

## FALCONIFORMS OF TROPICAL RAINFORESTS: A REVIEW

J.-M. THIOLLAY

*Laboratoire de Zoologie ENS, 46 Rue d'Ulm, 75230 Paris Cédex 05, France*

### ABSTRACT

The American, Indo-Malayan and African rainforests originally covered 5.9, 3.0 and 2.1 million square kilometres respectively, but they have now been so extensively destroyed that perhaps no more than 1.0 million square kilometres of virgin rainforest still exist.

Some 111 species and 280 subspecies, i.e. 39 percent of the world's Falconiform species are found in the rainforests, which today cover maybe less than 1 percent of the land surface of the world: 40 species in continental America, 12 in Africa, 13 in the Caribbean and western Indian Ocean, 28 from India to Celebes and 22 from New Guinea to north-eastern Australia. Most are very poorly known: for instance, the nest, eggs and voices of more than half the rainforest raptors have never been recorded.

Probably many additional taxa ought to be included in the *Red Data Book*, either because they are restricted to islands with a rapidly decreasing forest cover or because they are rare and sparsely distributed through a wide continental range; however, we have almost no information about most of them.

Habitat destruction is by far the main threat to the survival of rainforest raptors. Except very locally, killing of raptors is only occasional, but widespread overhunting of medium-sized mammals and large birds may reduce the food-supply of many eagles. The only way to prevent extinctions is to preserve areas of primary forest large enough to support self-sustaining populations of even the largest species, and so avoid the 'island effect'.

After a brief description of rainforest, this paper lists the raptors of this habitat in different parts of the world and stresses the paucity of information. It then discusses the main threats to these raptors and the steps necessary to conserve them.

### INTRODUCTION

Rainforests are among the highest and wettest forests in the world. They have an almost continuous canopy but their understorey is not usually dense. They are found in hot damp climates, with an annual rainfall of around 200cm (never below 170; locally up to 500 or more). The mean rainfall for the driest month is rarely less than 50–60mm with only 1 to 3 months below 100mm. There are two wet and two dry seasons near the equator, merging into a single wet and a single dry season further away (above 7–9° latitude). The mean annual temperature is around 26°C, monthly averages between 18° and 32°C, and the relative humidity usually between 75 percent and 95 percent. The light in the forest undergrowth is about 1 percent of that outside. The average cloudiness is more than 50 percent and the daily sunshine between 4 and 7 hours (Richards 1952).

The typical rainforest is evergreen, but further from the equator and depending on the length of the dry period, it becomes more seasonal (monsoon forest), then

semi-deciduous. Half the world's forests are tropical but only a part of them are in the rainforest belt where montane, cloud, swamp or mangrove forests are also found with specific avifaunas. The floristic richness of the rainforest is impressive: from more than 3000 vascular plant species in West Africa to 10,000 in Borneo. Commonly three to five layers can be recognized in the structure of mature forests, but the numerous climbing plants and epiphytes add greatly to their structural diversity.

## DISTRIBUTION AND DESTRUCTION OF THE RAINFOREST

The rainforest lies in the lowlands between the tropics, mostly within  $15^{\circ}$  of the equator, but more of its area is in the northern than in the southern hemisphere. Limited extratropical extensions of marginal humid evergreen forests are found in eastern Australia, Southeast Asia and northern Argentina. Its upper altitudinal limit is around 1500m.

Globally, the rainforest can be divided into three main zones:

**The American rainforest** from eastern and southern Mexico to extreme northern Argentina, mainly the 4.65 million  $\text{km}^2$  Amazon Basin. Distinct narrow belts are found on the western side of the Andes in Ecuador and Colombia and on the east coast of Brazil. Most of the Antilles belong to the same unit.

**The African rainforest** is divided into the Congo Basin (1,550,000 $\text{km}^2$ ), extending from Nigeria to western Uganda and central Zaire, and the West African (Upper Guinea) Forest (310,000 $\text{km}^2$ ) extending from Ghana to southern Casamance. The eastern forest of Madagascar and of some other western Indian Ocean islands, although distinct, can be added.

**The Indo-Malayan rainforest** from southwestern India to Sri Lanka and from lower eastern Himalaya to Burma, Thailand, South Vietnam, Malaya, Indonesia, Philippines, New Guinea, the western Pacific islands and northeastern Australia.

The intertropical zone comprises 26 percent of the world's land: 24 million  $\text{km}^2$  in Africa, 13.5 $\text{km}^2$  in Asia-Australia and 15.8 $\text{km}^2$  in Central and South America. Rainforests cover respectively 2.1, 3.0 and 5.9 million  $\text{km}^2$  (UNESCO 1979). From these 11 million  $\text{km}^2$  it is not certain whether more than 1 million are still pure primary undisturbed forest in 1982. Every year Asian rainforests decrease by about 50,000 $\text{km}^2$  and the Amazonian forest by 100,000 $\text{km}^2$ . The annual rate of destruction during the last twenty years has been 280,000ha, in the Malay Peninsula as well as in Ivory Coast. In the last 30 years, 50 percent of the forested area of Thailand, Philippines and southern Mexico (among others) has disappeared. Even in remote New Guinea, where forest covered 73 percent of the country, 8 million cubic metres of timber are exported annually. In some parts of Colombia and Panama the forest has been reduced by 40 percent within ten years (UNESCO 1979). Between 1964 and 1973, tropical rain and monsoon forests have disappeared at an average rate of 21ha per minute, and there is no evidence that this rate has decreased up to now (Whitmore 1980).

By far the most important cause of forest destruction is the system of shifting cultivation practised by native people throughout the tropics. A patch of forest is felled, the larger trees being sometimes spared: the vegetation is burnt and crops are planted, rarely for more than two consecutive years. Then the soil becomes impoverished and the plot is abandoned, giving way to dense secondary growth unsuitable for most primary forest species. If left undisturbed, this vegetation needs about 100 years to recover a primary forest structure and probably more

than 300 years to regain its former floristic and zoological composition. In the course of the succession, soil fertility is partially restored and the secondary forest may be cleared and cultivated again.

This extremely wasteful system is matched only by the very destructive exploitation of commercial timber. Even when logging is restricted to the more valuable trees, it damages the forest far more than in temperate countries because large machines and wide tracks are needed to remove each trunk. When 10 percent of the forest area is felled (selective exploitation yielding 5 to 10 m<sup>3</sup>/ha), an additional 55 percent is destroyed in extraction operations, leaving no more than 35 percent of the forest undamaged (Whitmore 1980 and pers. obs.). Roads and openings created by lumber men are quickly occupied by a growing peasant population, claiming more and more land for their uneconomical shifting cultivation. Today, large areas of forest are cleared and burnt to create extensive pastures or commercial plantations (including pines or eucalyptus for pulp), so preventing, indefinitely, the regeneration of the original forest.

## THE RAINFOREST RAPTORS

### Diversity and distribution

*Tables 1 and 2* give the numbers of species and subspecies in each biogeographical region. Only the main habitat of each species is considered: A = species of regular occurrence inside large tracts of unbroken primary forest; B = species occurring within large areas of primary forest but in and around natural openings (rivers, wooded marshes, gaps created by storms and fallen trees, rocky outcrops). Most, if not all, of the above species also inhabit secondary forests or clearings and many of the latter can even be more abundant there than in their natural habitat. Species found along forest edges, in galleries or secondary growth, but accidentally in virgin forest, are not included. When the habitat is undetermined from available literature or is mostly mountain forest, it is stated in *Tables 1* and *2* as '?' or 'M' respectively.

Some species may have subspecies in subtropical or temperate regions, or in habitats other than forest: these subspecies are not included in the last column of *Table 1*. The Sanford's Sea Eagle (*Haliaeetus sanfordi*) which commonly occurs in dense forest on the Solomon Islands and seems to behave more like a true eagle than a fishing eagle (Brown & Amadon 1968) could be added to *Table 1*. In Central America, the Turkey Vulture (*Cathartes aura*) and rarely the Lesser Yellow-headed Vulture (*C. burrovianus*) replace in the forest the Greater Yellow-headed (*C. melambrotus*) and sometimes coexist with it in South America.

*Table 1* is divided as follows:

**America** = Lowland rainforest of Central and South America. Endemics of the Antilles (*Anti.*) or only *Cuba* or Hispaniola (*Hisp.*) are included.

**Africa** = Lowland rainforest of continental Africa, including species restricted to Madagascar (*Mad.*) or Mauritius (*Maur.*).

**SE Asia** = Tropical forest zone of south-west India and Sri Lanka to Burma, Thailand, Malaya, Indonesia, Borneo, Philippines and Celebes. Species restricted to one particular island or archipelago are indicated: Andaman (*And.*); Borneo (*Bor.*); Celebes (*Cel.*); Java, Nicobar (*Nic.*); Philippines (*Phil.*).

**New Guinea** = Islands of the New Guinea archipelago, Moluccas (*Mol.*); New Britain (*Brit.*); Solomons (*Sol.*) and the tropical forest of north-eastern Australia.

*Table 1:* List of Falconiform species from tropical rainforests of the world (taxonomy from Mayr & Cottrell 1979). Distribution and habitat: see text. The next three columns point out if the voice, nest and eggs have been described in at least one subspecies (between brackets if found only 1 or 2 times), after Brown & Amadon, 1968. Subspecies = number of breeding subspecies within the rainforest zone.

Species	America	Africa	SE. Asia	New Guinea	Habitat	Described			Subspecies
						Voice	Nest	Eggs	
<i>Cathartes melambrotus</i>	+				A				1
<i>Sarcoramphus papa</i>	+				A	+	(+)	(+)	1
<i>Aviceda cuculoides</i>		+			A	+	+	+	3
<i>Aviceda madagascariensis</i>		Mad.			B			(+)	1
<i>Aviceda jerdoni</i>			+		A	+	+	+	5
<i>Aviceda subcristata</i>				+	B	+	+	+	16
<i>Leptodon cayanensis</i>	+				A	+	(+)	(+)	2
<i>Chondrohierax uncinatus</i>	+				A	+	(+)	(+)	4
<i>Henicopernis longicauda</i>				+	A		(+)		3
<i>Henicopernis infusata</i>				Brit.	?				1
<i>Pernis ptilorhynchus</i>			+		B	+	+	+	5
<i>Pernis celebensis</i>			+		?			(+)	2
<i>Elanoides forficatus</i>	+				A	+	+	+	1
<i>Machaeramphus alcinus</i>		+	+	+	B	+	+	+	3
<i>Harpagus bidentatus</i>	+				A	+	+	+	2
<i>Harpagus diodon</i>	+				A		(+)	(+)	1
<i>Ictinia plumbea</i>	+				A	+	+	+	1
<i>Ichthyophaga humilis*</i>			+		B	+	+	+	1
<i>Gypohierax angolensis</i>		+			B	+	+	+	1
<i>Spilornis cheela</i>			+		A	+	+	+	22
<i>Spilornis elgini</i>			And.		B				1
<i>Dryotriorchis spectabilis</i>		+			A	+			2
<i>Eutriorchis astur</i>		Mad.			A				1
<i>Polyboroides typus</i>		+			B	+	+	+	2
<i>Polyboroides radiatus</i>		Mad.			B	+	+	+	1
<i>Accipiter poliogaster</i>	+				A				1
<i>Accipiter trivirgatus</i>			+		A	+	+	+	10
<i>Accipiter griseiceps</i>			Cel.		A	+	(+)		1
<i>Accipiter tachiro</i>		+			A	+	+	+	5
<i>Accipiter castanilius</i>		+			A				2



<i>Accipiter butleri</i>			Nic.	?	+	(+)		2
<i>Accipiter francesii</i>		Mad.		A	+	+	+	4
<i>Accipiter trinitatus</i>			Cel.	A	+			1
<i>Accipiter fasciatus</i>				B	+	+	+	11
<i>Accipiter novaehollandiae</i>				B				23
<i>Accipiter melanochlamys</i>				M				2
<i>Accipiter albogularis</i>			Sol.	?				5
<i>Accipiter henicogrammus</i>			Mol.	?				1
<i>Accipiter luteoschistaceus</i>			Brit.	M				1
<i>Accipiter imitator</i>			Sol.	?				1
<i>Accipiter poliocephalus</i>				+				1
<i>Accipiter princeps</i>			Brit.	M				1
<i>Accipiter superciliosus</i>	+			B	+	(+)	(+)	2
<i>Accipiter erythropus</i>		+		A	+	(+)	(+)	2
<i>Accipiter virgatus</i>			+	A	+	+	+	7
<i>Accipiter nanus</i>			Cel.	M	+	(+)	(+)	1
<i>Accipiter cirrocephalus</i>				B	+	+	+	3
<i>Accipiter brachyurus</i>			Brit.	?				1
<i>Accipiter erythrauchen</i>			Mol.	?				2
<i>Accipiter rhodogaster</i>			Cel.	A				5
<i>Accipiter striatus</i>	+			M		+	+	3
<i>Accipiter bicolor</i>	+			A	+			1
<i>Accipiter gundlachi</i>		Cuba		A				1
<i>Accipiter melanoleucus</i>		+		A	+	+	+	1
<i>Accipiter henstii</i>		Mad.		A	+	(+)	(+)	1
<i>Accipiter meyerianus</i>				?				1
<i>Accipiter buergeri</i>				A				1
<i>Accipiter doriae</i>				A				1
<i>Urotriorchis macrourus</i>		+		A	+			1
<i>Geranospiza caerulescens</i>	+			B	+	+	+	4
<i>Leucopternis schistacea</i>	+			A				1
<i>Leucopternis plumbea</i>	+			A				1
<i>Leucopternis princeps</i>	+			M	+			2
<i>Leucopternis melanops</i>	+			A				1
<i>Leucopternis kuhli</i>	+			A				1
<i>Leucopternis lacernulata</i>	+			?				1
<i>Leucopternis semiplumbea</i>	+			A				1
<i>Leucopternis albicollis</i>	+			B	+	(+)	(+)	5

(continued)

Table I: Continued

Species	America	Africa	SE. Asia	New Guinea	Habitat	Described			Subspecies
						Voice	Nest	Eggs	
<i>Leucopternis polionota</i>	+				?				1
<i>Asturina nitida</i>	+				B	+	+	+	4
<i>Buteogallus urubitinga</i>	+				B	+	(+)	(+)	2
<i>Harpyhaliaetus solitarius</i>	+				B	+	(+)	(+)	2
<i>Buteo ridgwayi</i>	Hisp.				A	+	(+)	(+)	1
<i>Buteo platypterus</i>	Anti.				B				5
<i>Buteo brachypterus</i>		Mad.			B	+	+	+	1
<i>Morphnus guianensis</i>	+				A		(+)	(+)	1
<i>Harpia harpyja</i>	+				A	+	+	+	1
<i>Harpyopsis novaeguineae</i>				+	A	+	(+)		1
<i>Pitheophaga jefferyi</i>			Phil.		A	+	(+)	(+)	1
<i>Ictinaetus malayensis</i>			+		B	+	+	+	2
<i>Aquila gurneyi</i>				+	?				1
<i>Hieraaetus morphnoides</i>				+	B	+	+	+	2
<i>Hieraaetus kienerii</i>			+		A		+	+	2
<i>Spizastur melanoleucus</i>	+				B		(+)	(+)	1
<i>Spizaetus africanus</i>		+			A	+	(+)		1
<i>Spizaetus cirrhatus</i>			+		B	+	+	+	6
<i>Spizaetus bartelsi</i>			Java		M				1
<i>Spizaetus nipalensis</i>			+		M	+	+	+	2
<i>Spizaetus lanceolatus</i>			Cel.		A	+	(+)		1
<i>Spizaetus philippensis</i>			Phil.		?				1
<i>Spizaetus alboniger</i>			+		M	+			1
<i>Spizaetus nanus</i>			+		A				2
<i>Spizaetus tyrannus</i>	+				B	+	(+)		2
<i>Spizaetus ornatus</i>	+				A	+	(+)		2
<i>Stephanoaetus coronatus</i>		+			A	+	+	+	1
<i>Oroaetus isidori</i>	+				M	+	+	(+)	1
<i>Daptrius ater</i>	+				A	+		(+)	1
<i>Daptrius americanus</i>	+				A	+	(+)	(+)	1
<i>Micrastur ruficollis</i>	+				A	+			5
<i>Micrastur gilvicolis</i>	+				A	+			2

<i>Micrastur mirandollei</i>	+			A	+			1
<i>Micrastur semitorquatus</i>	+			A	+	(+)		2
<i>Micrastur buckleyi</i>	+			A				1
<i>Microhierax caerulescens</i>			+	B	+	+	+	1
<i>Microhierax fringillarius</i>			+	B	+	+	+	1
<i>Microhierax latifrons</i>			Bor.	B				1
<i>Microhierax erythrogenys</i>			Phil.	B		+	+	1
<i>Falco punctatus</i>		Maur.		B	+	+	+	1
<i>Falco zoniventris</i>		Mad.		B	+	(+)	(+)	1
<i>Falco rufigularis</i>	+			B	+	+	+	3
<i>Falco deiroleucus</i>	+			B	+	+		1

Note: \*The poorly known *Haliaeetus sanfordi* from Solomons islands may be included on account of its forest habitat.

Table 2: Taxonomic diversity of main tropical forest regions (from Mayr &amp; Cottrell 1979).

Region	Number of		Proportion of the world rainforest (%)	
	species	subspecies	species	subspecies
Continental America	40	70	36.1	25.0
Antilles	4	12	3.6	4.3
Continental Africa	12	22	10.8	7.8
Western Indian Ocean Islands	9	9	8.1	3.2
Southeast Asia (India to Celebes)	28	86	25.2	30.7
New Guinea (Moluccas to Solomon islands and northeast Australia)	22	82	19.8	29.3

The world's Falconiforms comprise 285 species and 726 subspecies, of which 111 and 280 respectively are found in rainforests. Thus 39 percent of species and subspecies of diurnal raptors belong to, and probably evolved in, this habitat which recently covered only 5 percent of the land surface of the world and may cover less than 1 percent today. Continental America is three times richer in species than Africa, with an area of rainforest two times larger. Dense forests of tropical Asia, as a whole, are even richer (49 species from India to New Guinea), a situation associated with their fragmentation into many islands (*Table 2*).

### Study and state of knowledge

As a group, rainforest birds of prey are extremely secretive and difficult to study. On average, during a full day spent slowly walking inside a primary forest, one can expect to see and identify only one raptor, often in view for no more than a few seconds (the mean on more than 300 days in several countries). Many more individuals are seen along forest roads, clearings or edges than under the canopy. The easiest way to detect raptors is to keep watch from an external lookout (large opening, river or mountain top), mainly in the morning when the birds soar and display. Nevertheless, many species seldom if ever soar, whereas others do so only when adult, before or during the breeding season and in fine weather.

Consequently, all but about a dozen of the rainforest species are either very poorly known or completely unknown except for what was learnt from the few specimens secured long ago. Moreover the better-known species (such as *Elanoides*, *Machaerhamphus*, *Gypohierax*, *Polyboroides*, *Accipiter melanoleucus*, *Asturina* and *Stephanoetus*) have been studied outside the rainforest, and their life histories may be quite different from those of the typical forest species. (*Harpia* from Guyana and *Pithecophaga* from Mindanao are notable exceptions.) Even the field research centres (such as Barro Colorado, Panama or Makokou, Gabon), where birds have been studied for 20 years, have added very little to our knowledge of forest raptors. Thus the voices of only 67 species have been described (*Table 1*). The nest and eggs of only 54 species (48 percent) have been found, but for 17 of these only once or twice and often not by a naturalist.

At the present rate of decrease, most of the species will disappear before becoming known. Even the basic knowledge necessary for any management of their habitat and populations is lacking. The distribution, density, population structure and interspecific relationships are not known for any single species or patch of natural rainforest. The same is true for food and feeding habits, and also for the times and success rates of breeding. However, many species probably have very low reproductive rates and live at low density.

Table 3: Tropical forest Falconiforms listed in the *ICBP Red Data Book* (King 1981).  
Status: E = Endangered; R = Rare; I = Indeterminate.

Species	Location	Status
<i>Accipiter francesii pusillus</i>	Anjouan	E
<i>Accipiter striatus fringilloides</i>	Cuba	R
<i>Accipiter striatus venator</i>	Puerto Rico	R
<i>Buteo platypterus brunnescens</i>	Puerto Rico	R
<i>Chondrohierax uncinatus mirus</i>	Grenada	E
<i>Chondrohierax uncinatus wilsonii</i>	Cuba	R
<i>Eutriorchis astur</i>	Madagascar	E
<i>Harpia harpyja</i>	Central and South America	R
<i>Morphnus guianensis</i>	Central and South America	R
<i>Leucopternis albigollis occidentalis</i>	Western Ecuador	I
<i>Leucopternis polionota</i>	Eastern Brazil	I
<i>Pithecophaga jefferyi</i>	Philippines	E
<i>Falco punctatus</i>	Mauritius	E

### Threat and conservation

The *ICBP Red Data Book* lists only seven tropical forest species and six subspecies known to be rare and declining, with five island forms acutely endangered (Table 3). This figure reflects lack of knowledge rather than the true situation. For instance, outside continental Asia, Australia and New Guinea, no less than 20 full species and 115 subspecies of Falconiforms are restricted to one or a few islands of the Indo-Malayan rainforest, sometimes to a particular altitude zone or forest type. Many of these islands are overpopulated and being rapidly deforested. Several other subspecies have limited ranges in the ever-shrinking forests of southern India, Southeast Asia, New Guinea or northern Australia.

Beside *Eutriorchis astur*, the only forest species listed in the *Red Data Book* for Madagascar (and which we have not yet been able to trace), three other species (*Aviceda madagascariensis*, *Accipiter henstii* and *Falco zoniventris*) seem rare if not endangered on this island where human pressure on forests is enormous (Thiollay & Meyburg 1981). Even within the large South American mainland, some species have restricted ranges (i.e. six forms of *Leucopternis*, *Micrastur bucklevi*, etc.), while others are rare or very localized throughout a wider range (*Morphnus guianensis*, *Harpyhaliaetus solitarius*, etc.).

However, apart from some island forms we have no data substantiating the decline of any species, which is only inferred from their habitat's reduction. Forest is not always turned into treeless cultivation, pastures or bare eroded ground. Large areas become a mosaic of different changing secondary vegetation types in which some species, but not others, can survive. We need studies on population dynamics and community composition along successional gradients from primary forests to derived habitats. The reduction and fragmentation of the forest drive many species into ultimate refuges, where populations are probably too small and too widely separated to persist in the long term.

The rapid destruction of evergreen forests throughout the tropical world is of far greater importance for the decline of rainforest birds, including raptors, than any other cause. This ruthless exploitation, unless checked, will undoubtedly result in tens of species of Falconiforms (and hundreds of others) being put at risk within the next ten years.

The only way to prevent extinctions is to preserve large areas of primary forest. Such tracts of nearly undisturbed virgin rainforest still exist where agriculture and even logging are not economically feasible, for instance in Amazonia, the Guianas, Eastern Gabon, Zaïre and New Guinea. Nevertheless they are increas-

ingly rare, and every year opportunities to create such reserves are lost for ever. Up to now only a few countries have protected significant areas of rainforest as properly enforced National Parks (Brazil, Ivory Coast, Indonesia, Malaya, Peru, Surinam, Venezuela).

Within the forest belt the species richness increases from the tropics to the equator by the addition of new species (the subspecies may change). Thus a reserve near the equator is likely to protect more species than one farther away. In Africa, the Falconiform communities are very similar at the species level throughout the rainforest zone, and one or two reserves could harbour a population of nearly all forms. In contrast, species diversity is much higher in tropical America or Indo-Malayan Islands because of many patchy or restricted distributions. Here, a much greater number of reserves would be necessary to ensure the protection of most forms.

Forest raptors are also declining for reasons of secondary or local importance. They are killed (especially eagles) by numerous hunters simply for food or to protect poultry, and also for sport or trophies, or for feathers to sell to tourists. Others are trapped alive for zoos, or their eggs are collected. Widespread hunter activity also results in a large-scale reduction of prey species, at least for eagles, and this striking impoverishment of most tropical faunas has probably indirect consequences for the forest equilibrium. I have spent weeks in large areas of nearly primary forest, e.g. in French Guiana or Ivory Coast, where large mammals, notably monkeys, have nearly disappeared through overhunting and where I failed to detect any Harpy or Crowned Eagles. The conservation of sections of natural habitat must go along with country-wide enforced protection of all raptors and some general hunting legislation. This minimum requirement is seldom met today in the Third World.

On small islands introduced predators may be a limiting factor for some raptors through competition for food, nesting and roosting sites (e.g. the Barn Owl towards indigenous kestrel and owl species in the Seychelles) or through nest predation (e.g. monkeys preying on Mauritius Kestrel). Pesticides are not a problem in tropical forests themselves but they are often heavily used just outside, where forest raptors may be poisoned.

Captive breeding and other management programmes could hardly be successful as long as the ecology and breeding requirements of most species are so poorly known. Manipulation of broods or improvement of breeding sites are also out of the question because of the difficulty of finding nests.

## THE CONSERVATIONIST'S DILEMMA

If present trends continue, any forest reserve which was established would rapidly become an island surrounded by large expanses of man-modified habitat unsuitable for forest species. The consequence of such insularization would be the inevitable loss of many species, even if the forest was left perfectly undisturbed. Extrapolation on historical examples of landbridge islands allow estimates of probable extinctions which may amount to as much as 10 percent of the initial species of the reserve within 50 years and about half in a few hundred years (Wilcox 1980).

The survival of isolated populations is strongly dependent on the population size, i.e. the reserve area. The probability of extinction rises sharply with decreasing area, especially if the potential colonization rate is much reduced, as when the island is widely separated from any other patch of natural habitat

(Terborgh & Winter 1980). Because of their large size, specializations and low densities, raptors, particularly eagles, are among the most extinction-prone species (Willis 1980). Thus, to be effective, protected areas must be very large and include whole ecosystems. Only the best National Parks, covering at least several thousand km<sup>2</sup> and containing complete sets of regional habitats, are adequate minimum requirements to ensure the long-term survival of eagle populations.

On the other hand many species are patchily distributed, even within continuous habitats, especially in species-rich areas such as Amazonia or Southeast Asia (Diamond 1980). In these areas multiple refuges are needed to conserve a fair proportion of regional faunas. Whatever the size of the reserves, they should be connected by scattered smaller patches of forest to allow faunal exchanges between them and thus prevent inbreeding and local extinctions.

As long as political considerations and shortage of virgin forests limit the total areas that can be set aside, the conservation strategy is likely to be a compromise between the need for large individual refuges and multiple smaller ones.

## REFERENCES

- BROWN, L. H. & AMADON, D. 1968. *Eagles, Hawks and Falcons of the World*. Country life Books. London.
- DIAMOND, J. M. 1980. Patchy distributions of tropical birds. Pp. 57–74. In: Soulé, M. & Wilcox, B. (eds) *Conservation biology*. Sinauer Ass., Sunderland.
- KENNEDY, R. S. 1977. Notes on the Biology and population status of the Monkey-eating Eagle of the Philippines. *Wilson Bull.* **89**, 1–20.
- KING, W. B. 1981. *Endangered birds of the world*. The ICBP Bird Red Data Book. Washington, Smithsonian Inst. Press.
- MAYR, E. & COTTRELL, G. W. (eds) 1979. *Checklist of the birds of the world*. Vol. 1. (2nd edition.) Mus. Comparative Zoology, Cambridge, Mass.
- RICHARDS, P. W. 1952. *The tropical rain forest*. An ecological study. Cambridge Univ. Press. Cambridge, England.
- TERBORGH, J. & WINTER, B. 1980. Some causes of extinction. In: Soulé, M. & Wilcox, B. (eds) *Conservation biology*. Sinauer Ass., Sunderland.
- UNESCO 1979. *Tropical forest ecosystems*. State of Knowledge report UNESCO-UNEP-FAO, Paris.
- WHITMORE, T. C. 1980. The conservation of tropical rain forest. In: Soulé, M. & Wilcox, B. (eds) *Conservation biology*. Sinauer Ass., Sunderland.
- WILCOX, B. A. 1980. Insular ecology. In: Soulé, M. & Wilcox, B. (eds) *Conservation biology*. Sinauer Ass., Sunderland.
- WILLIS, E. O. 1980. Species reduction in remanescent woodlots in Southern Brazil. *Acta XVII Cong. int. Orn. Berlin*, 783–786.