Balancing Biodiversity with Land Use in the Lowland Rainforests of Peninsular Malaysia, a Discussion Paper

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Abstract

The extinction risk among the terrestrial vertebrates of Southeast Asia, including Indo-Burma and archipelagic regions such as Philippines, Sundaland and Wallacea is among the highest in the world. The basis for this elevated risk in recent times is largely due to the clearing of forest habitat and subsequent conversion to plantations or human settlements where a significant fraction of vertebrate species are endemic. Among a total of 500 terrestrial species of birds (including inland species that occupy riparian habitats) found in Peninsular Malaysia, 156 are endemic to the Sundaland (Peninsular Malaysia, Sumatra, Java, Bali, Borneo and smaller island west of the Wallace Line) of which 82 (53%) are now red-listed by IUCN. Lowland forests, primarily the dipterocarp rainforests (as represented by the Pasoh Reserve Forest) have undergone the most extensive shrinkage of their former area; hence they carry the highest risk of extinction of biota. Continued expropriation of timber and conversion to plantation agroforestry will further fragment these forests and reduce the likelihood that fully functioning ecosystems can regenerate. We discuss a strategy to identify what remains of primary lowland forests in Peninsular Malaysia, especially patches of forest with adequate area to support viable populations of species as a functional community and to overcome the likelihood of loss through stochastic events. Stimulation of a competitive industry with the oil palm industry that maintains intact natural forest would bolster the security of the rainforest from an economic perspective.

Decline of tropical rainforests in the Sundaland

A wide range of factors have contributed to extinction events in geologic time but human factors are thought to be the most significant to the current threat of extinction (Pimm *et al*. 1995, Brooks *et al*. 1997, 2002). Among the anthropogenic threats to biodiversity the principal factors continue to be 1) habitat destruction or conversion of habitat to agriculture, human settlements and infiltration of habitat by roads, power lines and pipelines, 2) introduction of exotic species, 3) overexploitation, and 4) nitrogen deposition caused by runoff from agriculture, and other sources of chemicals and pollutants (Primack and Kunz 1996, Chapin *et al*. 2000). The influence of climate change upon species distributions has drawn more recent attention (Thomas *et al*. 2004).

Loss of habitat is the major determinant of species decline in tropical regions (Chapin *et al*. 2000) where estimates of forest loss on 3 continents between 1990 and 1997 ranged from 0.38% (Latin America) and 0.43% (Africa) to 0.91% (Southeast Asia) per year (Achard *et al*. 2002). Much of this worldwide deforestation has been focused in specific regions with rates as high as 4 – 6% (e.g., Central Sumatra and the Acre region of the Brazilian Amazon), while other regions and countries have exhibited lower rates of decline. While tropical rainforests cover less than 7% of the land area of the earth, they harbour up to two-thirds of the plant and animal species (Raven 1988, Wilson 1988). The Sundaland (Peninsular Malaysia, Sumatra, Java, Bali, Borneo and smaller islands west of the Wallace Line), together with 3 other regions in Southeast Asia (Wallacea, Indo-Burma and the Philippines), is among the top 10 hotspots in the world for biodiversity

(Myers *et al*. 2000). Given the high proportion of endemic plant and animal species here, large-scale extinctions are anticipated toward the end of this century without a redress of the rate and extent of deforestation (Brook *et al*. 2003, Sodhi *et al*. 2004). Hence there are compelling reasons to examine the current status of forests in terms of the extent of forests that were once present in the Sundaland and further plans to deforest what little remains.

From a geologic perspective, the fragmentation of forests in the Sundaland has a precedence that goes back to the Pleistocene Epoch when increased seasonality that produced an advance of glaciers in temperate regions gave rise to drier savannah throughout much of the central part of the Sundaland, while tropical forests retreated to isolated refugia around the perimeter (Gathorne-Hardy *et al*. 2002, Bird *et al*. 2005). At the close of the ice age, the rainforests advanced under relatively low levels of disturbance to occupy contiguous forest throughout much of the region (apart from Java) until the 1950s (Whitten *et al*. 1996, Whitmore 1997). Since then the fraction of primary forest in this region has shrunk to 7.8 % (Myers *et al*. 2000) in just 50 years.

The forests of the Malay peninsula are closely related to those of Borneo and the islands of the Sunda Shelf, which were once united 70 million years ago (Symington *et al*. 2004). Dipterocarps comprise a significant fraction of the trees and timber volume, and are well represented in terms of species diversity in Borneo (13 genera, 276 species), Peninsular Malaysia (14 genera, 168 species), Sumatra (12 genera, 72 species) and the Philippines (11 genera, 52 species) (Symington *et al*. 2004). Outside this region the number of dipterocarp genera and species drops off. Ecologically, the principal climax forests of Peninsular Malaysia consist of the following altitudinal formations (Symington *et al*. 2004): 1) lowland dipterocarp-forests (up to 300 m), 2) hill dipterocarp-forests (300 – 760 m), 3) upper dipterocarp-forests (760 – 1,220 m), 4) montane oak-forests (1,070 – 1,520 m), and 5) montane ericaceous-forests (> 1,520 m). Additionally there are several climax edaphic formations, including 6) mangrove swamp-forests, 7) beach forests, 8) peat swamp-forests, 9) riparian forests (alongside large rivers), 10) heath forests, 11) forests amid limestone rock formations, and 12) other swamp forests (subject to periodic inundation). Most of the commercial timber logging has occurred in the well-drained lowland dipterocarp-forests, where dipterocarps comprise a high proportion of the emergent trees and valuable timber. The distribution pattern of remaining lowland forest in Peninsular Malaysia as estimated through satellite imagery is described by Ab. Latif (2006).

From this overview of the ecological distribution and history of disturbance of the forests in Peninsular Malaysia, which ostensibly represents the terrestrial habitat available to wildlife in the region, we develop perspective on the conservation status of the birds found in Peninsular Malaysia. We highlight some recent studies of the groups that are most threatened with extinction and offer some insight to ways of improving their conservation status. While it would be useful to include overviews for the other 3 groups of land vertebrates (mammals, amphibians and reptiles) together with freshwater species of fish, these have not yet been developed for this report.

Red-listed birds of Peninsular Malaysia

A tabulation of birds that occupy terrestrial habitats of Peninsular Malaysia, including primary and secondary forests, scrublands, cultivated woodlands, gardens and their associated wetlands is indicated in Table 1. Not included in this list are the more strictly aquatic species, such as the ducks, geese and swans (Order Anseriformes), diving birds and seabirds (Order Ciconiformes). The classification is based on the revised taxonomy of birds as deduced from DNA-DNA hybridization studies (Sibley *et al*. 1988, Sibley and Monroe 1990, 1993, Monroe and Sibley 1993). The species listed in Table 1 are based on copious comparison of species lists for the peninsula, guidebooks for birds of SE Asia (Robson 2000, Strange 2000), and published articles (Lim et al. 1995, Francis and Wells 2003). Five hundred species are listed for the inland peninsula, of which 220 (44%) would be expected to occur in the Pasoh Forest Reserve (Total, Table 1b).

The bird data in Tables 1 and 2 have been ranked based on the proportion of red-listed species within each order or family in 4 risk categories established by the International Agency for Conservation of Nature (IUCN 2001). These categories describe the threat of extinction of species incrementally from near threatened to vulnerable, endangered and critically endangered.

The latter 3 groupings for "threatened" species are based on quantitative criteria together with life history data for the species. A database on birds throughout the world and assessment of species risk according to IUCN criteria is maintained by BirdLife International. The data depicted here are from information up to 2004 (IUCN 2004; BirdLife International 2004). Data from Table 1a are further elaborated into the red list categories in Table 2. Among the 500 species of terrestrial birds represented in Table 1 for Peninsula Malaysia, 99 (20%) fall into one of these 4 risk categories; the rest are at low risk of extinction. A significant proportion (74 = 75%) of these species occur in lowland dipterocarp rainforest as typified by the Pasoh Research Forest, where about one-third (34%) of the inhabiting bird species are red-listed.

For several groups listed in Table 1a, it can be seen that entire families or orders of birds are at risk of extirpation from Peninsular Malaysia and the Sunda region. Relative to the average for the entire peninsula (99/500 = 20%) the notable groups at risk include the pheasants and partridges (79% of member species red-listed), followed by hornbills (70%), frogmouths and trogons (67%), parakeets and parrots (50%) and pittas (43%). Birds that use excavated cavities or natural hollows (denoted by C in Table 1) show variable risk of extirpation (e.g., higher for hornbills than owls, both of which represent some of the larger birds that rely upon natural hollows in large diameter trees). Primary excavators of cavities, such as barbets, woodpeckers and piculets, nuthatches and tits are on average smaller in size than hornbills and owls. Fewer species are at risk in these groups.

Table 1a. Birds of Peninsular Malaysia and Pasoh Forest grouped by order or family and ranked on the basis of proportion of red-listed species within each group

Bird group	**Order [a]:** Family	cavity-user (C)	P. Malaysia	red-listed		Pasoh	red-listed	
Pheasants, partridges	**Galliformes**		14	11	0.79	8	7	0.88
Hornbills	**Bucerotiformes**	C	10	7	0.70	6	4	0.67
Frogmouths	**CA:** Batrachostomidae		3	2	0.67	3	2	0.67
Trogons	**Trogoniformes**	C	6	4	0.67	5	4	0.80
Parrots, parakeets	**Psittaciformes**	C	4	2	0.50	3	2	0.67
Pittas	**PA:** Pittidae		7	3	0.43	4	2	0.50
Bulbuls	**PA:** Pycnonotidae		24	8	0.33	13	6	0.46
Broadbills	**PA:** Eurylaimidae		7	2	0.29	4	2	0.50
Barbets	**PI:** Ramphastidae	C	11	3	0.27	6	3	0.50
Nightjars	**Caprimulgiformes (CA)**		**8**	**2**	0.25	**4**	**2**	0.50
Pigeons, doves	**Columbiformes**		19	4	0.21	6	2	0.33
Babblers, warblers, tailorbirds	**PA:** Sylviidae		60	12	0.20	27	12	0.44
Crows, drongos, ioras	**PA:** Corvidae		41	8	0.20	24	8	0.33
Fairy-bluebirds, leafbirds	**PA:** Irenidae		5	1	0.20	4	1	0.25
Cuckoos, malkohas, coucals	**Cuculiformes**		23	4	0.17	12	4	0.33
Perching birds	**Passeriformes (PA)**		**259**	**43**	0.17	**130**	**39**	0.30
Woodpeckers, piculets, barbets, honeyguides	**Piciformes (PI)**	C	**37**	**6**	0.16	**21**	**6**	0.29
Flycatchers, forktails	**PA:** Muscicapidae		45	7	0.16	20	5	0.25
Diurnal raptors	**CI:** Accipitridae, Falconidae		26	4	0.15	10	1	0.10

Kingfishers, bee-eaters	**Coraciiformes**		20	3	0.15	10	2	0.20
Owls	**Strigiformes**	C	14	2	0.14	9	2	0.22
Wading birds	**Ciconiiformes (CI)**		32	4	0.13	0		
Flowerpeckers, sunbirds, spiderhunters	**PA:** Nectariniidae		28	3	0.11	16	2	0.13
Rails, cranes, finfoots	**Gruiformes**		10	1	0.10	1	0	0.00
Woodpeckers, piculets	**PI:** Picidae	C	25	2	0.08	14	2	0.14
Swifts, treeswifts	**Apodiformes**		15	1	0.07	5	0	0.00
Honeyguides	**PI:** Indicatoridae	C	1	1	1.00	1	1	1.00

[a] Orders (boldface type) with abbreviations (CA, CI, PA, PI) include a composite listing together with individual families on separate lines.

In Peninsular Malaysia, 11 of 14 species in the order Galliformes (family: Phasianidae) are red-listed, 4 of which are threatened (36.4%). Three species are endemic to Peninsular Malaysia, Grey-breasted hill (Malayan) partridge (*Arborophila sumatrana*), Mountain peacock pheasant (*Polyplectron inopinatum*) and Malaysian peacock pheasant (*Polyplectron malacense*) of which the latter 2 species are listed as vulnerable. One of these pheasants is strictly lowland in distribution and the other is an upland species with range restricted to the Cameron and Genting Highlands. The Malayan partridge, a montane species, is at low risk of extinction. Among the 11 red-listed species, 3 threatened and 2 near-threatened species occupy strictly lowland forest (i.e., less than 500 ± 100 m); and all of these lowland birds are confined latitudinally to the Sunda region. The largest pheasants among the 11 red-listed species are the crested argus (*Rheinardia ocellata)* and great argus (*Argusianus argus*). Crested argus occurs throughout SE Asia but their range in Peninsular Malaysia is confined to upland elevations (790 – 1,100 m). The great argus and 3 small partridges occupy broadleaved evergreen forests with wide-ranging elevation, but all 4 of these species are confined latitudinally to the Sunda region.

Table 1b. Birds of Peninsular Malaysia and Pasoh Forest (not red-listed)

Bird group	**Order:** Family	cavity-user (C)	P. Malaysia	red-listed		Pasoh	red-listed	
Buttonquails	**Turniciformes**		1	0	0.00	0		
Hoopoes	**Upupiformes**		1	0	0.00	0		
Gerygones	**PA:** Pardalotidae		1	0	0.00	1		
Finches	**PA:** Fringillidae		1	0	0.00	0		
Nuthatches	**PA:** Sittidae	C	2	0	0.00	1		
Tits	**PA:** Paridae	C	2	0	0.00	1		
White-eyes	**PA:** Zosteropidae		2	0	0.00	1		
Shrikes	**PA:** Lanaiidae		3	0	0.00	1		
Cisticolas, prinias	**PA:** Cisticolidae		4	0	0.00	0		
Swallows	**PA:** Hirundinidae		5	0	0.00	1		
Starlings, mynas	**PA:** Sturnidae	C	7	0	0.00	1		
Wagtails, munias, sparrows	**PA:** Passeridae		16	0	0.00	1		
Total [a]			**500**	**99**	**0.20**	**220**	**74**	**0.34**

[a] Total species for Table 1.

Table 2. IUCN risk ratings for red-listed species of Peninsular Malaysia and Pasoh Forest

	IUCN risk category [a]							
	CR		EN		VU		NT	
Bird group	PM	Pasoh	PM	Pasoh	PM	Pasoh	PM	Pasoh
Pheasants, partridges					4	3	7	4
Hornbills					1		6	4
Pigeons, doves					1	1	3	1
Cuckoos, malkohas, coucals					1	1	3	3
Diurnal raptors	1				2	1	1	
Kingfishers, bee-eaters					2	1	1	1
Owls					1	1	1	1
Flycatchers, forktails					2	1	5	4
Ibises, storks (wading birds)			1		2		1	
Rails, cranes, finfoots					1			
All other species from Table 1a							52	47
	1		**1**		**17**	**9**	**80**	**65**

[a] IUCN risk categories (CR, critically endangered; EN, endangered; VU, vulnerable; NT, near-threatened) depict red-listed species as in Table 1a. PM = Peninsular Malaysia.

The basis for the high representation of red-listed species in Pasoh Forest is partly related to the elevational requirements of these species or the influence that elevation has upon habitat (e.g., edaphic factors and plant species composition) as shown in Table 3. A cumulative representation of red-listed bird groups in Pasoh confined to low elevation forests reveals that 16 families of birds (among 21 groups listed in Table 1a) have at least one species with a requirement for forest below 500 m. There are 19 species that strictly use lowland forest below 300 m: crestless fireback (*Lophura erythrophthalma*), crested fireback (*Lophura ignita*) and Malaysian peacock pheasant (*Polyplectron malacense*); grey-breasted (*Malacopteron albogulare*), chestnut-rumped (*Stachyris maculate*) and fluffy-backed tit babblers (*Macronous ptilosus*); large frogmouth (*Batrachostomus auritus*) and Gould's frogmouth (*B. stellatus*); giant pitta (*Pitta caerulea*) and garnet pitta (*P. granatina*); black magpie (*Platysmurus leucopterus*) and dark-throated oriole (*Oriolus xanthonotus*), the black hornbill (*Anthracoceros malayanus*), scarlet-rumped trogon, (*Harpactes duvaucelii*), long-tailed parakeet (*Psittacula longicauda*), puff-backed bulbul (*Pycnonotus eutilotus*), red-crowned barbet (*Megalaima rafflesii*), large green pigeon (*Treron capellei*), and brown-chested jungle flycatcher (*Rhinomyias brunneata*). Thus, low-elevation specialists are well represented among many families of birds and since this type of forest is declining disproportionately compared to other types of forest in Peninsular Malaysia they are at greater risk of extinction.

Table 3. Requirement for low-lying rainforest among red-listed species of birds in Pasoh Research Forest

	Elevation					
	≤ 200 m	≤ 300 m	≤ 500 m	≤ 900 m	≤ 1,500 m	Total
Number of species	12	7	13	30	16	78
Number of orders/families	9	6	9	14	11	
Species per order/family	1.3	1.2	1.4	2.1	1.5	
Cumulative representation	9	12	16	20	21	21

Conservation strategies for Peninsular Malaysia and the Sundaland

The foregoing summary of IUCN red list data for inland birds of Peninsular Malaysia (i.e., excluding off-shore species) reveals 2 orders of birds at the top of the list, the pheasants and the hornbills. There is also considerable risk of extirpation for frogmouths, trogons, parrots and parakeets, pittas, bulbuls, broadbills and barbets. The principal risk factors common to all these birds are loss of forest habitat, especially lowland rainforest, and their endemicity to the Sunda region.

The order Galliformes comprises the grouse (temperate regions), megapods (Australasia), chachalacas, guans, curassows (Central & South America), pheasants (worldwide), guineafowl (Africa), turkeys (Central & North America) and mesites (Madagascar). In Southeast Asia the group is well represented by the family Phasianidae, with 45 species, and Megapodiidae, 1 species (Robson 2000). With 284 species throughout the world, this order of birds tends to include a high proportion of threatened species (26.4%) compared to all the extant birds as a whole (12.4%) (IUCN 2004). The basis for their vulnerability can be attributed to loss of habitat together with exploitation for food, sport hunting and cultural practices. In an effort to distinguish these factors Keane *et al.* (2005) develop a set of correlates of extinction risk and hunting pressure to examine threatened species of the Galliformes on 3 continents. In Asia, significant correlates were found for elevation range (narrow range in elevation of habitat raises risk of extirpation), latitude range (smaller global home range correlates with greater extinction risk), and habitat diversity (use of fewer types of habitat heightens extinction risk). Against these ecological correlates there was little evidence for influence of human factors (i.e., as related to hunting pressure). However, some influence of human factors was revealed after controlling for pseudoreplication associated with closely related species (Keane *et al.* 2005).

The order Buceritoformes comprises the hornbills (Africa & tropical Asia) and ground-hornbills (Africa). Among the 56 species in the order, half occur in Asia most of which (19/28 = 68%) are red-listed and the other half are found in Africa of which only 2 (7.1%) are red-listed. Nine Asian species (16.1%) are threatened with extinction, of which 5 occur in the Philippines and another 2 are confined to small islands in SE Asia (Sumba & Narcondam Islands). The Asian hornbills are

Poonswad *et al.* 2000). Study of sympatric species of hornbills in two national parks in Thailand revealed different types of limiting factors for populations of these birds (Poonswad *et al.* 2005). In the 2,168 km2 Khao Yai National Park, the breeding success of 4 sympatric species of 1995, frugivores that rely upon large tracts of primary forest in which to find suitable natural hollows for nesting together with an adequate source of fruit trees nearby (Kemp 1995, Poonswad hornbills was studied over a period of 21 years. Hornbills re-use cavities for nesting year after year as long as they remain intact. This finding permits much information to be obtained about nesting success and the types of trees preferred. In order to test whether the availability of natural hollows limits growth of the hornbill population the research team repaired damaged cavities throughout the study area. Evidently nesting success could be boosted through this manipulation indicating that the hornbill population was below the carrying capacity for the area.

In southern Thailand, close to the border with Malaysia, the breeding success of 6 sympatric species of hornbills was studied over a 9-year period in the newly established (1999) Budo-Sungai Padi National Park (341 km^2) (Poonswad *et al.* 2005). Here the limiting factors for reproductive success of hornbills were quite different, wherein the number of available hollows suitable for nesting in the study area was considerably greater than the actual number used for nesting. Low entry of females to cavities was likely due to a combination of factors, namely illegal logging and clearing of forest for cultivation within the park boundary. More directly, hornbill nestlings were being removed from the nest cavities for the pet trade industry. Efforts to reverse this situation through persuasive enlightenment of the benefits of maintaining the hornbills as an asset for ecotourism proved successful; although, it was still too early to tell from the results to 2002 whether the tangible benefits to the local people had really altered the breeding success of the hornbills in the park.

The principal risk factors for the Asian hornbills are much like those described above for the pheasants: 1) shrinkage of primary lowland forest (Achard *et al.* 2002, Sodhi *et al.* 2004), exacerbated by 2) illegal deforestation within established parks and protected areas (Jepson *et al*. 2001, Curran *et al*. 2004), 3) large-scale wildfires (Kinnaird and O'Brien 1998), and 4) hunting for food and trapping for the pet trade industry (Marsden 1999, Poonswad *et al*. 2005). Based on these factors, 7 out of 10 species of hornbill are red-listed in Peninsular Malaysia, and one species is considered vulnerable.

Conservation strategies in Peninsular Malaysia that could meet the habitat requirements of the many species now listed as threatened are variable in terms of the degree of protection, area and distribution of protected areas across the country (Aiken and Leigh 1986, Abdul 1996, Laidlaw 2000). However, new initiatives have been launched by the present government that will endeavour to manage 5 large zones within the peninsula primarily as natural forest. These zones tout to conserve significant areas stringently as national parks and protected areas (many of which have already been established), while forested areas outside these protected areas allow for limited resource extraction with a return of the habitat and resource values through regeneration of the forest. We compare the intrinsic value of small protected forests throughout the peninsula with the larger forest management zones, presenting pros and cons documented in the literature, and pondering the critical question as to whether this forest network could afford to protect more lowland forest in a way that could avert the impending demise of biodiversity (Sodhi *et al*. 2004).

Up to 32% of the total land area of the peninsula has been gazetted in a system of interconnected reserve forests, largely encompassing marginal land and hill forest than lowland forest (Laidlaw 1994). Hence, allocation of large blocks of permanently reserved forest in Peninsular Malaysia is not a new concept. Oil palm and rubber plantations have encroached upon this forest network so as to fragment the remaining stands of productive and protected areas of forest (Laidlaw 2000). Numerous studies have shown that some species are locally extirpated after logging, while others can recover sooner or later after selective logging (Johns 1987, Johns 1996, Okuda *et al*. 2003, Takamura 2003, Dunn 2004, Styring and Zakaria 2004); but most certainly, species diversity declines precipitously when natural forest is converted to plantations or human settlement (Laidlaw 1994, Brook *et al*. 2003, Curran *et al*. 2004, Johnson *et al*. 2005).

A study of small protected areas (2 – 2,744 ha) in Peninsular Malaysia officially termed virgin jungle reserves (VJRs) revealed that the total area of natural forest within which VJR reserves were a part (i.e., VJR + adjoining forest) was the most important determinant for mammal diversity (Laidlaw 2000). When the collective area of natural forest fell below 10,000 ha, large carnivores and herbivores with greater home range requirements dropped out of the community. Chiarello (2000) describes a similar requirement for forest patch size in his study of remnant forests of Brazilian Atlantic forests, noting that a collective forest area of 20,000 ha would be needed to sustain viable populations ($N_e \approx 500$) for the 5 mammal species (3 primates and 2 rodents) in his study. For smaller fragments, some of these mammals were prone to predation by small cats or shortage of food. Thiollay and Meyburg (1988) in their survey of raptors on the island of Java estimate that the endemic Javan hawk-eagle, now an endangered species, might require at least 20,000 ha to support 10 breeding pairs. These estimates have since been narrowed down to 5,000 ha in favorable habitats.

The Pasoh Forest Reserve is a virgin jungle reserve, effectively representing 2,400 ha of lowland (with some hill) dipterocarp-forest, joined to a larger forest fragment (14,500 ha) of predominantly hill dipterocarp-forest. Species that can utilize the full range of forest, including many of the primates (white-handed gibbons, siamang, dusky langur, banded leaf monkey) stand to benefit from this pocket of natural forest barring further shrinkage of the total area. However, it is not clear how well the small area of lowland forest comprising Pasoh forest reserve itself can continue to support many of the lowland specialists threatened with extirpation. Insularity with surrounding lowland forest and stark edge against plantation forest are apt to cause problems in terms of effective population size and changes in the trophic community structure. For example it has been noted that the Pasoh forest has a prodigious overpopulation of wild pigs, *Sus scrofa*, with densities 7-fold higher than other VJRs in the peninsula and the highest ever recorded for the species (Ickes and Thomas 2003). Their impact upon understory plant species recruitment has been significant. The basis for the population increase is not clear but two hypotheses are: 1) there are no longer large carnivores (tigers and leopards) acting to cull the population, and/or 2) the adjoining oil palm plantation serves as a significant food source while the reserve forest constitutes preferred nesting terrain (Ickes and Thomas 2003). Changes in the understory structure could directly influence lowland forest-floor specialists such as pheasants and pittas, but the entire community structure could be profoundly affected by diminished recruitment of tree seedlings over the long-term.

One of the uninhabited Andaman Islands offers an interesting comparison to the Pasoh Forest Reserve and small reserves in Peninsular Malaysia. Narcondam Island provides no more than 700 ha of open deciduous and evergreen rainforest though suitably favorable habitat to support a stable population of approximately 300 hornbills (Birdlife International 2004). The Narcondam hornbill, Aceros narcondami, though small compared to any of the peninsular hornbills is a threatened species because of its small population and very confined distribution rendering it susceptible to disease and stochastic natural disasters (e.g., volcanic eruption). The island was uninhabited until 1969 when a police outpost was established that introduced feral goats and cats. Without any known predators the goats have proliferated to the detriment of the island's vegetation. There is no indication of the extent of damage to the forest caused by the tsunami on December 26, 2004 but the hilly nature of the island may afford some refuge while low-lying forest recovers from die-back caused by the flood.

An overview of the distribution and configuration of forests in the peninsula would serve to identify the largest blocks of remaining forests and the integrity of the surrounding forest landscape for better management of the forest network as a whole (Latif 2006). Options to conserve additional primary lowland dipterocarp and coastal swamp forests in Peninsular Malaysia were thought to be limited more than a decade ago because most of these forests have been logged or converted to oil palm and rubber plantations (Leong *et al.* 1991). Probably, the largest stands of primary lowland dipterocarp forest are situated within Endau-Rompin National Park, Endau-Kluang, Endau Kota Tinggi and Krau Wildlife Reserves and Taman Negara National Park as depicted on the map of Peninsular Malaysia (Figure 1).

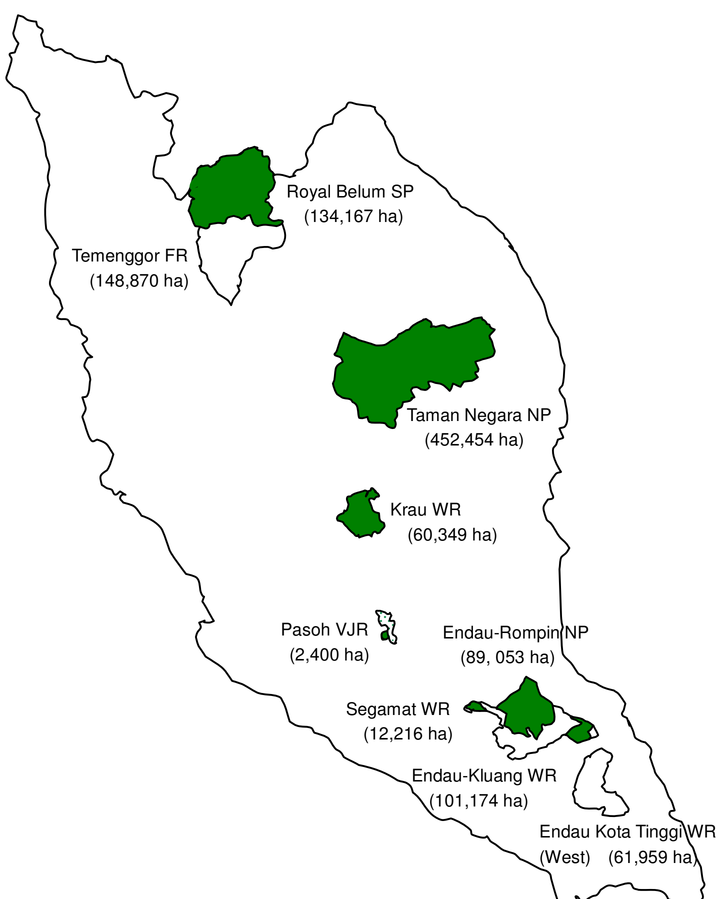

Figure 1: Largest protected areas of Peninsular Malaysia. Totally Protected Forest Areas (TPFA) [green box] such as National Parks (NP), State Parks (SP), Virgin Jungle Reserves (VJR), Wildlife Reserves (WR) and Wildlife Sanctuaries (WS) are distinguished from adjoining Forest Reserves (FR) or Wildlife Reserves which permit logging [white box] or adjoining intact forest without legal designation [dotted box] .

One of the critical issues for future landscape management is what becomes of the forest on the doorstep of these protected areas. In the case of the Endau-Rompin, the management plan that was eventually passed in 1993 gazetted an 89,000-ha national park through amalgamation of adjoining wildlife reserves in the region and an 110,000-ha buffer zone within which agriculture (and agroforestry) was to be excluded. These wildlife reserves were established in the 1930s to meet the habitat requirements of the endangered Sumatra rhinoceros and other large mammals (Flynn and Abdullah 1984, Aiken and Leigh 1986). As a test of the impact of logging in the buffer zone the landscape model should be evaluated to see whether the greater area of natural forest defined by the wildlife reserves and the national park at Endau-Rompin is continuing to meet the habitat requirements of a range of indicator species, notably the rhinoceros. The Endau-Rompin is also a critical watershed for 3 rivers and the hilly terrain could pose problems in terms of flooding, altered stream flow, soil erosion and sediment load exacerbated through logging (Davison 1988).

The collective area of the 4 largest protected areas depicted in Figure 1 together with the Cameron Highlands Wildlife Sanctuary (64,953 ha, not shown) is approximately 800,976 ha (6.1% of Peninsular Malaysia). Larger areas such as these are apt to embrace a wider range of different ecosystem types, and as we have discussed previously, size is a critical factor for wide-ranging species such as tigers, elephants, rhinoceroses and even hornbills. A gap analysis would ensure that representative ecosystem types, such as peat swamp and heath forests, are not missed among the list of conservation areas (Leong *et al*. 1991). But probably the most cogent initiative for this part of the world at this time would be to strengthen the management of the large protected areas (Figure 1). Is it reasonable to permit timber extraction in the wildlife reserves that surround the Endau-Rompin? If it is no longer possible to append lowland forest to the existing protected areas that have these types of forest, it may be possible to plan for restoration or recovery of such forest in the adjoining landscape. There are some interesting examples of recovery of degraded lowland forest in other tropical regions where previous land use failed (Aston *et al*. 2001, Arroyo-Mora *et al*. 2005).

Development of an industry that competes with the logging and plantation agroforestry sectors is often thought to be a good justification for conservation of more forest, all the more so if the recipients of financial benefits include the competing industries. Nevertheless, some countries such as Costa Rica have proven the case for ecotourism fortunes (Menkhaus and Lober 1996), wherein the ingredients for success appear to have been a government sympathetic to the need for parks and nature reserves, and a people who adapted to the concept. There is great interest in getting this to work in Malaysia and other parts of Southeast Asia. Quite possibly the newly established Royal Belum State Park and adjoining Temenggor Forest Reserve (Figure 1) with flocks of hornbills numbering in the thousands may help to galvanize some attention in this respect (Davison 1995, Lim and Tan 2000, Malaysian Nature Society 2000).

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