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Occupancy status of Malayan leopard prey species in a fragmented forest in Selangor, Malaysia

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A study concerning prey availability for Malayan leopard (*Panthera pardus delacouri* Pocock 1930) in a highly fragmented secondary forest, namely: Ayer Hitam Forest Reserve located in Selangor, Malaysia was conducted from February 2008 to March 2009. The main objectives of this study were to investigate (i) *a priori* unknown leopard potential prey species existed in the study area and (ii) occupancy status of *a priori* known leopard potential preys with regard to the presence of anthropogenic factors in the habitat. Findings suggested that leopards in Ayer Hitam Forest Reserve feed mainly on Eurasian wild pig (*Sus scrofa*) supplemented by macaque and lesser mouse deer (*Tragulus javanicus*). Occupancy and detection probabilities for wild boar, macaque and mouse deer were relatively high indicating that there is no evidence of lack of prey sufficiency in the study area. Moreover, there is a high probability of encountering prey species for each leopard individual throughout the forest. We identified four active anthropogenic disturbance factors in the study area (*i.e*. plantation, construction, deforestation and presence of indigenous and local settlements). Construction activities had the most profound effect on occupancy status of wild boar and macaque while mouse deer was mostly affected by deforestation activities. This study indicated that although there is little concern regarding prey sufficiency, lack of space and presence of active anthropogenic disturbances are the most critical factors in determining leopard population viability in the study area.

***Key words*:** occupancy modeling, *Panthera pardus delacouri*, Malayan leopard, PRESENCE, prey species, anthropogenic disturbance, fragmented forest, Ayer Hitam Forest Reserve, Selangor, Malaysia

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INTRODUCTION

One of the most important concerns with regard to sustaining the population of large predators in an ecosystem is availability of prey resources and prey sufficiency. There must be a balance between prey and predator populations in a particular habitat (Lovari *et al*. 2009). However, this idea of a balanced ecosystem becomes especially complex in human-dominated areas where humans knowingly or otherwise have altered some of the local ecological parameters (Karanth & Sunquist, 1995, Macdonald & Thom 2001).

Leopards are famous for having a catholic diet (with 92 prey species recorded in Sub-Saharan Africa alone). However, they are generally reported to prey on medium-sized ungulates (Mills & Harvey 2001, Hayward *et al*. 2006, Owen-Smith & Mills 2008). Various studies have been done to investigate the feeding ecology of leopards in different habitat types (e.g. Kruuk & Turner 1967, Busse 1980, Bothma & Le Riche 1989, Johnson *et al*. 1993). Consequently, several studies have suggested that leopard is a selective predator and that predation activities are based on the size and type of their primary prey species (Karanth & Sunquist 1995, 2000; Hayward *et al*. 2006) and not on prey densities (Balme *et al*. 2007, Wegge *et al*. 2009).

Hayward *et al*. (2006) analyzed the data from 13 countries in 41 locations and found that leopards prefer to hunt prey species with a mass of 25 kg (range of 10-40 kg). They concluded that prey species outside of this preferred range are generally avoided because: (1) they are restricted to open habitats or (2) they have sufficient anti-predator strategies. Selective hunting behavior of large predators upon larger preys is particularly important when more than one large carnivore species exist in a habitat. Studies in tropical forests suggest that the non-selective predation pattern of large carnivores in these areas could be due to insufficient numbers of prey ungulates (Karanth & Sunquist 1995, Kawanishi 2002).

In Malaysia's tropical rain forests, studies by Kawanishi (2002) in Taman Negara National Park revealed that four leopard fecal samples contained wild pig and macaque. Wild pig had the highest occupancy rate among ungulates after muntjac in the said park. However, there is no specific study on leopard feeding ecology in Malaysia particularly in human-dominated forests. The main objectives of this study were to investigate the occupancy rates of *a priori* known potential prey species (wild boar, macaque and mouse deer) and examine the effect of human factors on occupancy status of these species. In addition, the current study aimed to investigate existence of *a priori* unknown potential prey species coexisting with leopards in Ayer Hitam Forest Reserve.

MATERIALS AND METHODS

Study area. Ayer Hitam Forest Reserve (AHFR) is located in Malaysia's capital agglomeration in the State of Selangor at latitudes 2º 57´ N to 3º 04´N and longitudes 101º 38´E to 101º 41´E (Idris *et al*. 2001). The forest is a highly fragmented tropical lowland forest which has lost approximately 70% of its area in less than 14 years and its current estimated size is 1,248 ha (Noor *et al*. 2007). Despite such a small forest area and its location in a rapidly developing area, it is still rich in fauna and flora

(Zakaria & Rahim 1999, Zakaria & Rahmat 1999, Julsun 2001, Zakaria *et al*. 2001, Norini *et al*. 2003, Faridah Hanum & Khamis 2004).

In addition, the study site is affected by the southwest monsoon season (Mohd Deni *et al*. 2009) and the mean temperature and relative humidity are 26.6 ºC and 83%, respectively (Primus 2000). A complex of farms is located on the southern border of the forest. This includes agriculture, fishery, buffalo and chicken farms with a total area of 163 ha (TPU; www.tpu.upm.edu.my/bi/slp/slp_all.htm). Previously, these farms were also parts of the forest, but after deforestations they became two fragmented forests: Ayer Hitam Forest Reserve and another unnamed small forest patch that was cleared in April 2008. This study was conducted in both Ayer Hitam Forest Reserve (1,248 ha) and its neighboring farm with a total area of 1,411 ha (Figure 1).

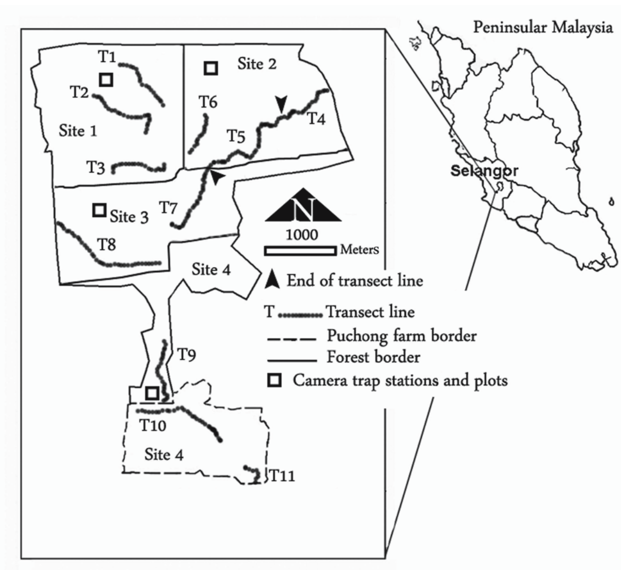

Figure 1. Location of study sites, transect lines and camera trap stations in Ayer Hitam Forest Reserve and Puchong Farm, Selangor, Malaysia.

Survey design and data collection. Data on direct observations, secondary signs (*e.g.* footprints, feces) and photographic images of four *a priori* identified prey species were collected for a duration of 13 months, starting from February 2008 . In addition, signs of other mammals were also recorded whenever encountered. The study area was divided into four main sites (Sites 1-4, see Figure 1) as this division was proportional to the resolution of required data (Henschel & Ray 2003). Previous studies suggested that some species show propensity for existing trails and riversides rather than thick vegetation (*e.g.* Stander 1998, Kawanishi 2002). In addition, it is not practical to track and identify the indirect signs of various species in the dense vegetation. Therefore, transect lines were selected based on main riversides or trails used by indigenous people. The uniformity of transect length per site was tested using the Chi-square test so that sampling efforts were uniform across all sites. Consequently, 11 transect lines with a total length of 11,685 meters were surveyed on a monthly basis to record the direct observations or secondary signs (*e.g.* tracks and dung) of preys in the sites (*i.e.* sampling units).

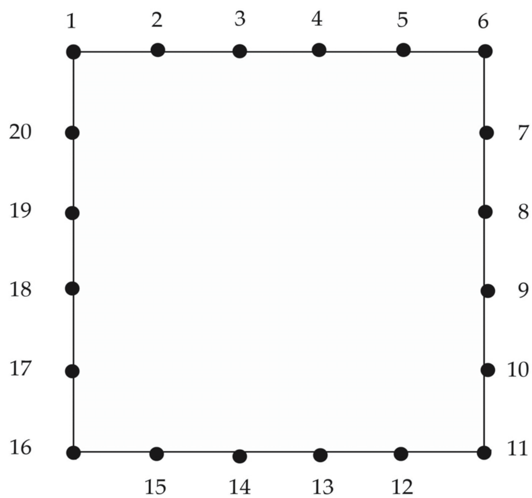

Figure 2. Establishment of plot at camera trap stations. Black dots denote the points where presence/absence of canopy cover was recorded.

In addition to direct observations and secondary signs, a total sampling effort of 247 camera trap nights were conducted in all four sites (1,411 ha) to: (1) explore the presence of any other potential prey/competitor species which might be coexisting with leopards; (2) confirm indirect signs of each prey species and (3) to supplement the detection/non-detection data from secondary signs in each site. Therefore, four digital cameras (Cuddeback Expert C-3300), with a one-minute shutter activation/delay, were set to monitor animal presence. A plot of 11 x 11 m was also established at each camera trap station to collect environmental data. The diameter of all live and dead trees with dbh (diameter at breast height) of more than nine cm was measured with diameter tape at 1.3 m above the ground level (McComb 2007) to obtain stand basal area (m^2) per ha. The number of stands in each plot was recorded to calculate stand density per ha. Furthermore, the percentage of ground slope/terrain gradient was obtained using a clinometer. To estimate the percentage of canopy cover, four sides of each plot were used and five equidistant points were selected along each side. As a result, the presence or absence of vegetation using a sighting tube was recorded at each point by 1 and 0, respectively. The total number of presence points (1s) was divided by 20 (total points) and multiply by 100 to estimate the percent cover in each plot (Figure 2; McComb 2007).

The probability of detecting each species based on their indirect signs in the first month of the study per site was estimated . The lowest detection probability which belonged to mouse deer (p = 0.24) was used to determine n_{power} (the total number of surveys required per month to maximize the probability of detection) in the study area. The following equations as discussed by Stauffer *et al*. (2002) were used:

$$Power_{unit} = 1-(1-p)^n$$

$$n_{Power} = \log(1-power_{unit})/\log(1-p)$$

where:

power unit = the probability of successfully detecting the species in the sampling unit and at least once;

p = detection probability in one survey when species is present;

n = the number of surveys in the sampling unit;

n = the number of surveys required.

Consequently, six sampling efforts (n = 5.86 rounded to 6) in each site were conducted per month to record the secondary signs.

Analysis. Single season subprogram of PRESENCE software version 2.4 (<www.mbr-pwrc.usgs.gov/software>) was used to estimate occupancy and detection probabilities of four *a priori* identified prey species. Selection of the model was based on: (1) sampling intervals (within the same year) and (2) the locations of study sites which were adjacent to each other (Figure 1) and thus, any entrance or exit by individuals of target species from one site to another is not considered as immigration or emigration (MacKenzie *et al*. 2003, MacKenzie 2005). This is a critical assumption of occupancy modelling indicating that sites should be demographically closed to changes of occupancy status within the study interval. This assumption hypothesizes at species level and therefore, even though there might be some movements of individuals into or out of the sites, these would not affect the model (Donovan & Hines 2007, Hines 2006, MacKenzie 2005).

Due to small size of the forest, heterogeneity in detection probabilities is unlikely (homogeneity assumption). However, predefined models provided by the program were developed to examine the possible heterogeneity in detection probabilities across the sites. In addition, four covariates were selected to take into account anthropogenic and natural sources of variation. These covariates included construction, plantation, deforestation activities and presence of accommodations of local settlements and indigenous people in the study area. Therefore, detection histories for wild pig (*Sus scrofa*), lesser mouse deer (*Tragulus javanicus*), long tailed macaque (*Macaca fascicularis*), pig-tailed macaque (*Macaca nemestrina*) and sampling covariates were made. To conclude detection/non-detection of each species for each month (*i.e.* sampling occasion) and each site, detection/non-detection data from 6 transect surveys conducted monthly/site and from camera trappings data in the same site were combined. This was done consistently across the sites. Therefore, the input spreadsheet data consisted of 13 sampling occasions per site indicating detection or non-detection (1 or 0, respectively) of the target species and construction activities, area of deforestation, plantations and number of accommodations on a monthly basis. Akaike's Information Criterion (AIC), the differences in AIC of each model and AIC of the best ranked model (ÄAIC) and AIC weights were used to select the best models. To examine fit of the data set to the model, goodness of fit test for the best ranked model was calculated for each species using PRESENCE software. Using goodness of fit test was done mainly to address the small size of the study area and its possible effect on dependency of detection histories in each site. As a requirement of the model, detection probabilities should be independent in the study sites (MacKenzie *et al.* 2005). Therefore, if there were any evidence of lack of fit over dispersion parameter, c-hat would be used to adjust the models (McCullagh & Nelder 1989). The models were run with 15,000 bootstraps to obtain the best performance of the program (Burnham & Anderson 2002, Khorozyan *et al.* 2008). The naïve occupancy rates (when detection probability = 1) and actual estimation of site occupancy as well as probability of detection were obtained with at least 95% confidence interval.

RESULTS

Table 1 shows the total months of survey that macaque, mouse deer and wild boar were detected in each study site. Table 2 signifies the anthropogenic factors were detected in the study area within the survey course. Data presented in Table 1 and 2 were used for PRESENCE modeling.

Predefined models indicated that homogeneity assumption of the model was met as AIC weights of single group model for wild boar ($W_i = 0.83$), macaque ($W_i = 0.99$) and mouse deer (W_i=0.87) were significantly higher than models with two or more groups of detection probability for each species (wild boar: W_i= 0.17, macaque: W_i = 0.01, mouse deer: W_i= 0.13; Table 3).

Goodness of fit test of the model sets revealed that 38% of the bootstrap Chi-square values for wild boar, 76% for macaque and 47% for mouse deer are lower than observed values. Therefore, it was concluded that there is no evidence of lack of fit in the data set. Table 4 shows three models which best fit each species when occupancy and detection rates are either constant or functions of selected covariates. Top ranked models (model likelihood = 1.00) developed for wild boar, macaque and mouse deer indicated that both naïve estimation of proportion of sites occupied by the species (when detection probability is perfect) and actual occupancy rates were constantly equal to one. These models suggested that the probability of detection of wild boar and macaque in the study area was relatively high as $p_{\text{wild boar}} \geq 0.64 \pm 0.069$ and $p_{\text{macaque}} \geq 0.72 \pm 0.064$. However, detection probability of mouse deer was lower than those of wild boar and macaque and it varied between 0.24 ± 0.066 and 0.72 ± 0.134. Moreover, results indicated that the distribution of wild boar and macaque were affected mostly by construction activities which took place in Site 3. In contrast, mouse deer was principally affected by deforestation activities.

Malayan leopard prey occupancy status

Table 1. Detections/non-detections of covariate species on a monthly basis in each site (Ayer Hitam Forest Reserve, Selangor, Malaysia).

Species	Site ID	Detected		Non-detected		Total	
		N	%	N	%	N	%
Wild boar	1	10	77	3	23	13	100
	2	12	92	1	8	13	100
	3	8	64	5	36	13	100
	4	9	69	4	31	13	100
Macaque	1	11	85	2	15	13	100
	2	7	54	6	46	13	100
	3	6	46	7	54	13	100
	4	9	69	4	31	13	100
Mouse deer	1	3	23	10	77	13	100
	2	2	15	11	85	13	100
	3	5	38	8	62	13	100
	4	8	62	5	38	13	100

N = number of survey month; % = percentages of total detections/non-detections for each species in each site.

Habitat characteristics and camera trapping results for wild boar, macaque and mouse deer are shown in Table 5. Although, vegetation is less dense in the vicinity of camera trap Site 4 (*i.e.* less canopy cover and stand density), the total number of photos taken from individuals of various species was much higher than the other sites. This result could be due to higher chance of detecting individuals in areas with less vegetation density. However, most of the potential prey species were photographed in the northern part of the forest (*i.e.* Sites 1 and 2) which had the highest canopy cover and stand density per ha. Even though camera trapping surveys were done continuously, the probability of photographing each species was much lower than direct observations and indirect signs ($p_{\text{wild boar}} \leq 0.06 \pm 0.04$ in all camera trapping occasions, $p_{\text{mouse deer}} \leq 0.25 \pm 0.21$ in 75% of camera trapping occasions and $p_{\text{macaque}} \leq 0.33 \pm 0.27$ in 87% of camera trapping occasions, respectively).

No endemic competitor species to the leopards or any other ungulates which could be considered as potential prey species for leopards were detected. However, porcupines were detected rarely in the study area. Feeding upon porcupine by leopard is supported by previous studies (Karanth & Sunquist 1995, Khorozyan *et al*. 2005, Sanei 2007). In addition, white-handed gibbon (*Hylobates lar*), stray dogs (feral species), jungle cat (*Felis chaus*; Sanei & Zakaria 2010) and common palm civet (*Paradoxurus hermaphroditus*) were the only mammals frequently detected (except for bat and small rodent species), while sun bear (*Helarctos malayanus*) was detected only once. Detections of these species were made through camera trappings, direct observations and indirect signs

DISCUSSION

One of the most important considerations regarding leopard population viability in an area is availability of prey species within the leopard's preferred weight range

Table 2. Frequency of anthropogenic factors detection in the study area during the study period (Ayer Hitam Forest Reserve, Selangor, Malaysia).

Month	Parameter[1]															
	Deforestation (ha)				Plantation (ha)				Construction (No.)				Accommodation (No.)			
Site ID	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0	0	0	0	0	0	0	0	0	0	1	0	0	3	2	22
2	0	0	0	0	0	0	0	0	0	0	1	0	0	3	2	22
3	0	0	0	42	0	0	0	0	0	0	1	0	0	3	2	22
4	0	0	0	42	0	0	0	0	0	0	1	0	0	3	2	22
5	0	0	0	42	0	0	0	0	0	0	0	0	0	3	3	21
6	0	0	0	42	0	0	0	0	0	0	0	0	0	3	3	21
7	0	0	0	42	0	0	0	0	0	0	0	0	0	3	3	21
8	0	0	0	42	0	0	0	0	0	0	0	0	0	3	3	22
9	0	0	0	42	0	0	0	0.64	0	0	0	0	0	4	3	22
10	0	0	0	42	0	0	0	0.64	0	0	0	0	0	3	3	22
11	0	0	0	42	0	0	0	0.64	0	0	0	0	0	3	3	22
12	0	0	0	42	0	0	0	0.64	0	0	0	0	0	3	3	22
13	0	0	0	42	0	0	0	0.64	0	0	0	0	0	3	3	22

[1]Area of deforestation and plantation was taken in to account for PRESENCE modeling. No = number of accommodations of local and indigenous settlements available in the study area as well as number of constructive projects conducted in each month of survey.

Table 3. Testing homogeneity of detection probabilities of prey species across the sites using predefined models provided by PRESENCE program.

Wild boar						
Model ranking	1	2	3	4	5	6
Model name	1 group C.P	2 groups C.P	1 group S.S.P	3 groups C.P	2 groups S.S.P	3 groups S.S.P
AIC	62.48	66.48	68.49	70.48	86.50	124.49
Δ AIC	0.00	4.00	6.01	8.00	24.02	62.01
W_i	0.83	0.11	0.04	0.02	0.00	0.00
Macaque						
Model ranking	1	2	3	4	5	6
Model name	1 group S.S.P	1 group C.P	2 groups C.P	2 groups S.S.P	3 groups C.P	3 groups S.S.P
AIC	64.72	73.29	76.41	78.18	80.39	97.86
Δ AIC	0.00	8.57	11.69	13.46	15.67	33.14
W_i	0.98	0.01	0.01	0.00	0.00	0.00
Mouse deer						
Model ranking	1	2	3	4	5	6
Model name	1 group C.P	1 group S.S.P	2 groups C.P	3 groups C.P	2 groups S.S.P	3 groups S.S.P
AIC	71.08	71.63	73.89	79.08	80.64	100.64
Δ AIC	0.00	0.55	2.81	8.00	9.56	29.56
W_i	0.49	0.37	0.12	0.01	0.00	0.00

Δ AIC - The difference of each model's AIC with AIC of the best ranked model; W_i - Model AIC weight; S.S.P - Survey-specific detection probability; C.P - Constant detection probability; Groups - clusters of sites with different probability of detection of the target species in each cluster.

Table 4. Top-ranked models developed for wild boar, macaque and mouse deer based on ΔAIC, AIC weights (W_i) and model likelihood. Three top models for each species are shown.

Wild boar			
Model name	ψ(.), *p*(construction)	ψ(.), *p*(.)	ψ(construction), *p*(construction)
AIC	62.07	62.48	64.01
ΔAIC	0.00	0.41	2.00
W_i	0.45	0..37	0.17
Model likelihood	1.00	0.81	0.36
Macaque			
Model name	ψ(.), *p* (construction)	ψ(.), *p*(.)	ψ(.), *p*(deforestation)
AIC	72.90	73.29	74.53
ΔAIC	0.00	0.39	1.63
W_i	0.44	0.36	0.19
Model likelihood	1.00	0.82	0.44
Mouse deer			
Model name	ψ(.), *p*(deforestation)	ψ(accommodation/deforestation/ plantation/ construction)[1], *p*(deforestation)	ψ(.), *p*(accommodation)
AIC	64.45	66.45	67.52
ΔAIC	0.00	2.00	3.42
W_i	0.33	0.12 x 5	0.05
Model likelihood	1.00	0.36	0.18

* = the relative difference in AIC of each model and AIC of the best ranked model.
** = ratio of each model's AIC weight over the top ranked model's weight.
Ψ = occupancy probability; *p* = detection probability. The best model has a lower AIC (*i.e.* Δ AIC= 0.00), a higher AIC weight and a model likelihood which equals to one.
[1]There is no difference between models when occupancy is a function of each of sampling covariates while detection probability is a function of deforestation.

Table 5. General characteristics of camera trap stations and summary of camera trapping data (Ayer Hitam Forest Reserve, Selangor, Malaysia).

Parameter	Station 1		Station 2		Station 3		Station 4	
	Station characteristics							
Stand density/ha	17,346.69		27,155.61		9,965.54		1,957.86	
Stand basal area (m^2/ha)	14.84		12.91		4.26		15.20	
Canopy cover (%)	85		95		90		40	
Slope (%)	3		45		30		12	
Elevation (meter above sea level)	138.68		95.70		111.25		49.07	
	Photo trapping summary							
	%	**N**	**%**	**N**	**%**	**N**	**%**	**N**
wild boar	0	0	50	1	0	0	50	1
macaque	10	1	30	3	0	0	60	6
mouse deer	23	3	54	7	8	1	15	2
Total photos	13	7	22	12	2	1	63	34
Total trap nights	63		60		64		60	

N = number of photo-trapped individuals of each species. % = percentages of total pictures taken for each species in each site. Simultaneous photographs and videos of the same species were excluded in the analysis. Pictures with more than one individual in a single frame were still counted as 1.

(Hayward *et al*. 2006). Even though the species is generally recognized as an opportunistic hunter which may feed on a wide variety of species, studies have proven the selective predation of leopards (Karanth & Sunquist 1995, 2000; Hayward *et al*. 2006). This is more critical in the rainforests as they generally support low ungulate biomass (Eisenberg & Seidensticker 1976, Eisenberg 1980). However, food consumption of an individual leopard is estimated at 1,008 kg/year for a female and 1,260 kg/year for a male individual (Bailey 1993, Stuart & Stuart 2000). Findings of this study revealed that conservation priorities of leopards in tropical forests may be affected in human-dominated habitats such as the Ayer Hitam Forest Reserve. PRESENCE modelling revealed that occupancy rates of wild boar, macaque and mouse deer were equal to one and detection probabilities particularly for wild boar and macaque were relatively high. Therefore, we concluded that despite the lack of prey sufficiency in primary tropical forests the individual leopard has a high chance of encountering a prey species within its preferred weight range. High occupancy rate and thus, high probability of presence of wild boar, macaque and mouse deer throughout the study area could be due to small size of the forest. Moreover, rapid shrinking of the forest (Noor *et al*. 2007) may have pushed the individuals of these species from surrounding deforested lands into the remaining habitat in the region (Knaepkens *et al*. 2004). Another hypothesis is that the movement of highly mobile leopard may be reduced by habitat fragmentation and hence, lead to a decrease of its population size, which in turn reduce the predation pressure on their preys thus, causing an increase in prey's population size. This is also viewed as the Mesopredator Release Hypothesis (Crooks & Soulé 1999; Ripple &Beschta 2003, 2004; Elmhagen & Rushton 2007).

Exceptionally high density of prey species in fragmented forests, particularly wild boar, has been reported previously from a lowland dipterocarp rain forest (Pasoh Forest Reserve, Negeri Sembilan) in Peninsular Malaysia giving an estimation of 1,837 and 1,346 kg/km^2 in 1996 and 1998, respectively (Ickes 2001). However, wild boar biomass in three study sites within Taman Negara National park, a primary forest in Peninsular Malaysia, was estimated at 133, 116 and 148 kg/km^2 (Kawanishi 2002) which is significantly lower than what was estimated in Pasoh Forest Reserve. Therefore, results of these studies support the fact that even though prey species, particularly ungulates, are expected to be rare in tropical rain forests, this situation may change in fragmented habitats such as Pasoh Forest Reserve and Ayer Hitam Forest Reserve.

It may be argued that white-handed gibbon could be considered as a potential prey species for leopards. However, white-handed gibbons are highly arboreal (Fleagle 1988) while leopards, particularly in dense vegetation, hunt by ambush (Hes 1991, Hart *et al*. 1996, Jenny & Zuberbuhler 2005). The body weight of an individual white-handed male gibbon is almost 5.7 kg (Macdonald 2001) which is lower than leopard preferred weight range of 10-40 kg (Hayward *et al*. 2006). In addition, the distribution of the gibbons is not wide spread in the study area since in 13 months of field surveys they were detected only a few times through direct observations. On the other hand, wild boar with body weight of 32 kg (Karanth & Sunquist 1992) and occupancy rate of 1 (100%) is present all over the study area. Therefore, it was concluded that the main prey of leopard is wild boar and this is supplemented by macaque and lesser mouse deer. Nevertheless, opportunistic predation on other species is possible as leopard has a diverse diet (Lekagul & McNeely 1977, Grassman 1997, Mills & Harvey 2001, Hayward *et al*. 2006).

Findings also indicated that construction activities at site 3 had the most profound effect on wild boar distribution. This is particularly important as leopard distribution in Ayer Hitam Forest Reserve is principally affected by wild boar presence (Sanei 2010). Considering the estimated annual food consumption of an individual leopard (female: 1,008 kg/year; male: 1,260 kg/year; Bailey 1993, Stuart & Stuart 2000) and estimated population size of four resident individuals in 1,411 ha of AHFR (Sanei *et al*. 2011), there is no evidence of lack of prey sufficiency in the study area. However, changes in distribution of wild boar in the habitat would affect the distribution and movement pattern of leopard individuals. Therefore, due to: (i) the small size of the forest; (ii) availability of high population of leopard in the study area and (iii) territorial behavior of leopard individuals changes in previously maintained spatial organization and movement pattern of each individual could result in conflicts and fatality among them (LeRoux & Skinner 1989). Extinction of the existing leopard population as the top predator of the forest would cause a considerable effect on the abundance of prey species, particularly wild boar and eventually, this would also change vegetation structure of the AHFR (Eisenberg 1989).

It is recommended that periodic survey efforts should be implemented within the study area to ascertain the density of wild boar, macaque and mouse deer as well as to estimate the carrying capacity of the habitat for both leopards and their potential prey species. Furthermore, annual surveys using distance sampling method should be conducted to monitor population trends of potential prey species over the years.

CONCLUSION

Wild boar, macaque and lesser mouse deer have been identified as the main leopard potential preys in the Ayer Hitam Forest Reserve. Occupancy rates of these species were constantly equal to one suggesting that populations of these species are sufficient in the study area. Detection probabilities of wild boar and monkeys were higher than those of mouse deer. In general, probability of detection through direct observations and indirect signs was significantly higher compared to camera trapping. Construction activities have been found as the main human causal factor affecting wild boar and macaque, while deforestation activities had affected the lesser mouse deer.

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