THE ROLE OF ANIMALS IN FOREST REGENERATION AND THE ECONOMICS OF RAIN FOREST CONSERVATION IN SOUTH-EAST ASIA

Dr. David J. Chivers
University of Cambridge
United Kingdom

INTRODUCTION

The evergreen rain forests of south-east Asia are an ancient and invaluable resource - nature's complex answer to relatively poor soils. Their rapid clearance, because of intense international, as well as local, pressures, is depriving the region of substantial long-term income and is seriously disrupting the environment - through flooding, soil erosion and climatic change - and threatening the welfare of people and their economies. The solution lies in the long-term protection of key areas such as watersheds and the management of extensive buffer zones for sustained yields of all kinds of animal and plant products (many of which are still undiscovered), involving at least 40% of the land areas of the countries involved.

The viability of such policies depends: on the long-term regeneration of such forests; on elucidating the biological processes ensuring this - both in undisturbed and disturbed forests; and on the relationships between the two. Previous work in the Malay Peninsula (West Malaysia) and current research in Kalimantan (Indonesian Borneo) has focused increasingly on these problems. In collaboration with the Ministry of Forestry, Agency for Forest Research and Development (Government of Indonesia) and the Smithsonian Institution (Washington, D.C.), the University of Cambridge has initiated (although core funding is still required) a programme of research into the role of animals - primates, bats, birds - in pollinations and seed dispersal, in the regeneration of primary and managed forests. This is being done in the face of increasing pressure on the forests for transmigration, oil exploration, gold prospecting and coal mining. A balance must be found for the long-term viability of the environment.

Tropical Rain Forests

This is a critical time for our planet - many ecosystems are seriously threatened by excessive and imprudent exploitation, none more so than tropical rain forests. Ever-expanding human populations have an increasingly urgent need for resources, but this struggle for survival is now seriously jeopardising survival in the future. Although the most threatened of ecosystems, because of the rapid rate of destruction, tropical rain forests offer the greatest potential for the future if managed properly. Not only are they rich reservoirs of plant and animal life, which can be exploited in perpetuity for an abundance of wood (fuel and construction), foods and chemicals (medicinal and industrial), but they prevent flooding and soil erosion locally and maintain climate - rainfall patterns and carbon dioxide levels - globally.[1,2,3]

TABLE 1

Forest formations of the tropical Far East

Climate	Soil water	Forest formation
Ever-wet	Dry land	Tropical lowland evergreen rainforest e.g. lowland & hill mixed dipterocarp forests
		Tropical lower montane rainforest e.g. upper dipterocarp & oak-laurel forests
		Tropical upper montane rainforests e.g. ericaceous forests
		Tropical subalpine forest
		Heath forest
		Forest over limestone
		Forest over ultrabasic rocks
	Water table high (at least periodically)	Mangrove forest
		Brackish-water forest
		Peat swamp forest
		Freshwater swamp forest
Seasonally dry	Moderate annual shortage	Tropical semi-evergreen rainforest
	Marked annual shortage	Tropical moist deciduous forest
		Other

Source: Whitmore (1985).

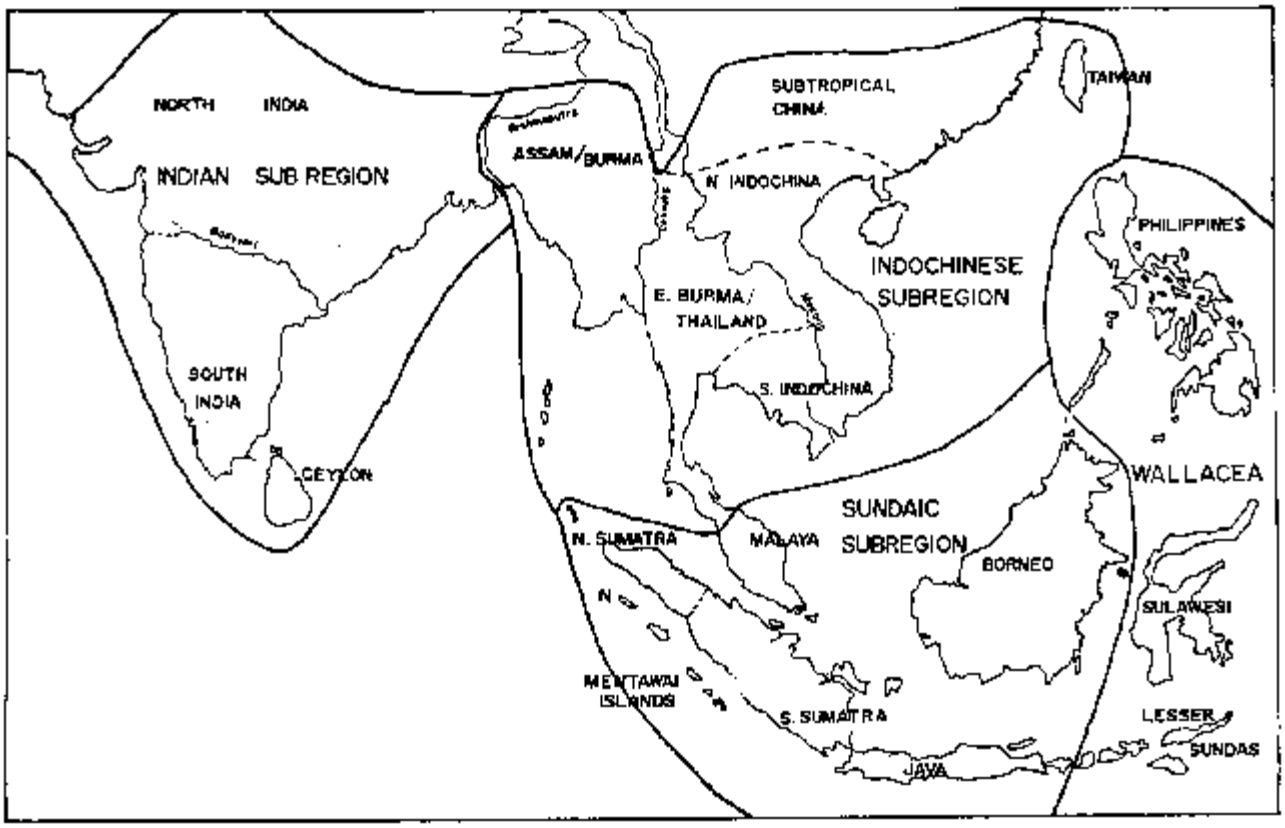
The tropical rain forest is the world's most complex ecosystem, in terms of habitat types (Table 1) and the diversity of biomass of plant and animal species.[4] This is especially true for south-east Asia, because of the antiquity of the forests there and the dramatic geologic events promoting isolation and specialisation during the Pleistocene Period.[5] Each biogeographical region and sub-region (Figure 1) contains unique animal communities, the main distinction being between the evergreen rain forests of the Sundaic sub-region and the more seasonal forests of the Indian and Indo-Chinese sub-regions to the north-west and Wallacea to the East. Indonesia is the country embracing the greatest area and diversity of such forests. Comparable areas of equatorial forests in the Neotropics and Africa are centred on the Amazon and Zaire (Congo) river basins, respectively - with Brazil and Zaire as the key countries involved.

Rain Forest Conservation

Conservation activity has tended to concentrate on "last-ditch fire-brigade" efforts to save species on the brink of extinction, e.g., among primates, in the Atlantic forests of south-east Brazil the lion tamarins (Leontopithecus) and the woolly spider monkey or muriqui (Brachyteles arachnoides)[6] and in the relic forests of West and East Africa for rare guenons (Cercopithecus), colobus monkeys (Colobus), chimpanzees and gorillas (Pan troglodytes and Pan gorilla)[7,8] Such efforts involve habitat protection and, in some cases, captive breeding and reintroduction, with the important development of new techniques. Conservation education in threatened areas has also become a sophisticated and useful tool.[9]

Increasingly, however, as reflected in the World Conservation Strategy of IUCN/WWF, conservation activities are focusing on long-term strategies to avoid such crises in the future, for humans as well as animals. This involves a combination of the protection of habitat and its management in relation to economic development. Hence the importance of those countries with the most such resources - Brazil, Zaire and Indonesia - even though such forests are crucial to all countries that contain them, little remains. Upland forests are easiest to justify protection, because they contain the watersheds vital to the whole country, but lowland forests are more difficult to protect. They grow on better soil - although still not adequate for long-term agriculture - and they contain the greatest abundance and variety of plants and animals, which factors offer the best potential for sustainable exploitation. It is these rich resources, however, which are disappearing most rapidly, because they are the most accessible and fertile, including some rare and unique forest formations, such as peat-swamp and mangrove forests.[10]

Thus, the strategy must be to protect key forest ecosystmems and to effectively manage extensive buffer zones for sustained yields, thereby both maintaining adequate forest cover and genetic resources and deriving the very considerable benefits that tropical rain forests have to offer, economically and on a sustainable basis.



Forestry and Ecological Research

Trends in the reduction of tropical forests, subsequent degeneration of the land and frequent failure of plantations pose major problems for tropical forestry (C.M. Pannell, pers. comm.). Principal among these are:

1. high wastage of many tree species;
2. slow regeneration times;
3. inadequate reafforestation; and,
4. poor understanding of natural regeneration, hence misdirection of management procedures.

Such understanding of the natural processes of regeneration is vital to the development of effective sustained-yield forest industries, which are now encouraged by international timber concerns, and which are essential for environmental stability in tropical countries. Major World Bank projects have been especially damaging in the past; they now have an environmental section to critically assess the environmental impact of projects, but this seeks advice mainly from foresters and not from wildlife biologists. It is wildlife biologists who hold the key to the crucial processes in forest regeneration, since it is often animals which disperse pollen and seeds.

Previous studies of forest regeneration have concentrated on:

1. monitoring species composition and growth rates in forest gaps or logged areas;
2. seed banks; or,
3. rain and soil conditions.[4]

The interactions between forest animals and plants in tree reproductive biology have mostly been neglected, but they have been tackled in some long-term studies of primates on all continents.[11] Johns[12,13,14] and Skorupa[15] have pioneered research into the effects of selective logging on animal and plant communities. This has inspired the development of studies, on whole forest communities in relation to pollination and seed dispersal, by teams of specialists in all relevant disciplines. This is the rationale behind Project Barito Ulu, our project in Central Kalimantan, Indonesia.

Studies of these plant-animal interactions will contribute both to the conservation of representative forest types and to the use of these areas as reservoirs of the animal and plant species necessary for regeneration in adjacent logged areas. It is necessary to:

1. distinguish between species thriving in logged areas and those affected adversely;

2. identify the regeneration processes disrupted by simplification of the food web;
3. maintain the requirements for primary forest refuges (including frequency, size and shape); and,
4. decide whether and how forestry procedures should be modified to promote natural regeneration (C.M. Pannell, pers. comm.).

Birds turned out to be the main fruit-eaters active by day, while bats are also very important pollinators and seed dispersers, both by day and by night. Primates also avoided the meat or leaf-eating specialisations of most mammalian groups, by focusing on the reproductive plant parts of flowers and fruit, changing from nocturnal insectivores into a great variety of diurnal frugivores. They owe their success, and we, our presence on this planet, to such evolutionary behaviour. Because of their close relationship to humans, and because they are among the largest arboreal animals in tropical forests with the greatest needs in terms of space and food, apart from large cats, elephants, and other hoofed mammals and large birds such as hornbills, they merit the research attention that they have received. They provide an excellent indication of the health of their rain forest habitats. Primates have been the focus of our research over the last 20 years, mainly in south-east Asia. Hence they are an excellent example for study in this region.

PRIMATES AND RAIN FOREST ECOLOGY

Species Diversity

There are four main kinds of primate in the Sundaic sub-region of south-east Asia - the Malay Peninsula, Sumatra, Java and Borneo (Figure 1):

1. the nocturnal slow loris (Nycticebus coucang) and, on Borneo and Sumatra (as well as Sulawesi and the Philippines), the tarsier (Tarsius);
2. just two species of macaque - the long-tailed (Macaca fascicularis) and pig-tailed (M. nemestrina);
3. about 10 species of langur or leaf monkey (Presbytis) and the "odd-nosed" colobine monkeys of Borneo and the Mentawai Islands (the proboscis monkey (Nasalis larvatus) and the simakobou (N. concolor) respectively), related to the golden (Rhinopithecus) and douc (Pygathrix nemaeus) monkeys of the Indo-Chinese sub-region; and,
4. apes - six of the nine species of gibbon or lesser ape (Hylobates) and, on Borneo and Sumatra, the only Asian great ape, the orang-utan (Pongo pygmaeus).

The great diversity of langurs and gibbons, and the restriction of the tarsier and orang-utan, has resulted from the alternate periods of isolation and conjunction of the various parts of the Sunda Shelf, due to changes in sea level during the glacial and inter-glacial eras of the Pleistocene Period, encouraging the speciation of the former.5,16 The slow loris and macaques were not affected by these transient barriers, because of the early origin and low mobility of the former, and the recent origin and great mobility of the latter. Apart from the tarsier and oran-utan, all these primates have close relatives in the Indo-Chinese sub-region. There is intense interest, as yet unresolved, as to how they have adapted to these drier and more seasonal forests.

This complex biogeographical pattern, mirrored in other animal groups, provides the first consideration for rain forest conservation across any such region, identifying the contrasting fauna and flora of, in this case, the 19 provinces (Figure 1). Recognising national boundaries then allows for the formulation of specific strategies for each nation, according to their needs and the needs of the region. The great species richness of south and south-east Asia stems from:

1. their derivation from Indian and Chinese stocks;
2. their mixture on the Sunda Shelf;
3. their mixture in the East of the Indo-Chinese sub-region (centred on Burma); and,
4. successive reinvasions by new "mainland" species the from the "islands" of the Sunda Shelf.

TABLE 2

Socio-ecology of representative South-east Asian forest primates - a summary[1]

	Loris *Nycticebus coucang*	Tarsier *Tarsius spectrum*	Macaque *Macaca fascicularis*	Macaque *Macaca nemestrina*	Langur *Presbytis obscura*	Langur *Presbytis melalophos*	Gibbon *Hylobates lar*	Gibbon *Hylobates syndactylus*	Orangutan *Pongo pygmaeus*
Habit	Nocturnal	Nocturnal	Diurnal		Diurnal		Diurnal		Diurnal
Habitat	Forest edge	Forest + edge	Forest edge	forest	Forest	forest + edge	Forest		Forest
Postural behavior	Slow climber	Vertical clinger and leap	Quadrupedal—run, walk trees + ground		Quadrupedal/leaping		Suspensor—hang, climb, brachiate		Quadrumanous climb + swing
Social organization	"Solitary"	Monogamous territorial	Multimale polygyny multilevel		One-male polygyny non territorial		Monogamous territorial		"Solitary"
Group size	1	4	23	30	14	12	4	6	1.5
Body weight adult female (kg)	0.7	0.1	3.5	7	6.5	6.5	5.5	11	40
Group wt. (kg)	0.7	0.3	73	74	72	69	16	31	60
Biomass (kg/km²)	15	23	180	45	240	386	29	97	100
Diet	Frugivore (faunivore)	Faunivore	Frugivore(Omnivore)		Folivore/frugivore		Frugivore/folivore		Frugivore
leaves (%)	0	0	20	17	56	39	30	43	38
fruit (%)	71	0	63	74	43	58	61	44	58
animals (%)	29	100	17	9	1	3	8	8	14
Day range (km)	0.19	0.20*	3.08	~3.0	0.76	0.95	1.67	0.87	0.64
Home range (km²)	0.05	0.09*	0.48	~3.3	0.30	0.21	0.55	0.52	1.50
DR / BW	0.7	2.0	0.5	0.4	0.3	0.2	0.3	0.08	0.02
HR / BW	0.07	0.10	0.11	1.19	0.05	0.03	0.10	0.03	0.04

[1]Where more values are given—for comparative simplicity—each behavioral aspect can be very variable over an annual cycle and between groups of the same species.
*Estimate
Source: Rodman and Chivers (1980), also Harrison (1962); Caldecott (1980); MacKinnon and MacKinnon (1980); Rijksen (1978); I. M. Y. Peterson (personal communication)

Socio-ecology

The next essential for primate and rain forest conservation is knowledge of the ecological and behavioural needs of each species. That is their place in the rain forest community -- in terms of population distribution, density and structure, habit, habitat preferences, social structure, biomass, ranging patterns, diet and interactions within and between species (Table 2).

Lorises and tarsiers are nocturnal and faunivorous (partly or wholly so, respectively); hence, they are small, living in small territories at low biomass. Lorises are "solitary", tarsiers monogamous.[17,18] Tarsiers are much more numerous than the more frugivorous slow loris, but their much smaller size results in a comparable biomass.

The other primates are diurnal and frugivorous to varying extents, occurring at different densities, mainly because of body size and diet, and with differing social structures.

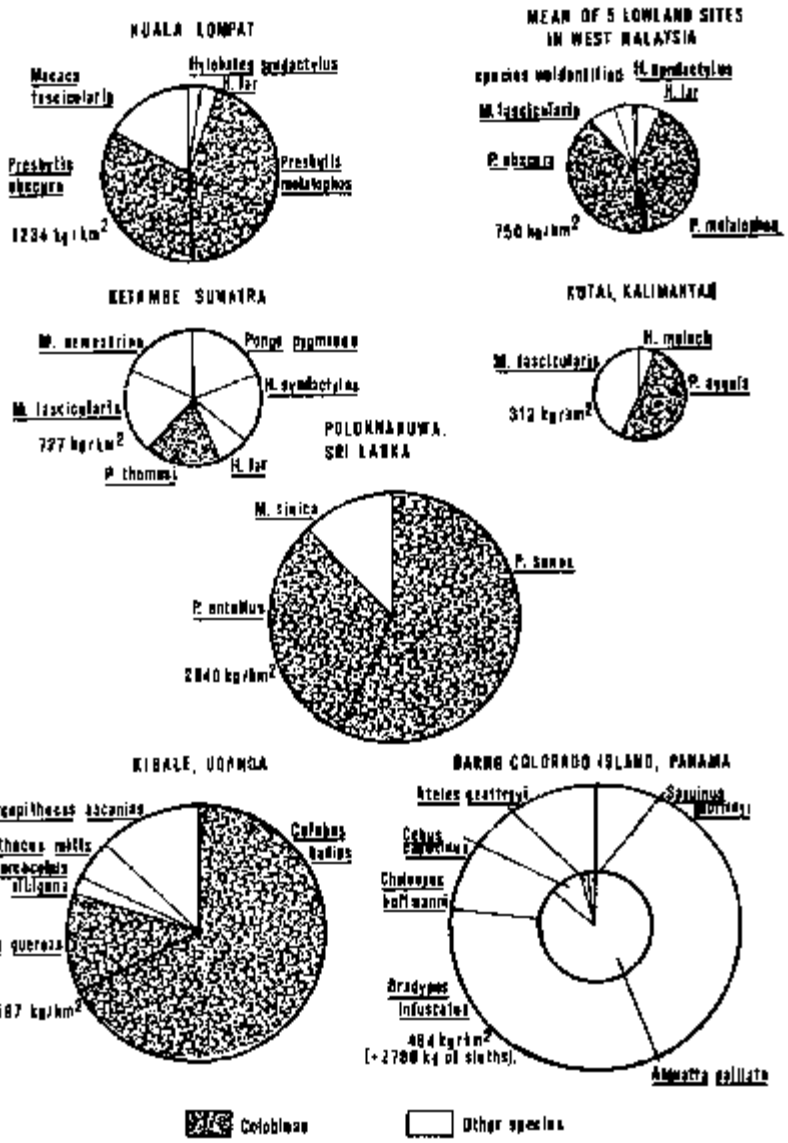
The macaques are opportunistic frugivores, living in multi-male social groups. Since their food is more abundant, they occur at higher biomass. The long-tailed macaque is a forest-edge species, thriving in rural, and even urban, areas.[19,20,21] It is replaced in the forest interior by the pig-tailed macaque, which is also seen at the forest edge and the tops of mountains. It is the most ground-dwelling of all these forest primates with its large complex, multi-level, social groups living in vast home ranges.[22,23] Caldecott[24] identifies two socio-sexual strategies among macaques:

1. adult males that are single-mount ejaculators, showing paternal care, with equal sex ratios and much inbreeding, associated with richer habitats; and,
2. adult males that are multiple-mount ejaculators, showing no paternal care, with highly-skewed sex ratios, tense social relations and much outbreeding, associated with poorer habitats.

Since langurs are adapted to folivory, through their sacculated stomachs in which bacterial fermentation takes place, they exploit the most abundant food - leaves - and occur at the highest biomasses. Social groups are smaller than in macaques, almost always based around one adult male. There are usually two species present in any Sundaic forest, with one eating more fruit, mainly the seeds and tending towards the lower canopy and forest edge, and the other more folivorous.[25,26,27,28] The seed-eating behaviour, occurring more on the poorer soils where leaves are better-defended chemically, has special significance for any deleterious effects on forest regeneration.

Gibbons are monogamous, territorial and frugivorous (particularly exploiting small sources), with elaborate suspensory and singing (duetting) behaviour. Thus, they have converged closely on bird niches. They occur at low biomass and, like colobines, live in small territories. Two species only occur together where one is larger and thus more folivorous and less mobile -- the siamang in the Malay Peninsula and Sumatra.[29]

Orang-utans are essentially solitary, because of sexual dimorphism and incompatible foraging requirements. The smaller females seek out high-quality foods, while males need more, thus lower-quality, food. They are frugivorous and relatively wide-ranging, so, despite their large size, their population density is low. The home range of an adult male overlaps those of several females, with whom he consorts, defending them from other males.[31,32,33,34]



Little is known about the behaviour of the "odd-nosed" monkeys, except that they are typically folivorous colobines. The proboscis monkey is now being studied in the north-west[26] and south-west[35] of Borneo. While it is classically associated with mangrove forest, which is floristically impoverished, it thrives better in drier lowland forests.

In summary, while some species live in small groups in small home ranges (thus at high biomass) because they are leaf-eaters, the rest occur at low biomass, whether they be small meat-eaters, medium-sized fruit-eaters in small, localised groups or in large wide-ranging groups, or large, wide-ranging frugivores in small groups. The long-tailed macaque is at intermediate biomass, because groups are large and home ranges small - this would be expected for frugivores.[36] The other frugivores are scarcer, because of the relative scarcity of suitable foods in Sundaic forest, perhaps partly because of competition between the numerous frugivores. Food is not as abundant, however, in tropical forests as is often assumed - there is a more delicate balance, which is easily upset.

From wide-ranging surveys in the Malay Peninsula, Marsh and Wilson10 showed by regression analysis, that gibbons prefer forest dominated by the large dipterocarp trees (providing high canopy and ample travel and resting supports, but not food) and a high diversity of tree families (implying high dietary diversity, or fruits in particular). Langurs, however, prefer forest rich in leguminous species, with large trees (not specifically dipterocarps) and a high diversity of tree families (again for dietary reasons). For long-tailed macaques the only significant relationship was an avoidance of dipterocarps, which are scarce in the edge-habitats which they prefer. They also quantified the biomass of these primates, for comparison with data from Borneo and North Sumatra, illustrating the smaller communities in the floristically poorer East of Borneo and the predominance of folivorous colobines in all except North Sumatra, where fruiting trees are super-abundant (Figure 2).

These south-east Asian communities are exceeded, however, by primate densities at sites in Sri Lanka, East Africa and Central America (if one includes sloths, along with howler monkeys, as the main folivores).

Thus, we have made good progress in understanding how the variety of macaques, langurs and gibbons (in particular) co-exist and partition the resources. It is perhaps the nocturnal species, and the more specialised and restricted colobines, that are most endangered, as much by our ignorance of them as by their biology and threats to their habitats. While gibbons are ecologically very similar across their range (apart from the larger siamang), the specific and sub-specific populations of langurs and, to a lesser extent, macaques, merit special attention because of their socio-ecological diffferences. So too does the orang-utan, because of its large size and needs (for space and food) and its slow and low reproductive rate.

Effects of Disturbance

Clear felling is obviously devastating to the primates and other animals involved. They either remain in a forest isolated until trapped or hunted, of they eventually perish from lack of food. They may escape into adjacent forest, which they will disrupt, in addition to the ecological and social disturbance they themselves suffer. Primates show particularly strong affinities to their home range, especially the more territorial species. They are very reluctant to move into a strange area.

Selective logging represents the compromise between human and animal needs, although, in the long term, it is the only viable strategy. It will only work, however, if timber extraction is light and carefully controlled. Even if only 10 trees per hectare are extracted (4% of trees), 45% of the total stand (68% of plant biomass) is damaged in the process of access, felling and extraction.[12] Apart from Johns' study in West Malaysia, there was a study of the effects of logging in East Kalimantan[37] and a discussion by Marsh and Wilson10, based on surveys in undisturbed forests and in areas disturbed at different times. While orang-utans and proboscis monkeys are shown to be intolerant of logging, gibbons and langurs (and macaques, of course) are remarkably tolerant, at least at low extraction levels. While their behaviour may be affected in the short term by disturbance and disruption of food supplies, it may be 20-30 years before the original population levels are restored as long as no hunting or cultivation follows the access created. The more adaptable and faster-breeding langurs recover more quickly than gibbons.[14]

Both gibbons and langurs adapt their foraging strategies by eating more leaves, as fruit availability declines in newly-logged forest.[12] Gibbons maintain their territories, but the stress affects their breeding. Langurs may emigrate temporarily from the disturbed area, and there is increased mortality of immature monkeys, because of travel difficulties across gaps, which adds to the breeding loss.[10] Johns[14] demonstrates statistically that it is the larger and more frugivorous species which are more vulnerable.

Thus, the effects of light selective logging are not as drastic to primates and other rain forest animals as was suspected. It enhances the diversity of microhabitats characteristic of the mosaic of successional stage of climax forest and it is these colonising species and plants of immature forest which provide more nutritious and less chemically-defended foods. Squirrels shift from fruit to bark and sap, and browsing mammals and small predators become more abundant because of increased food supply. Bird communities maintain much the same trophic structure, but species composition may be changed markedly: dietary generalists survive better than insect and fruit specialists, whose food supply may be very disrupted. Mosaics of primary and logged forests can maintain viable populations of the large, wide-ranging hornbills. In contrast, amphibians and other cold-blooded animals cannot survive the increased temperatures and sunshine, and decreased humidity.[12]

Selective logging, therefore, that is light and carefully controlled, can produce a habitat with a diverse and abundant fauna, but significantly different from the fauna of undisturbed climax forest. Even if such conditions are adhered to rigidly, current selective logging techniques pose additional problems:

1. the cutting of climbers prior to felling reduces food supply, although it does reduce tree fall damage; and,
2. post-felling poison-girdling to eliminate defective and commercially- unimportant trees also reduces food supply, along with resting sites and travel supports.

The least damaging extraction techniques are prohibitively expensive at present, but, in view of the benefits, ways should be found to make them more economically viable. Thus, if aerial cables or helicopters provide the solution, this should be reflected in the price of tropical hardwoods to the consumer. Less damage and more produce, on a sustainable basis, has to be the target.

TROPICAL FOREST CONSERVATION

Tropical rain forests are of immense value locally and globally for both environmental and economic reasons (Table 3). There are increasing devastating examples of the effects of excessive forest clearance on water, soil and climate - on urban and rural development and survival, most recently in Bangladesh. Tropical forests are nature's answer to poor soils, with a mass of vegetation continuously juggling and recycling nutrients. It is difficult enough to cultivate such soils, but worse when they are washed off the slopes. Even more so when they clog up fertile alluvial land and urban centres and pollute marine life, with serious loss of life and damage to health and property and to the economy.

Other irreplaceable values of the forests centre on genetic diversity and pivotal plant-animal links among the 40-50% of all the world's plants occurring therein. On the sustained yields that can be obtained from timber, cane, fibres, gums, waxes, resins, dyes and other industrial and agricultural chemicals, foods of many kinds (animal and plant) and medicines, many as yet undiscovered.[1,2,3] There are also the not insignificant benefits of research, education and recreation such as tourism.

The pressures on tropical forests centre on immediate short-term economic necessities for survival, which tend to work against long-term economic viability. Short-term prosperity jeopardises the future. The forests can contribute so much more to a country's economy in the long term than by the one-off contribution from timber sales. However much income for development can be derived from such sacrifice, and whatever one's beliefs about the viability of monocultures in monsoonal regions, the costs in terms of environmental catastrophes and poor or lost yields are likely to be prohibitive.

Pressures are increasing on all fronts - from local needs for fuel, materials and food, national needs for power, agriculture and trade, to international demands for forest products. It is often external pressures on a tropical country, which, while being welcome at present, in the long term are so damaging. Everyone on this planet will suffer if tropical forests do not remain central to national and international economies, especially in tropical regions where these forests play such a critical role in environmental stability.

There is a tri-partite solution (Table 3) that is already being developed in various countries:

1. The establishment of national parks and reserves to give total protection to watersheds, protecting ecosystems at higher altitudes, and protecting adequate areas for faunal and floral viability representative of each forest type (dry- and wet-land) in the rich lowlands of each country;
2. The efficient management of substantial buffer zones to these sanctuaries, and other available tracts of forest, for sustained yields of the great variety of animal and plant products (many as yet undiscovered) that these forests offer; and,
3. The more efficient use of land already deforested for agriculture, with the development of agro-forestry and "natural" reafforestation projects where possible.

While it may not be economically viable to protect totally more than 10% of the total land area in most countries, it seems to be environmentally essential to maintain forest cover over 40% of the land area: environmental and economic problems seem to escalate when forest cover dips below 50% of the land area. It is for regional considerations outlined above, that there should be international co-ordination and co-operation for an environmental management that will operate nationally.

TABLE 3

Conservation of tropical rainforests

Values (Long-term)	Pressures	Solutions
Water & soil balance Climate rainfall pattern atmospheric gas balance 40-50% world's plant & animal species genetic diversity pivotal plant/animal links Sustained yields timber, canes, fibres, gums, waxes, resins, dyes, foods-plant & animal medicines Education & research Recreation	Hunting Harvesting Farming Pet trade Power Water oil Selective logging Clear-felling for timber, fuel & agriculture	Total protection of watersheds & significant representatives of each ecosystem, especially those with high plant/animal diversity Wide-ranging management of buffer zones to reserves for sustained yields Agro-forestry & agriculture in areas cleared of forest, with improved efficiency

Protection

Even on the well-forested Sunda Shelf of south-east Asia, the rate at which forest is disappearing is alarming, especially in the lowlands where plant diversity is highest and wildlife most abundant. Lowland forests outside sanctuaries are expected to have disappeareed by the end of the century, and there are few enough of these sanctuaries. In between the heavier monsoons, with the floods and erosion, there now come

droughts previously unheard of in this "ever-wet" region of humid tropics and fires of horrendous extent and duration, such as that over 50,000km^2 of the Kutai Reserve in eastern Borneo during 6 months in 1983.

TABLE 4

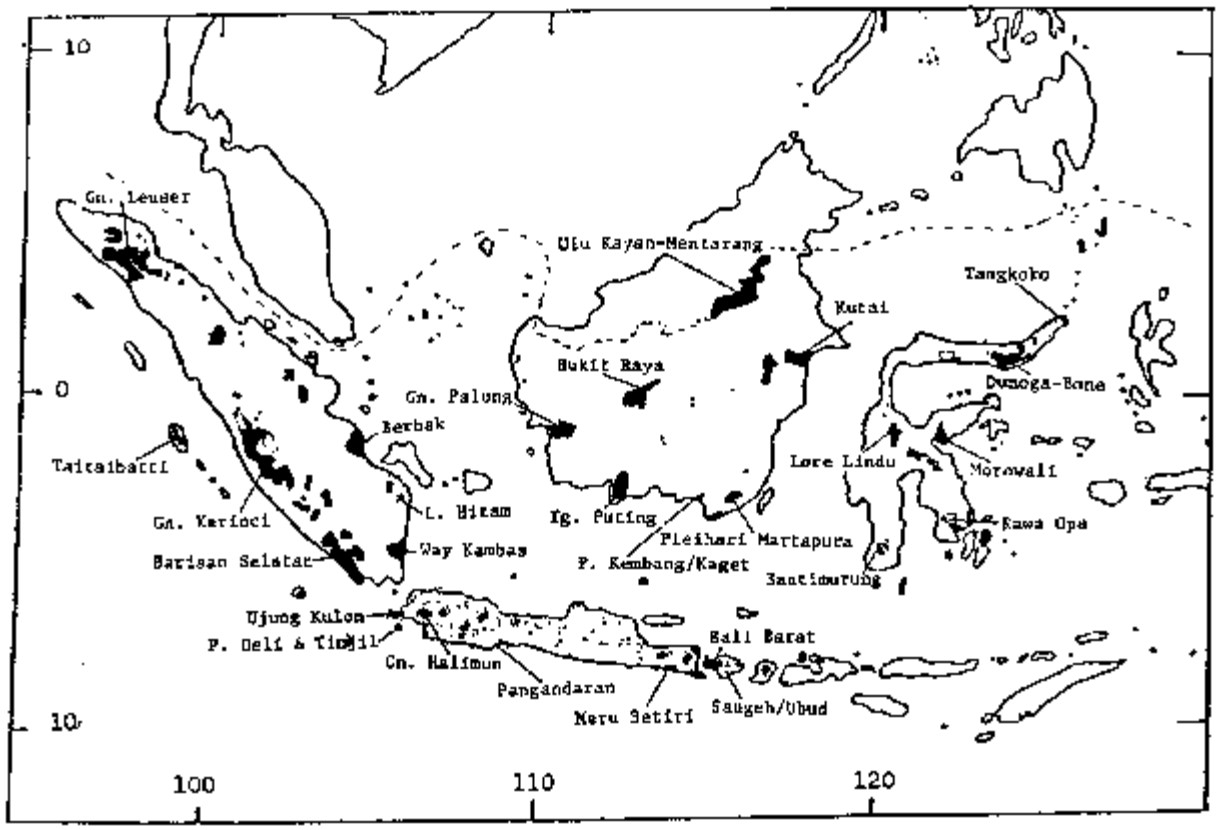
Protected Forests in Some Southeast Asian countries

	1975[1]			1985[2]			
		Protected forests					
	Total land area km^2	Forested area km^2	%	Protected forests km^2	%	Actual & proposed land area km^2	% (Proposed only)
"Assam"	121,900	47,900	39	235	0.2	4,937	4 (0)
Bangladesh	142,776					4,498	3 (1)
Burma	678,033					11,886	2 (1)
Thailand	514,910	94,452	18			41,484	8 (0)
W.Malaysia	128,013	66,950	52	8,150	6	39,138	31 (5)
E.Malaysia	201,727	28,700	64	1,740	1	71,297	35 (2)
Indonesia							
Sumatra	473,970	260,000	55	18,280	4	76,597	16 (3)
Java	126,501	28,000	22	2,422	2	12,294	10 (4)
Kalimantan	539,500	419,000	78	11,410	2	105,724	20 (11)

[1]From Chivers (1977).
[2]From Protected Areas Data Unit, Conservation Monitoring Centre, Cambridge.

Recent figures on areas of protected forests in some Asian countries are superficially encouraging (Table 4). Indonesia, for example, is developing an extensive network of reserves (Figure 3). However, accurate data on forested and protected areas are difficult to come by and do not necessarily mean real protection. Furthermore, some countries include areas protected for timber production. As has been discussed above, while such forest estates may be valuable to some animals, they are unsuitable to others. Effort is urgently needed to establish effectively and maintain such protected areas. This means clear demarcation and regular patrols, at the very least, ideally supplemented with baseline surveys on a regular basis and a wide range of ecological research (e.g. Sutton et al.[38]; McNeely et al.[29]).

A welcome innovation in Bolivia and Costa Rica has been the establishment of national parks to safeguard the forests for future generations in exchange for reduction in their national debt through substantial donations from foreign donors. Such applications of big business and finance have a major contribution to make in the protection of habitat.



Management

The key features for management of forests for sustained yields were outlined in the section on Foresty and Ecological Research, emphasising our current ignorance of the mechanisms of forest regeneration, especially of the roles of animals. This needs to be rectified rapidly, if the appropriate practices of "sustained commercial yields from natural regeneration" are to be realised. The aims must be to identify animal and plant species of commercial value and to ensure that their viability is maintained within managed areas, with whatever "assistance" is needed from adjacent primary forest. The maximum economic benefits should be derived from such managed forests on a sustainable basis; the emphasis in each area will inevitably be different, according to the main target product, as they cannot all be derived from the same forest. This seems simple and yet there are complex ramifications, which will be discussed further below. It is a challenge, however, to which we must respond.

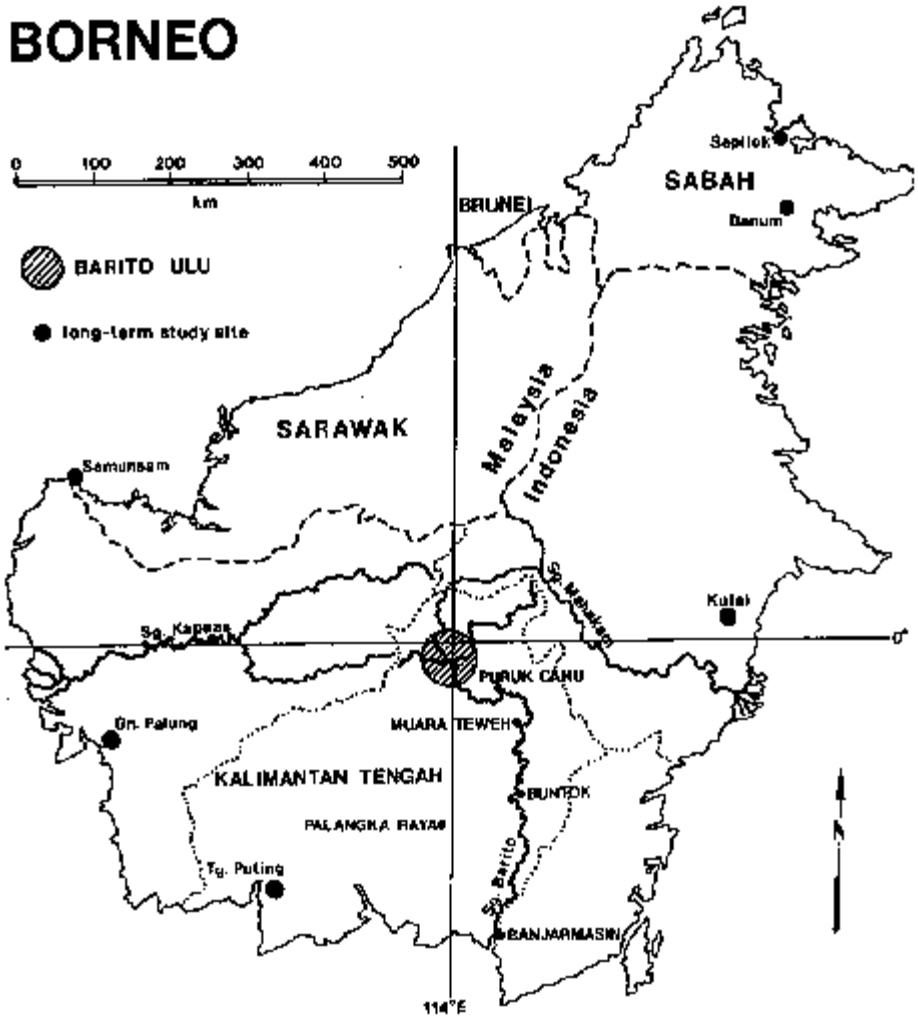
Forest products can produce revenues of $1,000 million per annum for developing countries, often being the primary or secondary source of GNP. It is mismanagment, however, which jeopardises future prosperity and even survival. Vast agricultural, irrigation, ranching and hydroelectric schemes upset the environment and climate. Even shifting cultivation is losing its traditional sustainability because of increased population pressure and over-exploitation. Potentially beneficial plants are destroyed every week, before even being discovered! Such are the problems to be resolved.

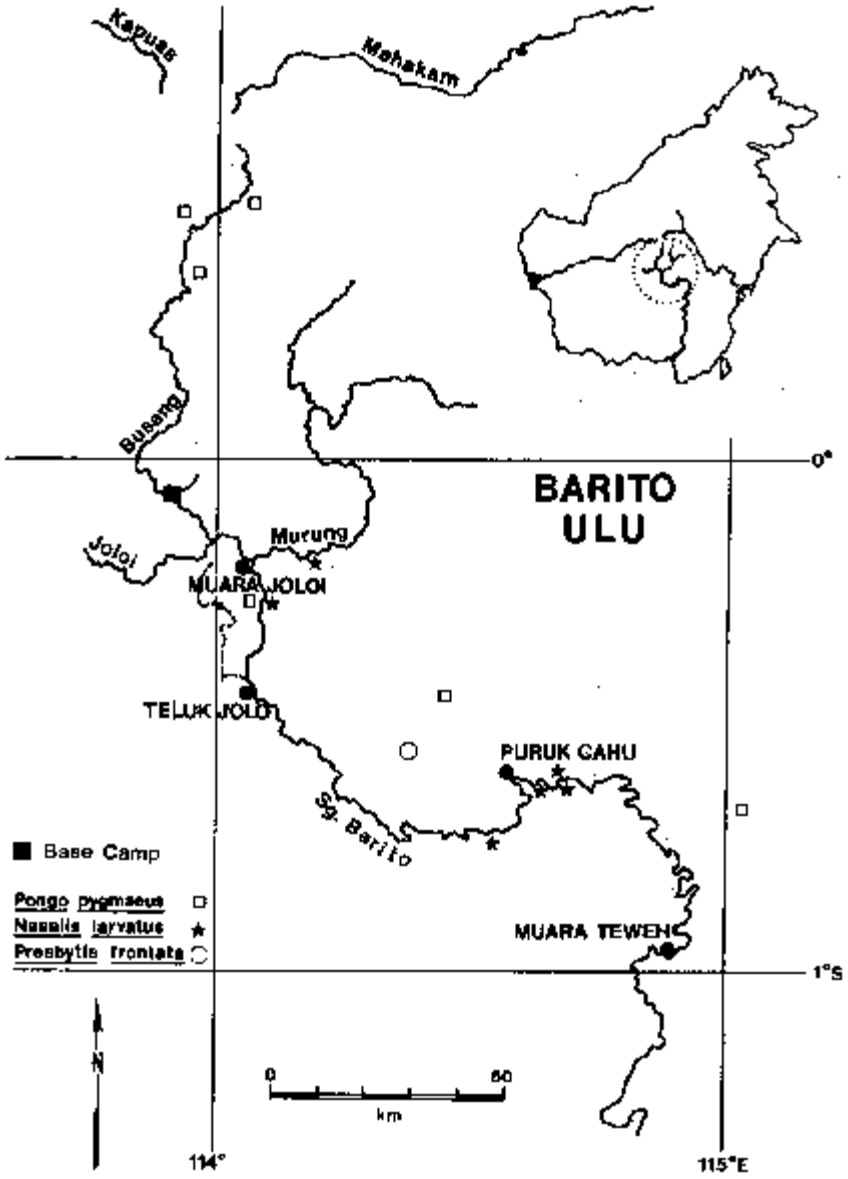
CONCLUDING DISCUSSION

The island of Borneo, containing animals found nowhere or hardly anywhere else in the world (such as the proboscis monkey and orang-utan, respectively), has been identified as a key area in the world for tropical rain forest. Systematic and long-term studies of Bornean ecology and behaviour have so far been on or near the coast (Figure 4). For primates, as a typical example, in East Malaysia in Sarawak at Samunsam and in Sabah on the Segama river, near or in the Danum Valley([40,26,32,22] Crompton and Andau, 1987; A.D. Johns, in progress); in Kalimantan at Kutai in the East, at Tanjung Puting in the South-west, and now at Gunung Palung in the West[31,41,42,43,44,24,45,46,47,35] (and M. Leighton, in progress).

Not only have there been no comparable studies towards the centre of the island, where most of the forest is to be found[48], but there is virtually no information on the abundance and distribution of primates and other animals. Furthermore, the headwaters of the Kapuas and Barito rivers, right in the centre of the island, provide the weak link in the barrier between the Sumatran immigrants into the South-west of Borneo at the end of the Pleistocene Period and the endemic Bornean fauna, which then retreated to the maritime influence in the north-east of the island. Thus, one has intriguing incidences of hybridisation between closely related species, such as the Bornean (Hylobates muelleri) and

agile (H. agilis) gibbons; this provides unique opportunities to study the biology of such animals, and of even greater interest, the closer their relationship to humans. Proboscis monkeys have also been found in this area, well away from their usual coastal habitats and the alluvial riverine forests further down the Barito river; the orang-utan is also present, at least in small numbers.





Thus, the conservation value of this area, and the biogeographical interest, make this the obvious location for a long-term inter-disciplinary investigation of rain forest ecology and management in central Borneo - Project Barito Ulu.

Initiated in 1984, with reconnaissances to Jakarta and Bogor in 1985 and 1986 and to the study area in 1986, the project finally started in April 1988 with primate studies and a pilot study on bats in October 1988. Base Camp has been established at the mouth of the Rekut tributary on the Busang branch of the Barito river (Figure 5). In collaboration with the Ministry of Forestry (Agency for Forest Research and Development) and the National Biological Institute, Government of Indonesia, the University of Cambridge has initiated a programme of research into the role of animals - primates, bats, birds - in pollination and seed dispersal, the key processes in the natural regeneration of primary and managed forests. Also participating are the Smithsonian Institution, with scientists from the universities of Oxford, Strathclyde and Bogor and from the Institute of Terrestrial Ecology, United Kingdom, with technical assistance from the herbaria at Bogor, Leiden and Kew. It is associated with the Royal Society's South-east Asia Rain Forest Research Programme and has the support of the Royal Geographical Society and, most recently, sponsorship from the Indonesian national airline, "Garuda".

1. The aims are to elucidate:
2. plant-animal interactions in undisturbed and disturbed forests;
3. acceptable levels of disturbance; and,
4. the relationship between primary and managed forests, in terms of size, shape and spatial inter-relations.

Thus the key elements are:

1. ecological research, including bio-geography, botany, plant chemistry and all branches of zoology;

2. the application of these results to forest management on a sustained basis; and,
3. the training of wildlife biologists, especially Indonesian nationals, staff and students, in the relevant techniques of wildlife biology, forest management and conservation.

Plant and animal collections, especially of living material, will be used for breeding programmes and applied research. The chemical analysis of plants offers exciting prospects for the discovery and application of new medicinal and industrial compounds; there is an urgent need to combat the more serious diseases that threaten to overwhelm us (such as the recent discovery of a plant compound that may inhibit the AIDS virus), and to improve industrial and agricultural efficiency. There are also opportunities to discover new organisms that can combat pests. The emphasis has to be on biological compounds and agents of commercial use.

All this is being done in the face of increasing pressures on the forests for the transmigration of people from Java, with their agricultural needs, oil exploration and drilling prospecting for the rich new deposits of gold, and coal mining. A balance must be found for the long-term viability of the environment. By such approaches, forest could be cropped indefinitely on a long-term cycle, for all sorts of products in addition to timber, instead of being "mined" briefly and heavily for timber, as has occurred too often in the humid tropics, and which is now causing much concern among foresters and policy-makers in tropical countries. Excessive demands for Indonesian hardwoods in Europe have exacerbated the problem; 25% of all furniture hardwood used in Europe comes from Indonesia, and 52% of all plywood. The family Dipterocarpaceae is the key hardwood family and key structural element in the rain forests of the region. There is an urgent need for research before forestry destroys countless species of value. Such overcropping has caused damage to the forest fabric that we lack the technical knowledge to repair, but we have joined those who are seeking to rectify this.

With the active involvement of wildlife biologists there is real hope for escaping the current "vicious spiral" of rapid profits from drastic exploitation, leading to loss of crucial resources that besets and threatens "development" and survival from sustained commercial yields from natural regeneration.

ACKNOWLEDGEMENTS

I thank all those who have in some way contributed material that has been used in this paper. I am also indebted to Dr. Agni Vlavianos-Arvanitis and the Biopolitics International Organisation for the opportunity to participate in their international conference "Bios in the Next Millennium" in Athens.

REFERENCES

1. Myers N., The Sinking Ark, Pergamon, Oxford, 1979.
2. Myers N., A Wealth of Wild Species: Storehouse for Human Welfare, Westview, Boulder, Colarado, 1983.
3. Myers N., The Primary Source: Tropical Forests and our Future, Norton, New York, 1984.
4. Whitmore T.C., Tropical Rain Forests of the Far East, Clarendon, Oxford, 1985.
5. Verstappen H.T., On palaeoclimates and land form development in Malesia. In Modern Quaternary Research in South-east Asia (Bartstra G.J, & Casparie W.A., eds.), Balkema, Rotterdam, pp3-36.
6. Mittermeier R.A., Primate conservation priorities in the Neotropical region. In Primates: The Road to Self-sustaining Populations (Benirschke K., ed.) Springer-Verlag, New York, 1986, pp221-240.
7. Oates J.F., African primate conservation: general needs and specific priorities. In Primates: the Road to Self-sustaining Populations (Benirschke K., ed.) Springer-Verlag, New York, 1986, pp21-29.
8. Harcourt A.H., Gorilla conservation: anatomy of a campaign. In Primates: the Road to Self-sustaining Populations (Benirschke K., ed.) Springer-Verlag, New York, 1986, pp32-46.
9. Aveling R.J., Environmental education in developing countries. In Primate Conservation in the Tropical Rain Forest (Marsh C.W., & Mittermeier R.A., eds.) Alan Liss, New York, 1987, pp231-262.
10. Marsh C.W., & Wilson W.L., A Survey of Primates in Peninsular Malaysian Forests. Universiti Kebangsaan Malaysia and University of Cambridge, 1981.
11. Chivers D.J., Current issues and new approaches in primate ecology and conservation. In Primate Ecology and Conservation (Else J.G, & Lee P.C., eds.) Cambridge University Press, 1986a, pp3-17.
12. Johns A.D., Ecological effects of selective logging in a West Malaysian Rain Forest (Unpublished) Ph.D. thesis, Cambridge, 1983.
13. Johns A.D., Effects of selective logging on the behavioural ecology of West Malaysian primates, 1986, Ecology 67:684-694.
14. Johns A.D., Responses of rain-forest primates to habitat disturbance: a review. 1987, Int. J. Primatol. 8:157-191.
15. Skorupa J.P., Responses of rain forest primate to selective logging in Kibale Forest, Uganda: a summary report. In Primates: the Road to Self-sustaining Populations (Benirschke K.) Springer-Verlag, New York, 1986, pp58-70.
16. Chivers D.J., The lesser apes. In Primate Conservation (Prince Rainier and Bourne G.H., eds.) Academic, New York, 1977, pp539-598.
17. Barrett E.B.M., The Ecology of some Nocturnal Arboreal Mammals in the Rain Forest of Peninsular Malaysia (Unpublished) Ph.D.

thesis, Cambridge, 1984.

18. MacKinnon J.R., & MacKinnon K.S., The behaviour of wild spectral tarsiers, 1980, Int. J. Primatol. 1: 36-379.
19. Aldrich-Blake F.P.G., Long-tailed macaques. In Malayan Forest Primates (Chivers D.J., ed.), Plenum, New York, 1980, pp147-165
20. Mah Y.L., Ecology and behaviour of Macaca fascicularis (Unpublished) Ph.D. thesis, Universiti Malaya, 1980
21. Lindburg D.G., The Macaques: Studies in Ecology, Behavior and Evolution, Van Nostrand Reinhold, New York, 1980.
22. Caldecott J.O., An ecological and behavioural study of the pig-tailed macaque, 1986a, Contrib. primatol.21:1-259.
23. Robertson J.M.Y., On the evolution of pig-tailed macaque societies (Unpublished) Ph.D. thesis, Cambridge, 1986.
24. Caldecott J.O., Mating patterns, societies and the ecogeography of macaques, 1986b, Anim. Behav.34:208-220
25. Curtin S.H., Dusky and banded leaf monkeys. In Malayan Forest Primates (Chivers D.J., ed.) plenum, New York, 1980, pp107-145.
26. Bennet E.L., The banded langur: ecology of a colobine in West Malaysian Rain Forest (Unpublished) Ph.D. thesis, Cambridge, 1984.
27. Davies A.G., An ecological study of the red leaf monkey (Presbytis rubicunda) in the dipterocarp forests of northern Borneo. (Unpublished) Ph.D. thesis, Cambridge, 1984.
28. Davies A.G., Caldecott J.O., & Chivers D.J., Natural foods as a guide to nutrition of Old World primates. In Standards in Laboratory Animal Management (UFAW, ed.), Universities Federation for Animal Welfare, Potters Bar, England, 1984, pp225-244.
29. Preuschoft H., Chivers D.J., Brockelman W.Y., & Creel N., The Lesser Apes: Evolutionary and Behavioural Biology, Edinburgh University Press, 1984.
30. Wrangham R.W., On the evolution of ape social systems, 1979, Soc. Sci. Inform. 18: 335-368.
31. Rodman P.S., Population composition and adaptive organisation among orang-utans of the Kutai Reserve. In Comparative Ecology and Behaviour of Primates (Michael R.P., & Crook J.H., eds.) Academic, London, 1973, pp171-209.
32. MacKinnon J.R., The behaviour and ecology of wild orang-utans (Pongo pygmaeus), 1974, Anim Behav. 22: 3-74.
33. Rijksen H.D., A Field Study of Sumatran Orang-utans (Pongo pygmaeus abelii Lesson 1827): Ecology, Behaviour and Conservation Veeman H., & Zonen BV, Wageningen, Netherlands, 1978.
34. Galdikas B.M.F., Orang-utan adaptation at Tanjung Puting Reserve, Central Borneo (Unpublished) Ph.D. thesis, California, Los Angeles, 1978.
35. Yeager C., Behavioural ecology of the proboscis monkey (Nasalis larvatus) (abstract), 1987, Amer. J. Primatol. 12: 377.
36. Hladik C.M., & Chivers D.J., Ecological factors and specific behavioural patterns determining primate diet. In Recent Advances in Primatology, vol. 1, Behaviour (Chivers D.J., & Herbert J., eds.) Academic, London, 1978, pp433-444.
37. Wilson C.C. and Wilson W.L., The influence of selective logging on primates and some other animals in East Kalimantan, 1975, Folia primatol 23: 245-274.
38. Sutton S.L., Whitmore T.C., & Chadwick A.C., Tropical Rain Forest: Ecology and Management, Blackwell, Oxford, 1983.
39. McNeely J.A., Miller K.R., & Thorsell T.W., Objectives, selection and management of protected areas in tropical forest habitats. In Primate Conservation in the Tropical Rain Forest (Marsh C.W., & Mittermeier R.A., eds.) Alan Liss, New York, 1987, pp181-204.
40. Salter R.E., MacKenzie N., Nightingale N., Aken K.M., & Chai P.P.K., Habitat use, ranging behaviour and food habits of the proboscis monkey Nasalis larvatus in Sarawak, 1985, Primates 26: 436-451.
41. Rodman P.S., Diets, densities and distributions of Bornean primates. In The Ecology of Arboreal Folivores (Montgomery G.G., ed.) Smithsonian Institution Press, Washington, D.C., 1978, pp465-478.
42. Wheatley B.P., Foraging patterns in a group of long-tailed macaques in Kalimantan Timur, Indonesia. In Recent Advances in Primatology, vol.1, Behaviour (Chivers D.J., & Herbert J., eds.), Academic, London, 1978, pp347-349.
43. Mitani J.C., The behavioural regulation of monogamy in gibbons (Hylobates muelleri), 1984, Behav. Ecol. Sociobiol. 15: 225-229.
44. Berenstain L., Responses of long-tailed macaques to drought and fire in eastern Borneo, 1986, Biotropica 18: 257-262.
45. Sugardjito J., Behavioural ecology of the dark-handed gibbon, Hylobates agilis albibarbis, in Kalimantan Tengah, Indonesia (Unpublished) Drs. thesis, Universitas nasional, Jakarta (in Indonesian), 1978.
46. Bismark M., Populasi dan tingkahlaku bekantan (Nasalis Larvatus) Laporan no. 57, Lembaga Penelitian Hutan, Bogor, 1980.
47. Supriatna J., Manullang B.O., & Soekara E., Group composition, home range and diet of the maroon leaf monkey (Presbytis rubicunda) at Tanjung Puting Reserve, Central Kalimantan, Indonesia, 1986, Primates 27: 185-190.
48. Chivers D.J., South-east Asian primates. In Primates: the Road to Self-sustaining Populations (Benirschke K., ed.) Springer-Verlag New York, 1986b, pp127-151.
49. Marsh C.W., A framework for conservation in Asian moist tropical forests. In Primate Conservation in the Tropical Rain Forest (Marsh C.W., & Mittermeier R.A., eds.) Alan Liss, New York, 1987, pp343-354.
50. Raemaekers J.R., & Chivers D.J., Socio-ecology of Malayan Forest Primates. In Malayan Forest Primates (Chivers D.J., ed.) Plenum, New York, 1980, pp279-316.
51. MacKinnon K.S., The conservation status of nonhuman primates in Indonesia. In Primates: The Road to Self-sustaining Populations Benirschke K., ed.) Springer-Verlag, New York, 1986, pp99-126.

Dr. **David John Chivers** was awarded his Ph.D. in 1972 by the Department of Physical Anthropology, Sidney Sussex College, Cambridge, for his study on the ecology and behaviour of gibbons in Malaysia. Since then he has organised research on the ecology and behaviour of rain-forest primates in Malaysia, Indonesia, India, Bangladesh and Brasil, with special reference to conservation, and taught anatomy to veterinary students and primate biology to anthropology students. Since 1977 he has been a University Lecturer in Veterinary Anatomy, Department of Anatomy, University of Cambridge, and since 1989 a Fellow and Tutor of Selwyn College. He has spent a total of 50 months in the field, mostly in the countries mentioned, attended numerous conferences, and supervised the theses of 20 research students. He has published extensively on the subject of primates and is a member of many learned international societies.