# WILDLIFE MONITORING AT LABIS TIMUR ECOLOGICAL CORRIDOR (CFS2:PL1) IN JOHOR, MALAYSIA

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## ABSTRACT

Deforestation and illegal poaching caused unprecedented biodiversity loss in Labis Timur Ecological Corridor (CFS2:PL1), Johor, Malaysia. Habitat fragmentation from deforestation caused wildlife diversity depletion by reducing habitat connectivity into degraded forest patches. Thus, it had become a major issue in wildlife management. The diversity of mammals in this corridor was largely unknown and had seldom been quantified. The objectives of this study are to determine the diversity and occupancy of mammals in Labis Timur Ecological Corridor (LTEC) and to determine which location in LTEC is most suitable for building a viaduct. We conducted a camera trap and wildlife sign survey at 34 locations within the LTEC. The study was carried out from 17$^{th}$ October 2016 to 7$^{th}$ January 2017. During a total of 2,503 trap nights, 24 species of terrestrial mammals were photo-captured represented by eight orders and 14 families. This included mammals such as Sunda Pangolin (*Manis javanica*) and Malayan Tapir (*Tapirus indicus*) which were listed as critically endangered and endangered species respectively, based on IUCN Red List. From this 24 species, 11 species were Carnivora, five species were Artiodactyla, and three species were Primates. One species each represented the Order Perissodactyla, Proboscidea, Rodentia, Pholidota and Eulipotyphla. The Wild boar species (RAI ± SE; 9.78 ± 2.30) represents the highest Relative Abundance Index (RAI) amongst the mammals' species recorded, while Leopard cat species (RAI ± SE; 0.03 ± 0.41) represents the lowest RAI. We recommend: (1) viaduct to be built at locations with the highest species richness (camera traps A037 and A078); (2) demarcating LTEC as High Conservation Value (HCV) area; (3) comply firmly on Reduced Impact Logging guidelines for logging activities in this area.

**Keywords**: Mammal diversity, camera trap, habitat fragmentation, species occupancy, species richness.

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## INTRODUCTION

Conversion of natural forests into development areas, habitat fragmentation and illegal harvesting of flora and fauna is currently one of the massive threats to biodiversity (Nowell & Jackson, 1996; Ewers *et al*., 2009) and contributes to challenges in conservation. The large scale conversion of natural forests caused habitat destruction and raised concerns about the impacts on biodiversity. In the year 2015, Malaysia lost more than 4,930 $km^2$ of land due to deforestation and plantation activity (Mongabay, 2018). Thus, it had reduced species richness and composition in terms of biodiversity (Fitzherbert *et al*., 2008; Danielsen *et al*., 2009; Foster *et al*., 2011).

Studies on biodiversity, including wildlife, need to be carried out at different sites to record species patterns of diversity and compositions and also in diverse forest settings, in order to make an accurate prediction concerning ecological corridors to enhance biodiversity conservation. The best setting of such ecological corridors can mitigate the impacts of habitat fragmentation by providing safe movements for various wildlife species between fragmented forest complexes. In addition, such ecological corridors provide better foraging ground and ensure gene pool perpetuation of the wildlife species (Ford *et al*., 2009; Downs & Horner, 2012).

Malaysia is equally concerned about conserving its rich biodiversity resources by reducing these threats. This concern was reflected in the adoption of the Central Forest Spine (CFS) Master Plan in Peninsular Malaysia (IC-CFS Master Plan, 2009). The CFS initiatives aimed to maintain a contiguous network of forest complex through the creation of ecological corridors to link fragmented forests. In addition to local funding, the project also received international funding from the Global Environmental Fund (GEF) through the Improving Connectivity in The Central Forest Spine Landscape (IC-CFS) Project.

The CFS Master Plan recommended 37 ecological corridors, including the LTEC, to be established in Peninsular Malaysia. In addition, to secure the water catchment and the healthy functioning of various ecological functions, the CFS Master Plan aimed to conserve many of the endangered wildlife, including Asian elephants (*Elephas maximus*), Malayan tigers (*Panthera tigris*), Malayan tapirs (*Tapirus indicus*) and Malayan gaurs (*Bos gaurus*). In LTEC, the development of an ecological corridor includes the construction of viaducts or underpasses along existing roads or railway lines. The Department of Wildlife and National Parks (PERHILITAN) had proposed a potential site to construct the viaduct based on the recommendations of the CFS Master Plan and with some preliminary monitoring. However, a scientific study is needed to verify this proposal. Therefore, this study aims to answer three research questions: (1) What is the diversity status of mammals in LTEC? (2) What is the mammals' species occupancy in LTEC? (3) Which location is the most suitable for building viaduct in LTEC?

## METHODOLOGY

### Study Site

LTEC (Figure 1) consists of several forest reserves located in the eastern part of Johor state. Among them are Lenggor Timur Forest Reserve (FR) (83.6 km$^2$), Lenggor Tengah FR (231.36 km$^2$), Semberong Tambahan FR (46.38 km$^2$), Labis Timur FR (306.77 km$^2$), Labis Tambahan FR (37.87 km$^2$), Ulu Sedili Timur FR (57.95 km$^2$), Ulu Sedili Tambahan FR (158.63 km$^2$) and Mersing FR (229.88 km$^2$). The total estimated area of LTEC is 1,152.44 km$^2$. The highest elevation of LTEC is 348 m above sea level and most of the forest here are lowland dipterocarp forest. Little is known about the recent diversity status of mammals at various sites in LTEC.

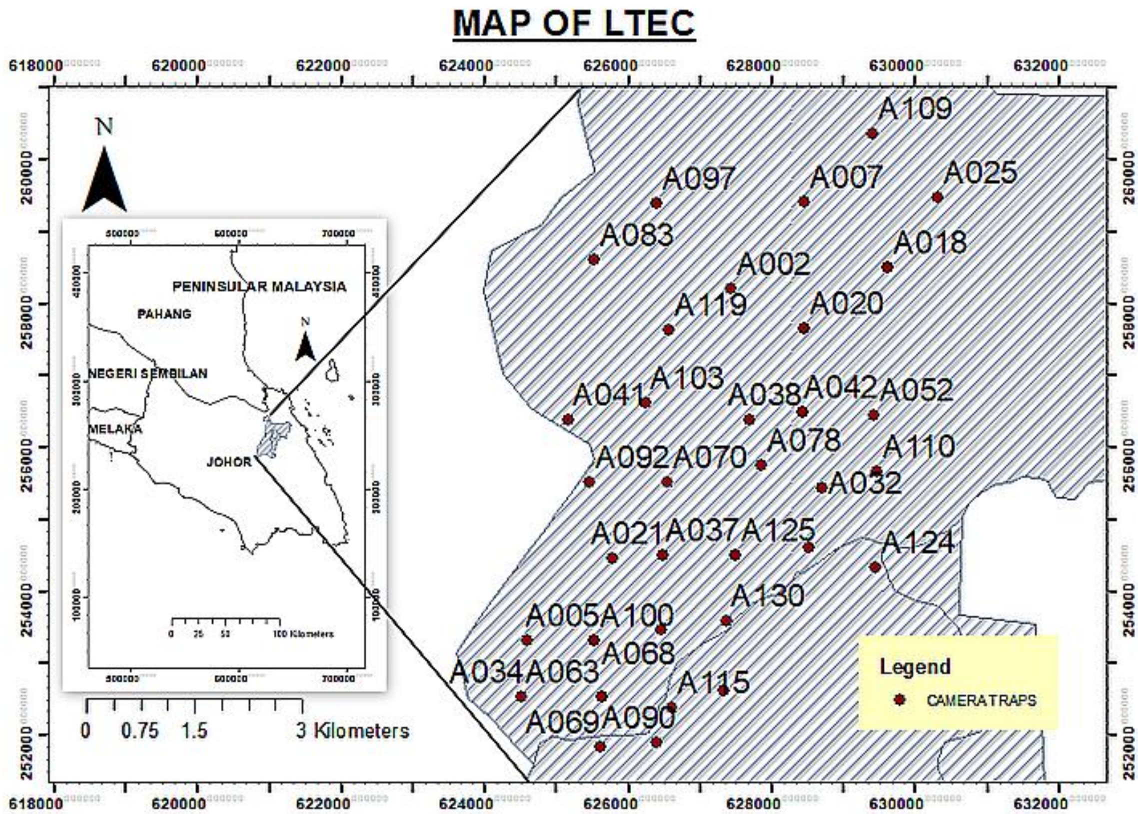


**Figure 1** Location of camera traps in LTEC

### Sampling design

Camera trap surveys were carried out for almost three months from 17$^{th}$ October 2016 to 7$^{th}$ January 2017 at 34 locations (Figure 1). The grid sampling method was employed at a density of one trap-point per 1 km$^2$ plot and the camera traps were monitored monthly. All photographs were digitally stamped with date and time, following the camera trap settings.

Location and name of the species in each captured image were recorded following Duckworth and Pine (2003). Lesser mouse-deer (*Tragulus kanchil*) and Greater mouse-deer (*Tragulus napu*) were both labelled as Mouse-deer as it was physically hard to differentiate between both species based on camera trap photographs. Thus, they were considered as morphospecies. In total, 23 species instead of 24 species of mammals were used in the data analysis. Due to a similar reason, small mammals such as shrews, bats, treeshrews, rats, and squirrels were not identified at species level. The photographs also documented human presence (visitors, rangers, villagers, and poachers). To optimise data gathering and time used, wildlife sign survey was done simultaneously during each camera trap survey. Direct and indirect observations such as live sounds, scratch marks, faecal deposits, footprints, wallows and feeding signs were documented during the camera trap survey.

### Data analysis

Wildlife photographs were identified into species-level after detailed characteristic observation following Francis and Barrett (2008). Detection list was provided following the number of mammals present in all installed camera traps in LTEC. Relative Abundance Indices (RAI) was calculated by the detection rate of each species. RAI was demarcated as the number of independent photographs of each species per 100 camera-trap nights (O'Brien *et al*., 2003). Uninterrupted photographs of similar species were classified independently when separated by more than 30 minutes (Yasuda, 2004; Phan *et al*., 2010).

Multi-species occupancy was estimated in which each species was considered independently (MacKenzie *et al*., 2006). This was calculated using R-Statistic Software version 3.4.1, GNU (Bell Laboratories). Occupancy estimation took into account the percentage of location occupied by each species across all camera trap locations. Large mammals were defined as mammals with mass of more than 20 kg (Morrison *et al*., 2007). To select the highest species count of mammals across all camera trap locations, species richness analysis of mammals detected was done following each camera trap location compared to all camera trap locations.

## RESULTS

### Overall Mammal Species Detection

A total of 24 species from eight orders and 14 families of wild mammals were recorded in the consecutive 2,503 total trap nights (Table 1). Mammals photo-captured included 11 species of Carnivora, five species of Artiodactyla, and three species of Primates. There were one species each of Perissodactyla, Proboscidea, Rodentia, Pholidota and Eulipotyphla recorded. Six species of large mammals were recorded which comprised of the Asian elephant (*Elephas maximus*), Barking deer (*Muntiacus muntjac*), Bearded pig (*Sus barbatus*), Malayan sun bear (*Helarctos malayanus*), Malayan tapir (*Tapirus indicus*), and Wild boar (*Sus scrofa*). Wild boar had the highest RAI (RAI ± SE; 9.78 ± 2.30) amongst the mammals' species recorded followed by Pig-tailed macaque (*Macaca fascicularis*) (RAI ± SE; 9.03 ± 2.25) (Table 2). The lowest RAI were Leopard cat (RAI ± SE; 0.03 ± 0.41) followed by Small-toothed palm civet (RAI ± SE; 0.04 ± 0.04).

Amongst the 24 species of mammals recorded, Sunda pangolin (*Manis javanica*) was listed as Critically Endangered based on International Union for Conservation of Nature (IUCN) Red List while Asian elephant and Malayan tapir were listed as Endangered. Although this forest complex is part of the tiger habitat range (DWNP, 2008), we did not detect any Malayan tiger (*Panthera tigris*) during this survey. Mesopredator such as Leopard (*Panthera pardus*) was also not recorded.

**Multi-species Occupancy of Mammals**

Based on occupancy analysis using a 95% confidence level, several mammals have high occupancy compared to others. This included Wild boar, Pig-tailed macaque, Mouse-deer, Malayan porcupine (*Hystrix brachyura*), and Barking deer (Figure 2). Mammals with low occupancy included Malayan tapir, Moonrat (*Echinosorex gymnura*), Banded palm civet (*Hemigalus derbyanus*), and Marbled cat (*Pardofelis marmorata*). However, based on the overall graph in Figure 2, the long lines of the credible interval on the dots suggest that more data was needed to make the outcome of the study more robust. The occupancy of large mammals such as the Asian elephant, Bearded pig, Malayan tapir, and Malayan sun bear was still relatively low.

**Table 1** Detection of mammal species in LTEC. Note on the abbreviation of IUCN Status (V= Vulnerable; LC= Least Concern; E= Endangered; NT= Near Threatened; CE= Critically Endangered)

| No | Scientific Name | Common Name | Family Name | IUCN Status |
|---|---|---|---|---|
| | **Artiodactyla** | | | |
| **1** | *Sus barbatus* | Bearded pig | Suidae | V |
| **2** | *Sus scrofa* | Wild boar | Suidae | LC |
| **3** | *Muntiacus muntjac* | Barking deer | Cervidae | LC |
| **4** | *Tragulus napu* | Greater mouse-deer | Tragulidae | LC |
| **5** | *Tragulus kanchil* | Lesser mouse-deer | Tragulidae | LC |
| | **Perissodactyla** | | | |
| **6** | *Tapirus indicus* | Malayan tapir | Tapiridae | E |
| | **Proboscidea** | | | |
| **7** | *Elephas maximus* | Asian elephant | Elephantidae | E |
| | **Primates** | | | |
| **8** | *Macaca nemestrina* | Pig-tailed macaque | Cercopithecidae | V |
| **9** | *Macaca fascicularis* | Long-tailed macaque | Cercopithecidae | LC |
| **10** | *Trachypithecus obscurus* | Dusky langur | Cercopithecidae | NT |
| | **Carnivora** | | | |
| **11** | *Prionailurus bengalensis* | Leopard cat | Felidae | LC |
| **12** | *Pardofelis marmorata* | Marbled cat | Felidae | NT |
| **13** | *Herpestes urva* | Crab-eating mongoose | Herpestidae | LC |
| **14** | *Martes flavigula* | Yellow-throated marten | Mustelidae | LC |
| **15** | *Helarctos malayanus* | Malayan sun bear | Ursidae | V |
| **16** | *Prionodon linsang* | Banded linsang | Viverridae | LC |
| **17** | *Arctictis binturong* | Bearcat | Viverridae | V |
| **18** | *Viverra zibetha* | Large Indian civet | Viverridae | LC |
| **19** | *Paradoxurus hermaphroditus* | Common palm civet | Viverridae | LC |
| **20** | *Arctogalidia trivirgata* | Small-toothed palm civet | Viverridae | LC |
| **21** | *Hemigalus derbyanus* | Banded palm civet | Viverridae | NT |

| No | Scientific Name | Common Name | Family Name | IUCN Status |
|---|---|---|---|---|
| | **Rodentia** | | | |
| **22** | *Hystrix brachyura* | Malayan porcupine | Hystricidae | LC |
| | **Eulipotyphla** | | | |
| **23** | *Echinosorex gymnura* | Moonrat | Erinaceidae | LC |
| | **Pholidota** | | | |
| **24** | *Manis javanica* | Sunda pangolin | Maniedae | CE |

*In data analysis, Greater mouse-deer and Lesser mouse-deer were considered as one species because of difficulty in separating the two species.

**Table 2** RAI of photo-captured species of some mammals in LTEC

| Species | N | RAI ± SE |
|---|---|---|
| Wild boar | 243 | 9.78 ± 2.30 |
| Pig-tailed macaque | 238 | 9.03 ± 2.25 |
| Barking deer | 82 | 3.45 ± 0.86 |
| Malayan porcupine | 76 | 3.00 ± 0.68 |
| Bearded pig | 31 | 1.15 ± 0.42 |
| Malayan tapir | 9 | 0.34 ± 0.30 |
| Malayan sun bear | 5 | 0.19 ± 0.08 |
| Asian elephant | 3 | 0.13 ± 0.09 |
| Binturong | 2 | 0.07 ± 0.05 |
| Marbled cat | 1 | 0.04 ± 0.04 |
| Small-toothed palm civet | 1 | 0.04 ± 0.04 |
| Leopard cat | 8 | 0.03 ± 0.41 |

*Confidence level 95%

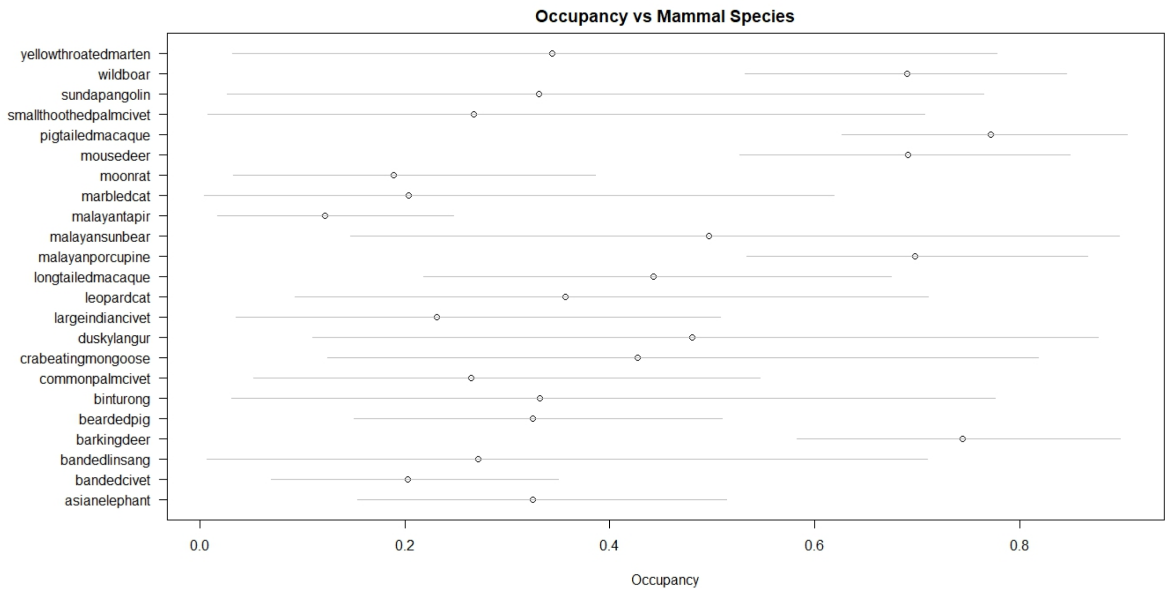


**Figure 2** Occupancy of photo-captured mammal species in LTEC

The distance of camera traps to the closest road was used as a covariate, to determine species occupancy of mammal in LTEC (Figure 3). This may determine the possibility of mammals to use the suggested ecological viaduct and to determine if it contributed to roadkill cases in LTEC. Some species of mammals prefer to avoid road as they prefer to avoid any human disturbances. Malayan porcupine, Wild boar, Long-tailed macaque, Yellow-throated marten, Small-toothed palm civet, Marbled cat, Barking deer, and Binturong tend to avoid the road. However, the road did not limit the distribution of species like Sunda pangolin, Mouse-deer, Leopard cat, Dusky langur, Crab-eating mongoose, Common palm civet, Banded linsang, and Banded palm civet, which may suggest potential usage of the viaduct. Conversely, there were some species where the distance to the road did not have any significant effect on species occupancy. This can be seen in Malayan tapir, Bearded pig, Asian elephant, and Moonrat.

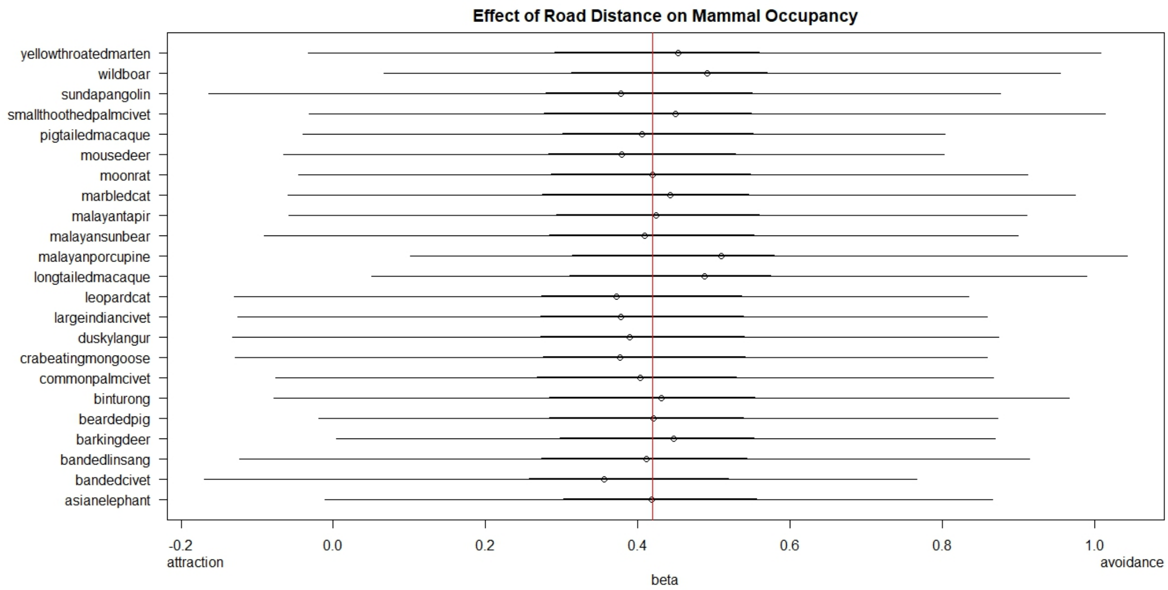


**Figure 3** Effect of distance to the road on occupancy of photo-captured mammal species in LTEC

**Species Richness of Mammals Across All Camera Traps**

Based on Species Richness analysis, it corroborates two camera traps with the highest species count detected which were camera A037 (XY; 626473, 254507) and A078 (XY; 627852, 255763) (Figure 4). These two camera traps were located close to the proposed viaduct area. The proposed viaduct area was located near camera A069 (XY; 625613, 251835) and A115 (XY; 626592, 252394). Some of the mammals detected within camera A037 and A078 included Banded palm civet, Barking deer, Bearded pig, Crab-eating mongoose, Dusky langur, Long-tailed macaque, Malayan porcupine, Moonrat, Greater mouse-deer, Lesser mouse-deer, Pig-tailed macaque, and Wild boar.

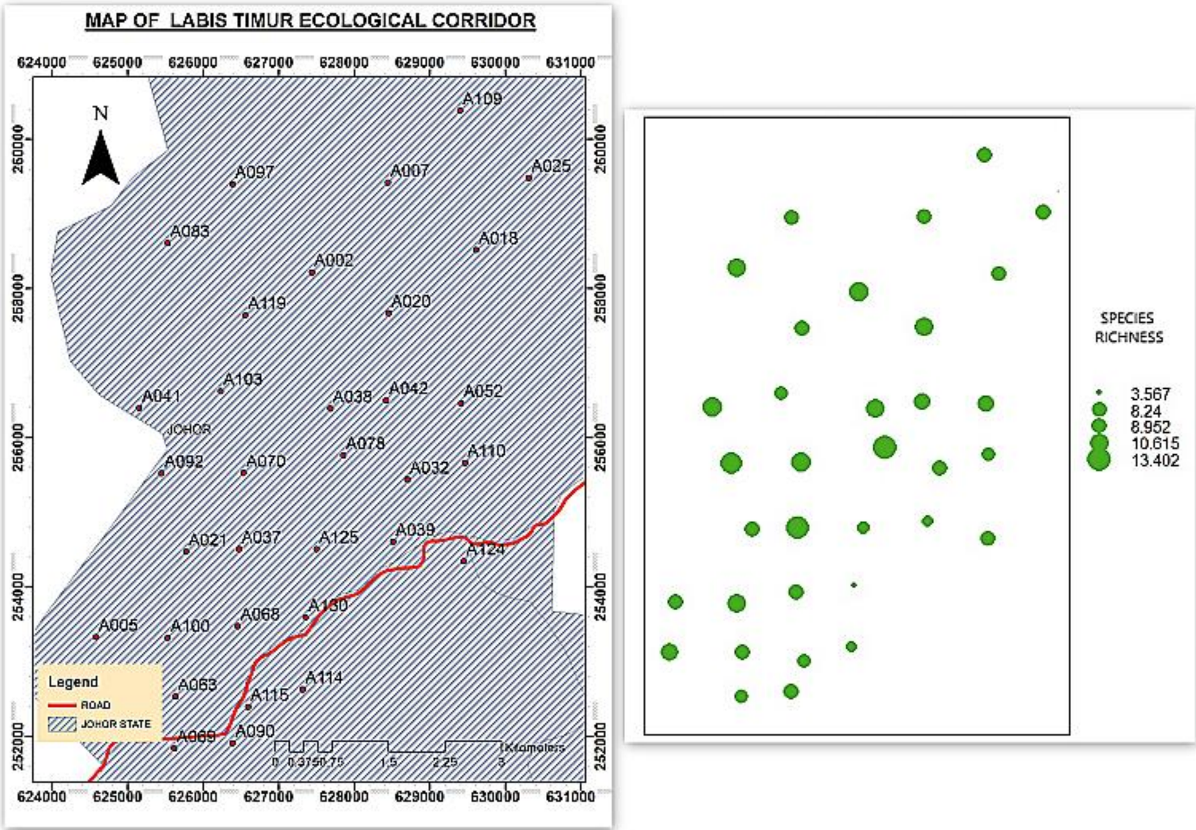


**Figure 4** Species richness in each camera trap location of LTEC (biggest green dot represents the camera with the highest richness)

## DISCUSSION

Studies in LTEC focusing on mammal diversity are limited. Therefore, this study can be considered the first few studies that address such an issue. Our study proved that LTEC is still a suitable habitat for mammal species. However, rapid forest fragmentation, illegal poaching, and agricultural development in the surrounding areas can be a major contributor to the decline of mammal diversity in LTEC. Although some of the forest reserves have been disturbed by logging activities, rejuvenation and regeneration of the forest will provide a suitable habitat for the affected wildlife species (Granados *et al*., 2016). Nonetheless, among other three study sites under the IC-CFS project, LTEC had the lowest mammal species detected compared to the Sungai Yu Ecological Corridor (SYEC), Pahang (Meisery *et al*., unpublished) and Gerik Ecological Corridor (GEC), Perak (Liwauddin *et al*., unpublished). This might be due to the fact that LTEC experience a higher deforestation rate and no ecological viaduct was build compared to the other two study sites which already have ecological viaducts. SYEC had the highest mammal species detected (28 species) while in GEC, 27 mammal species were detected. However, in an earlier study by Tan *et al*. (2015) in GEC, an astounding 34 mammal species comprising of 12 large mammals and 22 medium-sized mammals were recorded. This further support the need for an ecological viaduct in LTEC to halt or reduce wildlife diversity decline.

In LTEC, we did not detect the presence of the Malayan tiger (*P. tigris*) which is the main predator in the forest of Peninsular Malaysia. Mesopredator such as Leopard (*Panthera pardus*) was also absent. Conversely, the detection for prey species such as Barking deer (RAI ± SE; 3.45 ± 0.86) and Wild boar (RAI ± SE; 9.78 ± 2.30) were high. The higher number of detection for these species is possibly due to the lack of natural predators in the corridor and that these species can adapt better in disturbed forest.

Distance to the road did not have any significant effect on species occupancy for some mammals. This can be seen in Malayan tapir, Bearded pig, Asian elephant, and Moonrat. Human disturbances did not influence these mammals preference in distribution as demonstrated in this study. This could potentially be a contributing factor to many roadkill cases happening throughout Peninsular Malaysia, among other factors. Clevenger *et al*. (2003) found that occurrence of roadkills of mammals and birds are less near wildlife corridors in Canada. Elevated roads, highway fences, and presence of vegetation cover also had significant effects on the mortality rate of these targeted groups (Clevenger *et al*., 2001; Clevenger *et al*., 2002; Clevenger & Waltho, 2005). Neumann *et al*. (2012) suggested that low lighting and poor road conditions were highly likely the cause of wildlife roadkills in Sweden. These factors should be considered to mitigate the depletion of wildlife diversity in LTEC for future conservation efforts.

Humans compete with wildlife for living space more than any other species in the world. We also consume food sources the most and demolished nearly half of the entire food accessible to the rest of wildlife diversity (Ceballos & Ehrlich, 2002; Gaston, 2010). With rampant human population growth and agricultural development that leads to more forest fragmentation, anthropogenic conflicts toward wildlife diversity occurred, causing a severe plummet in biodiversity level. This led to a near extinction level of some wildlife species in the wild such as Sumatran rhinoceros (*Dicerorhinus sumatrensis*), Sunda pangolin (*M. javanica*), and Banteng (*Bos javanicus*). This particular study had been able to identify the human activities that caused this calamity, which are oil palms and other major crops agricultural plantation, and also high poaching activity.

Illegal poaching cases had well been documented throughout Malaysia (DWNP, 2017). Many records of poaching activities were gathered throughout the year and during this study. The poachers focused on gaining animal parts to generate revenues for international economic activities compared to traditional hunters who used the gains for local consumption (Bellwood, 1999; Kramer, 2001). Wire snares, artificial saltlicks used to attract wildlife, empty bullet shells and small mammal traps were among of the recorded pieces of evidence showing the rampant wildlife hunting activities throughout Malaysia (DWNP, 2017). The conversion of forest to agricultural plantation and development of roads had partitioned forest into separate patches. The building of roads and infrastructures also made it easier for the human population to access the forest, including illegal poachers (Corlett, 2007). This distorted the process of gene pool continuation for wild mammal species in LTEC. The “Improving Connectivity in the Central Forest Spine Landscape” project is pivotal now in LTEC as an effort to reduce wildlife depletion by establishing ecological viaducts in key places within the study site.

## CONCLUSION

LTEC provides a safe haven for mammal species and is still capable of hosting wildlife. The species occupancy data and species richness information are essential for the relevant authorities such as PERHILITAN. Findings in this study showed the diversity trend of some wildlife species and supported the proposed locations for the construction of a viaduct which will help to improve the implementation of the National Biological Diversity Policy in Malaysia. We recommend to: (1) build ecological viaduct in locations with the highest species richness (camera traps A037 and A078); (2) demarcating LTEC as High Conservation Value (HCV) area; and (3) comply firmly on Reduced Impact Logging guidelines for logging activities in this area. The project should proceed with the building of wildlife crossings or viaducts to reconnect isolated and fragmented forest patches in LTEC.

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## REFERENCES

Bellwood, P. (1999). Archaeology of Southeast Asian hunters and gatherers. In *The Cambridge Encyclopedia of Hunters and Gatherers* (Lee, R.B. & Daly, R., eds.), pp. 284–288. Cambridge, UK: Cambridge University Press.

Ceballos, G. & Ehrlich, P.R. (2002). Mammal population losses and the extinction crisis. *Science*, **296**(5569): 904-907.

Clevenger, A.P. & Waltho, N. (2005). Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. *Biological Conservation*, **121**(3): 453-464.

Clevenger, A.P., Chruszcz, B. & Gunson, K.E. (2001). Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife Society Bulletin*, **29**(2): 646-653.

Clevenger, A.P., Chruszcz, B. & Gunson, K.E. (2003). Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. *Biological Conservation*, **109**(1): 15-26.

Clevenger, A.P., Wierzchowski, J., Chruszcz, B. & Gunson, K. (2002). GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. *Conservation Biology*, **16**(2): 503-514.

Corlett, R.T. (2007). The impact of hunting on the mammalian fauna of tropical Asian forests. *Biotropica*, **39**(3): 292-303.

Danielsen, F., Beukema, H., Burgess, N.D., Parish, F., Bruehl, C.A., Donald, P.F., Murdiyarso, D., Phalan, B., Reijnders, L., Struebig, M. & Fitzherbert, E.B. (2009). Biofuel plantations on forested lands: double jeopardy for biodiversity and climate. *Conservation Biology*, **23**(2): 348-358.

Downs, J.A. & Horner, M.W. (2012). Enhancing habitat connectivity in fragmented landscapes: spatial modeling of wildlife crossing structures in transportation networks. *Annals of the Association of American Geographers*, **102**(1): 17-34.

Duckworth, J.W. & Pine. R.H. (2003). English names for a world list of mammals, exemplified by species of Indochina. *Mammal Review*, **33**: 151–173.

DWNP (2008). National Tiger Conservation Action Plan for Malaysia 2008–2020. Kuala Lumpur, Malaysia: Department of Wildlife and National Parks Peninsular Malaysia.

DWNP (2017). Laporan Tahunan 2016. Available from www.wildlife.gov.my/ images/document/penerbitan/laporantahunan/LP2016%20%2020022018.pdf. (Version on July 2018).

Ewers, R. M., Scharlemann, J. P., Balmford, A., & Green, R. E. (2009). Do increases in agricultural yield spare land for nature? *Global Change Biology*, *15*(7), 1716-1726.

Fitzherbert, E.B., Struebig, M.J., Morel, A., Danielsen, F., Brühl, C.A., Donald, P.F. & Phalan, B. (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution,* **23**(10): 538-545.

Ford, A.T., Clevenger, A.P. & Bennett, A. (2009). Comparison of methods of monitoring wildlife crossing-structures on highways. *Journal of Wildlife Management,* **73**(7): 1213-1222.

Foster, W.A., Snaddon, J.L., Turner, E.C., Fayle, T.M., Cockerill, T.D., Ellwood, M.F. & Yusah, K.M. (2011). Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. *Philosophical Transactions of the Royal Society B*: *Biological Science*, **366**(1582): 3277-3291.

Francis, C.M. & Barrett, P. (2008). *A field guide to the mammals of South-East Asia*. United Kingdom: New Holland Publishers.

Gaston, K.J. (2010). Biodiversity. In *Conservation biology for all (*Sodhi, N.S. & Ehrlich, P.R., eds.), pp. 27-42. Great Britain: Oxford University Press.

Granados, A., Crowther, K., Brodie, J.F. & Bernard, H. (2016). Persistence of mammals in a selectively logged forest in Malaysian Borneo. *Mammalian Biology,* **81**(3): 268–273.

IC-CFS Master Plan (2009). United Nation Development Programme. Available from https://www.thegef.org/improving-connectivity-central-forest-spine-cfs-landscape-i. (Version on July 2018).

Kramer, K. (2001). *Legal controls on small arms and light weapons in Southeast Asia; occasional paper No.3*. Geneva, Switzerland: Small Arms Survey, Graduate Institute of International and Development Studies and Nonviolence International South East Asia.

Liwauddin, A., Ghazali, A.N., Hasnan, M.H.S. & Meisery, A.A.H.A. (unpublished). Wildlife usage of viaduct at Gerik ecological corridor, Perak. Unpublished paper.

MacKenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L. & Hines J.E. (2006). *Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence*. New York: Academic Press.

Meisery, A.A.H.A., Ghazali, A.N. & Liwauddin, A. (unpublished). Diversity of mammals in Sungai Yu ecological corridor (CFS1:PL1) in Pahang, Malaysia. Unpublished paper.

Mongabay (2018). Palm oil company revs up deforestation in Malaysia. Available from https://news.mongabay.com/2015/11/palm-oil-company-revs-up-deforestation-in-malaysia. (Version on July 2018).

Morrison, J.C., Sechrest, W., Dinerstein, E., Wilcove, D.S. & Lamoreux, J.F. (2007). Persistence of large mammal faunas as indicators of global human impacts. *Journal of Mammalogy*, **88**(6): 1363-1380.

Neumann, W., Ericsson, G., Dettki, H., Bunnefeld, N., Keuler, N.S., Helmers, D.P. & Radeloff, V.C. (2012). Difference in spatiotemporal patterns of wildlife road-crossings and wildlife-vehicle collisions. *Biological Conservation*, **145**(1): 70-78.

Nowell, K., & Jackson, P. (Eds.). (1996). *Wild cats: status survey and conservation action plan* (Vol. 382). Gland: IUCN.

O'Brien, T.G., Kinnaird, M.F. & Wibisono, H.T. (2003). Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, **6**(2):131-139.

Phan, C., Prum, S. & Gray, T.N.E. (2010). Recent camera-trap records of globally threatened species from the Eastern Plains Landscape, Cambodia. *Cambodian Journal of Natural History*, **2**: 89-93.

Tan, C.C., Sivananthan, T.E., Saaban, S. & Wan Shaharuddin, W.N. (2015). *Gerik ecological corridor; a safe passage for wildlife*. Kuala Lumpur: Department of Wildlife and National Parks.

Yasuda, M. (2004). Monitoring diversity and abundance of mammals with camera traps: a case study on Mount Tsukuba, central Japan. *Mammal Study*, **29**(1): 37-46.