mass-extinction episode in its full scope.

Moreover, in cases where there is inadequate documentation of quantitative sort, one should not

be preoccupied with what can be counted to the detriment of what also counts. After all, to decide that an area should not be evaluated because it lacks a conventional degree of accurate data, is effectively to decide that its conservation needs cannot be evaluated either – in which case its cause tends to go by default. As in other policy-and-planning realms where uncertainty is a salient factor, it will be better for us to find we have been roughly right than precisely wrong.

Hot-Spot Areas: Additional Sites

Tropical forests

During the course of the 'first cut' analysis of hot-spot areas in tropical forests (Myers, 1988), it became apparent that a second-order list of areas warrants analysis. They are described below, four in all (for location, see Fig. 1; and for a tabulated review, see Table 1).

First, a brief point of clarification. In many instances, a patch of forest may be grossly disrupted without being destroyed outright. Or, when a deforested area regenerates, the result is secondary forest, with species complements that differ markedly from those of the original primary forest. This paper confines itself to primary forest, on the grounds that only primary forest contains the high species diversity that characterises the tropical-forest biome. Moreover there appears to be little overlap in species composition between primary forest and secondary forest. In certain sectors of the Brazilian Amazonia, for instance, secondary vegetation as much as 15 years old shows little regeneration of primary forest species, even though the new vegetation is structurally similar to the original forest (Lisboa *et al.*, 1989).

1) *Southwestern Ivory Coast*. The southwestern sector of the Ivory Coast features part of a centre of diversity that straddles the border with Liberia, and coincides with the so-called Upper Guinea Pleistocene Refuge. Its forest area supports 2770 of the country's 4700 plant species, with perhaps 200 of these being endemic (Guillaumet, 1984; Hamilton, 1976; Myers, 1982).

Of Ivory Coast's original forest cover totalling 160,000 km², or 50 percent of the country, 118,000 remained as recently as 1956. But today there are only 16,000 km² at most, or 10 percent of the original expanse; and of this, only 4,000 km² can be classified as primary forest (Maitre, 1987; Myers, 1989; Spears, 1985).

The remnants are being cut at a rate of up to 2,000 km² per year (see Figs 2–4; and if present trends continue, there will surely be next to nothing left outside protected areas by the mid-1990s.

This makes the Tai National Park all the more important, as the only large tract of original forest left, this contains 870 plant species, around 150 of them endemic (17 percent) (Assi, 1988; Bousquet, 1978; Dosso *et al.*, 1981; Roth, 1984). Nominally the park covers 3,300 km²; but it is being steadily reduced by logging (both legal and illegal), by gold prospecting, and most of all by encroaching cultivation. Less than 2,000 km², or 61 percent, are reported to be in primary-forest form, comprising half of the remaining primary forests in the country.

The main cause of deforestation lies with slash-and-burn farmers, who in turn reflect recent immigration patterns. Following the Sahel droughts, Ivory Coast has received 1.4 million foreigners from countries to the north, and by the mid-1980s every fifth person in the country was a foreigner (Ahonzo, 1984). Given the continuing drought situation in the Sahel, it can be anticipated that a persistent influx of environmental refugees will maintain the country's annual population growth rate at more than 4 percent.

2) *The Eastern Arc Forests of Tanzania*. Ranging along central-eastern Tanzania is an arc of montane forests. They include, from north to south, the Pare, Usambara (see Fig. 5), Nguru, Uluguru, Ukaguru, Rubeho, Uzungwa, Mahenge and Matengo forests. Their expanse amounts to 15,000 km² out of an original expanse thought to have totalled some 31,000 km². Moreover, less than half, and probably only about 40 percent, *i.e.* 6,000 km² is considered to be primary forest. Being located on ancient hills and mountains, these forests have mostly enjoyed lengthy periods of isolation, leading to much speciation and high levels of endemism. In the East Usambara mountains, for instance, close to 80 percent of millipedes, gastropods and amphibians are endemic. Some biologists consider the region is of paramount importance at global level for its potential insights into biogeography and evolution. (This review is based on Brenan, 1978; Hamilton, 1976; Hawthorne, 1984; Lovett, 1987 and 1989; Myers, 1982; Polhill, 1989; Rodgers and Homewood, 1982; Rodgers *et al.*, 1986).

Altogether these forests contain an estimated total of 1,600 plant species, endemics totalling 535 species (33 percent). They thus contain

almost 15 percent of Tanzania's 11,000 plant species. Further, they contain a greater wealth of endemic species than the forest expanse of West Africa covering 150,000 km²; and they feature 1,600 of the 30,000 plant species in all of tropical Africa with its 20 million km², *i.e.* over 5 percent of species in 0.075 percent of the land area.

Population pressures on the forests are high and rising rapidly, expressed in the form of agricultural encroachment, fuelwood gathering and commercial logging (Lovett, 1989; Rodgers and Hall, 1986). The formerly continuous forest of the East Usambaras is believed to have lost 70 percent of its original expanse in just the last 30 years, and has been fragmented into a patchwork of some 30 remnants of mixed primary and secondary forest. The Usambara mountains feature over 300 people per km², one of the highest densities in the world for an agriculture-based economy. Much the same story can be told of most of the forest tracts listed.

All the more regrettable is that certain of the plant species offer marked potential for economic development (Lovett, 1988). For instance, the African violet, an ornamental flower popular in affluent nations, enjoyed a retail trade of \$30 million in 1983; of 20 known species of the violet, 18 are confined to Tanzania's montane forests. Only three species have so far been exploited for cultivation, but others could lend themselves to development, including a hardy variety that grows at 2,000 m altitude on the Uluguru mountains where it has become adapted to occasional frosts. Tanzania's forests also contain 16 species of wild coffee, 10 of them endemic; only three have been exploited as commercial crops. The worldwide trade in coffee in 1981 was worth \$12 billion.

As recently as 1987 the protected-areas system in Tanzania had almost entirely collapsed, as a result of the country's declining economy and extreme poverty (average GNP per head today, \$220, one of the lowest in the world).

3) *The Western Ghats of India.* Of India's 15,000 plant species with 5,000 endemics (33 percent), there are 4,050 plants with 1,600 endemics (40 percent) in a 17,000 km² strip of forest along the seaward side of the Western Ghats mountains in Maharashtra, Karnataka, Tamil Nadu and Kerala States (Collins *et al.*, 1990; Dayanandan, 1983; Jain and Sastry, 1983; Kendrick, 1989; Nair *et al.*, 1986; Nayar and Sastry, 1987; World Conservation Monitoring Centre, 1988). Forest tracts up to 500 m elevation, comprising one fifth of the entire

forest expanse, are mostly evergreen, while between 500 and 1,500 m the forest becomes semi-evergreen. There are two main centres of diversity, the Agasthyamalai Hills and the Silent Valley/New Amarnbalam Reserve basin.

Little has recently been documented about the status of the forest cover, except that it seems to have declined between 1972 and 1985 at a rate paralleling that for India as a whole, *viz.* a loss of over 2.4 percent per year (Munni and Naidu, 1988). If we extrapolate from 1986 to 1989, this means a total loss for 1972/1989 of almost 34 percent. Still worse is the decline of the primary forest: the amount remaining seems to be no more than 8,000 km². All but isolated pockets of original forest have been opened up by shifting cultivation, allowing a take-over by deciduous species and bamboo among other forms of 'degenerate' vegetation.

4) *Southwestern Sri Lanka.* The 65,610 km² island featured forest cover in more than 50 percent of its expanse as recently as 1950. Today, this residual forest had been reduced by over half, and much of it amounts to scattered fragments. Worse, of the island's richest biodiversity zone, the wet sector in the southwest, there remains only 670 km² of montane forest and 740 km² of lowland forest, a total of 1,410 km² (roughly half being primary forest), or a mere 9 percent of original forest covering almost 16,000 km² (This review is based on Ashton and Gunatilleke, 1987; Balasubramaniam, 1985; Collins *et al.*, 1990; Erdelen, 1988; Geiser and Sommer, 1982; Gunatilleke and Ashton, 1987; Gunatilleke and Gunatilleke, 1985; Ishwaran and Erdelen, 1990; Kendrick, 1989; Nanayakkara, 1982; Senanayake *et al.*, 1977; Sumithraarachchi, 1989; Werner, 1982).

Of Sri Lanka's 3,365 species, at least 1,000 species (30 percent) are endemic to the island. Of these endemics, 497 (50 percent) are confined to the lowland wet forest in the southwestern sector of the island; they constitute half of the 1,000-plus species (rough estimate, probably on the low side) found in the lowland forest. The only large remaining patch of this lowland forest is the 89 km² Man and Biosphere Reserve of the Sinharaja Forest (now a World Heritage site), where more than 70 percent of tree species are endemic (in some families of trees, *e.g.* the dipterocarps, endemism is greater than 90 percent); indeed the Reserve harbours 75 percent of Sri Lanka's endemic tree species. Of bird species endemic to Sri Lanka, 95 percent have

Table 2 Mediterranean-type hot spots: summary

Area (km ²)	Extent of former habitat (km ²)	Extent of present habitat (km ² , and % of former habitat)	Present plant species	Species endemic to area (% of plants total)	Known to be threatened or rare (% of total flora)
Cape Floristic Province of South Africa	134,000	89,000 (66)	8,600	6,300 (73)	1,500 (17)
Southwestern Australia	112,260	54,700 (49)	3,630	2,830 (78)	860 (24)
California Floristic Province	324,000	246,000 (76)	4,450	2,140 (48)	1,140 (26)
Central Chile	140,000	46,000 (33)	2,900	1,450 (50)	580 (20)
Totals	710,260	435,700 (61)	19,580	12,720 (65)	4,080 (21)
<i>In summary</i> , almost 7.8 percent of Earth's plant species (65 percent of them endemic) occur in 0.3 percent of Earth's land surface.					
Mediterranean Basin as generalised mega-zone	n/a	n/a	25,000	12,500 (50)	3,000 (12)

Sources: numerous, as cited under the area reviews in the texts.

been recorded in Sinharaja, plus 58 percent of mammals and 51 percent of butterflies.

The wet forest offers insights into the floristics of all Southern Asia. It is truly primeval, with an ancestry that traces back to the Deccan flora when an unbroken stretch of forest covered both Peninsular India and Sri Lanka (today's forests contain many more relict forms than the whole of southern India). The endemic plants are mostly phylogenetic hangovers, with closest relatives in Malaysia, Sumatra, Madagascar and South Africa. Hence the exceptional significance of the wet forest in general, and the Sinharaja Forest in particular, for ecological and biogeographic reasons as well as because of the sheer numbers of plant species. Moreover the relict status of many species leaves them confined to very small localities such as a single hilltop; 195 species are considered to be very rare, thus subject to summary extinction.

While the Sinharaja sector is thought to have once covered at least 150 km², today the reserve amounts to only 89 km² (59.3 percent), and only 56 km² (62.9 percent) rank as primary forest. During the 1970s the State Timber Corporation engaged in logging, and there are still threats from a major plywood complex that faces shortages of raw materials. The reserve is situated in the most densely populated sector of the island, surrounded by settlements of 5,000 people or more, many of them practising various forms of shifting cultivation. At least 8 percent of this populace is

entirely dependent upon forest products.

Summary of tropical-forest areas

In a brief review (see Table 1) of these further four hot-spots in tropical forests, an aggregate area of 18,700 km² of primary forest harbours an estimated total of 9,420 plant species, of which 2,835 (30 percent) are deemed to be endemic. In other words, 0.013 percent of Earth's land surface harbours 1.13 percent of the Earth's plant species, for an area/species index of 87.

If, as seems all too likely, these areas lose 90 percent of their original forest within the foreseeable future, they will then be able, according to island biogeography theory, to support only 50 percent of their original complements of species. This implies the impending demise of almost 1,420 plant species. If there is an associated stock of endemic animal species, in a conservative ratio of 20 animals to one plant (probably a good deal higher), there would be an accompanying extinction of at least 28,400 of these animal species.

These figures compare with those for the leading 10 hot-spots areas in tropical forests, identified earlier (Myers, 1988): 34,400 endemic plant species in an aggregate forest expanse of 292,000 km², *i.e.* 13.8 percent of Earth's species in 0.2 percent of Earth's land surface, for an area/species index of 69.

In addition to these four further tropical-forest areas, a number of others could qualify as

subsidiary hot-spot localities. They include. The Mosquitia Forest of Honduras and Nicaragua; the Darien Gap of Panama; the Mount Nimba area of Liberia; lowlands forests of southeastern Nigeria and northwestern Cameroon; eastern Zaire; the Ethiopian highlands; the Andamans/Nicobar Islands of the Indian Ocean; the uplands of northern Burma; southern Thailand; and certain sectors of Sumatra and Sulawesi in Indonesia. They are not included here since they do not appear to be quite so exceptional in species richness, nor in degrees of threat, as the fourteen tropical-forest areas already considered.

Mediterranean-Type Areas

Mediterranean-type zones, located in the sub-tropics, are exceptional in terms of their species abundance and diversity, and the degree of destruction overtaking them. The principal areas are: the Cape Floristic Province of South Africa, southwestern Australia, the California Floristic Province and central Chile. For locations, see Fig.1; and for a tabulated review, see Table 2. Note that the Mediterranean Basin itself obviously qualifies as well, but it is far too large to rank as a hot-spot area (see below).

Insofar as the four areas identified are widely separated geographically, they are dissimilar in their floras and faunas, as in their evolutionary histories (Cody, 1986; Cody and Mooney, 1978). Their characteristic vegetation is dry grassland and shrub, known locally as chaparral, fynbos, maquis, etc. They feature high levels of endemism, especially narrow endemism: in the South African Cape, 80 percent of plant species have distributional ranges of less than 100 km² (Cody, 1986), while in southwestern Australia 12 percent are similarly limited (Pate and Beard, 1984). Moreover the areas mostly feature large human populations. hence their natural environments have been much disrupted.

1) *The Cape Floristic Province of South Africa.* The Cape flora is so remarkable that it has been accorded a floristic kingdom of its own, one of six in the world. In this 89,000 km² area, with almost 78,000 km² of fynbos heathlands, there occur 8,600 plant species, over 6,300 (73 percent) of them endemic; and in the southwestern tip of the Cape, only 18,000 km² in extent, there are about 6,000 plant species, at least 4,200 (70 percent) of them endemic. (This review is based on Bond and Goldblatt, 1984; Cowling and Roux, 1982; Gibbs-Russell, 1985 and 1987; Goldblatt,

1978; Hall, 1987; Jarman, 1986; Moll and Bossi, 1984; Moll and Jarman, 1984; Rutherford and Westfall, 1986; Tansley, 1988; Werger, 1987).

Those species known to be rare or threatened (plus 26 extinct) total around 1,500 (over 17 percent), or more than the entire flora of the British Isles. The true total could well be more like 2,000 species, or as many threatened plants as in all the United States. One third of the original fynbos has already been lost to agriculture among other forms of development, or to invasion of exotic plants; and much of the remaining two-thirds suffers accelerating attrition. Much wildland habitat is broken up into a patchwork of relicts dispersed among farmlands and urban areas. Most species occur in areas of less than one square kilometre, and many feature fewer than the 500 individuals often regarded as a minimum for genetic viability (Soule, 1987).

If one anticipates that original habitats will shortly be reduced to 10 percent of their original extent, and if one applies the findings of island biogeography to the total of 6,300 endemic plant species, then one must expect the early extinction of 3,150 species in this area. There would be numerous extinctions too of associated animal species, though whether one can here apply the ratio of one plant to 20 animal species is debatable and unascertainable. All one can assert is that animal extinctions would surely total tens of thousands.

In summation, this area qualifies as one of the hottest of all hot-spots, both in terms of its plant diversity and its extreme threats on habitat destruction. The area is exceptional in one further respect: there is a large scientific presence, there are numerous conservation bodies, and the government may be starting to show more readiness to tackle the challenges at issue.

2) *Southwestern Australia.* With its 54,700 km² of remnant 'kwongan' heathlands and associated Mediterranean-type vegetation (out of a former expanse of 112,260 km²), this area features 3,630 plant species. At least 2,830 species (78 percent) are endemic; and at least 430 species have geographical ranges of less than 100 km². More than 860 species (24 percent) are classified as rare or threatened, and the true total should surely exceed 1,000 species. (This short summary is based on Hopper, 1979; Hopper and Muir, 1984; Pate and Beard, 1984; Rye, 1982; Rye and Hopper, 1981).

The main forms of habitat depletion lie with agricultural clearing of wildlands, mining, wild

Table 3 Eight additional hot-spot areas: overview

Zone	Extent of present habitat (km ²)	Total plant species	Endemic plant species (% of total plant species)
Tropical forests (4 areas)	18,700	9,420	2,835 (30)
Mediterranean-type areas (4 areas)	435,700	19,580	12,720 (65)
Totals	454,400	29,000	15,555 (54)

In summary, 11.6 percent of Earth's plant species (54 percent of them endemic) occur in 0.3 percent of Earth's land surface.

Sources: numerous, as cited under the area reviews in the texts.

fires, and spread of weeds and fungal pathogens – most of which are growing worse rapidly. Fortunately the government, at both state and federal levels, seems to be taking greater interest in the conservation challenge.

3) *California Floristic Province*. The California Floristic Province, originally comprising 324,000 km², possesses at least 4,450 plant species, 2,140 (48 percent) of them endemic. The Province is as large as the State of California with 411,000 km²; and 10 percent of it extends into southern Oregon and northern Baja, California. But 4,119 of the Province's species (93 percent) occur within California. The Province's flora is equivalent to roughly one quarter of all plants in the United States and Canada combined. The 1.5 million km² of the northeastern United States feature only 5,500 plant species, only a few hundred of them being restricted to the region. (This review is based on Barbour and Major, 1988; California Department of Forestry and Fire Protection, 1988; Elias and Nelson, 1987; Jones and Stokes Associates, 1987; Keeley, 1988; Raven and Axelrod, 1978; Smith, 1987; Smith and Berg, 1988; Stebbins, 1980; Stebbins and Major, 1965).

By 1980 the Province had lost at least 78,000 km² of its former expanse to urbanisation and irrigation agriculture, leaving an undisturbed area of 246,000 km² (O'Neill, 1990). A good deal more was being disrupted by stock grazing, logging and mining. Moreover, California is projected to have an extra 5 million people by the year 2000. As a result the flora has been much depleted. Plant species known to be rare or threatened (including those already extinct) number around 1,140 (26 percent). Another

Table 4 Eighteen hot-spot areas: composite review

Zone	Extent of present habitat (km ²)	Total plant species	Endemic plant species
Tropical forests			
Original 10 areas	292,000		34,400
Further 4 areas	18,700	9,420	2,835
Mediterranean-type areas, 4 of them	435,700	19,580	12,720
Totals	746,400		49,955

In summary, almost 50,000 endemic plant species, or one fifth of Earth's plant species, occur in 0.5 percent of Earth's land surface.

* It has been unrealistic to sum total figures for total plant species in the original 10 hot-spot areas, on the grounds that there is some overlap between adjacent hot-spot areas, e.g. some plants in Peninsular Malaysia, Northern Borneo and the Philippines.

Sources: numerous, as cited under the area reviews in the texts.

500-plus (11 percent) would probably qualify as threatened if they were checked in detail. The problem lies not only with habitat destruction through human activities. It derives too from the localised distribution of many species: at least 163 species are confined to 100 km², and 73 are limited to 13 km² or less. As a measure of the general disregard that has been directed at the issue, consider that a human community with one of the finest scientific concentrations in the world remains so uniformed about its threatened biodiversity that another 10 plant species, mostly endemics, are still being discovered each year.

4) *Central Chile*. In central Chile there remain roughly 46,000 km² of Mediterranean-type habitat, or 33 percent of an original expanse of 140,000 km². The area contains more than 2,900, probably well over 3,000, of the country's 5,200 plant species, i.e. 56 percent of the national flora in 6 percent of national territory. Of these species, endemics total at least 1,450, or 50 percent of the area's total. Because of the exceptional amount of habitat diversity and 'border effects', the true figure could well be over 2,000 species, or 69 percent; after all, the endemism level for the entire country is 57 percent, and central Chile is biotically the richest sector in terms of species numbers. But for the sake of caution, the figure accepted here is the one documented (albeit a strictly minimum

figure), 50 percent. Endemism is even more remarkable at generic level: at least 10 percent, by contrast with less than 4 percent in the California Floristic Province. (This short account is based on Arroyo, 1990; Corporacion Nacional Forestal, 1989; Fuenzalida, 1984; Gajardo, 1983; Marticorena, 1980; Pizarro, 1977; Poblete, 1985; and Ramirez, 1984).

This is the most densely inhabited part of Chile, containing over half the national population. Rural families rely heavily on natural vegetation for fuelwood and fodder. It seems as if wildland environments will continue to be depleted if only because of the rate of population growth, 1.7 percent per year, which means that human numbers double in just over 40 years. It is estimated that one fifth, or 580, of the plant species can already be characterised as rare or threatened – through again, the true figure could be a good deal higher.

Summary of Mediterranean-type areas

In summary, of these four Mediterranean-type hot-spots areas, their 435,700 km² (0.3 percent of Earth's land surface) contain 19,580 plant species, or 7.8 percent of the Earth's plant species. Of these hot-spot species, 12,720 (65 percent; 5.1 percent of Earth's total of plant species) are endemics. This means an area/species index of 26. At least 4,080, or 21 percent, are already designated as officially rare or threatened (the true figure would probably be more like 5,000, 26 percent) (Table 2). It is these at-risk species that dominate national or regional lists of threatened plant species: in the United States, California's 1,140 rare or threatened species make up almost 57 percent of the national threatened species total. But in terms of island-biogeography constraints we must consider that for longer-run purposes, the total threatened with ultimate extinction must surely be more like one half, viz over 6,360 species.

There is also the Mediterranean Basin itself. Within its 2.3 million km² occur at least 25,000 plant species (Gomez-Campo, 1985; Henly, 1977; Le Houerou, 1977), or 28 percent more than in all the four areas described above, and 10 percent of all plant species on Earth in 1.6 percent of Earth's land surface. Roughly half of these species are endemic to the basin, and 3,583 are endemic to individual countries (excluding Turkey, Syria and Lebanon). Most of the basin's vegetation has been transformed from its native state, and all too few species appear to be part of the region's climax

formations. Habitat disruption persists apace: the Mediterranean's 40,000 km of coastline now support 360 million people in littoral zones, plus 100 million tourists each year. Rare or threatened plant species already total about 3,000, or 12 percent of the flora; the number can be expected to rise swiftly in the foreseeable future.

This figure of rare or threatened species in the Mediterranean Basin increases the total for Mediterranean-type areas described by 42 percent. But clearly the Mediterranean Basin is so extensive that it cannot rank in itself as a single hot-spot area. Rather it would be necessary to identify key sectors that warrant special treatment, such as southern Greece, Cyprus and the Atlas Mountains of Algeria.

On top of present habitat disruptions, there is a further threat to two of the Mediterranean-type areas. While global warming will prove detrimental to species communities in many parts of the world (Peters, 1991), it could well be specially damaging to those in the Cape Region of South Africa and Southwestern Australia. As temperature bands move away from the equator, vegetation bands will try to follow them (Oppenheimer and Boyle, 1990; Schneider, 1989). This will be difficult enough in most parts of the world because plants will be trying to migrate through lands that amount to a 'development desert'. But in the case of the two hot-spot areas mentioned, there will not even be any land available: plant communities movement would be into the sea. They face the prospect of wipeout.

Summation and Conclusion

This second hot-spot analysis shows that another eight areas – four in tropical forests and four in Mediterranean-type zones – deserve consideration for urgent conservation support (Table 3). The four tropical-forest areas contain at least 2,835 endemic plant species in 18,700 km² of primary forest, or 1.1 percent of Earth's plant species in 0.013 percent of the Earth's land surface (for an area/species index of 87). Taken together with the original 10 hot-spot areas in tropical forests, this means that at least 37,235 endemic plant species occur in 310,700 km², or 14.9 percent of Earth's plant species occur in 0.2 percent of the Earth's land surface (an index of 74.5). If, as is likely, in the absence of much more vigorous conservation measures, these forest areas lose 90 percent of their original forest cover within the next decade or shortly thereafter, we

shall witness the imminent demise of at least half of these plant species, *i.e.* 18,600 species in these areas alone.

The four Mediterranean-type areas harbour at least 12,720 endemic plant species in 435,700 km², or 5.1 percent of Earth's plant species in 0.3 percent of the Earth's land surface (for an index of 17). These areas too seem set to lose 90 percent of their original habitat within the foreseeable future, involving the extinction of at least 6,360 plant species.

Considering these 18 areas together, they support a total of at least 49,955 endemic plant species, or at least 20 percent of Earth's plant species, in 746,400 km², or 0.5 percent of the Earth's land surface (Table 4). (This translates into one fifth of all plant species in half of one percent of the Earth's land surface). It also means that insofar as all these areas are threatened with imminent destruction of their natural vegetation, the elimination of at least 25,000 plant species, or 10 percent of Earth's plant species, could be witnessed in these areas alone, unless greatly increased conservation measures are implemented forthwith. In addition there will surely ensue the extinction of at least 500,000 endemic animal species (probably several times more), in these areas.

Fortunately this biological debacle can still be forestalled in major measure, provided that suitable-scale conservation initiatives are undertaken during the last decade of this century – preferably during the next few years, since any delay will mean that much more action will have to be undertaken at much greater cost while achieving only a fraction as much success.

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