Comparative Study on Mammalian Fauna in Different Harvesting Intensities with Reduced-Impact and Conventional Logging in Sabah, Malaysia

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Introduction

Habitat destruction including logging and forest clearing for agriculture has always been a major threat for most mammals in Southeast Asia and other parts of tropical regions (Cuaron 2000). Large proportion of tropical production forests (i.e. zoned for timber production) has already become logged-over forests, on which much of its biodiversity depends now (Frumfoff 1995). We must establish a strategy to conserve these threatened animals in production forests as well as those in primary forests (Frumhoff 1995; Johns 1997; Meijaard et al. 2006).

Selective logging is one of the most prevalent land uses in Southeast Asia and other tropical regions. The method is known to severely damage the residual stand and affect forest structure and biodiversity even though only a small proportion of the trees are often removed (Johns 1988; Cannon et al. 1994; Pinard and Putz 1996; Laurance and Laurance 1996).

There are several techniques for controlling and minimizing logging damage (e.g., Crome et al. 1992). One of such methods, reduced-impact logging (RIL), is a set of guidelines to reduce the physical impacts on the ground, remaining standing trees, streams and ecosystem as a whole with the combination of a pre-harvest census, carefully controlled felling and skidding, lowered allowable cut and regulated machinery use (Putz and Pinard 1993).

Some studies examined the effects of reduced-impact logging in retaining forest biomass and in damage reduction to forests in Southeast Asia and reported that reduced-impact logging reduced the damage or injury to residual stand by 18-27% (Pinard and Putz 1996; Bertault and Sist 1997; Sist et al. 1998). However, there is no study available on the mammalian responses to reduced-impact logging (Meijaard et al. 2006), although mammals have important ecological roles such as seed dispersal and/or pollination in the forests.

In this study, we examined the effects of reduced-impact logging on the mammalian fauna by comparing the diversity and the abundance in a reduced-impact logged forest and a conventionally logged forest in Sabah, Malaysia.

Materials and Methods

Study site

Our study was conducted in Deramakot Forest Reserve (55,083ha), a reduced-impact logged forest and adjacent Tangkulap Forest Reserve (27,550ha), a conventionally logged forest, in Sabah, Malaysian Borneo. The climate is humid equatorial with a mean annual temperature of about 26℃. Mean annual rainfall is

about 3,500 mm (Huth and Ditzer 2001). The major vegetation of Deramakot is a mixed dipterocarp forest dominated by the family Dipterocarpaceae, while that of Tangkulap consists of abundant pioneer species of the genus *Macaranga* (Euphorbiaceae) (Seino et al. 2006).

Focal species and camera trap

Table 1 shows known middle- to large-sized mammal species in Deramakot (Matsubayashi et al. in press). We focused middle to large mammals because they are more likely to respond to landscape-level changes. Species of Chiroptera (bats), Dermoptera (colugo), small Insectivora (shrews), Scandentia (tree shrews), and small Rodentia (squirrels and rats) were excluded from this study. We follow the nomenclature by Payne et al. (1998).

A total of fourteen camera-traps were placed in the reduced-impact logged forest (7 traps) and the adjacent conventionally logged forest (7 traps) in February-March and August-September, 2006. In each forest, cameras were set up along animal trails at intervals of about 1km. We used automatic camera-traps (sensor camera Field note □, Marif, Yamaguchi, Japan) triggered by passive infrared motion sensors. All camera-traps were mounted on trees and set approximately 50cm from the ground, and were baited with durians or chicken, which were hung so high that animals could not consume them easily. All camera-traps operated 24 hours/day or until the film was fully exposed. We checked camera-trap sites every week to replace bait, and changed films and batteries if necessary. Day and time were recorded on each photograph.

We identified each photographed animal to species. As for genera *Muntiacus* (*Muntiacus atherodes* and *Muntiacus muntjak*) and *Tragulus* (*Tragulus napu* and *Tragulus javanicus*), we combined the congeneric species for each because they are indistinguishable on photographs. To exclude repetitive shots within a visit, we defined photographs of the same species within 60 minutes as 1 event. Number of camera-days was calculated for each camera trap. Since photographic rates correlate with animal density (Carbone et al. 2001), we used the number of independent photographs per camera-day as relative-abundance index (O'Brien 2003). In addition to camera-trap data, simultaneous field observations of larger mammals by night walking, driving census, and trace existence were also added to the species diversity list (Table 1).

We defined CNV/RIL ratio as the ratio between the relative-abundance index of each animal in the conventionally logged forest and that in the reduced-impact logged forest in order to discuss the relation between diet type and the persistence to heavy disturbance.

Differences in photographic rates between two forests were tested statistically using the Mann-Whitney *U* tests for each species recorded.

Results

Total study effort was 797 camera-days. Figure 1 shows species accumulation carves in each forest. Total 158 photographs were taken, of which 109 (396 camera-days) were from the reduced-impact logged forest and 49 (401 camera-days) were from the conventionally logged forest. In addition to the photographs of animals, there were 6 human records in conventionally logged forest.

Camera-trapped mammals consisted of 19 species, one Insectivora, three Primates, three Rodentia,

eight Carnivora, and four Artiodactyla (Table 1). Of these 19 species, 18 species appeared in the reduced-impact logged forest and 11 in the conventionally logged forest (Table 1). Six species including sun bear and clouded leopard were recorded only in the reduced-impact logged site whereas only short-tailed mongoose was not detected in the reduced-impact logged forest.

The most numerous species trapped was mouse-deer *Tragulus* spp. (29 photos) followed by Malay civet *Viverra tangalunga* (27 photos), bearded pig *Sus barbatus* (24 photos), and pig-tailed macaque *Macaca nemestrina* (21 photos). Muntjac *Muntiacus* spp. and pig-tailed macaque *Macaca nemestrina* showed a significantly higher photographic rate in the reduced-impact logged forest ($p<0.05$; $p<0.05$), while no species were significantly more abundant in the conventionally logged forest. Total photographic rate was also significantly larger in the reduced-impact logged site ($p<0.05$). CNV/RIL was lower in frugivorous primates and higher in omnivorous pigs or carnivorous civets.

Discussion

Difference in mammalian fauna and abundance

The forest harvested by reduced-impact logging showed greater species richness than the forest logged conventionally (Table 1). However, the observed difference in the number of detected species may just reflect lower animal density in the conventionally logged forest but not the species number per se. Comparative studies of mammalian fauna in several paired sites of closely located logged and unlogged forests in Indonesia and Peninsular Malaysia showed that species presence was similar between logged and unlogged forests in some areas although slight differences were observed (Johns 1997; Laidlaw 2000; Wilson and Johns 1982).

The results suggest that forests exploited using reduced-impact logging is able to carry a higher density of the middle to large mammals compared with forests logged conventionally. A previous study also revealed that the density of Bornean orangutan *Pongo pygmaeus* in our focal reduced-impact logged site (Deramakot) was 1.50 individuals/km^2, which was more than twice as high as 0.62 individuals/km^2 in the site logged conventionally (Tangkulap) (Ancrenaz et al. 2005). Earlier studies have already documented that large mammals in Borneo often become less abundant in selectively logged forests (Felton et al. 2003; Heydon and Bulloh 1996, 1997).

Effect of difference in habitat quality and human presence

Table 2 shows the summary of results from current and another study in Deramakot and diet type for each species. Among the six species listed here, two primates are the most fruit-dependent animals, mouse-deer and muntjac are less dependent, and bearded pig and Malay civet are the least. CNV/RIL was lower in frugivorous primates and higher in omnivorous pigs or carnivorous civets. This tendency that frugivorous animals are more vulnerable to logging and omnivores or carnivores are tolerant indicates that heavy logging reduces fruit production in forest and reduces animal population consequently. It is known that primates' degree of frugivory negatively correlates with species' persistence to logging (Johns and Skorupa 1987). Logging activities reduce the availability of food resources for frugivores, even where timber trees are not themselves used by animals (Johns 1988; but see Ganzhorn 1995). Poor logging operation in the

conventional method may cause the reduction in food resources and negatively affect the abundance of mammals.

In addition to food habitat, Marsh et al. (1987) suggested that the degree of territoriality could influence the adaptability of animals. Some primates and civets in Deramakot were strictly arboreal, although they were hardly recorded in this survey. Increased amount of canopy gap disrupts aerial pathway and arboreal species experience difficulties in locomotion (Johns 1997). Therefore, arboreal mammals can be more susceptible to logging.

Human activities accompanying logging practices can also affect mammals. It is known that hunting poses a great threat to large forest animals in many parts of the tropics (Linkie et al. 2003; Marshall et al. 2006). It can be even a greater threat to wildlife than timber harvesting in some cases (Bennet et al. 2002; Matthews and Matthews 2002; Walsh et al. 2003). In Deramakot and adjacent Tangkulap, hunting of wildlife is prohibited, but illegal hunting still occurs by villager and outsiders. Hunting pressure was higher in Tangkulap (conventionally logged area) because of easier access and insufficient prevention there. Therefore, Sabah Forestry Department has enforced regulation on the illegal hunting in Tangkulap area since 2005 (P. Lagan, Assistant District Forestry Officer, Deramakot, Sabah Forestry Department, pers. comm.).

Reduced-impact logging and the regulation of illegal hunting could maintain the food resources for mammals and secure their population. Further investigation is needed on the logging impact on the ecological functions of mammals in addition to that on the population density.

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Table 1. Known middle – large mammals in Deramakot and summary of photographic records from the reduced-impact logged forest (RIL) and the adjacent conventionally logged forest (CNV).

Species [a]	Common names	Records/camera-day RIL	Records/camera-day CNV	IUCN 2006
INSECTIVORA				
Erinaceidae				
Echinosorex gymnurus	Moonrat	0.005	N/A	LC
PRIMATES				
Lorisidae				
Nycticebus coucang	Slow loris	N/A	N/A	LC
Tarsiidae				
Tarsius bancanus	Western tarsier	0.002	0.002	LC
Cercopithecidae				
Presbytis rubicunda	Red leaf monkey	N/A	N/A	LC
Presbytis cristata	Silvered langur	N/A	N/A	Not listed
Nasalis larvatus	Proboscis monkey	N/A	N/A	EN A2c, C1+2a
Macaca fascicularis	Long-tailed macaque	0.002	0.002	NT
Macaca nemestrina	Pig-tailed macaque	0.043 *	0.010	VU A1cd
Hylobatidae				
Hylobates muelleri	Bornean gibbon	N/A	N/A	NT
Pongidae				
Pongo pygmaeus	Orangutan	N/A	N/A	EN A2cd
PHOLIDOTA				
Manidae				
Manis javanica	Pangolin	N/A	N/A	NT
RODENTIA				
Hystricidae				
Trichys fasciculate	Long-tailed porcupine	0.005	N/A	LC
Hystrix brachyuran	Common porcupine	0.012	N/A	VU A1d
Thecurus crassispinis	Thick-spined porcupine	0.008	N/A	NT
CARNIVORA				
Ursidae				
Helarctos malayanus	Sun bear	0.010	N/A	DD
Mustelidae				
Martes flavigula	Yellow-throated marten	N/A	N/A	LC
Mydaus javanensis	Malay badger	0.005	0.002	LC
Aonyx cinerea	Oriental small-clawed otter	N/A	N/A	NT
Viverridae				
Viverra tangalunga	Malay civet	0.040	0.026	LC
Cynogale bennettii	Otter-civet	N/A	N/A	EN A1ce, C2a
Arctictis binturong	Binturong	0.008	0.005	LC
Arctogalidia trivirgata	Small-toothed palm civet	N/A	N/A	LC
Paguma larvata	Masked Palm civet	N/A	N/A	LC
Paradoxurus hermaphroditus	Common palm civet	0.010	0.007	LC
Hemigalus derbyanus	Banded palm civet	0.003	N/A	LC
Herpestidae				
Herpestes brachyurus	Short-tailed mongoose	N/A	0.002	LC
Herpestes semitorquatus	Collared mongoose	N/A	N/A	LC
Felidae				
Neofelis nebulosa	Clouded leopard	0.002	N/A	VU C2a(i)
Prionailurus planiceps	Flat-headed cat	N/A	N/A	VU C2a(i)
Prionailurus bengalensis	Leopard cat	N/A	N/A	LC

[a] Listed by Matsubayashi et al. (in press). *Arctogalidia trivirgata* was added. [b] Two species were pooled. * Significantly more abundant, $P < 0.05$IUCN status of each species is also given: EN-endangered; VU-vulnerable; NT-near threatened; LC-least concern; DD-data deficient

Table 1. Known middle – large mammals in Deramakot and summary of photographic records from the reduced-impact logged forest (RIL) and the adjacent conventionally logged forest (CNV).(*Continued*)

Species [a]	Common names	Records/camera-day RIL	Records/camera-day CNV	IUCN 2006
PROBOSCIDEA				
Elephantidae				
Elephas maximus	Asian elephant	N/A	N/A	EN A1cd
ARTIODACTYLA				
Suidae				
Sus barbatus	Bearded pig	0.040	0.019	LC
Tragulidae		0.050 [b]	0.025 [b]	
Tragulus javanicus	Lesser mouse-deer			LC
Tragulus napu	Greater mouse-deer			LC
Cervidae		0.025 * [b]	N/A	
Muntiacus atherodes	Bornean yellow muntjac			LC
Muntiacus muntjak	Red muntjac			LC
Cervus unicolor	Sambar deer	0.005	0.003	LC
Bovidae				
Bos javanicus	Tembadau / Banteng	N/A	N/A	EN A1cd+2cd, C1+2a
	TOTAL	0.277 *	0.105	

[a] Listed by Matsubayashi et al. (in press). *Arctogalidia trivirgata* was added. [b] Two species were pooled. * Significantly more abundant, $P < 0.05$IUCN status of each species is also given: EN-endangered; VU-vulnerable; NT-near threatened; LC-least concern; DD-data deficient

Table 2. Summary of mammalian density (as indexed by the relative-abundance index) in Deramakot and diet type

Survey method	Species	Density RIL	Density CNV	CNV / RIL	Diet type	% Frugivory (Source)
Camera-trapping [a]		records/camera-day				
	Mouse-deer	0.050	0.025	0.50	Frugivore/ Browser	
	Malay civet	0.040	0.026	0.65	Carnivore/ Insectivore	15% (Davis 1962)
	Bearded pig	0.040	0.019	0.48	Omnivore	
	Pig-tailed macaque	0.043	0.010	0.23	Frugivore	88% (Caldecott 1986)
	Muntjac	0.025	0.000	0	Frugivore/ Browser	
Aerial nest count [b]		individuals/km^2				
	Orangutan	1.50	0.62	0.41	Frugivore	100 - 21% (Knott 1998)

[a] Only species trapped > 9 times were listed.

[b] Data from Ancrenaz et al. (2005)

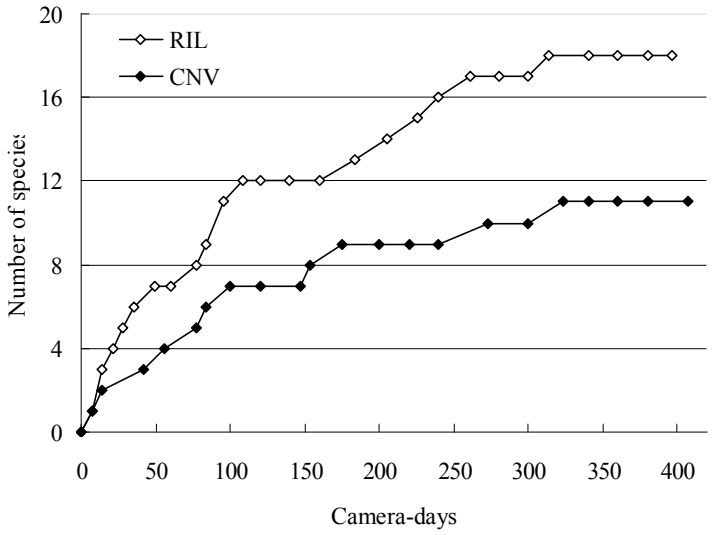

Fig. 1. Species accumulation carves in the reduced-impact logged forest (RIL) and the conventionally logged forest (CNV).