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Recovery of a Peninsular Malaysian rainforest avifauna following selective timber logging: the first twelve years

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The long-term ecological effects of selective timber logging operations are being studied in Peninsular Malaysia in a research project initiated in 1979. Results of the initial ornithological studies were reported in a past volume of *Forktail*. In 1987, the second phase of study was undertaken. Results now cover the response of the original rainforest avifauna to logging and population changes occurring up to 12 years after the logging event.

A very high proportion of birds recorded in unlogged forest had reappeared by 12 years after logging. Some had not, notably terrestrial litter-gleaning and understorey flycatching species. The avifauna even in the older logged forests was still dominated by frugivore/insectivores, however, particularly by bulbuls Pycnonotidae of species uncommon in unlogged forest. The species-abundance patterns even in older logged forests were markedly dissimilar to those of primary forest.

INTRODUCTION

Within a few years, almost all lowland dipterocarp forests in Peninsular (West) Malaysia are likely to be cleared for plantation agriculture (Wells 1985). Only a few reserve areas are likely to remain exempt, and many of these are designated as timber production areas (Forest Reserves). In total, Peninsular Malaysia plans to retain 41,000 km^2 of dipterocarp forest as sustained-yield forestry concessions; most of this is upland forest which is less suitable for conversion to plantations. This amounts to 31% of the original forests of the country.

Following several years of decline, due mainly to the exhaustion of readily accessible forests and tightening of government controls on logging activity, the Malaysian timber industry is currently experiencing a major upturn. Log production was 15.4% up in 1987, reaching a level of 33.7 million m^3. Prices increased from an average of US\$60/m^3 in 1986 to US\$75/m^3 in 1987, the highest quality timber peaking at US\$185/m^3. Increased production was, however, largely a political move, designed to alleviate Malaysia's economic problems. Resurgence of other major commodities will allow reduction of output, particularly of unsawn timber, perhaps by 1990 (*Asiaweek* 1988).

To maintain this valuable resource there is considerable commitment within Malaysia towards the sustainable management of productive forest on land unsuitable for plantation crops. Forest management is likely to remain financially viable in the long term. The effect is evident in the large amount of research being conducted into the scientific basis of sustained-yield management.

Given the probable persistence of large areas of managed forest and the considerably smaller areas of totally protected forest, it is important to consider the extent to which rainforest wildlife can persist in the former. Logically, the maintenance of a healthy stock of native timber trees should not be wholly incompatible with the maintenance of other components of the forest ecosystem.

During 1979–1981, an intensive field study was carried out in Peninsular Malaysia on the initial effects of selective timber logging on a rainforest avifauna (Johns 1986). At that time, a community was studied throughout a typical logging operation, data being collected before, during and immediately after felling. Forests logged up to six years previously were also surveyed briefly. The sites studied during 1979–1981 were revisited in 1987 and further surveys undertaken. Data have thus been extended to cover fluctuations in species abundances up to 12 years after the completion of tree felling. This paper considers changes that have taken place in the avifauna during this time, and forms the second part of a continuing study designed to examine responses over a complete logging and regeneration cycle.

STUDY AREA

Data were collected in tropical dipterocarp forest (for a description of this vegetation type, see Whitmore 1984) in the Tekam Forest Reserve, Pahang, West Malaysia (4°10′N 102°40′E). This region, formerly called the Sungai Tekam Forestry Concession, was part of a large block of forest, most of which had been logged over the previous 12 years. Study sites (Figure 1) were all at least 12 km from any sizeable unlogged forest area.

Study sites were the same as those surveyed during the 1979–1981 studies. At the time of the 1987 work, the areas contained 6–7 year-old (C13C), 7–8 year-old (C5A), 9–10 year-old (C1A) and 11–12 year-old logged forests (C2). The sites ranged from 80 to 400 m above sea level and were originally of similar vegetation-types.

The damage levels and changes in vegetation caused by logging are discussed in detail elsewhere (Johns 1988a). The logging operation employs both conventional tractor haulage and overhead cable systems (for hauling logs up steep slopes). Both cause considerable damage to the forest: largely uniform under tractor logging; more severe but more localized (to the vicinity of haulage routes and winch sites) under cable logging.

Overall, about 50% of the trees originally present were lost during logging, causing considerable changes in microclimate and tree species composition within the forest, especially once colonizing trees became established. The main colonizing trees were euphorbs of genera *Macaranga* and *Mallotus*, and *Trema orientalis* (Ulmaceae), all of which are scarce in unlogged forest. The change in species composition is exacerbated by the planting of alien species (mostly *Acacia mangium*, *Albizia falcateria* and *Eucalyptus* spp.) as shade trees on heavily damaged land that would otherwise be very slow to develop ground cover (Borhan *et al.* in press).

METHODS

Data were collected in the form of spot observations; notes were made on first observing an individual bird and not subsequently. Observations were made while walking 3–4 km survey trails cut along abandoned logging roads at each site. Most observations were made between 06h00 and 12h00 daily; some were made between 16h00 and 19h00, and between 20h00 and 23h00 for nocturnal species. Between 12 and 14 days were spent at each site, but no more than six in any 30-day period. Observations were made between March and June 1987, the dry season, matching the seasonality of previous surveys.

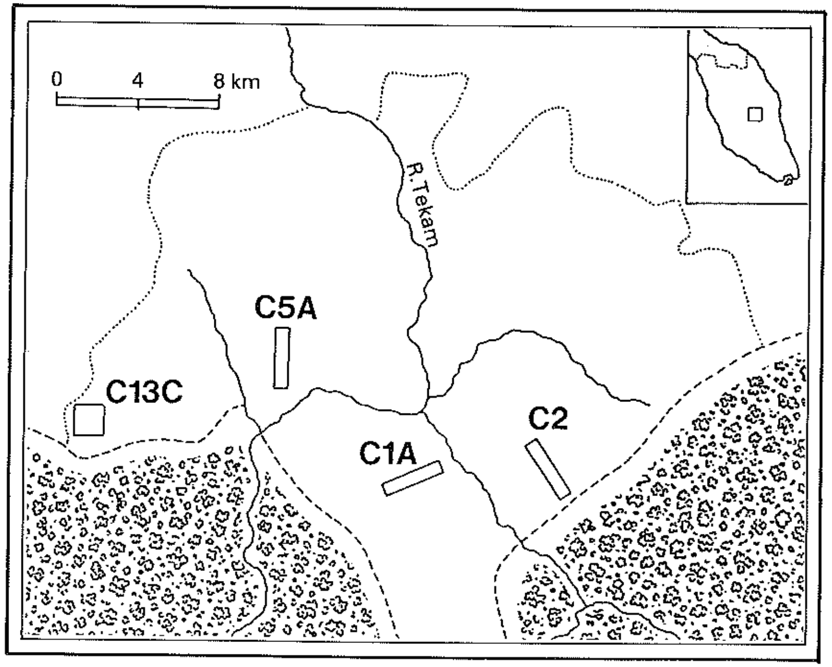
Details of the methodology and some problems associated with this approach have been discussed previously (Johns 1986).

RESULTS

Species composition

A total of 225 bird species have been observed at the Tekam F.R. These are

Figure 1. Location of study areas within the Tekam Forest Reserve. Shaded areas are clear-felled forest, now under plantation crops; all remaining land is logged-over forest. The area logged before 1981 is delimited by the dotted line. Boxes enclose the study sites. [Note: the scale given on a similar map by Johns (1986) was incorrect.]



listed in the Appendix, together with their relative abundances during selected study periods.

Eight species were seen for the first time during the 1987 surveys, namely Lesser Fish-Eagle *Ichthyophaga humilis*, Greater Coucal *Centropus sinensis*, Barred Eagle-Owl *Bubo sumatranus*, Pied Hornbill *Anthracoceros albirostris*, Stripe-throated Bulbul *Pycnonotus finlaysoni*, Yellow-rumped Flycatcher *Ficedula zanthopygia*, Spectacled Spiderhunter *Arachnothera flavigaster* and Thick-billed/Brown-backed Flowerpecker *Dicaeum agile/everetti*. All species apart from the Lesser Fish-Eagle, Barred Eagle-Owl and Pied Hornbill are secondary forest or edge specialists: these three are rare species that may have been overlooked previously.

The number of birds recorded in the logged-over forest (all sites) has now reached 181 species, slightly less than the total for unlogged forest (193 species). This statistic has little meaning, however; the observation time in primary forest is greater (bias in favour of primary forest) but the logged forest sample is generated from observations at several sites with slight differences in altitude, vegetation-type and so on (bias in favour of logged forest).

More meaningful is the observation that of the 22 commoner species defined as intolerant of recently logged forest by the earlier study (Johns 1986), all but five have now been observed in older logged forests. The five exceptions are Reddish Scops Owl *Otus rufescens*, Rufous-collared Kingfisher *Actenoides concreta*, White-crowned Forktail *Enicurus leschenaulti*, Mugimaki Flycatcher *Ficedula mugimaki* and Grey-headed Flycatcher *Culicicapa ceylonensis*. This contrasts with the fact that the majority of the 20 colonizing species listed in the earlier study were still present in the older logged forest, and, as mentioned above, some new colonists were added. Even the oldest of the logged forests has a species composition quite different to that of unlogged forest.

Similarity between areas

The similarity in species composition can be examined, albeit simplistically, by the use of Horn's (1966) Index of Overlap, *viz*:

$$\frac{2\sum_{j=1}^{n}(p_{ij})(p_{hj})}{\sum_{j=1}^{n}(p_{ij})^2+\sum_{j=1}^{n}(p_{hj})^2}$$

where p_{ij} = the proportion of species j out of the ten most abundant observed in forest i,
p_{hj} = the proportion of species j out of the ten most abundant observed in forest h.

Because this index considers only the ten most abundant species in each sample it is clearly limited in sensitivity. The ten most abundant species also occupy a higher proportion of the sample in logged-over forest due to the dominance of a few species (often over 40% of the sample); in unlogged forest the top ten species occupy less than 20% of the sample. Nevertheless, an examination of the similarity between sites as determined by this index (Table 1) makes three main points:

a) Most logged forests are remarkably dissimilar to unlogged forest. The exception is area C1A, which showed a higher similarity both in 1980–1981 and in 1987, probably because of the patches of swampy, relatively undisturbed forest remaining at this site.

b) The calculated index of overlap between the various logged forest sites averaged 0.54 (n=3) in 1980–1981, but had decreased to 0.38 (n=6) in 1987. That is, the species composition became more divergent over time.

c) There was no tendency for forests logged within the same few years to be similar to each other. Neither was similarity evident when comparing the same site as surveyed during the two study periods, 1980–1981 and 1987 (in this case the index averages 0.55: n=3).

Changes in individual species abundances

There is a tendency in the literature towards the examination of differences between habitats by the use of simple diversity indices. Bird species diversity correlates strongly with vegetational height diversity (MacArthur *et al.* 1962); structurally complex vegetation-types buffer effects of seasonality such that resources become predictable (Karr 1976). In the case of disturbed habitats, such simple indices merely express obvious changes in the vegetation resulting from disturbance. A simple index overlooks the fact that different subsets of the avifauna react to disturbance in different ways (Karr and Roth 1971).

Examined in terms of feeding groups, there are considerable changes

Table 1. Similarity of primary and logged forest avifaunas as described by Horn's Index of Overlap. Calculations of the ten most numerous species omit nomadic species (e.g. green pigeons *Treron*; hornbills of the genus *Rhyticeros*) and migrants (e.g. Blue-throated Bee-eater *Merops viridis*).

	Area and time since logging (years)							
	C13C (Unlogged)	C5A (1–2)	C1A (3–4)	C2 (5–6)	C13C (6–7)	C5A (7–8)	C1A (9–10)	C2 (11–12)
C13C	–							
C5A	.10	–						
C1A	.38	.43	–					
C2	.04	.71	.49	–				
Area								
C13C	.07	.22	.33	.37	–			
C5A	.09	.66	.49	.78	.46	–		
C1A	.36	.19	.52	.29	.32	.57	–	
C2	.09	.38	.23	.46	.32	.32	.29	–

occurring in relative abundances after logging, although these may not be expressed immediately (Table 2). As would be expected from the variable degree of transience among species, recently logged forest exhibits an avifauna showing characteristics of both primary and older logged forests. Data collected at a single site (C13C) emphasize the dominance of arboreal insectivore/frugivores (particularly bulbuls Pycnonotidae) in disturbed forest and the decline of certain insectivore groups, notably terrestrial and sallying (flycatching) species. The susceptibility of these groups was suggested in the earlier paper (Johns 1986), extrapolating data from a number of sites. The number of species recorded declines steadily: a reflection of the lesser numbers of rare species and consequently higher equitability typical of disturbed systems. Older logged forests show evidence of the re-establishment of many of these rare species (see Appendix): thus equitability would be expected to increase as the forest regeneration process continues. The structurally complex vegetation in tall rainforest does not allow dominance by a few species.

An important factor affecting the recolonizing capacity of species intolerant of the environmental conditions within recently logged forest appears to be the re-establishment of a closed lower canopy. This is not associated with re-establishment of the vegetation typical of unlogged forest, but may create similar microclimatic conditions in the understorey. This

Table 2. A comparison of feeding guild membership within samples of 800 individual birds observed at area C13C. Calculating from the original numerical data, divergence from the unlogged forest sample 6–7 years after logging is greater than that shown 1–6 months after logging, although both change significantly (χ^2 = 219.5 and 43.2 respectively; df = 8, p <.001 in both cases).

		% sample (n = 800)		
Trophic group	Feeding guild	Before logging	1–6 months after logging	6–7 years after logging
Frugivores	Terrestrial	0	0.4	0
	Arboreal	10.6	10.6	14.9
Faunivore/ Frugivores	Arboreal	11.5	10.3	5.8
Insectivore/ Frugivores	Terrestrial	0.6	0	0
	Arboreal	15.1	8.8	39.2
Insectivore/ Nectarivores	Arboreal	3.9	2.0	4.5
Insectivores	Terrestrial	3.6	1.4	0
	Bark-gleaning	5.3	3.4	3.0
	Foliage-gleaning	31.1	34.5	28.5
	Sallying	16.2	24.1	2.0
Carnivores	Raptors	2.0	4.5	2.0
	Piscivores	0.1	0	0
No. species in sample		120	100	86

may be achieved on tractor-logged land after about 10 years (Figure 2). At site C2, the abundance of babblers Timaliidae (typically intolerant species) had risen from 3.1% of the sample in 1980–1981 to 10.4% in 1987: an improvement, but still well below their abundance in unlogged forest (17.1%). This lesser relative abundance reflects the continued presence of many bulbuls Pycnonotidae along the margins of the larger logging roads. Similar responses are seen among understorey flycatchers Muscicapidae, conspicuously low in abundance during the 1980–1981 surveys but beginning to reappear in 1987 (although still much less abundant than in primary forest which suggest that they may be more prey-specific than the foliage-gleaning babblers, or have more specific habitat requirements when foraging or nesting).

Intra-habitat variation

Important differences were seen to arise in the recolonization of land logged by different techniques. Patches of forest logged by conventional tractors, which cause less soil compaction than do cable systems, quickly support a regrowth of herbs, such as bananas Musaceae and gingers Zingiberaceae, which create shade and enable the germination of seeds from many of the forest trees (Plate 1). These areas are rapidly occupied by a variety of birds, particularly understorey spiderhunters *Arachnothera affinis* and *A. longirostra*, which are associates of these herbs. In area C1A, where the banana/ginger understorey was particularly well developed, these species together made up 5.5% of birds encountered.

On the other hand, patches of forest logged using overhead cables suffer much more from soil compaction, particularly on the ridgetops, and have large areas completely cleared of vegetation. The compacted and cleared areas are colonized by plants which grow inwards from the verges, notably the fern *Gleichenia*, a sprawling shrub *Leuconotis* and various tough grasses

Figure 2. Re-formation of the lower canopy in conventionally logged forest (area C2). The profile diagrams are constructed from 50 × 7.5 m transects that show all trees ≥ 4.5 m tall. Stippled trees are colonizing softwoods.

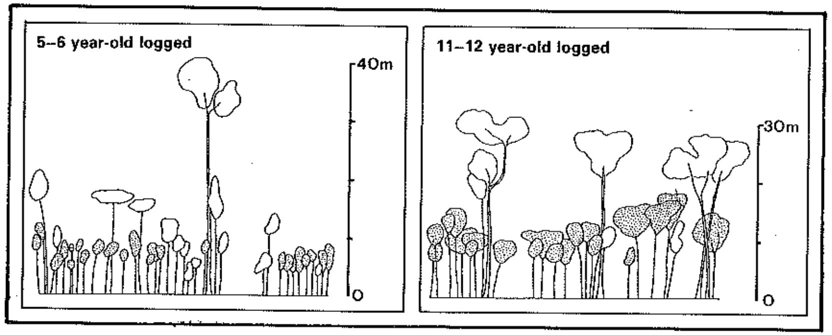


Plate 1. Understorey regeneration in conventionally logged forest 9–10 years after the felling event (area C1A). Note the preponderance of bananas and gingers growing over the old logging road.

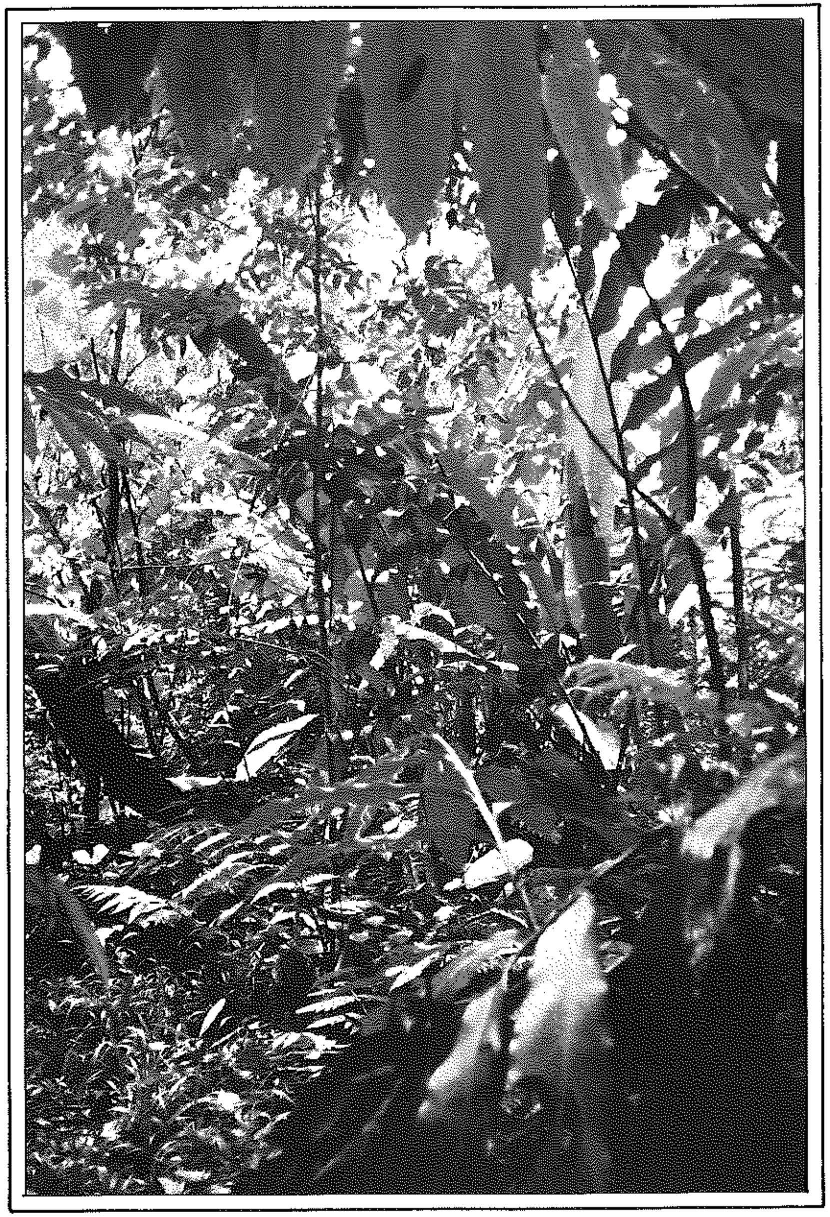
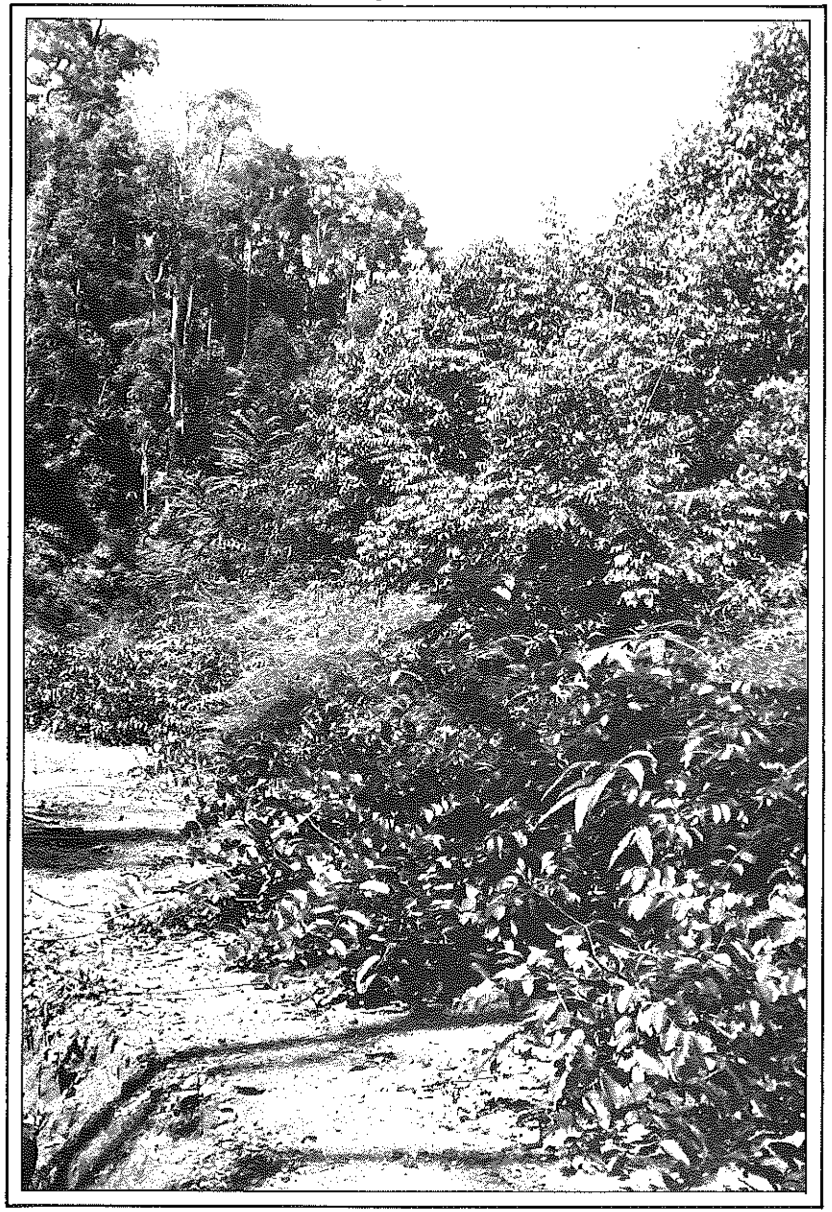


Plate 2. Regeneration in a cable-logged area 7–8 years after the felling event (area C5A). Note the sparse regeneration extending only gradually over the heavily compacted ridgetop soil. The medium-sized trees in the middle distance are planted *Acacia mangium*.



(Plate 2). This seral community is occupied by only two bird species, the Black-necked Tailorbird *Orthotomus atrogularis* and Fluffy-backed Tit-Babbler *Macronous ptilosus*. The time taken before the compacted ground is broken up by these plants and colonization by others becomes possible is not clear, but is likely to be at least 10 years.

Replanting with rapidly growing colonizing trees, notably *Acacia*, certainly aids the re-establishment of undergrowth. It appears, however, that tree seedlings that become established beneath these trees are of their own species, not of native species. Birds may visit inflorescences of eucalypts, but there is little evidence of their exploiting fruit or foliage insects on these trees.

The obvious effect of these differences is that the distribution of forest birds will be highly uneven in cable-logged areas (they will be largely restricted to the less-damaged valley bottoms). For example, babblers (excluding Fluffy-backed Tit-Babblers) occupied 2.3% of the population sample on ridgetops at C5A (1987 surveys) but 10.0% of the sample in less damaged valleys. Their distribution is likely to be much more even in tractor-logged areas. Both systems of logging preserve areas of lightly damaged forest, however, at least under current logging systems.

DISCUSSION

Species tolerances

Results of the 1987 surveys emphasize, to a large extent, trends observed six years previously (Johns 1986). In this earlier paper, attempts were made to explain why certain groups of birds were affected in certain ways. Exclusion from recently logged forest was found to result from a variety of environmental changes, of which the two most important concerned food supply and microclimate, particularly in the understorey. Broad feeding groups most likely to decline, and within which individual species were statistically most likely to be locally eradicated, were defined. (There were few consistencies at the level of individual species.) The main conclusions have since been proved to hold for several other forest-types in the humid tropics (India: Beehler *et al.* 1987; Brazilian Amazonia: Johns unpublished; Uganda: J. Holmes *in litt.*). Given the fact that some groups are identified as severely affected by logging, the most important question that now arises is when, if ever, they are able to recolonize the regenerating forest.

It is clearly beyond the scope of the current dataset to answer this question for the entire avifauna. Many terrestrial birds were, largely because of the effects of microclimatic changes on the microfauna of the leaf-litter, found to be entirely absent from recently logged forest; partridges Phasianidae, pittas Pittidae and wren-babblers of the genus *Napothera* have still never been observed in the logged forests at the Tekam F.R., even 12 years after logging. Admittedly, these were uncommon birds at the study site, but a continuing lack of observations is becoming conclusive. Some understorey flycatchers of unlogged forest, and aquatic invertebrate specialists such as White-crowned Forktails, have also failed to recolonize after 12 years.

On the other hand, a high proportion of the bird species observed in unlogged forest have now been found in logged-over areas, though at lesser abundances. The formation of an interlocking lower canopy, as colonizing euphorbs fill gaps created during logging, re-creates the cool and humid microclimate typical of the understorey of unlogged forest and allows re-establishment of many understorey birds (such as babblers of the genus *Stachyris*). The vegetational composition of the regenerating forest does not appear to be a major influencing factor for such species: foliage insects occupying the early successional vegetation are likely to be of different taxonomic disposition to those occurring in primary forest (as has been suggested, though not well proven, elsewhere: Henwood 1986, Shelley 1988), but appear sufficiently accessible and palatable to support the insectivores. It has elsewhere been shown that physiological considerations (heat and water balance) can be more important in determining the ranging of understorey birds than local food abundance (Karr and Freemark 1983).

The recovering population of foliage-gleaning insectivores may be contrasted with the declining abundance of bark-associated species (mostly woodpeckers Picidae). The loss of large trees during logging obviously reduces the foraging substrata available to such birds. They continue to decline in abundance even 12 years after logging, in line with continuing mortality among large remnant old trees. Woodpeckers are unlikely ever to regain former numbers in logged-over forest since periodic re-cropping will greatly reduce the average age of trees, their size and the numbers becoming senescent (senescent trees being preferred by boring insects upon which many woodpeckers feed).

A reliance upon remnant trees as food sources might also be expected to limit abundances of canopy frugivores in logged-over forest. Hornbills Bucerotidae are a case in point: these birds suffered a loss of 56% of their food trees during logging operations at the Tekam F.R. and are rarely observed to feed from colonizing vegetation (Johns 1987). Their numbers appear depressed in logged forests (see Appendix), but this is actually an artifact of the appearance of overdominants in the sample (i.e. a few species of small bird that are extremely numerous). Calculated estimates of hornbill density, obtained from line transect surveys, actually show hornbills to occur in the logged forests at close to their former densities (Johns 1988b). These wide-ranging birds, and others such as green pigeons *Treron*, appear wherever suitable trees are in fruit. Because of the lesser density of such trees, the amount of fruit eaten from each will be greater, unless the birds switch to other types of food (which may happen to some extent: F. Lambert, verbally). The continued presence of hornbills and pigeons suggests that any increase in exploitation levels does not necessarily result in competition for suddenly limiting resources. This is perhaps explainable by the observation that mature specimens of many of these trees produce a superabundance of fruit. This is particularly true of fig trees *Ficus*, large free-standing specimens of which also tend to be avoided during the felling operation because of the inconvenience caused by their copious and sticky sap, and because of superstitious beliefs. Fig tree density has been reported to be a primary determinant of the abundance of several frugivorous mammals and birds (Rijksen 1978); although some non-free-standing fig trees are destroyed by logging, losses do not appear to be at a critical level.

Community changes

While presence/absence statistics suggest that most species re-establish themselves in logged-over forests, an examination of relative abundances emphasizes the differences that remain. This is demonstrated very clearly by the indices of similarity: overdominant birds common to most logged areas give a generally higher similarity between logged forests than between any logged forest site and primary forest. The only exception to this is area C1A, which retained larger patches of less disturbed, or undisturbed, forest than is usually the case.

Disturbance to complex ecosystems is more often expressed in terms of changes in the relative abundance of species than in terms of species deletions. While most species of bird observed in unlogged forest may persist or reappear in logged-over areas, it may take a very long time for the logged areas to regain the species-abundance characteristics of unlogged forest. This is particularly true in cable-logged areas where regeneration is much less successful than in conventionally logged areas (Borhan *et al.* in press). Full recovery is likely to be achieved only with the regeneration of full vegetational diversity and a complete age-range of vegetation (including senescent and dead trees), which may take in excess of 70 years.

The continuing study

Given sufficient time, the vegetation and then the fauna of logged-over forest would probably regain a close to natural state. Sufficient time will not be allowed, however. Re-logging is scheduled on a 35-year cycle, much less time than the natural regeneration cycle (e.g. Meijer 1970). Also, the forest will not be allowed to regenerate naturally. One silvicultural practice has already been mentioned: the planting of fast-growing alien tree species on heavily damaged land to speed up the re-establishment of ground cover. Removal of non-commercial trees and climbers is another potentially damaging silvicultural practice – designed to increase the representation of a few timber tree species in the stand at the expense of others – the economic feasibility of which is currently being researched at the Tekam F.R.

Acting together, these procedures may deflect regenerative processes and cause a gradual breakdown of the food web. Such changes may take several logging cycles to become expressed fully, and the timber industry or markets may undergo major changes in the interim period, but the potential danger is there to see. Studies at the Tekam F.R. are planned to continue, covering the whole of the current logging cycle. This will enable assessment of the extent to which the avifauna is able to reachieve its former state before being disturbed by another felling episode.

A long-term study of this kind is able to address several questions. Principal among these are: to what extent do lesser damage levels (the retention of patches of less damaged or undamaged forest) aid recovery; to what extent does this differ according to the local logging system; are those birds identified as intolerant of logging ever able to re-establish their former numbers and re-create the patterns of species-abundance common to primary forests? Even a study of this length will not address all questions, however; what is the effect of isolation from large tracts of unlogged forest as a potential source of colonizers during the second and subsequent logging cycles?

If long-term sustained-yield management for timber is possible, then the maintenance of rainforest animals should be also. But a permanent change in the avifauna may well occur with the first logging event; the original organization of the community may never be regained.

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APPENDIX

BIRD SPECIES RECORDED IN UNLOGGED AND SELECTIVELY LOGGED FORESTS AT TEKAM FOREST RESERVE

Migrant species are marked (Mig); montane species, probably accidental at Tekam F.R., are marked (Mont). Species which follow logging roads, and may thus occur along open roads even within otherwise unlogged forest, are marked with an asterisk (*).

Above-canopy feeding species are not included in the population sample (they would be underestimated in unlogged forest where the canopy is closed); their presence is marked 'p'. Species producing loud and characteristic calls may also be marked in this way in areas where they were heard but not seen.

Feeding guild data are from Wells (1988) and my own personal observations. Feeding guild codes are as follows: TF, terrestrial frugivore; AF, arboreal frugivore; FF, faunivore/frugivore; TIF, terrestrial insectivore/frugivore; AIF, arboreal insectivore/frugivore; IN, insectivore/nectarivore; TI, terrestrial insectivore; BGI, bark-gleaning insectivore; FGI, foliage-gleaning insectivore; SaI, sallying insectivore; SwI, sweeping insectivore; R, raptor; P, piscivore.

Survey sites are as follows: Unlogged (C13C: results from 1979–1980), 1–6 year-old logged (C5A, C1A, C2: 1980–1981 surveys, combined), 7–12 year-old logged (C5A, C1A, C2: 1987 surveys, combined). Species observed at Tekam F.R. outside of these surveys are included in brackets [].

Nomenclature follows Johns (1986), with minor additions.

Family and species	Feeding guild	% Total Sample: Unlogged	% Total Sample: 1–6 year-old logged	% Total Sample: 7–12 year-old logged
ACCIPITRIDAE				
[*Aviceda jerdoni* (Mig)]				
[*Pernis ptilorhyncus*]				
Accipiter trivirgatus	R	0.3	0.2	0.2
A. gularis (Mig)	R	0.05	0	0
[*Butastur indicus* (Mig)]				
Spizaetus cirrhatus	R	0	0.05	0
S. nanus	R	0.2	0.1	0.1
S. alboniger	R	0.1	0.1	0.3
Hieraaetus kienerii	R	0.3	0.05	0.2
Ictinaetus malayensis (Mont)	R	0	0	0.05
Ichthyophaga humilis	R	0	0	0.1
Spilornis cheela	R	0.4	1.0	1.6
FALCONIDAE				
*Microhierax fringillarius**	R	0.3	0.7	0.7
Falco sp.	R	0	0.05	0
PHASIANIDAE				
Rhizothera longirostris	TIF	0.3	0	0
[*Arborophila charltonii*]				
[*Rollulus rouloul*]				
Polyplectron malacense	TIF	0	0.2	0
Argusianus argus	TIF	p	p	p
COLUMBIDAE				
Treron curvirostra	AF	2.9	0.05	0.4
[*T. olax*]				
T. vernans	AF	0	1.5	0.1
Ptilinopus jambu	AF	0.05	0	0.1
Ducula badia (Mont)	AF	0.1	4.5	10.6
[*Streptopelia chinensis**]				
Chalcophaps indica	TF	0.1	0.5	0.4
PSITTACIDAE				
Psittacula longicauda	AF	0	0	3.6
Psittinus cyanurus	AF	1.0	3.6	2.6
Loriculus galgulus	AF	1.6	1.1	2.8
CUCULIDAE				
[*Clamator coromandus* (Mig)]				
[*Cuculus vagans*]				
C. micropterus	FGI	0.1	0.4	0.1
Cacomantis sonneratii	FGI	0	0.05	0
C. variolosus	FGI	0.3	0.3	0.1
Chrysococcyx xanthorhynchus	FGI	0	0	0.05
Surniculus lugubris	FGI	0.1	0	0.1
Phaenicophaeus diardi	FGI	0.2	0.1	0
P. sumatranus	FGI	0	0.4	0.2
P. chlorophaeus	FGI	1.6	0.3	0.6
P. javanicus	FGI	0.7	0.4	0.3
P. curvirostris	FGI	0.4	0.6	0.6
Centropus rectunguis	TI	0.3	0.2	0.1
C. sinensis	TI	0	0	0.05
TYTONIDAE				
Phodilus badius	R	–	p	–
STRIGIDAE				
Otus rufescens	R	p	–	–
O. bakkamoena	R	p	p	p
[*Bubo sumatranus*]				
Ketupa ketupu	R	p	p	p
Glaucidium brodiei (Mont)	R	p	–	–
Ninox scutulata	R	p	–	–
CAPRIMULGIDAE				
Eurostopodus temminckii	SwI	p	p	p
Caprimulgus indicus (Mig)*	SwI	–	p	–
*C. macrurus**	SwI	p	p	–
APODIDAE				
Collocalia sp.	SwI	p	p	p
Hirundapus giganteus	SwI	p	–	p
H. cochinchinensis	SwI	p	–	p
Raphidura leucopygialis	SwI	p	p	p
HEMIPROCNIDAE				
Hemiprocne longipennis	SwI	p	p	p
H. comata	SaI	0.1	1.4	1.2
TROGONIDAE				
Harpactes kasumba	FGI	0.6	0	0.05
H. diardii	FGI	0.05	0.05	0
H. orrhophaeus	FGI	0.05	0	0
H. duvaucelii	FGI	0.4	0.2	0.1
H. oreskios	FGI	0.05	0	0
ALCEDINIDAE				
Alcedo euryzona	P	0	0.05	0
Ceyx erithacus	TI	0.3	0	0.05
Actenoides concreta	TI	0.3	0	0
Lacedo pulchella	TI	0.05	0	0.05

Family and species	Feeding guild	% Total Sample		
		Unlogged	1–6 year-old logged	7–12 year-old logged
MEROPIDAE				
[*Merops leschenaulti* (Mig)]				
M. viridis (Mig)	SaI	4.5	8.7	2.6
Nyctyornis amictus	SaI	0.3	0.1	0.3
CORACIIDAE				
Eurystomus orientalis	SaI	0	0.2	0.2
BUCEROTIDAE				
Berenicornis comatus	FF	0.2	0.1	0.2
Anorrhinus galeritus	FF	1.9	2.3	0.2
Rhyticeros corrugatus	FF	0	0.4	1.0
R. undulatus	FF	1.9	0.6	0.7
Anthracoceros malayanus	FF	0	0.7	0.2
[*A. albirostris*]				
Buceros rhinoceros	FF	5.1	0.6	1.3
B. bicornis	FF	0.4	0	0
Rhinoplax vigil	FF	1.9	0.7	0.6
CAPITONIDAE				
Megalaima chrysopogon	AIF	0.3	0.4	0.1
[*M. rafflesii*]				
M. mystacophanos	AIF	0.1	0.9	p
M. henricii	AIF	0.05	0.3	0.05
M. australis	AIF	p	0.2	p
Calorhamphus fuliginosus	AIF	1.6	1.0	0.9
PICIDAE				
Sasia abnormis	BGI	0.4	0	0.2
Celeus brachyurus	BGI	0.1	0	0.1
Picus puniceus	BGI	1.4	0.4	0.4
P. mentalis	BGI	0	0.05	0
P. miniaceus	BGI	0.05	0.2	0.1
Dinopium rafflesii	BGI	0	0.05	0.05
Meiglyptes tukki	BGI	0.5	0.1	0.5
Muelleripicus pulverulentus	BGI	0	0.4	0
Dryocopus javensis	BGI	0.1	0.4	0
Picoides canicapillus	BGI	0.1	0.05	0
Hemicircus concretus	BGI	1.1	0.4	0.5
Blythipicus rubiginosus	BGI	1.0	0.3	0.3
Reinwardtipicus validus	BGI	0.4	0.05	0.4
EURYLAIMIDAE				
Corydon sumatranus	FGI	0	0.1	0
Cymbirhynchus macrorhynchos	FGI	0	0.05	0.1
Eurylaimus javanicus	FGI	0	0	0.1
E. ochromalus	FGI	0.6	0.3	0.05
Calyptomena viridis	AF	0.8	0.7	0.2
PITTIDAE				
Pitta granatina	TI	0.05	0	0
HIRUNDINIDAE				
Hirundo rustica (Mig)	Swl	p	p	p
CAMPEPHAGIDAE				
Hemipus picatus	SaI	0	0	0.3
H. hirundinaceus	SaI	0.6	0	0.3
Tephrodornis virgatus	FGI	1.6	0.1	0.5
Coracina fimbriata	AIF	0.4	0.2	0.2
Pericrocotus divaricatus (Mig)	FGI	0.1	0.8	0
P. cinnamomeus	FGI	0.6	0	0.3
P. flammeus	FGI	2.5	0.9	3.0
AEGITHINIDAE				
Aegithina viridissima	FGI	0.3	0.5	0.3
A. lafresnayei	FGI	0.1	0	0
Chloropsis cyanopogon	AIF	0.3	0.6	0.6
C. sonnerati	AIF	0.8	0.5	0.7
C. cochinchinensis	AIF	1.1	1.1	1.4
Irena puella	AF	2.7	1.6	0.6
PYCNONOTIDAE				
Pycnonotus melanoleucos	AIF	0	0.1	0
P. atriceps	AIF	0.05	0.7	0.3
P. squamatus	AIF	0.5	2.3	0.1
P. cyaniventris	AIF	0.3	0.5	0.8
P. finlaysoni	AIF	0	0	0.1
P. eutilotus	AIF	0.2	0.3	0.4
*P. goiavier**	AIF	0	1.8	0.8
P. simplex	AIF	0.8	8.5	0.7
P. brunneus	AIF	1.1	1.7	4.4
P. erythrophthalmos	AIF	0.4	0.6	0.8
Criniger finschii	AIF	0.1	0.4	0.1
C. bres	AIF	2.1	0.9	1.0
C. phaeocephalus	AIF	0.6	0.1	0
Hypsipetes criniger	AIF	1.3	0.8	3.1
H. charlottae	AIF	0.05	0.05	0.9
H. malaccensis	AIF	2.1	0.7	1.1
DICRURIDAE				
Dicrurus annectans (Mig)	FGI	0.2	0	0
D. aeneus	FGI	0.6	0.9	2.0
D. paradiseus	FGI	2.4	0.8	1.6
ORIOLIDAE				
Oriolus xanthonotus	FGI	0.6	0.3	0.4
CORVIDAE				
Platylophus galericulatus	FGI	0.4	0.5	0.1
Platysmurus leucopterus	AIF	0.1	0.2	0.5
Corvus enca	AIF	0	1.6	0.05
PARIDAE				
Melanochlora sultanea	FGI	0.1	0.4	0.3
SITTIDAE				
Sitta frontalis	BGI	0.8	0.1	0
TIMALIIDAE				
Pellorneum capistratum	TI	0	0	0.1
Trichastoma malaccense	TI	0.7	0.05	0.3
T. bicolor	FGI	0.6	0.05	0.1
[*T. sepiarium*]				
Malacopteron magnirostre	FGI	1.3	0.4	0.6
M. affine	FGI	0.6	0	0.7
M. cinereum	FGI	1.9	0.4	1.2
M. magnum	FGI	3.2	1.1	1.4
Pomatorhinus montanus	FGI	0.9	0.05	0.2
Kenopia striata	FGI	0.6	0.05	0
Napothera macrodactyla	TI	0.1	0	0
Stachyris poliocephala	FGI	0.3	0	0.3
S. leucotis	FGI	0.2	0	0.1
S. nigricollis	FGI	0.9	0.4	0.1
S. maculata	FGI	0.6	0.1	0.1
S. erythroptera	FGI	1.9	1.4	1.7
Macronous gularis	FGI	0.8	0.9	1.6
M. ptilosus	FGI	0.05	0	1.7
Alcippe brunneicauda	FGI	0.5	0.5	0.6
Yuhina zantholeuca	FGI	1.9	0.3	0
TURDIDAE				
Erithacus cyane (Mig)	TI	0.1	0	0
*Copsychus saularis**	FGI	0.7	2.6	1.8
C. malabaricus	FGI	1.6	0.8	0.7
C. pyrropyga	FGI	0.3	0	0.05
Enicurus ruficapillus	TI	0.8	0.5	0.3
E. leschenaulti	TI	0.3	0	0
Turdus obscurus (Mig)	TI	0	2.7	0
Zoothera citrina (Mig)	TI	0.2	0	0
SYLVIIDAE				
Gerygone sulphurea	FGI	0.1	0	0
[*Phylloscopus inornatus* (Mig)]				
P. borealis (Mig)	FGI	0.1	0.1	0
P. coronatus (Mig)	FGI	1.6	0.1	0.3
[*Abroscopus superciliaris*]				
Orthotomus sericeus	FGI	0.6	0.2	0.5
O. atrogularis	FGI	1.4	1.3	2.7
[*O. ruficeps*]				
*Prinia rufescens**	FGI	0	0	0.1
MUSCICAPIDAE				
Rhinomyias umbratilis	SaI	0.05	0	0
[*Muscicapa sibirica* (Mig)]				
M. latirostris (Mig)	SaI	0.9	0.1	0.1
M. williamsoni (Mig)	SaI	0.05	0	0
[*M. ferruginea* (Mig)]				
Eumyias thalassina	SaI	0.1	0	0.05
[*Ficedula zanthopygia* (Mig)]				
F. mugimaki (Mig)	SaI	0.3	0	0
[*F. solitaria* (Mont)]				
[*F. dumetoria*]				
[*Cyanoptila cyanomelana* (Mig)]				
Cyornis unicolor	SaI	0.05	0	0.05
Culicicapa ceylonensis	SaI	0.9	0	0
Rhipidura perlata	SaI	1.6	0	0.1
Hypothymis azurea	SaI	1.3	0.1	0.8
Philentoma velatum	SaI	0.5	0.1	0.2
P. pyrhopterum	SaI	0.7	0.1	0.1
Terpsiphone paradisi	SaI	0.6	0.3	0.3

Family and species	Feeding guild	% Total Sample		
		Unlogged	1–6 year-old logged	7–12 year-old logged
MOTACILLIDAE				
Motacilla cinerea (Mig)*	TI	0.1	0.4	0
[*Dendronanthus indicus* (Mig)]				
LANIIDAE				
Lanius cristatus (Mig)	FGI	0	0.05	0
L. tigrinus (Mig)*	FGI	0.1	0.3	0.2
STURNIDAE				
*Aplonis panayensis**	AF	0.05	0	0
Gracula religiosa	AF	0.3	3.8	1.9
NECTARINIIDAE				
Anthreptes simplex	IN	0.8	0.3	0.2
[*A. rhodolaema*]				
A. singalensis	IN	1.1	0.3	0.3
Hypogramma hypogrammicum	IN	0.6	0.1	0.3
[*Aethopyga siparaja*]*				
A. mystacalis	IN	0.05	0.05	0
Arachnothera longirostra	IN	0.3	0.6	2.3
A. crassirostris	IN	0	0.6	0.1
A. robusta	IN	0.1	0.2	0
A. flavigaster	IN	0	0	0.1
A. chrysogenys	IN	0.3	0.05	0.7
A. affinis	IN	0	0.9	0.4
DICAEIDAE				
[*Prionochilus thoracicus*]				
P. maculatus	AF	0	0	0.7
P. percussus	AF	0.2	0	0.1
Dicaeum trigonostigma	AF	0.05	0	0
D. concolor	AF	0.3	0	0.2
D. agile/everetti	AF	0	0	0.05
ZOSTEROPIDAE				
Zosterops everetti	AIF	0	1.1	0
ESTRILDIDAE				
Lonchura leucogastra	AF	0	0.1	0.3
Number of individuals		1,603	2,263	2,748