The distribution and persistence of primate species in disturbed and converted forest landscapes in Sabah, Malaysia: Preliminary results

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As disturbance and conversion of tropical rainforests due to man-made activities in many parts of the world continue at alarming rates, the future of many tropical rainforest species will depend more than ever on the effective management of a mixture of human-modified landscape. We studied the non-human primate community by direct and indirect sightings across a gradient of habitat disturbance, from old growth forest to heavily logged forest to oil palm plantation, in and around the Stability of Altered Forest Ecosystems (SAFE) Project experimental area in Kalabakan Forest Reserve, south central part of Sabah, Malaysian Borneo. Here we provide the preliminary analysis of our data. We confirmed the existence of nine, of the total of 10 species of non-human primates found in Sabah, within the surveyed areas. By using occupancy analysis we found no evidence of differential habitat disturbance effects on the primate community. We also found no evidence supporting differential habitat disturbance effects on the primate community based on animal body size or feeding habit. The lack in such evidences is surprising and it is likely due to the artifact of the small data set of this study. Interestingly, however, the presence of eight species of primates within the heavily logged forest sampling sites, which included endemic species and species of high conservation concern, e.g. orangutan, proboscis monkey and Bornean gibbon, shows that even highly disturbed forests are still valuable for primate conservation.

INTRODUCTION

Borneo is a center of biodiversity and endemism (Woodruff 2010). Yet it is under substantial threat from logging and other human-related pressures such as large-scale agriculture (Sodhi et al. 2004). Timber extraction rates in Borneo are among the highest globally (Sodhi et al. 2004), and the vast majority of forest outside conservation areas has already been intensively logged (Curran et al. 2004). Logged over forests, especially highly degraded ones, are under constant pressure for conversion to agricultural plantations, such as oil palm, or other uses (Fitzherbert 2008, Wilcove and Koh 2010).

The situation in the Malaysian state of Sabah, which occupies about 10 percent of the northern part of Borneo, is no exception. Here, disturbed forests and other converted habitats are increasingly covering much larger areas (Reynolds et al. 2011). Since this trend of land use is likely to continue in the foreseeable future, many tropical forest faunas in the long run will inevitably depend more heavily on the management of a mixture of natural forests and derived habitats on a landscape scale which include highly degraded forest areas and forest fragments

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within converted habitat matrix. It is, therefore, pivotal to address the question of whether tropical forest animals are able to adapt to significant changes in their natural habitats. Knowledge of how animals respond to habitat disturbance and conversion will enable conservation efforts to be concentrated where suitable habitats are still present. In this study we investigated the non-human primate species across a gradient of habitat disturbance from old growth forest to heavily logged forest to oil palm plantation. Our objectives were to document what species of primates are present across the varying levels of habitat disturbance and to examine the habitat disturbance effects on their persistence. We also examined two species characteristics i.e. body size and feeding habit, to explain species persistence across the different habitat disturbance levels.

METHODS

Study Sites

This study was carried out mainly at the Stability of Altered Forest Ecosystem (SAFE) Project experimental area within the Kalabakan Forest Reserve (4°33' N, 117° 16'E) in south central part of Sabah, Malaysian Borneo (Ewers et al. 2011). The SAFE project is a new rainforest fragmentation experiment where up to 800 ha of land will be set aside as forest fragments. Other sampling sites were located at the Barantian Tantulit Virgin Jungle Reserve (VJR), Ulu Segama Forest Reserve (USFR), Maliau Basin Conservation Area (MBCA) and an oil palm plantation (Fig. 1, Photo 1 and 2). With the exception of MBCA which is located

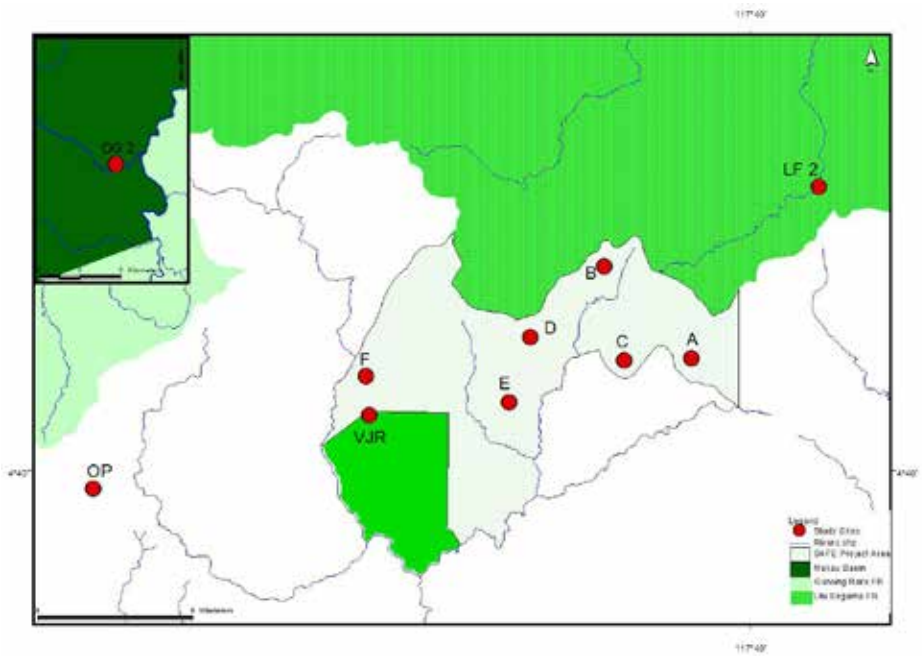

Figure 1. Map of the study area indicating the 10 sampling sites located in south central part of Sabah, Malaysian Borneo. The experimental area depicting Block A-F is the location of the Stability of Altered Forest Ecosystems (SAFE) project area.

Photo 1. One of the proposed forest fragments in Block F of the SAFE project area in central Sabah, Malaysian Borneo.

Photo 2. Sampling site in oil palm plantation (OP) located in the west of the SAFE project area.

approximately 60 km away from the SAFE project area, all other sampling sites were located within 10 km radius from this area.

The SAFE project area encompasses 7,200 ha of lowland dipterocarp rainforest most of which have already undergone multiple (two or three times) intensive rounds of logging, beginning in 1978 and ongoing until early 2000s. As a result of this treatment the remaining vegetation is highly disturbed and consists of a range of habitat types from grassy open areas and low scrub vegetation, to lightly logged forest on steep slopes and in rocky areas. The VJR is a lowland dipterocarp rainforest, adjoining Kalabakan Forest Reserve, which is strictly protected for forestry research and biodiversity conservation. Even so, while most part of the VJR is undisturbed or near pristine old growth forest, some levels of disturbance are apparent particularly near access roads. MBCA is a large totally protected area where logging is prohibited. Although in the past some logging activities have been carried out, this area consists mainly of undisturbed lowland dipterocarp rainforest. USFR is a lowland dipterocarp forest and being managed as

a commercial forest reserve. Many parts of USFR have been logged twice approximately 20 years ago.

Sampling design and methods of data collection

In order to achieve the objectives of this study, we walked through 10 existing human-made trails, each of which was between 800 - 1000 m long, in 10 sampling sites representing four habitat classes as follows: Old growth forest (OG), logged forest (LF), heavily logged forest (HLF) and oil palm plantation (OP). The OG habitat class was represented by two sampling sites in the MBCA and VJR, respectively. The LF habitat class was represented by one sampling site located in USFR. The HLF habitat class was represented by six sampling sites (i.e., the proposed fragments within the SAFE project area - Block A to F). The OP habitat class was represented by one sampling site located in a mature oil palm plantation in the west of the SAFE project area. All sampling sites were located between 200-500 m elevations.

We walked, day (0600-1200hrs) and night (1900-2400hrs), along the trails at all sampling sites once a month over a period of 12 months from November 2011 to October 2012. Each monthly sampling period lasted for about 10-14 days. We recorded all detections of both diurnal and nocturnal primates during the walk. Primate detections were made either directly through visual contacts or indirectly through animals' calls or the presence of newly constructed nests. Head lamps and spot light were used during night walks to assist nocturnal primates detection.

Data Analysis

In this report we provide information on the number of direct and indirect detections of each non-human primate species across all sampling sites and the distribution range of the primate species detected. In addition we also provide the relative abundance index (number of detections per month) of all primate species pooled across all sampling sites. An analysis was conducted to assess the occupancy probability of the primate community between habitat types based on the monthly primate detections/non-detections data set. We performed the analysis using the software PRESENCE (MacKenzie et al. 2006). Our aim here is to do a preliminary analysis of our data to explore if there is any signal indicating differential habitat effects on the primate community. We lumped together all primate species detections/non-detections data across all 10 sampling sites in 12 sampling occasions. Before running the analysis, we grouped the sampling occasions into 3- consecutive month periods, hence giving an overall number of four sampling occasions. For sites where the consecutive sampling period was less than 3-month, we scored such sites with a dash, '-'only. We used "habitat" in four different categories as covariate in the analysis. The four habitat categories were old growth forest (OG), logged forest (LF), heavily logged forest (HLF) and oil palm plantation (OP).

We also tested for differential patterns in occupancy probability across habitat types based on differences in body size and feeding habit or diet of the primate species using the same monthly detections/non-detections data set. For these analyses we carried out the tests separately for effect of "body size" and "feeding habit" as covariate. Body size was divided into three categories: Large (> 6 kg), Medium (3-6 kg) and Small (< 3 kg). While feeding habit was divided into four categories: Frugivorous, Folivorous, Insectivorous and

Omnivorous. Information on primate body size and feeding habits was based from Payne et al.(1985) and Johns & Skorupa (1987).

PRELIMNARY RESULTS

Overall results

The detection rates of primate species during the 12 months study period was generally low. Although the overall cumulative number of detections recorded was 259, the number of detections based on direct sightings was only 74 (or 28 % of the total number of detections). The remaining 185 were based on indirect detections. On the average, the detection rate recorded per month for each primate species based on direct sightings was < 1 detection/ month (Range: 0.08 -1.25 detections/month) (Table 1).

Altogether, nine species of primates were detected consisting of seven diurnal and two nocturnal primate species as follows: diurnal primates - the Bornean gibbon (*Hylobates muelleri*), orangutan (*Pongo pygmaeus*), proboscis monkey (*Nasalis larvatus*), red-leaf monkey (*Presbytis rubicunda*), grey-leaf monkey (*Presbytis hosei*), long-tailed macaque (*Macaca fascicularis*), pig-tailed macaque (*Macaca nemisterina*); and nocturnal primates - slow loris (*Nycticebus menagensis*) and western tarsier (*Trasius bancanus*). Three of the species are classified as Endangered on the IUCN Red List of Threatened Species (orangutan, proboscis monkey and Bornean gibbon), four are classified as Vulnerable (slow loris, western tarsier, grey-leaf monkey and pig-tailed macaque) and two species are regarded as Least Concern (red-leaf monkey and long-tailed macaque). The Bornean orangutan subspecies (*Pongo pygmaeus morio*), proboscis monkey, Bornean gibbon, grey-leaf monkey and red-leaf monkey are all Bornean endemic species (Payne et al. 1985).

All nine primate species recorded in this study were directly seen in the field, with two species were also detected indirectly through their calls or vocalization (Bornean gibbon, n = 47) and nests (orangutan, n = 138). Primate species that were most frequently detected by direct sightings were the orangutan (n = 15), pig-tailed macaque (n = 15),

Table 1. Summary of frequency of direct detection, indirect detection and average number of direct detection per month for nine species of non-human primates in and around the Stability of Altered Forest Ecosystem (SAFE) area in central Sabah, Malaysian Borneo.

Species	Direct detection	Indirect detection	Total number of detection	Averagedirect detection/month
Pongo pygmaeus	15	138	153	1.25
Macaca nemesterina	15	0	15	1.25
Tarsius bancanus	11	0	11	0.92
Hylobates muelleri	10	47	57	0.83
Presbytis rubicunda	8	0	8	0.67
Nycticebus menagensis	7	0	7	0.58
Macaca fascicularis	6	0	6	0.42
Nasalis larvatus	1	0	1	0.08
Presbytis hosei	1	0	1	0.08
Total	74	185	259	

western tarsier (n = 11) and Bornean gibbon (n = 10). Together, the four species accounted for 69 % of the total number of direct detections. The least number of detections were for proboscis monkey (n = 1) and grey leaf monkey (n = 1).

Distribution

Primate species that were detected in the most number of sampling sites were orangutan (9 sites), Bornean gibbon (8 sites) and red-leaf monkey (6 sites). Three species: long-tailed macaque, pig-tailed macaque and western tarsier- were detected in 5 sites, respectively, and slow loris in 4 sites. Two species, the proboscis monkey and grey leaf monkey, were detected in only one site, representing the least widespread species in this study. The number of primate species recorded in the old growth forest sites (OG & VJR) was 7 species, heavily logged forest sites (Block A-F) 8 species, logged forest site (LF) 2 species and oil palm plantation (OP) 2 species (Table 2).

Occupancy

Results of occupancy analysis on the effects of habitat types on primate community are shown in Table 3. In general, by considering models with Delta AIC < 2, two models have been selected as the best models i.e., psi(.),p(habitat) and psi(habitat),p(habitat). Both models are equally likely, but psi(habitat),p(habitat) appeared to be more realistic. The largest occupancy probability was recorded for the old growth forest sites, whereas the lowest were recorded for oil palm and logged forest sites. Nevertheless, occupancy probability was not significantly different across all habitat types (occupancy probability between habitats is significant when 95 % CI does not overlap). The individual site occupancy probability (psi) estimates by habitat types are as follows: old growth forest, psi = 0.6690 (95 % CI: 0.3878-0.8570), heavily logged forest psi = 0.4530 (95 % CI:0.4034-0.6788), Oil palm plantation, psi = 0.2909 (95 % CI: 0.4445 - 0.9013) and Logged forest, psi = 0.2222 (95 % CI:0.0562-0.5813).

Results of occupancy analyses on the effects of habitat types based on body size and feeding habits of primates are shown in Table 4 and 5, respectively. Occupancy probability was not significantly different between body size or between feeding habit categories, respectively. For both analyses, psi(.),p(size) and psi(.),p(diet) emerged as the best model (Delta AIC < 2). The occupancy probability estimate across all body size categories was 0.4617 (95 % CI: 0.350-0.5773). Whereas, the occupancy probability across all feeding habit categories was 0.5806 (95 % CI: 0.4348-0.7135).

DISCUSSION

In this study all primate species were rarely seen in any of the disturbed and converted habitats in and around the SAFE project area. Even in less disturbed sampling sites, in areas of old growth forest at MBCA and VJR, we also found similarly low densities. In a large undisturbed forests of Danum Valley Conservation Area (438 km^2) in the north of the SAFE project area the pig-tailed macaque and western tarsier were known to be abundant (ca. 15 individuals/km^2), but all other primate species were rare (Johns 1992, Heydon 1998). Our data add to these and other observations made on the primate community in disturbed and undisturbed forest elsewhere in central Sabah (Davis & Payne 1982), and indicate that the primate community in this region may generally exist at low densities.

Table 2. Details of the frequency of detections (via direct and indirect observations) of nine species of non-human primates at 10 different sites in and around the Stability of Altered Forest Ecosystems (SAFE) in central Sabah, Malaysian Borneo. Site A-F (Heavily logged forest), OG & VJR (Old growth forest), LF (Logged forest), OP (Oil palm plantation). Number in parenthesis indicates total primate species detected at the respective sampling sites.

Habitat type	OG		LF	HLF						OP	
Primate Species/Sampling site	OG	VJR	LF	A	B	C	D	E	F	OP	Total
Pongo pygmaeus	0	5	13	16	21	24	15	39	19	1	153
Hylobates muelleri	14	6	13	2	3	0	7	9	3	0	57
Macaca nemesterina	1	0	0	0	2	10	0	1	0	1	15
Tarsius bancanus	2	1	0	2	0	0	1	5	0	0	11
Presbytis rubicunda	2	1	0	1	0	0	1	2	1	0	8
Nycticebus menagensis	0	0	0	1	0	1	0	3	2	0	7
Macaca fascicularis	2	1	0	0	1	0	1	0	1	0	6
Nasalis larvatus	0	0	0	0	0	0	0	0	1	0	1
Presbytis hosei	1	0	0	0	0	0	0	0	0	0	1
Total	22(6)	14(5)	26(2)	22(5)	27(4)	35(3)	25(5)	59(6)	27(6)	2(2)	259
No. of visits	6	6	9	11	11	11	12	12	9	9	

Table 3. Detailed outputs of non-human primate occupancy analysis using "habitat" as covariate.

Model	AIC	Delta AIC	AIC Wgt	Model Likelihood	No. Par	-2*Log Like
psi(.),p(habitat)	263.94	0.00	0.4562	1.0000	5	253.94
psi(habitat),p(habitat)	264.91	0.97	0.2809	0.6157	8	248.91
psi(habitat),p(.)	265.99	2.05	0.1637	0.3588	5	255.99
psi(.),p(.)	266.99	3.05	0.0993	0.2176	2	262.99

Table 4. Detailed outputs of non-human primate occupancy analysis using body size as covariate.

Model	AIC	Delta AIC	AIC Wgt	Model Likelihood	No. Par	-2*Log Like
psi(.),p(size)	259.14	0.00	0.8626	1.0000	4	251.14
psi(size),p(size)	263.12	3.98	0.1179	0.1367	6	251.12
psi(.),p(.)	266.99	7.85	0.0170	0.0197	2	262.99
psi(size),p(.)	270.87	11.73	0.0024	0.0028	4	262.87

Table 5. Detailed outputs of non-human primate occupancy analysis using feeding habits as covariate.

Model	AIC	Delta AIC	AIC Wgt	Model Likelihood	No. Par	-2*Log Like
psi(.),p(diet)	246.73	0.00	0.8176	1.000	5	236.73
psi(diet),p(diet)	249.75	3.02	0.1806	0.2209	8	233.75
psi(diet),p(.)	258.97	12.24	0.0018	0.0022	5	248.97
psi(.),p(.)	266.99	20.26	0.000	0.0000	2	262.99

Despite consisting mainly of disturbed and converted habitats, the present study have confirmed the existence of nine, of the total 10 primate species found in Sabah, in the surveyed areas. The most frequently and most widespread species detected detected based on direct and indirect observations were orangutan and Bornean gibbon. The orangutan was even encountered in the oil palm plantation near a riverine forest, though the species is unlikely to be a permanent resident in the plantation area. As a species which is non-territorial, the orangutan is known to move great distance and it is known to be resilient to habitat disturbance (John 1985, Davies & Payne 1982, Ancrenaz et al 2010, Meijaard et al 2010). By contrast, the Bornean gibbon occupies exclusive home ranges and do not move at all from their former territories (Davies & Payne 1982, Hezebroek et al. 2012). The resilience of Bornean gibbon to habitat disturbance in the present study was therefore unexpected. The only primate species that was not detected was the silvered langur (*Trachypithecus cristatus*), a species mainly associated with coastal, riverine and swamp forest (Payne et al. 1985). Since these forest types are not typical habitats in the inland areas of Sabah, the absence of the silvered langur from the surveyed areas was not unexpected. The proboscis monkey, which share comparable habitats to that of silvered langur, was detected only once. Most observations of this species have been made in areas located less than 50 km away from the coast, but the species is also reported to be found much further inland, sometimes up to 750 km inland (Meijaard & Nijman, 2000; Sha et al., 2008). Proboscis monkeys are occasionally sighted in non-typical habitats of this monkey such as in hill forest and 'kerengas' or heath forest, but it is believed that the species is not resident in these forests, including the extensive hill dipterocarp forest throughout most of inland Borneo (Bennett & Sebastian 1988). Finally, The grey leaf monkey was also detected only once. This species was estimated to number on average 1.3 groups/ km square in pristine habitats in lowland forest in Sabah (below 500 m elevations), but no estimate is available in disturbed habitats (Davies & Payne, 1982). Johns & Skorupa (1987) suggested that the grey-leaf monkey is highly negatively affected by habitat disturbance and may therefore exist at low densities in such habitat.

Based on our preliminary data analysis, there is no evidence to indicate that the primate community is affected differently by habitat disturbance and conversion, which is rather unusual. The lack in such evidence is not known with certainty, though it is possible that this could be due to the artifact of the small data set in this study. Hence, further studies are necessary. Nevertheless, it is interesting to note that the heavily logged forest sites within the SAFE project area have recorded the highest number of primate species (8 species). Among the eight species of primates recorded here, three species are mainly leaf-eaters (leaf monkeys and proboscis monkey), three other species are mainly frugivorous though leaves also included as part of their diet (orangutan and macaques), while two species are insectivorous (western tarsier and slow loris). In terms of body size, the eight primate species varied from the heaviest > 50 kg (orangutan) to the lightest ca. 0.08 kg (western tarsier) (Payne et al., 1985). Thus, it seems that almost the full spectrum of life history characters present in the regional species pool are retained in these heavily logged forest.

The higher number of primate species detected within the SAFE project sampling sites classified

here as heavily logged forest, could be due to the effect of larger areal size surveyed at this area as opposed to the other sites. In general, studies at Danum Valley indicate that although some primate species are more affected than others, most primate species will be negatively affected by habitat disturbance in the long run (Johns, 1992). Two factors i.e., body size and the degree of frugivory, have been shown to affect survival ability of primates in moderately disturbed forest with smaller species and species less dependent on fruit as food sources surviving better (Johns & Skorupa, 1987). However, there is no evidence from the present study indicating differential effects of habitat disturbance in relation to body size and feeding habit of primate species.

The degree to which habitat disturbance will affect primate community will be related in some way to the severity of the disturbance. It may be logical to predict that repeated logging before full regeneration has taken place is likely to cause permanent species loss. But the fact that even in highly degraded forest, such as the SAFE project area, where a relatively high number of primate species are found is an indication that our knowledge on how wildlife response to habitat disturbance is still unsatisfactory. While more studies are required to clarify the processes and factors influencing vertebrate species persistence in heavily degraded forests, the implication of the findings of the present study is clear - that heavily degraded forests are still valuable for primate conservation including many species that are of conservation concern. Though not equivalent to areas of undisturbed forest, but given that the areal coverage of disturbed habitat in Sabah is increasing each year and undisturbed habitat is undergoing corresponding decreases, the role of disturbed habitat for biodiversity conservation in general should not be ignored.

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マレーシアサバ州での生息地の質の評価に基づく森林の喪失、劣化、断片化に対する霊長類の反応

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熱帯雨林の伐採と改変は、世界の多くの場所で懸念すべき速度で進行中で , 熱帯雨林に生息する種の生存は、人為的に改変された生態系で , どれだけ生き残ることができるかにかかっている . われわれは、マレーシア領ボルネオ島のサバ州の南部で , 原生林から重度に伐採された森林 , アブラヤシのプランテーションまでの様々な環境で , ヒト以外の霊長類がどのように生息しているのかを、直接観察と間接証拠の蓄積に基づいて調査した . ここでは , その予備的な結果を紹介する . サバに生息する 10 種の霊長類のうち , 調査域内で 9 種の霊長類の存在を確認した . 占有モデルの解析を行ったところ , 人為的な植生改変が霊長類の生息に与える影響は認められなかった . この傾向は , その種の体重や食性を考慮に入れても変わらなかった . この結果は予期しないものであり , おそらくはまだ観察事例数が小さいことに由来するものだろう . しかしながら , 重度に伐採された森林でも , オランウータンやボルネオテナガザルのように , 保全上注意すべき種を含む 8 種の生存が確認されたことは , このような森林でも霊長類の保全上の価値があることを示している .

（半谷吾郎訳）

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