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DIVERSITY AND ABUNDANCE OF SELECTED ANIMAL SPECIES IN UNDISTURBED FOREST, SELECTIVELY LOGGED FOREST AND PLANTATIONS IN EAST KALIMANTAN, INDONESIA

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ABSTRACT

Animal surveys were conducted in six habitat types within the timber concession of PT International Timber Corporation Indonesia, East Kalimantan. Species diversity was found to be similar in undisturbed forest and in 3- to 5-year-old selectively logged forest, although densities in the latter were considerably less. Both diversity and density declined drastically in forestry plantations, but certain of the species remaining caused significant damage to young trees. Although few animals were observed in areas where there was active road construction and timber felling, their densities in adjacent undisturbed forest areas did not increase, suggesting that the level of local migration actually is low. It is suggested that recolonisation of old logged forest can occur successfully provided that the level of hunting is low and that adjacent areas of undisturbed forest remain to provide a population pool from which colonists can spread.

INTRODUCTION

In 1973, a brief survey was conducted on the PT International Timber Corporation Indonesia (ITCI) concession, south of the Mahakam River in East Kalimantan (Eastern Borneo). It was then concluded that selective harvesting at low

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density did not cause a significant decrease in the densities of several primate species (Wilson & Wilson, 1975*a*). This may be related to the fact that the trees of greatest commercial value (*Shorea* spp., *Hopea* spp.) are generally not used as food trees by resident primate species (for Western Malaysian species see Chivers *et al.*, 1975; Curtin, 1976; Raemaekers, 1977). Though some exceptions have been reported, e.g. *Hylobates klossii* (Tenaza, 1975), *Presbytis rubicunda* (A. G. Davies, pers. comm.), in no case do these trees provide a major part of the species' diet.

It should be emphasized, however, that selective felling, even at the low level of 8–12 trees per hectare, destroys 50 % of the timber stand (Wilson & Wilson, 1975*a*), and removal of 10 % of the trees destroys 65 % of the timber stand (Burgess, 1971). Numerous non-timber trees are destroyed during logging, and many of these are food trees used by resident animal species. For example, strangling figs *Ficus* spp., which grow preferentially on large trees such as the high-value timber species, may be particularly susceptible to damage. As these are considered to be of major importance to many forest animals (Raemaekers, 1977; Rijksen, 1978), their loss contributes significantly to the lessening of animal density in logged forest.

On the other hand, Chivers (1972, 1974) considers that the moderate disturbance caused by selective logging at a low density may increase the available food through stimulation of new growth and fruiting where gaps are formed in the canopy. For this reason, both Chivers (1972, 1974) and Wilson & Wilson (1975*a*) believe that a limited degree of habitat disturbance is not necessarily detrimental to the primate population. Wilson & Wilson (1975*a*) further indicate that most hornbill species and many terrestrial mammals may not be seriously affected.

These findings contrast with those of Stevens (cited in Burgess, 1971), who reports that 48 % of the resident animal species disappeared after logging. Stevens' estimate, however, was based on areas with a far greater extraction level, at least 25 trees per hectare. Both Rijksen (1978) and D.R. Leighton (pers. comm.) also believe that selective logging in Indonesia seriously affects the resident fauna. There is thus a difference of opinion (Ewel & Conde, 1976) and the present study was designed to provide more information on the effects of logging.

This report compares the diversity and abundance of selected species in six habitat types ranging from primary forest through various levels of disturbance to plantations, the results of a further survey by W.L.W. The limitations of the fieldwork, particularly the relatively small areas surveyed, should be considered in interpreting our results.

SURVEY AREAS

Five locations on the PTITCI concession were surveyed:

(1) KM-6, 2-year-old forestry plantation and surrounding 5-year-old logged forest, forest fringe and scrub (belukar).

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(2) KM-21, 6-month-old forestry plantation and surrounding 3- to 4-year-old logged forest and forest fringe.
(3) KM-6-JB, road through 5-year-old logged forest.
(4) KM-8, logging spur (skid-track) through 5-year-old logged forest.
(5) 2022 Line, initially surveyed when primary forest and then resurveyed after road construction and subsequent logging.

KM-6 forestry plantation

Census walks were taken over 10·5 km of plantation habitat, 2·1 km of scrub, 3·15 km of 5-year-old logged forest and 3 km of linear forest fringe. (As both length and number of repetitions of survey walks were variable, total distance walked for habitat type is presented.)

The clear-felled 35 ha had been planted with seedlings 2 years before the survey, and the seedlings had reached an average height of about 2 m. The plantings included small experimental plots of *Pinus caribaea*, *P. oocarpa*, *Eucalyptus deglupta*, *Gemellina arborea* and *Anthocephalus chinensis*, with larger areas of *Albizia falcateria*.

The surveyed area of logged forest had been cut at a density of about 5 large trees per ha and subsequent thick secondary growth had reached a height of 8–12 m.

The scrub was a successional vegetation type developing in areas of abandoned smallholdings. The vegetation was composed predominantly of colonising species such as *Macaranga* spp. and *Trema* spp., and had reached an average height of about 8 m.

The surveyed forest fringe was juxtaposed between the scrub and logged forest. While a difficult habitat type to define, it is thought to differ slightly from adjacent forest because the greater availability of light permits the growth of colonising and photophilic species.

This area ranges from 0 to 25 m above sea level.

KM-21 forestry plantation

Census walks in the KM-21 plantation totalled 8·31 km. This area had been planted with *P. caribaea* and *A. falcateria* 6 months before the survey. The circular plantation is centred on a large hill. In the surrounding logged forest (cut at a density of 5–7 trees per ha), census walks were taken along 30·6 km of old logging roads and spurs. In addition, 5·60 km of forest fringe was surveyed.

This area ranges from 100 to 200 m above sea level.

KM-6-JB and KM-8 roads

Census walks along KM-6-JB and KM-8 roads totalled 25·2 km. Both areas were logged at an intensity of about 8 trees per ha 5 years before the study. Both were surveyed by walking a road cut through the forest, KM-6-JB along a brand new

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laterite road and KM-8 along an old logging spur. These areas were directly adjacent, the distance between the two survey routes ranging from 1·8 to 4 km.

Both roads range from 15 to 30 m above sea level.

2022 line

Initially, 18 km of trail were surveyed in undisturbed forest. Two months later, after half of the area had been logged, 9 km of trail were resurveyed in unlogged forest and 9 km in logged forest.

The area is hilly, with many small streams, and ranges from 220 to 400 metres above sea level.

CENSUS METHODS

Surveys were conducted by systematically walking mapped transects, always between 0600 and 1200 h. Transects were usually between 2 and 4 km in length.

All sightings, vocalisations and tracks encountered were recorded, noting time of day, species, number of individuals, compass direction from the transect, and direction of travel. Tracks were always wiped out after identification. Often several compass readings could be made on a vocalising animal and its position estimated by triangulation. Tracks of civet and mongoose species were impossible to identify at the species level, so all are referred to collectively as viverrids. All species for which data were collected are listed in Table 1.

Mean density of species for each habitat type was estimated using the transect method described by Southwick & Cadigan (1972), Seber (1973) and Wilson & Wilson (1975*b*). When visibility is assumed to be 50 m on both sides of the transect, walking 100 m equals 1 ha surveyed. In addition, the positions of gibbons, hornbills and argus pheasants could be reliably mapped from their vocalisations up to at least 100 m on each side of the trail, so that walking 100 m represents 2 ha surveyed. The proportion of the population recorded from vocalisations is not known, however, so these results were not used in final calculation of density.

This method undoubtedly has shortcomings, particularly in that it assumes equal 'visibility' among both species and habitat type, obviously an unrealistic assumption. Previous experience in Sumatra (Wilson & Wilson, 1975*b*) indicated that this was a workable technique however, and it was thus used in the absence of a proven detectability-related technique (C. Janson & J. Terborgh, pers. comm.).

RESULTS

Species presence in habitat type

Species presence in each of the six habitat types is summarised in Table 1.

Plantation. Only four species were observed in the plantations. Sambar deer

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TABLE 1

SPECIES PRESENCE IN DIFFERENT HABITAT TYPES

Habitats:	*Plantation*	*Scrub*	*Forest fringe*	*3- to 5-year-old logged forest*	*Recently logged*	*Primary forest*
KM surveyed:	*18·81*	*2·10*	*8·50*	*58·95*	*9·00*	*27·00*
Bornean gibbon *Hylobates muelleri*	—	O	O	O	O	O
Maroon langur *Presbytis rubicunda*	O	O	O	O	—	O
Sambar deer *Cervus unicolor*	O	R	O	O	T	T
Barking deer *Muntiacus muntjac*	T	R	O	O	—	T
Mousedeer *Tragulus* spp.	R	R	R	T	—	T
Bearded pig *Sus barbatus*	O	R	R	T	—	T
Viverrids (Viverridae)	T	R	T	T	T	T
Sun bear *Helarctos malayanus*	—	—	—	—	—	O
Pied hornbill *Anthracoceros convexus*	—	R	O	O	—	O
Bushy-crested hornbill *Anorrhinus galeritus*	—	—	—	O	—	—
Rhinoceros hornbill *Buceros rhinoceros*	—	—	—	O	O	O
Helmeted hornbill *Rhinoplax vigil*	—	—	O	O	—	O
Argus pheasant *Argusianus argus*	—	—	—	O	—	O

O = observer record (seen or heard)
T = tracks found
R = reported by ITCI employees (reliability of reports unknown)

entered them at night to feed on the young *Albizia* and drink from the small pools of rain water or natural springs. They caused severe damage to the young *Albizia*, often breaking the main stems or knocking the trees over, but did not seem interested in the other tree species on the plantations. The maroon langurs also entered the *Albizia* plantation at KM-6, travelling along the ground from adjacent forest. They fed by pulling the seedlings over and peeling off the leaves with their fingers, usually without breaking the stems themselves. There is no evidence that the bearded pigs disturbed any of the plantation trees; they usually entered the plantation areas to wallow in the abundant pools of water. The tracks of barking deer and viverrids were also observed near pools of water; neither of these species is known to damage the plantation trees. The only other known offenders are the porcupines (Hystricidae), which may uproot young seedlings while rooting for food or digging burrows.

Scrub. The only gibbon seen in the scrub seemed to be using it as a route between

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two patches of logged forest. The maroon langurs, however, fed on the leaves of some of the colonising tree species; they also hid in the scrub when employees chased them out of the plantation.

Forest fringe. The primates and hornbills observed in the forest fringe were usually feeding in tall emergents, though the langurs also frequently slept in such trees. These species probably entered the forest fringe a great deal (disproportionate to its area) owing to a greater abundance of certain fruiting and flushing trees. In this respect, forest fringe resembles riverine forest. As a transition zone between disturbed habitat and old logged forest, forest fringe was visited by both pied hornbills, typically a secondary forest species, and helmeted hornbills, typically a tall forest species (Kemp & Kemp, 1974).

Three- to five-year-old selectively logged forest. More species were recorded for the logged forest around KM-21 plantation than in any other area surveyed on the concession (though this was also the largest area surveyed).

Primary forest. Fewer species were observed in primary forest than in regenerating logged forest, but densities were considerably higher.

Recently logged forest. One week after the eastern 1 km^2 of the 2022 line survey area had been logged (i.e., one week after all people and machines had moved out), the whole area was resurveyed. Seven species seen previously were no longer observed.

Species diversity

Table 2 summarizes the species diversity recorded for the six habitat types. Bear in mind, when interpreting the results, that unequal areas of each habitat were surveyed. It is reasonable to assume a reverse logarithmic relation between area surveyed and number of species observed; most species will be observed within a fairly small area but some, particularly hornbills (Kemp & Kemp, 1974), show an irregular dispersion through a habitat. It cannot be assumed that all species are equally distributed through space; therefore, the larger the surveyed area (within a uniform habitat type) or the greater the number of surveys, the greater the

TABLE 2
SPECIES DIVERSITY IN SIX HABITATS

Habitat	*km trail surveyed*	*No. species recorded*
One-week-old selectively logged forest	9·00	4
Plantation	18·81	6
Forest fringe	8·50	8
Scrub	2·10	9
Primary forest	27·00	12
3- to 5-year-old selectively logged forest	58·95	13

Total number of species recorded = 14 (Viverrids included as a single species).

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probability of a random sample. Similarly, unequal time was spent in each habitat type, which would affect the results in the same way. Encounters may be the result of probablistic accidents, so the probability of encountering all groups within an area will increase with time.

It is apparent, for those species recorded, that primary and 3- to 5-year-old logged forests have a similar species diversity. The lower diversity for forest fringe habitat is somewhat unexpected, but may well be due to its limited area. On the other hand, the lower diversity recorded for scrub was to be expected. Plantations show a 50% reduction in species diversity. This is unrealistic, however, since the recorded species were entering the plantations from adjacent forest; far fewer can survive in the monoculture alone (A. G. Davies & J. B. Payne, pers. comm.).

The recently logged forest showed over a 60% reduction in species diversity matched against a control. Table 3 shows the occurrence of species units (normally groups of varying size but occasionally single animals) before and after logging. The number of records in the logged area showed a significant decline at the level $P = 0{\cdot}005$ (Wilcoxon test), whereas those for the control area showed no change.

Species density

Sufficient data were collected for four of the six habitat types to allow estimation of the population size and density (Table 4).

For several reasons, these figures should be interpreted with some caution. Some of the problems associated with estimating the density of forest wildlife have been pointed out by Seber (1973) and Wilson & Wilson (1975*b*). There are three major limitations to be considered.

(1) A widely dispersed group may be counted as two or more groups.
(2) Vocal species such as gibbons, langurs, most hornbills and the argus pheasant are more easily detected than quiet or nocturnal species such as deer, viverrids and the sun bear.
(3) If only a small area is surveyed, wide-ranging species present at low density are likely to go undetected.

Certain of these limiting factors are reflected in the error terms presented in Table 4 (the value of s_x is the only statistic possible given the small sample sizes). Estimates of gibbon density show a comparatively small value of s_x, which can be interpreted as due to their relatively small range size and their high level of conspicuousness (through their frequent morning calling bouts). On the other hand, most hornbills, although conspicuous due to their frequent vocalisations, range over a very large area. This tends to result in sporadic appearance in the survey area and a high s_x attached to estimates of their density.

As mentioned previously, comparison between habitat types may be susceptible to bias resulting from differences in area surveyed, time spent and visibility. For this reason, the density results of selected species were weighted to give a relative index of

TABLE 3
ESTIMATED NUMBER OF GROUPS PER KM² IN 2022 LINE AREA

	$\bar{X}$ Group size	Logging area Pre-logging	Logging area Post-logging	Control area Pre-logging	Control area Post-logging
Bornean gibbon	3	3	3	7	7
Maroon langur	5	1	0	4	2
Sambar deer	2	3	1	1	4
Barking deer	2	2	0	6	4
Mousedeer	2	3	0	3	2
Bearded pig	2	3	0	6	4
Viverrids	1	1	2	1	1
Sun bear	1	0	0	1	1
Pied hornbill	5	2	0	0	2
Rhinoceros hornbill	2	3	1	3	4
Helmeted hornbill	1	1	0	3	2
Argus pheasant	1	3	0	0	0
Comparison (Wilcoxon test)		$T = 2, n = 10, p < 0{\cdot}005$		$T = 21, n = 8, p > 0{\cdot}005$	

TABLE 4
ESTIMATED GROUP DENSITY (GROUPS KM⁻²)

	Plantation $\bar{x}$	Plantation s_x	3- to 5-year-old logged forest $\bar{x}$	3- to 5-year-old logged forest s_x	1-week-old logged forest $\bar{x}$	1-week-old logged forest s_x	Primary forest $\bar{x}$	Primary forest s_x
Bornean gibbon			5·0	3·30	2·3	1·60	7·3	3·85
Maroon langur	0·5	1·18	1·3	2·26			2·2	1·20
Sambar deer	3·2	1·85	0·4	1·15	1·1	1·56	4·1	4·10
Barking deer	1·1	1·69	0·7	1·58			5·8	4·87
Mousedeer			0·6	1·55			3·0	2·30
Bearded pig			0·7	1·58			6·7	3·98
Viverrids			0·4	1·20	2·2	3·11	1·6	1·07
Sun bear							0·7	1·14
Pied hornbill			1·2	1·67			1·1	1·41
Bushy-crested hornbill			0·3	1·13				
Wrinkled hornbill			0·1	0·24				
Rhinoceros hornbill			0·9	1·45	1·1	1·56	3·5	1·91
Helmeted hornbill			0·5	0·92			2·8	2·70
Argus pheasant			0·1	0·28			1·1	0·92

s_x = standard deviation.

diversity between habitat types (Table 5). The weighted scores were calculated from survey data as follows:

(1) Weighting by area surveyed: mean number of observations per survey walk divided by km² surveyed.

(2) Weighting by time: mean number of observations per survey walk divided by hours spent in that habitat type.

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TABLE 5
RELATIVE INDICES OF DENSITY FOR SELECTED SPECIES

	Bornean gibbon	*Maroon langur*	*Sambar deer*	*Pied hornbill*	*Helmeted hornbill*
Unweighted					
Primary forest	6·50	2·00	1·85	1·00	2·50
Recently logged	2·00	0	0·50	0	0
Old logged	3·11	1·00	0·17	0·56	0·33
Plantation	0	0·17	1·00	0	0
Weighted by time					
Primary forest	0·39	1·20	0·12	0·06	0·14
Recently logged	0·12	0	0·03	0	0
Old logged	0·32	0·80	0·02	0·09	0·04
Plantation	0	0·01	0·06	0	0
Weighted by area					
Primary forest	14·50	4·40	4·05	2·22	5·53
Recently logged	4·60	0	1·10	0	0
Old logged	10·00	2·53	0·38	2·24	0·97
Plantation	0	0·48	3·52	0	0

These may be compared with the unweighted mean of observations per survey walk also given in Table 5, and density estimates given in Table 4.

It is apparent that weighting the results does not greatly affect the relative differences between habitat types for each species. This indicates that variance due to differences in area surveyed and time spent are not highly significant in demonstrating differences between habitat types, at least for the four types considered. It should be pointed out, however, that error terms to these relative indices are rather large, a result that might be expected from the small sample size.

It is interesting to note that the only alteration affected by weighting the data is to increase the relative representation of the pied hornbill in old logged-over primary forest. Small sample size may have accounted for the higher calculated density of this species in primary forest; it is generally a secondary forest species (Smythies, 1960; Kemp & Kemp, 1974).

DISCUSSION

Immediate response to logging

Within the limitations of these results, it is apparent that immediately after logging, almost none of the considered species could be seen. This result has been noted by previous authors and frequently is interpreted as reflecting a mass migration away from the logging area (Burgess, 1971). It is perhaps more likely that only the less territorial species, such as hornbills, deer and pigs, move away from the logging area; hornbills may simply exclude it from their normally huge ranges,

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whereas deer and pigs may move outward into adjacent forest areas. The more territorial species, such as gibbons, stay within territorial boundaries whenever possible and seem reluctant to move outside their territories (personal observation), but may eventually travel outside if necessary to skirt the focus of logging activity. An exception to this seems to be the orang-utan, which has been reported to migrate away from operating logging areas (MacKinnon, 1971), though this is not inevitably the case (A. G. Davies, pers. comm.). Long-distance migration away from logging areas has also been reported for the indri *Indri indri* in Madagascar, although this species recolonises when logging ceases (Petter & Peyrieras, 1974).

The apparent lack of any increase in species density in undisturbed forest adjacent to logging areas (Table 3) suggests that the level of avoidance movement is probably low, even for species that are not bound by territorial restrictions. That so few animals were seen in recently logged forest is probably due largely to difficulties of surveying such areas; trails are destroyed and it is extremely difficult to cut new ones through the debris caused by logging. Surveys are necessarily restricted to logging tracks where walking is possible, but the chances of seeing animals before they see the observer are much lower. We believe that the survey results probably under-represent the density and diversity of species that remain.

Survival ability in logged forest

The degree to which a species' breeding population is influenced may be expected to be a function of the behaviour and ecology of that particular species and the nature of habitat disruption. In the present study, habitat disturbance is relatively low: 5–8 trees cut per ha with moderate associated damage leaving some 50 % of the stand (Wilson, personal observation). In such conditions, it may be assumed that only those species that have a specialised diet will be seriously affected. In comparable conditions, this has been demonstrated for the sun bear (Wilson & Wilson, 1975*a*; this study), orang-utan (MacKinnon, 1971; Rijksen, 1978), proboscis monkey (Wilson & Wilson, 1975*a*) and all four endemic Mentawaian primate species, *Hylobates klossii*, *Presbytis potenziani*, *Simias concolor* and *Macaca pagensis* (Wilson & Wilson, 1973; WWF, 1980; A. J. Whitten, pers. comm.). The serious effects of logging on certain species could occur either because the animals eat very specialised foods that are reduced by logging, or because the species already lives closer to ecological and physiological tolerance limits.

Many species, including primates of the genera *Hylobates*, *Presbytis* and *Macaca*, have fairly diverse diets (Curtin, 1976; Raemaekers, 1977; Mah, 1980), reflecting highly diverse food species (Clutton-Brock & Harvey, 1977). Where this is true, the population should be able to withstand a certain degree of habitat alteration. Selective logging at a low extraction level should not cause a reduction in food availability on a permanent basis; food may be less available at first, but with the rapid sprouting of colonising seedlings and the growth response of damaged trees, both diversity and availability of fruit and young leaves is likely to increase

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(Chivers, 1972, 1974). Even where there is a major change in available food types, primates are frequently able to adjust (e.g. Poirier, 1969). Thus the environment should continue to support large and healthy populations of many animal species.

From the present study it appears that this view is somewhat optimistic. All recorded mammals show a marked decrease in density in logged forest, as do the larger hornbill species and argus pheasant. It would appear that the arboreal primates are better able, and the terrestrial mammals less able, to withstand pressures imposed by logging. The success of the former probably reflects their high dietary diversity: there is a high probability of tolerance to shifts in vegetational composition. Their high diversity of locomotor ability (Fleagle, 1976) may also be important in enabling them to move around easily in logged forest (even when a certain number of arboreal pathways have been disrupted).

Unlike primates, both deer and pig are hunted a great deal, particularly in logged forest where access is much easier (most animals are shot from logging roads). Theoretically, since deer feed largely by browsing, they should be well suited to the abundance of secondary vegetation. All species also feed on fallen fruit (Lekagul & McNeely, 1979), which should be more common in secondary than in primary forest. The large reduction in the population of pigs certainly reflects high levels of hunting in logged forest.

The above-mentioned species serve to illustrate one of the main subsidiary problems associated with logging. Even if logging does not directly influence the species populations, the opening up of an area through construction of logging roads encourages invasion by local people both for hunting and for practising shifting agriculture.

The sun bear does not survive well in disturbed habitat, but reasons for this are not clear. Wilson & Wilson (1975*a*) suggest that they may depend on bees' nests as a food source, but such nests are equally common in recently logged forest. Termites, another important part of their diet, are also abundant in logged forest. It may simply be that this species actively avoids the presence of humans.

Hornbills range widely in search of specific food sources (Medway & Wells, 1971). Their frequency of occurrence can be related to spatial arrangement of their preferred fruiting trees (e.g. *Ficus* spp., *Milletia atropurpurea*, *Parkia speciosa*, and species of the Fagaceae). The larger species (e.g. helmeted and rhinoceros hornbills) tend to travel in pairs, spending a long time at each fruit source and picking the ripest fruit. The smaller species (e.g. bushy-crested and pied hornbills) usually travel in flocks or family groups, remaining only a short time at each fruit source and being less selective. The numbers of larger species decline in logged forest (Rijksen, 1978), probably because many of their preferred food trees are high canopy species that are destroyed by logging and not compensated for by the flush of new growth. The smaller species may be more tolerant of differences in fruit availability and also better able to move around in the more scrubby regenerating forest vegetation. Kemp & Kemp (1974) have reported that all species previously present in primary

forest have reappeared in 15-year-old logged forest. Their ability to recolonise, provided that areas of primary or maturing logged forest remain, seems to be high.

Effects of logging on community structure

Logging necessarily has a considerable effect on the species composition of the plant community, and it may be expected that this will be reflected in changes within the animal community. The effect will be most severe where the forest is clear-felled and replaced by plantations of alien species; in fact, only a few rain forest species can exist in such areas.

Where selective logging is carried out at a low density, most species are able to survive in some numbers. Most seem able to maintain viable breeding populations although there may be a gradual decline to a point of stability; one-year-old logged forest may show a species density comparable with that in undisturbed forest (Wilson & Wilson, 1975*a*), whereas 3- to 5-year-old logged forest shows considerably lower population figures (this study). For many species, such as primates, the logged forest population has a healthy group structure (normal numbers of infants and juveniles, etc.; personal observations), so an ability to persist may be expected.

Associated with changes in population levels, there may also be marked shifts in species composition and dominance. McClure & Hussein bin Othman (1965) and Medway & Wells (1971) showed that bird population structure is modified considerably as a result of logging. Bernstein *et al.* (1976) and Martin & Asibey (in press) showed similar changes in primate populations in South America and West Africa, respectively. Struhsaker (1972) demonstrated a shift in species dominance: the black-and-white colobus monkey *Colobus guereza* is one of the least common species in primary forest, but the commonest in logged areas, while the reverse is true for the red colobus *C. badius*. In more general terms, Muul & Lim (1978) demonstrated a gradual shift in species composition and dominance among flying squirrels (Petauristinae) from primary forest through partially logged to secondary forest. It is beyond the scope of the present study to indicate such shifts, but it is hoped that longer-term studies now under way in West Malaysia will generate such information.

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