Original Research Article

Assessing habitat requirements of Asian tapir in forestry landscapes: Implications for conservation

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A B S T R A C T

The iconic large-bodied Asian tapir (*Tapirus indicus*) is endemic to Southeast Asia and is currently listed as endangered. To date, little is known about how tapir respond to habitat fragmentation in forestry landscapes. This study aimed to assess tapir occurrence in eight forestry reserves, outside the main protected areas in Peninsular Malaysia, using non-intrusive camera trapping methods. These reserves include logged or unlogged, contiguous or fragmented, peat swamp forest and lowland dipterocarp forest. Out of 345 camera-trapping locations, over six years, we detected tapir at 39 locations, represented by 960 images. An assessment of vegetation structure and landscape variables was conducted to identify the key factors associated with their tapir presence. We found that tapir occurrence significantly increased with the number of trees with a DBH of 5−45 cm, number of saplings, percentage of canopy cover, trees with a DBH of more than 45 cm and distance from the nearest road. While, tapir detection decreased with the number of dead fallen trees and number of palms. Our data highlights the importance of conserving these remaining fragmented forest reserves, particularly peat swamp forests and ways in which suitable habitat conditions may be created to support tapir populations. We conclude by discussing intervention approaches such as relocation, reintroduction and restocking and restoration to improve the structural attributes of vegetation utilised by tapirs.

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1. Introduction

Southeast Asian tropical forests have been cleared and fragmented significantly due to the conversion of forest ecosystems and land-use change associated with rapid economic development (Sodhi et al., 2010). Human activities such as poaching, urbanisation and conversion to agriculture have had negative impacts on terrestrial mammals, particularly on large-bodied mammals such as elephants and tigers (Ripple et al., 2016; Ripple et al., 2017). By 2100 it is predicted that about 21−48% of mammals in Southeast Asia will be extinct (Brook et al., 2003).

Reintroducing key species in disturbed and fragmented forests can reverse defaunation (Galetti et al., 2017), although, reintroduced populations generally experience a period with a relatively small population size, which makes them prone to inbreeding and loss of genetic variation (Seddon et al., 2014). While, restocking existing populations can boost population size, avert Allee effects (which might have contributed to past reintroduction failures), and increase genetic diversity (Seddon et al., 2014). Finally, wildlife corridors are commonly advocated to improve landscape connectivity and promote dispersal and thus increase genetic diversity. However, developing wildlife corridors for a single species can be costly (Dilkina et al., 2017) and building the least-expensive linkages can lead to ecologically poor outcomes (Dilkina et al., 2017).

The iconic large-bodied Asian tapir (*Tapirus indicus*) is endemic to Southeast Asia and is currently under threat. There are less than 2500 estimated mature individuals remaining in the wild (Brook et al., 2003; Traeholt et al., 2016). It is likely to become extinct in the wild without major management actions and is listed as endangered on the IUCN red list and listed in Appendix 1 of CITES. Anthropogenic impacts, such as deforestation and hunting, are major threats to tapir populations (Traeholt et al., 2016; Campbell et al., 2019). Paleontological evidence suggests that the species has been declining due to hunting pressure and populations are being further stressed by alteration and loss of its natural habitats across Southeast Asia (Cranbrook and Piper, 2013).

Modified landscapes such as agriculture, oil palm plantations and pasture are usually avoided by tapir, and the expansion of these land-uses are considered to be the greatest threat to its survival (Gemita et al., 2007; Medici, 2010). Tapir populations are also negatively affected by road accidents and infectious diseases from domestic livestock, which are set to increase with increasing modification of natural landscapes due to development (Medici, 2011). Finally, landscape fragmentation reduces connectivity and influences tapir dispersal in tropical forests (Carrillo et al., 2019). Cove et al. (2014) reported that major protected areas located adjacent to a corridor could boost tapir occurrence.

The occurrence of tapir varies significantly across Southeast Asia with the highest densities in Malaysia and Sumatra and with the lowest in Thailand and Myanmar (Linkie et al., 2013). In Malaysia the density of tapir in a primary forest in Krau Wildlife Reserve, Peninsular Malaysia was recorded at 3.72 adult tapirs/100 km^2; much higher than the countrywide average (Traeholt and Mohd Sanusi, 2009). While, a camera trapping study conducted by Rayan et al. (2012) in Gunung Basor Forest Reserve in Peninsular Malaysia estimated the population density of tapir to be 9.49 adult tapirs/100 km^2. Clements et al. (2012) reported that about 37% of forested land in Peninsular Malaysia is potentially suitable habitat for tapir.

The ecology of large mammal populations in unprotected forest fragments remains poorly understood (Canale et al., 2012). For most conservation priority species in Peninsular Malaysia, in particular, endangered species, management actions are limited to protected areas (e.g. national parks) (Jambari et al., 2019) even though some populations extend beyond protected areas and live within production forests (Magintan et al., 2017). Until 2017, there was about 5.77 million ha of forested land in Peninsular Malaysia and around 4.81 million ha of that area is categorized as Permanent Reserved Forest and managed under the Sustainable Forest Management (SFM) (Forestry Department Peninsular Malaysia, 2017). In Malaysia, forestry reserves are subjected to selective logging, which results in biodiversity loss (Jamhuri et al., 2018). Selective logging removes commercial timber trees and leaving the rest intact. However, on average, for every tree harvested, up to 30 more can be severely damaged, causing substantial canopy damage (Asner et al., 2005). In addition, logging requires the construction of temporary dirt roads and those frontier roads become more permanent and wider over time; in conjunction with promoting access for other activities which in turn accelerate deforestation (Asner et al., 2005).

This study aims to assess the occurrence of tapir in fragmented forestry reserves, which are located outside the main protected areas (e.g. national parks and wildlife reserves) using non-intrusive camera trapping methods. Our study is the first to examine the effect of forest fragmentation on tapir populations in forestry reserves. We predict that the occurrence of tapir is higher in larger fragmented forest, as their home ranges are usually over 10 km^2. Furthermore, this study also aims to identify the key environmental factors that influence the occurrence of tapir in fragmented forest landscapes in Peninsular Malaysia, to determine whether tapir populations could persist in forest patches of differing quality. Our findings will make an essential contribution to developing conservation strategies for the Asian tapir in forestry landscapes and offer insights into what and when measures (i.e. corridor and conservation translocation) should be taken by government stakeholders to conserve the tapir subpopulations.

2. Methods

2.1. Study area

The study area presents a rare opportunity to study tapir subpopulations in forest patches, embedded in a highly urbanized and semi-urban matrices. Camera-trapping was conducted in eight forestry reserves across Peninsular Malaysia, mainly in the states of Selangor and Negeri Sembilan (Fig. 1): Pasoh Forest Reserve (PFR), Sungai Menyala Forest Reserve (SMFR), Kenaboi Forest Reserve (KFR), The North Selangor Peat Swamp Forest (NSPSF), Sungai Lalang Forest Reserve (SLFR), Ayer Hitam Forest Reserve (AHFR), Bukit Cerakah Forest Reserve (BCFR) and Bangi Forest Reserve (BFR). These forestry reserves consisted of logged and unlogged forest and comprised fragmented and contiguous forested areas (Table 1).

Pasoh Forest Reserve (PFR) (2°58′55″N, 102°18′47″E) is located in Negeri Sembilan and reached an altitude of 75−150 m above the sea level (Fig. 1). The forest consists of lowland and hill dipterocarp forest, which includes about 600 ha of primary forest within a total area of 2,450 ha and is separated from the contiguous forest.
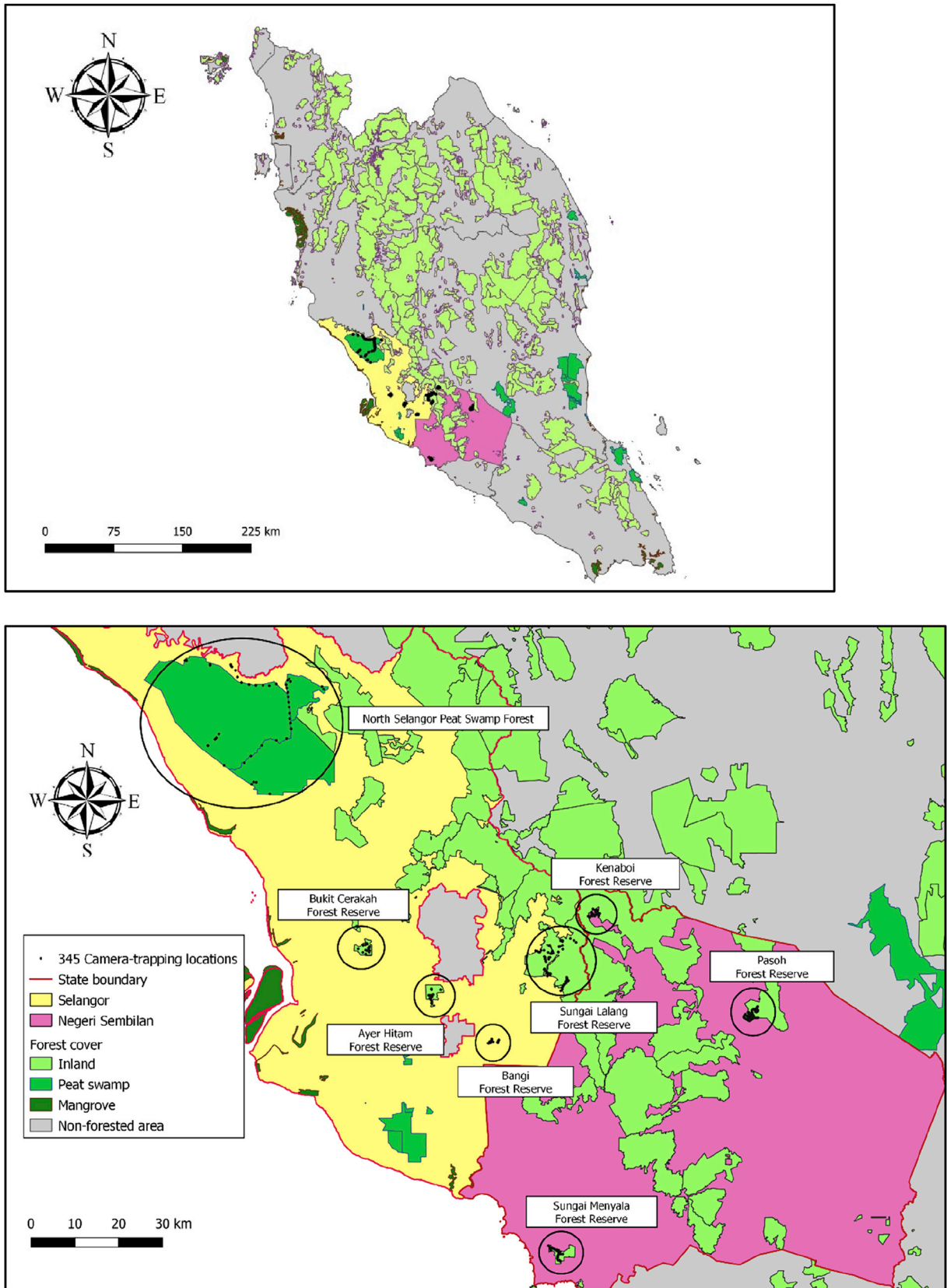
Fig. 1. Location of eight forestry reserves in the states of Selangor and Negeri Sembilan, Peninsular Malaysia.

Table 1
Summary of field survey camera trapping effort and site attributes.

Study areas	Survey dates	Area (ha)	Altitude, mean ± SD (m)	Forest type	Habitat type	Landscape type	No. sampling locations
NSPSF	March 2013−October 2014	78,000	23.40 ± 10.15	Peat swamp	Logged	Continuous	45
SLFR	November 2015−April 2016	17,028	244.50 ± 80.27	Lowland dipterocarp	Logged	Continuous	60
	June 2016−August 2016						30
BFR	March 2017−May 2017	100	74.03 ± 24.56	Lowland dipterocarp	Logged	Patch	30
AHFR	December 2016−February 2017	1,248	73.90 ± 43.46	Lowland dipterocarp	Logged	Patch	30
BCFR	August 2016−October 2016	817	75.50 ± 39.75	Lowland dipterocarp	Logged	Patch	30
PFR	May 2015−November 2015	2,450	132.10 ± 11.20	Lowland dipterocarp	Unlogged	Patch	60
SMFR	January 2018−March 2018	1,305	42.20 ± 13.71	Lowland dipterocarp	Unlogged	Patch	30
KFR	March 2018−May 2018	9,420	309.50 ± 66.13	Lowland dipterocarp	Logged	Continuous	30

Sungai Menyala Forest Reserve (SMFR) (2° 29′ 39.61″ N, 101° 53′ 22.272″ E) is located in Negeri Sembilan (Fig. 1). It is a fragmented forest of 1,305 ha, at an altitude of 20−60 m above sea level. SMFR consists of lowland dipterocarp forest that includes some areas of virgin forest, including a 300-year-old hollow tree and a 45 m high Jelutong tree.

Kenaboi Forest Reserve (KFR) (3° 7′ 39.72″ N, 102° 2′ 56.4″ E) is located in Negeri Sembilan, comprising lowland and hill dipterocarp forests (Fig. 1). With the total area of 9,420 ha, it has been extensively logged-over. It is found at an altitude range of 180−550 m above the sea level.

The North Selangor Peat Swamp Forest (NSPSF) (3° 27′59.2″N, 101°26′13.2″E) is the second largest remaining extensive patches of peat swamp forest in the Peninsular Malaysia (Fig. 1). NSPSF is located in Selangor. The forest area consisted of a few forestry reserves, covering nearly 78,000 ha. NSPSF is made up of a secondary mixed swamp forest and lowland dipterocarp forest at an average altitude up to 250 m above the sea level. It comprises the Sungai Karang Forest Reserve (50,106 ha), the Sungai Dusun Wildlife Reserve (4,330 ha) and the Raja Musa Forest Reserve (23,486 ha) (Parish et al., 2014).

Sungai Lalang Forest Reserve (SLFR) (3° 3′26.31″N, 101°53′13.95″E) is located in Selangor. SLFR consists of an extensive lowland and hill dipterocarp forest reserve (Fig. 1). The majority of the reserve is a contiguous forest with an estimated area of 17,028 ha.

Ayer Hitam Forest Reserve (AHFR) (3° 1′12.52″N, 101°38′46.76″E) covers an area of about 1,248 ha of isolated forest. AHFR is located in Selangor. (Fig. 1). AHFR is categorized by its lowland dipterocarp forest, standing at an altitude of 15−250 m above sea level.

Bukit Cerakah Forest Reserve (BCFR) (3° 6′34.43″N, 101°30′10.17″E) is a forest patch, characterized by lowland dipterocarp forest (Fig. 1). BCFR is located in Selangor. BCFR is located at an altitude of about 150 m above sea level and has a total area of 817 ha, encircled by housing and commercial areas.

Bangi Forest Reserve (BFR) (2°54′50.68″N, 101°46′1.18″E) is located in Selangor (Fig. 1). With an average altitude of 40−130 m above sea level, BFR is the smallest fragmented forest of lowland dipterocarp forest among all the study sites we investigated, with a total area of about 100 ha.

2.2. Sampling design and camera trapping

Three hundred and forty-five camera-trapping locations were established in the eight forestry reserves (Table 1). We set up one camera (Bushnell Trophy Cam HD) at each location. The first data collection period was at NSPSF in March 2013, and the final collection period was in April 2018 at Kenaboi Forest Reserve. The camera traps were deployed at potential tapir sites, such as locations with visible animal trails, wallows, tributaries, animal droppings and at forest edges (Sasidhran et al., 2016). The camera traps were attached to suitable trees, 30−50 cm above the ground and at least 300 m away from each other. As these were ground facing camera traps, we cleared away debris and vegetation that could obscure animals or reflect the flash, making the image appear overexposed and also triggering the sensor producing empty images (Rovero et al., 2010). The camera traps were activated for 24 h with a 1- or 10-s interval between exposures, taking three photographs per second or 10 s. The cameras were left for a total of two weeks or a month at each location before relocating them to new locations. Nichols and Karanth (2002) suggested that two weeks is the minimum sampling period, but we sampled some locations for four weeks to increase the probability of detecting tapir. All camera-trapping locations were marked using a Global Positioning System (GPS). By the end of the survey, all cameras were retrieved, and all images of Asian tapir were compiled and sorted with over-exposure photographs that were unidentifiable excluded.

2.3. Assessment of stand and landscape attributes

We measured six stand-level attributes at each camera-trapping location, which were used as fixed variables in a model of tapir detection. Vegetation plots of 20 m × 20 m were established to measure the following vegetation attributes: (1) number of trees with a DBH of 5−45 cm, (2) number of trees with a DBH of more than 45 cm, (3) number of saplings, (4) number of palms, (5) percentage of canopy cover and (6) number of dead fallen trees. The measurements taken in the peat swamp forest were from the plots of vegetation of 20 m × 50 m. Therefore the measured variables were corrected to match the vegetation plots of 20 m × 20 m. We used a camera to capture images of tree canopy cover at each location. We then analyzed the images using MATLAB 7.1 to estimate canopy cover, with a light gap image analysis script developed by Korhonen and Heikkinen (2009). We also recorded landscape-level attributes including: (1) forest type (lowland dipterocarp or peat swamp), (2) habitat type (logged or unlogged), and (3) landscape type (continuous or patch) and (4) distance from each camera-trapping location to the nearest road measured using Google Earth Pro. The continuous forest encompasses an area of more than 5000 ha, but the patch covers less than 5000 ha (Fischer and Lindenmayer, 2005; Kraaijeveld-Smit et al., 2007). Finally, the sampling duration (two weeks or one month) was also included in the model to characterise sample effort. The selection of these attributes was based on previous studies (Sasidhran et al., 2016; Jamhuri et al., 2018; Tee et al., 2018) conducted in tropical forests, which mainly assessed the abundance of mammal species (Table 2).

2.4. Data analysis

We applied a generalised linear mixed model (GLMM) in the GenStat v12 statistical package VSN International to assess the relationship between Asian Tapir occurrence and the predictor variables. To prevent over-fitting during model selection, we built two sets of models, one set including just stand-level attributes and another set, including landscape-level attributes. We first performed a correlation test for multicollinearity among variables in the global models, which comprised all predictor variables. Predictor variables characterized by strong collinearity ($|r| > 0.7$) were dropped from the subsequent model (Dormann et al., 2013). However, none of the predictor variables was removed from the global models as all variables were found to be independent. Tapir detection in the camera traps was used as a proxy for the occurrence and characterised by the number of photographic images recorded at each of the 345 sites. Location and year were included as random variables, whereby the ten stand- and landscape-level attributes and sampling duration were included as fixed variables. The GLMM used a Poisson distribution and logarithm link function. The dispersion parameter for the variance of the response is fixed at 1 to adjust for overdispersion. If overdispersion occurs in a dataset, it can distort the estimated standard errors and test statistics the overall goodness-of-fit (Harrison et al., 2018).

We then selected the most parsimonious model using a subset of the predictor variables based on the minimum Akaike's Information Criterion (AIC) values and then calculated the AIC weights (Burnham and Anderson, 2002). Since the sample size (n), relative to the parameter (K), was large (n/K > 40) for at least one of the models (sample size, n = 345), we used an AIC to compare the models (Burnham and Anderson, 2002). To complement the AIC values, we used the r.squaredGLMM function in the MuMIn package to compute marginal R^2 values (variance explained by only fixed effects) for each best model (Barton, 2014). We selected the candidate models from all possible combinations of all parameters, which were then fitted to the data and ranked by ΔAIC values (AIC − AICmin).

Table 2
Responses of tapir detection to predictor variables.

Variable	Slope	Standard errors	95% confidence interval	
			2.5%	97.5%
Number of trees with DBH 5−45 cm	0.057	0.007	0.042	0.071
Number of trees with DBH >45 cm	0.143	0.039	0.066	0.217
Number of saplings	0.064	0.005	0.054	0.073
Number of palms	−0.031	0.008	−0.048	−0.015
% of canopy cover	0.005	0.001	0.002	0.007
Number of dead fallen trees	−1.049	0.091	−1.227	−0.871
Distance from the nearest road	0.145	0.006	0.132	0.157
Forest type	Lowland dipterocarp: 0.000 Peat swamp: 6.602	2.955	0.810	12.394
Landscape type	Continuous forest: 0.000 Patch: 0.493	2.448	−5.292	4.306
Sampling duration (stand-level)	One month: 0.000 Two weeks: 6.266	8.661	−23.240	10.709
Sampling duration (landscape-level)	One month: 0.000 Two weeks: 0.658	1.342	−3.287	1.971

3. Results

3.1. General occurrence pattern of Asian tapir

Out of 345 camera-trapping locations, 39 recorded tapir, with a total of 960 photographs taken throughout the field survey. NSPSF recorded the most occurrences of tapir with a total of 908 photographs. PFR recorded 25 photographs of tapir whereas BCFR captured 24 photographs and three photographs of tapir were captured in SLFR. Throughout our sampling, no tapir was detected in BFR, AHFR, SMFR and KFR.

3.2. Key factors of the occurrence of Asian tapirs

The GLMM summary statistics showed that tapir detection was associated with some of the predictor variables (Table 2). Out of 13 predictor variables, 12 were associated with the occurrence of Asian tapirs. The most parsimonious stand-level model (the lowest value of AIC = 3944) explained 15.20% (marginal R^2) of the variation in tapir occurrence corresponded to best subsets with seven terms. The model accounted for 70% of the Akaike weights in the model set (Table 3). The occurrence of tapir increased with the number of trees with DBH 5 cm–45 cm, trees with DBH more than 45 cm, canopy cover, and the number of saplings. Interestingly, the occurrence of tapirs decreased with the percentage of number of palms and the number of dead fallen trees. The detection of tapirs in stand-level model was six times lower in a two-week sampling duration than one-month sampling duration.

The most parsimonious model (the lowest value of AIC = 2763) explained 51.76% (marginal R^2) of the variation in the detection of tapirs corresponded to best subsets with five terms. The model accounted for 63.13% of the Akaike weights in the model set at the landscape level (Table 3). Our study revealed that the occurrence of this species was positively related to distance from the nearest road. Forest type, landscapes and sampling duration were also important factors in predicting tapir's occurrence in our study. Tapir detection in peat swamp forests was seven times higher than the lowland dipterocarp forests. It was 0.11 times lower in forest patches than contiguous forests. The tapir detection landscape-level model was 0.7 times lower in a two-week sampling duration than one-month sampling duration.

4. Discussion

4.1. Distribution patterns of Asian tapir

Based on the photographic evidence, Asian tapirs were found mostly in larger forestry reserves (NSPSF, PFR and SLFR) rather than small fragmented areas, which is most likely due to their preference for larger home ranges of over 10 km² (Abdul Ghani, 2009; Traeholt, 2005; Traeholt and Sanusi, 2009). Most tapir sightings were in the peat swamp area of NSPSF, as they prefer tropical moist forest and wetter locations with closed forest surroundings (Lynam et al., 2012). However, this may also be due to the longer sampling duration in NSPSF compared to other study sites. Tapir occurrences are commonly correlated

Table 3
Best subsets from the selected models, with the most parsimonious model with comparatively high adjusted R^2 and the lowest value of AIC in bold.

Model	Best subsets with n term(s)	Explanatory variables	AIC	Δi	Relative likelihoods	Akaike weights, Wi
Stand-level	1	Tree with DBH 5–45 cm abundance	5485.6	1542	0	0
	2	Sapling abundance + Sampling duration	4711.8	768.2	1.540×10^{-167}	1.079×10^{-167}
	3	Tree with DBH 5–45 cm abundance + Dead fallen tree abundance + Sampling duration	4253.6	310	4.835×10^{-68}	3.387×10^{-68}
	4	Tree with DBH 5–45 cm abundance + Dead fallen tree abundance + Palm abundance + Sampling duration	4012.4	68.8	1.149×10^{-15}	8.048×10^{-16}
	5	Tree with DBH 5–45 cm abundance + Dead fallen tree abundance + Palm abundance + Sapling abundance + Sampling duration	3962.6	19	7.485×10^{-5}	5.244×10^{-5}
	6	Tree with DBH 5–45 cm abundance + Tree with DBH > 45 cm abundance + Dead fallen tree abundance + Palm abundance + Sapling abundance + Sampling duration	3945.3	1.7	0.427	0.299
	7	**Canopy cover + Tree with DBH 5–45 cm abundance + Tree with DBH > 45 cm abundance + Dead fallen tree abundance + Palm abundance + Sapling abundance + Sampling duration**	**3943.6**	**0**	**1**	**0.701**
Landscape-level	1	Forest type	3190	427.2	1.717×10^{-93}	1.084×10^{-93}
	2	Distance from nearest road + Forest type	2775.5	12.7	0.002	0.001
	3	Distance from nearest road + Forest type + Habitat type	2773.3	10.5	0.005	0.003
	4	**Distance from nearest road + Forest type + Landscape type + Sampling duration**	**2762.8**	**0**	**1**	**0.631**
	5	Distance from nearest road + Forest type + Habitat type + Landscape type + Sampling duration	2763.9	1.1	0.577	0.364

with water bodies, where most of their active time occurs, such as for foraging (Medici, 2010). In general, tapirs need to remain close to permanent water bodies, and their home ranges may even shrink during dry season (García et al., 2012). Surprisingly, tapir were also detected in the fragmented BCFR. This could be because BCFR is an important lowland habitat for large mammals (Tee et al., 2018) like tapir, even though it is relatively isolated. Fragmentation of the forest habitat will not only reduce the viability of tapir populations in BCFR, but also further expose them to anthropogenic threats such as poaching and road accident because of easy access and close proximity to human habitation (Azhar et al., 2013; Malaysian Nature Society, 2018).

4.2. Relationships between occurrence of Asian tapir and habitat quality

Our findings provide a more thorough understanding of the ecological processes influencing tapir persistence in fragmented forestry landscapes. We found that tapirs have specific ecological requirements, and thus may be particularly sensitive to habitat loss, degradation and fragmentation. Vegetation structural characteristics are key factors influencing habitat quality for tapirs. Our results revealed that the number of saplings, palms, trees with DBH 5 cm−45 cm, trees with DBH more than 45 cm and dead fallen trees and percentage of canopy cover greatly influenced the occurrence of tapir. Previous studies revealed that all five tapir species select their habitations according to two main factors: accessibility to food and water resources (Salas and Fuller, 1996; Foerster and Vaughan, 2002; Naranjo, 2009). Tapirs are exclusively herbivorous, mainly feeding on young leaves, buds, and soft twigs, as well as fruits and leaves of some palm species. We also found that tapir prefer oil palm plantations around the NSPSF, most likely due to an extensive variety of food sources available in the ecotone between oil palm plantations and forests (Azhar et al., 2014).

Our study showed that the occurrence of tapir was higher when the number of forest palms were lower. Higher palm tree abundance and bamboo bunches may result in a lower occurrence of mammal species like tapir, as higher palm tree abundance could be a barrier to movement. For example, medium-to large-sized mammals such as tapirs are more likely to use broader forest trails rather than ones full of obstacles (Bernard et al., 2013; Mohamed et al., 2013) like bamboo bunches and palms. The presence of bamboo also limits the growth rate and survival of trees, which slows forest succession (Griscom and Ashton, 2003) by decreasing the number of saplings, which is also a valuable food resource for tapir. Tapirs generally prefer secondary forests, particularly for foraging, due to the high rate of production of young stems stimulated by increased light availability (Tobler, 2002). The presence of lianas and young trees are also a key factor determining mammal species richness (Jamhuri et al., 2018). In Peninsular Malaysia, tapirs are most likely to prefer foraging in forests where many medium-sized trees, shrubs and saplings are present (Mohamed and Traeholt, 2010).

We found that the abundance of trees with both a DBH of 5−45 cm and more than 45 cm are among the important factors that affected the occurrence of tapir. Thick vegetation with a high diversity of stand trees with a DBH of 5−45 cm and more than 45 cm, fallen trees, liana and palms are likely to affect movement and food availability for large-sized mammal species such as tapir (Tee et al., 2018). According to Adila et al. (2017), mammal species richness increases with the abundance of trees with a DBH between 30 and 45 cm. In addition, large trees are very important in providing habitat and food resources for forest mammals like tapir. The absence of large trees has been shown to influence the survival of forest mammal species (Adila et al., 2017). Similarly, our study showed that the occurrence of tapir was relatively low when the number of dead fallen trees increased. This could also be due to limitations on tapir movement (Sasidhran et al., 2016), with obstructions to foraging making it difficult for large-bodied mammals like tapir to rummage within their habitat and browse for food.

We found that the occurrence of tapir increased with the percentage of canopy cover. Tapir throughout the year, depending on temperature and rainfall (Oliveira-Santos et al., 2010), prefers dense canopy cover. Generally, dense forest cover are important during times of extreme in temperature, while open environments are used during transitional temperatures.

Our results revealed that tapir occurrence increased with distance from the nearest road, which is consistent with other studies that suggest tapir tend to avoid disturbances. Most tapir species prefer highly vegetated areas rather than open and disturbed surroundings (Lira et al., 2004). There is evidence that animals tend to avoid areas perceived as being of higher risk of predation or hunting (Laundre et al., 2010). Tapirs become more cryptic in areas with high hunting pressure, avoiding locations with human presence and shifting their activity patterns to evade contact with humans (Cruz et al., 2014; Lira et al., 2004).

Our photographic evidence also revealed that tapir were found mostly in larger forest landscapes, which were commonly connected to other tracts of non-reserve forests. Among the four forest patches, tapir were also found in BCFR, which provides significant and unique lowland habitat for large mammals like tapir, although it lacks connectivity to other patches or contiguous forests (Tee et al., 2018).

Large-sized herbivores such as tapirs are commonly found in unlogged and logged forests (Magintan et al., 2017). The occurrence of tapir in the logged habitats is possibly attributed to the combination of large protected areas and significant tracts of unlogged forest (Linkie et al., 2013). One of the key ecological factors for differences in mammal diversity found in logged and unlogged forests is the variation in food resource availability (Magintan et al., 2017). The occurrences of mammals in logged forests are not unusual, and our study, like other studies, show that logged forest can support a wide variety of medium-to large-sized mammals like tapir (Mohd Azlan, 2006).

4.3. Conservation implications

Our data raises an important question concerning the management of isolated subpopulations of tapir and threatened large-bodied mammal species in fragmented forests. What should be done with the existing subpopulations of tapir and other conservation priority species in the fragmented and sizeable (>500 ha) forestry reserves (i.e. BCFR and AHFR)?

A commonly advocated solution is the creation and protection of wildlife corridors; one of the most common conservation strategies for addressing fragmentation worldwide (Hilty et al., 2019). However, corridors have limited effectiveness, especially within the urban matrix which surrounds many of the fragmentated reserves we assessed. Both linear- and stepping stone-type corridors can be impractical and very costly because urban land acquisition is socially challenging and identifying wildlife corridors requires time-consuming surveys (Pinter-Wollman, 2012; Riggio and Caro, 2017). In reality, the corridors may not be readily applicable to developing or impoverished nations lacking adequate financial resources and institutional support.

There are three alternative options to addressing what should be done with the existing subpopulations. First, stakeholders can consider relocating the remaining tapirs from the fragmented forestry reserves to the nearest contiguous forests (i.e. SLFR). However, relocation should only be considered as a last resort option as any isolated population should be protected *in situ*. Second, subpopulations should be consistently monitored and restocked to maintain viable populations in the fragmented reserves. Third, tapirs should be reintroduced into their former habitats (i.e. AHFR and SMFR). Given that most of the fragmented forestry reserves are located within highly urbanized Klang Valley (i.e. BFR, AHFR and BCFR), it is imperative that the stakeholders should speed up their effort to conserve the subpopulations of tapir and its habitat. However, these reserves still need to be protected from hunters and other anthropogenic threats affecting tapirs in the smaller forest fragments (Medici and Desbiez, 2012).

A reintroduction and restocking strategy has great potential for the Asian tapir as translocation risk is low, in terms of feasibility and benefits (Louys et al., 2014). Tapir have existing populations in the wild and ex-situ breeding facilities that make it a good candidate for restocking or reintroduction (Louys et al., 2014). Even though tapirs are mostly associated with forests, they can survive in almost all types of degraded habitat, are highly adaptable to changes in diet, and being relatively near to human populations if left undisturbed (Louys et al., 2014). Furthermore, tapirs are least likely to be involved in significant human-wildlife conflict (Louys et al., 2014). Restoring habitat in fragmented ecosystems would also help prevent further decline of tapir populations. Habitat restoration should be implemented by emphasizing the maintenance of vegetation structural characteristics that tapir may utilize across their range. At the same time, better law enforcement is needed to curtail poaching and forest encroachment.

5. Conclusion

Forest fragmentation and habitat loss are undoubtedly the main threats towards declining tapir population in Southeast Asia. Our findings provide useful information for governments, NGOs and conservation stakeholders concerning their habitat requirements and distribution patterns to support conservation planning. Most importantly, the findings highlight the importance of conserving the remaining tapir subpopulations in fragmented forestry reserves. To safeguard tapir populations in forestry reserves, it is strongly recommended that the government step up law enforcement and consider animal relocation, restocking and reintroduction, and ecological restoration to improve degraded habitat.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2020.e01137.

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