Comparing landscape characteristics to understand Malayan tapir (Tapirus indicus) conflicts: A case study in Negeri Sembilan

Article *in* Malayan Nature Journal · April 2024

DOI: 10.62613/mnj.24761.01

Amirul Hakimi Zanuari
Universiti Teknologi MARA

Mohd. Sanusi M.
Copenhagen Zoo

David Magintan
Ministry of Energy and Natural Resources (NRECC)

Kamarul Hambali
University of Malaysia, Kelantan

Malayan Nature Journal 2024, 76(1), 1-10
doi: 10.62613/mnj.24761.01

Comparing landscape characteristics to understand Malayan tapir (*Tapirus indicus*) conflicts: A case study in Negeri Sembilan

AMIRUL HAKIMI ZANUARI[1], KHADIJAH BINTI OTHMAN[1], MOHD SANUSI MOHAMED[2], DAVID MAGINTAN[3], KAMARUL HAMBALI[4], MOHAMMAD SAIFUL MANSOR[5] and KAMARUDDIN ZAINUL ABIDIN[1*]

Abstract: The IUCN Red List has listed the Malayan tapir (*Tapirus indicus*) as an endangered species in 2016, owing to its declining population trend. Human-caused forest degradation and encroachment on wildlife habitats drive this species to roam out of its natural range, resulting in human-tapir conflict (HTC). This study executes kernel density analysis on 78 HTC points recorded in Negeri Sembilan from 2013 to 2018 to determine the high and low HTC zones, and investigates the influence of five landscape variables on the occurrence of HTC. Values of five landscape variables in high and low HTC zones were extracted, and the significance of occurrence between these two zones was tested using an independent sample t-test. In terms of spatial distribution, Kuala Pilah and Jelebu covered high-conflict zones, while the lowest conflict zone was in Rembau. The t-test indicated that elevation ($t = –3.551$, $p < 0.05$) and slope ($t = –2.012$, $p < 0.05$) were significant between high and low conflict zones. Distance to the forest ($t = 1.424$, $p > 0.05$), distance to water ($t = –0.106$, $p > 0.05$), and distance to urban areas ($t = –1.536$, $p > 0.05$) were not significant for HTC. HTC tends to occur in low topographic areas, while tapirs outside of their natural habitat forage in close proximity to the forest and water bodies, but restrict their movement near human settlements. Hot Spot Analysis (Getis-Ord Gi*) on forest patches revealed an overlaping region between high HTC zones and low forest-patch contiguity, indicating that forest fragmentation may promote tapir conflicts. Hence, by systematically recording the conflict distribution in Negeri Sembilan, many actions could be taken into consideration to mitigate HTC in this state.

Keywords: Malayan tapir, conflict hotspot, patch contiguity, forest edge, wildlife management

INTRODUCTION

The Malayan tapir (*Tapirus indicus* or also known as *Acrocodia indica*)[a] is the largest of four Tapiridae species and the only one native to Southeast Asia (Traeholt *et al.* 2016). Malayan tapir are forest dwellers that live in primary and secondary tropical rainforests

[a] The species was reclassified into a distinct genus, *Acrocodia* by Groves and Grubb. This was discerned from anatomical characteristics and molecular divergence, indicating a distinct Asian clade separate from American tapirs. As a result, the scientific name *Acrocodia indica* was designated for the Malayan tapir. See Groves, C. and Grubb, P. (2011). "*Acrocodia indica*". *Ungulate taxonomy.* Baltimore: Johns Hopkins University Press. p. 20. ISBN 9781421400938. – ed.

[1] Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM) Cawangan Pahang, Kampus Jengka, Lintasan Semarak, Bandar Jengka, 26400 Bandar Tun Razak, Pahang, Malaysia
[2] Copenhagen Zoo (Malaysia), Masreca 19, Persiaran Rimba Permai, Cyber 10, 63000 Sepang, Selangor Malaysia
[3] Department of Wildlife and National Parks, Peninsular Malaysia, KM 10, Jalan Cheras, 56100 Kuala Lumpur, Malaysia
[4] Faculty of Earth Science, Universiti Malaysia Kelantan, Locked Bag 100, 17600 Jeli, Kelantan, Malaysia
[5] Department of Biological Sciences and Biotechnology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
***Corresponding author: kamaruddinzainul@uitm.edu.my**

(Williams 1978; Khan 1997; Holden *et al*. 2003; Steinmetz *et al*. 2008; Lynam *et al*. 2012; Traeholt *et al*. 2016; Walb *et al.* 2021) with water sources near their habitat (DWNP-DANCED 2001). Tapirs were typically thought to be solitary (Department of Wildlife and National Park 2021b). However, this species may sometimes be seen in groups of two or three individuals, typically comprising of mating pairs or mother-offspring groups (Kusuda *et al*. 2007; Donny *et al.* 2022). With the declining population trend, the Malayan tapir was classified as endangered in 2016 (IUCN 2016) and is totally protected under the Wildlife Conservation Act 2010 (Magintan *et al.* 2021). Human activities such as habitat encroachment and hunting pressure have posed substantial threats to tapirs across their range (Zainal Zahari *et al.* 2001; Magintan *et al.* 2012).

Deforestation for agriculture causes habitat loss, degradation, and fragmentation, which isolate tapir populations by forcing them to live in patchy habitats (Department of Wildlife and National Park 2021b). Tapirs traverse across matrix of different landscapes, including both suitable and non-suitable patches (Kasmuri *et al.* 2020). Tapirs that roam near human-dominated areas are likely to cause conflicts outside their natural habitats. In 2021, the data from the Department of Wildlife and National Parks (DWNP or PERHILITAN) revealed 67 public reports of human-tapir conflicts (HTC) and 23 road-kill incidents involving Malayan tapir across Peninsular Malaysia (Lim *et al.* 2022). Tapirs move across their habitat range to forage for food and mate, making them susceptible to collisions with vehicles while crossing roadways (Clement *et al*. 2012; Mohamad *et al.* 2021).

Spatial distribution of Malayan tapirs has been discussed in previous studies (Clements *et al.* 2012; Rayan *et al.* 2012; Mohamad *et al.* 2019; Samantha *et al.* 2020; Arumugam *et al.* 2022). Even so, there appears to be a scarcity of information on HTC hotspots, and the contributions of environmental factors (i.e., biotic and abiotic) to the occurrence of the current HTC trend. The occurrences of tapir conflict are consistently observed, highlighting a lack of understanding regarding the underlying causes and influential factors, particularly when considering the broader landscape context. In this study, HTC data was compiled to determine the high and low zones of HTC, and investigate the influence of landscape variable factors on the spatial distribution of current HTC cases in Negeri Sembilan.

DWNP reported that Negeri Sembilan is regarded as a state with severe HTC in Peninsular Malaysia (Magintan *et al.* 2012). From 2019 to 2021, Negeri Sembilan recorded 34% of the 175 human-tapir conflict cases in Peninsular Malaysia, followed by Pahang (22.3%) and Johor (10.3%). In both 2020 and 2021, Negeri Sembilan had the highest number of HTC reports compared to other states (Department of Wildlife and National Parks 2019, 2020, 2021a). Given that previous data revealed substantial cases of HTC in Negeri Sembilan, this study may provide insight into future tapir conflict mitigation.

MATERIALS AND METHODS

Study area

The study is conducted in Negeri Sembilan, located around 2º 45’ N, 102º 15’ E, with a total area of 6,686 km^2. The state of Negeri Sembilan consists of seven districts: Jelebu, Seremban, Port Dickson, Kuala Pilah, Jempol, Tampin, and Rembau (Wahab and Bahauddin 2019). Forest regions in Kenaboi, Jelebu, Ulu Bendul, and Senaling Inas have been reported to be important habitats for Malayan Tapir by DWNP (2012).

Data collection

A total of 78 independent HTC points were compiled from DWNP, comprising cases recorded in Negeri Sembilan between the years 2013 and 2018. To ensure data accuracy, the HTC data was filtered to remove case redundancy (only one case was picked from a set of duplicated records) and georeferencing errors were rectified.

Spatial data of forest, urban, and water body areas were obtained from a 2015 land cover map acquired from the Department of Survey and Mapping Malaysia (JUPEM). This data is appropriate as it aligns with the range of HTC points used. The Shuttle Radar Topographic Mission (SRTM) elevation model was downloaded from the website (http://srtm.csi.cgiar.org) and used as a Digital Elevation Model (DEM) in metres. The slope (in degrees) was derived from DEM using ArcGIS 10.8.2 spatial analyst tools. All the landscape variables were converted into raster datasets (grid form) with Kertau RSO Malaya projection at 1 km resolution.

Data analysis

The HTC raw data was simplified and summarised through pivot analysis, which used Excel filters to sort and present onflict cases based on various factors such as location, time, landscape variables, and conflict type (Grech 2018). Kernel Density function in ArcGIS 10.8.2 was executed to calculate the magnitude of HTC cases per unit area in Negeri Sembilan, which helped to determine the high and low HTC zones. The resulting Kernel Density (KD) Malayan tapir conflict map was classified into three categories (i.e., low, moderate, and high HTC) using the Natural Jenks classification. This method is typically used for spatial classification as it maximises variability between groups, and minimises variability within groups (Jenks 1967; North 2009).

The values of the landscape variables from all HTC points distributed in high and low zones were extracted. Five continuous landscape variables were used, including elevation, slope, distance to forest, distance to urban areas (e.g., settlements, towns, and villages), and distance to waterbody (e.g., river and lake) (Table 1). Multiple studies have demonstrated a significant correlation between these variables and the occurrence of Malayan tapir. To test for significant influence of each landscape variable on HTC, independent sample t-test was used to determine statistical differences of mean value between landscape variables extracted from high and low KD zones. The analyses was performed in the Statistical Package for the Social Sciences (SPSS) version 28.0. Moreover, the spatial pattern of forest patch contiguity with KD Malayan tapir conflict was examined using Getis-Ord Gi* (Getis and Ord 1992) through ArcGIS. This hotspot analysis tool helps to identify clusters of data points and prioritise areas with high values (hotspots) and low values (cold spots) (Rossi and Becker 2019).

RESULTS AND DISCUSSION

Distribution and classification of Malayan Tapir conflict in Negeri Sembilan

From 2013 to 2018, a total of 78 human-tapir conflicts were mapped in Negeri Sembilan (Figure 1). Among the seven districts, Kuala Pilah recorded the highest cases of Malayan tapir conflict, followed by Jelebu, Tampin, Seremban, Rembau, and Jempol, while no cases were reported in Port Dickson (Table 2). Four districts (Tampin, Seremban, Jempol, and Rembau) had fewer than 15 human-tapir conflicts as compared to Kuala Pilah and Jelebu, which recorded 35 and 24 cases, respectively.

In general, seven types of human-tapir conflict were recorded over the period, with "causing emotional disturbances" being the most common cases reported, followed by roaming, damaging crops, road killing, damages to properties, and causing fright (Table 2).

Causing emotional disturbances (11 cases), crop damage (11 cases), road-kill (4 cases), and damage to properties (4 cases) predominantly occurred in Kuala Pilah. More than half of the roaming conflicts were reported in Jelebu, with 14 out of 18 cases. There were two cases of HTC causing fright, with Kuala Pilah and Rembau contributing one incidence each. DWNP had initially compiled seven categories of human-wildlife conflict, which are currently used in both the raw data and annual reports of DWNP. Some categories can be subjective, such as causing emotional disturbance and fright. Most often, only those who have been affected by HTC can discern the difference between these two classes. Emotional disturbance is experienced if they have sustained an attack or direct disturbances. On the other hand, they will experience panic if the animal is reported in the vicinity, causing them to feel frightened or anxious in any of these instances. Roaming is when the animals are frequently sighted foraging in human-dominated areas, such as in plantations, settlement areas, and roadside, without causing disturbances or damages to crops and properties. Conflict reports that were unclear, lack details, or did not fit into any of the six categories were marked as "others".

Table 1. Landscape variables used in this study for assessing the potential Malayan Tapir conflict area.

Variables	Data sources	Type	Authors
Distance to forest	Calculate from JUPEM datasets using ArcMap 10.8.2	Continuous	(Lynam *et al.* 2012; Taher *et al*. 2017; Samantha *et al.* 2020; Zainol *et al.* 2021; Kuswanda *et al*. 2023)
Distance to water body	Calculate from JUPEM datasets using ArcMap 10.8.2	Continuous	(Lynam *et al.* 2012; Reza *et al*. 2013; Sasidhran *et al*. 2016; Taher *et al*. 2017; Zainol *et al.* 2021)
Distance to urban and settlements	Calculate from JUPEM datasets using ArcMap 10.8.2	Continuous	(Lynam *et al*. 2012; Magintan *et al.* 2012; Sasidhran *et al*. 2016; Zainol *et al.* 2021; Kuswanda *et al.* 2023)
Elevation	SRTM	Continuous	(Lynam *et al*. 2012; Reza *et al*. 2013; Taher *et al.* 2017; Zainol *et al*. 2021; Kuswanda *et al*. 2023)
Slope	Calculate from SRTM data using ArcMap 10.8.2	Continuous	

Spatial pattern of human-tapir conflict hotspots

Figure 1 illustrated the spatial pattern of HTC zones classified into three Kernel Density (KD) levels. There were nine HTC points in low, 38 in moderate, and the remaining 31 in high HTC KD. The highest case density occurred in Jelebu, Kuala Pilah, and Rembau, while low KD was randomly distributed in Jelebu, Jempol, Seremban, and Tampin. High KD zones showed a clumped distribution of conflicts and close association of neighbouring points, while moderate and low KD zones featured a considerable gap between neighbouring points.

Table 2. Conflict types and number of HTC cases in each district of Negeri Sembilan between 2013–2018.

Types of conflict/ Districts	Causing emotional disturbance	Roaming	Damage crops	Road-kill	Damage to properties	Causing fright	Other	Total
Kuala Pilah	11	2	11	4	4	1	2	35
Jelebu	5	14	4	1	0	0	0	24
Tampin	4	0	0	2	0	0	2	8
Rembau	1	2	0	0	0	1	0	4
Seremban	3	0	0	0	0	0	1	4
Jempol	1	0	1	1	0	0	0	3
Total	25	18	16	8	4	2	5	78

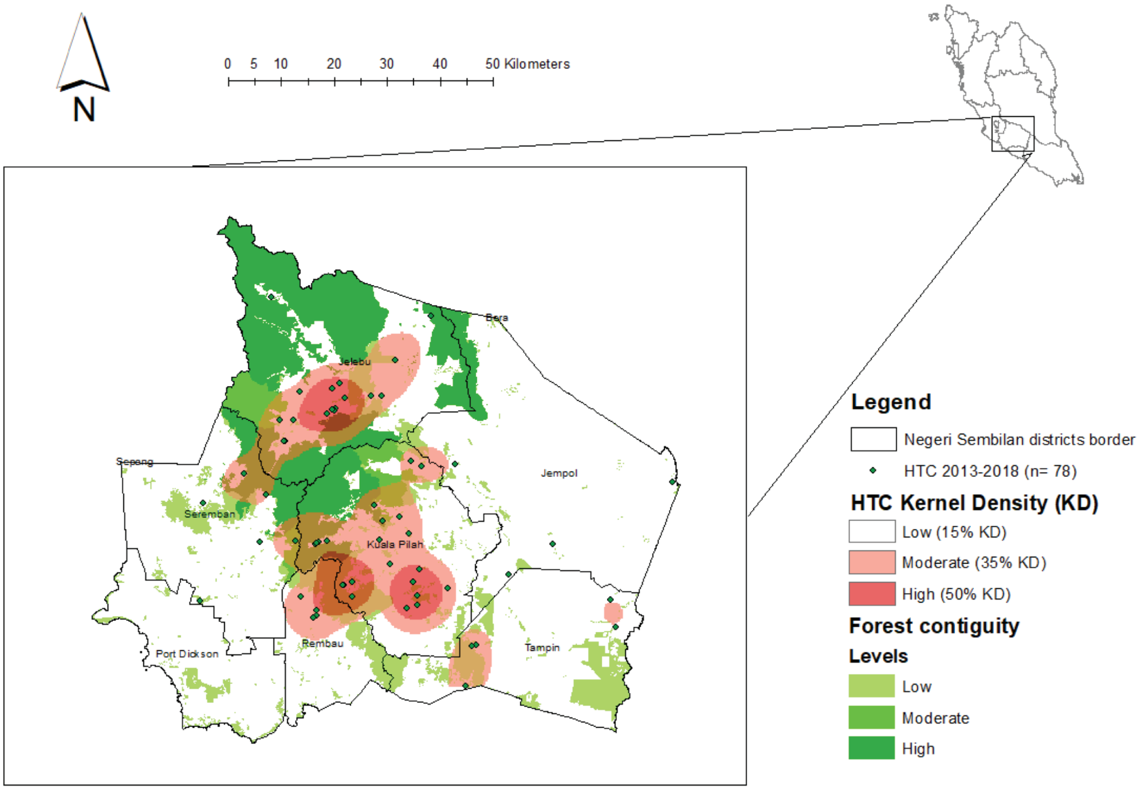

Figure 1. Map of HTC Kernel Density and forest patch-contiguity of Negeri Sembilan analysed using Getis-Ord Gi*. The light-to-dark-red region indicates the spatial distribution of low to high HTC KD zones, while the light-to-dark green area indicates the low to high forest patch-contiguity levels, representing the preferred natural tapir habitat. The white area on the map includes plantations, settlements, and other non-forest land uses.

Significance of the landscape variables towards human-tapir conflicts (HTC)
Table 3 showed each landscape variable's means, t-value, and standard error mean in both low and high conflict HTC. The elevation ($t = –3.551$, $p < 0.05$) and slope ($t = –2.012$, $p < 0.05$) were two landscape variables that differed significantly between high and low HTC zones. The other three landscape variables, distance to the forest ($t = 1.424$, $p > 0.05$), distance to water ($t = –0.106$, $p > 0.05$), and distance to urban ($t = –1.536$, $p > 0.05$), indicated no significant differences between HTC zones.

Table 3. T-test results comparing low and high HTC on five landscape variables.

Variables	Conflict level	Mean	t-value	Significance value	Mean Standard Error
Elevation (m)	Low	92.4444	–3.551	**p ≤ 0.05**	15.1117
	High	180.9355			12.6224
Distance to forest (m)	Low	1941.8387	1.424	p > 0.05	560.3176
	High	1124.9199			122.1928
Distance to urban area (m)	Low	3367.4527	–1.536	p > 0.05	968.7226
	High	4872.2188			448.1247
Distance to water (m)	Low	6070.4038	–0.106	p > 0.05	1153.7295
	High	6210.8310			627.2812
Slope (index)	Low	3.4098	–2.012	**p ≤ 0.05**	1.3355
	High	7.5176			1.0244

* Variables significant towards HTC cases were in **bold**.

The data revealed a significance difference in elevation between high and low HTC. HTC was found to potentially occur in elevated areas, with the mean elevation of 180m for high HTC areas, while the mean elevation for low HTC area is 92 m. Even so, both areas were considered as lowland from a biological perspective (Whitmore *et al.* 1985). This also exemplified the common occurrence of mammal conflicts in the lowland areas below 300 m (Abidin *et al.* 2018; Sharma *et al.* 2020; Figel *et al.* 2023). In higher elevation areas, tapirs are more likely to pass through the area rather than establishing permanent dwellings (Traeholt and Sanusi 2018). Furthermore, slope was also found to be correlated with HTC. Even though Malayan tapirs have been documented at altitudes of up to 2,000 metres, there were correlations between tapir abundance and elevation or slope, with the highest tapir population found on lower slopes and valley bottoms (Department of Wildlife and National

Parks 2012). Occurrences of tapir in lowlands may be attributed to their preferences for agricultural areas (e.g., oil palm and rubber plantations), secondary forests, and semi-urban areas (Holden *et al.* 2003; Novarino *et al.* 2005; Magintan *et al.* 2012). Expansion of agricultural and urban development in lowlands has resulted in forest fragmentation and isolation, forcing the tapirs to gradually adapt to refuge and forage in habitats outside of their intact forest (Kuswanda *et al.* 2023; Magintan *et al*. 2012).

The occurrence of HTC was found to be less influenced by distance to the forest. The mean distance to the forest for cases recorded in the high HTC zone was 1.1 km, whereas cases reported in the low zone had a mean distance of 1.9 km. Even though there was no significant difference between these two zones, tapir conflicts were considerably prone to occur in areas near the forest. Most mammal conflicts were commonly reported within a three-kilometre radius of the forest (Sharma *et al.* 2020). Spatial KD zones, as shown in Figure 1, reveal that high HTC predominantly occurred in patchy forests situated near contiguous forest areas. This implied that the increase in HTC is not solely attributable to forest edge factors; clump forest patches near intact forests may also augment tapir presence. Tapirs were observed in forest fringes and logged disturbed areas, including secondary forests. Selective logging may result in an increased abundance of saplings, attracting tapirs to forage on forest edges near human-dominated areas, where food availability is high (Zainal Zahari *et al.* 2001; Mahathir *et al*. 2014).

The distance to urban areas also showed no significance towards HTC. Despite this, the cases reported in high HTC areas tend to occur at a greater distance to urban areas (4.9 km) compared to cases reported in low HTC (3.4 km). This demonstrated that, although tapirs can be found in almost any type of land cover (Medway 1974; Williams 1978; Khan 1997; Kawanishi *et al.* 2002; Novarino 2005; Steinmetz *et al*. 2008; Lynam *et al*. 2012), they are more ambiguous in places with high human presence and will shift their activity patterns to avoid contact with humans (Samantha *et al.* 2020).

Low and high HTC cases were found near a water source, particularly six kilometres away. This highlighted the importance of water bodies to tapirs and other mammals. Tapir sightings were often associated with water bodies while foraging (Lynam *et al.* 2012; Samantha *et al.* 2020; Arumugam *et al.* 2022). Despite being the least aquatic of the Tapiridae, Malayan tapirs swim in rivers and marshes to avoid insect bites (Gilmore 2001) and to cool off under the hot sun (Arumugam *et al.* 2019; Mohamad *et al*. 2019). Tapir tracks have been identified in major rivers and were regularly sighted around headwaters and wetlands (Traeholt and Sanusi 2009; Lynam *et al.* 2012; Zainol *et al*. 2021). Given that the presence of water sources in its habitat area is critical, removing or deteriorating water quality may influence tapir survival and result in more HTC.

The relationship between tapir conflicts with the spatial pattern of forest fragments

Key factors that contributed to the Malayan tapir conflict throughout its ranges include habitat loss, fragmentation, and rapid infrastructure development (Gong *et al.* 2013; Traeholt *et al.* 2016). Forest conversion to oil palm plantations had a substantial impact on wildlife habitats (Koh *et al*. 2011; Stibig *et al.* 2014). In some regions, there was a clear association between the increase in certain HTC types and the expansion of plantations (Magintan *et al.* 2012; Traeholt *et al.* 2016). In general, the HTC spots in Negeri Sembilan were found between forest patches that have been fragmented from the plantation landscape, particularly in the white region on map in Figure 1. The figure showed that Getis-Ord Gi* identified the northern part of Negeri Sembilan, including Jelebu bordering Seremban and Kuala Pilah, as having high forest patch-contiguity in comparison to other regions. Meanwhile, the spatial pattern of Kernel Malayan tapir conflict mostly occurred around the areas of low forest-patch contiguity, where the high KD zones (dark red) overlapped with the light green region. Getis-Ord Gi* analysis on forest patches demonstrated an overlap region between high HTC zones and low forest-patch contiguity, suggesting that forest fragmentation may promote tapir conflicts. KD zones were less extended in Jempol, Tampin, south of Rembau, Port Dickson, and southwest of Seremban, despite the forest landscape in these areas mainly featured with low forest-patch contiguity. This may be related to the factor of large forest proximity, as indicated in Table 3 and Figure 1, where the majority of tapir conflicts occurred in areas less than 2 km from large contiguous forests. High forest fragmentation at the margins of a large forest may highlight some concerns as such areas may promote wildlife conflicts, not only involving tapir, but also with other forest-dependent mammals.

CONCLUSION

Human-tapir conflict was more prevalent in Jelebu and Kuala Pilah compared to the remaining five districts in Negeri Sembilan. Most cases involved tapirs passing through or roaming around human activity areas, including plantations. This led to the emergence of emotional disturbances, crop damage, and road-kills. HTC tends to occur in low topographic regions. In contrast, tapirs outside their natural habitat forage close to the forest and water bodies, but restrict their movement near human settlements. The increased possibility of HTC in areas with considerable forest fragmentation has alarmed authorities, regional wildlife departments, and stakeholders, prompting them to implement appropriate mitigating measures. As such, sustainable and wildlife-friendly development may lessen the impact of land-use changes on wildlife. Protecting the natural habitat will not only benefit the Malayan tapir, but also aid in the safeguarding of other species.

Acknowledgements: The authors would like to thank the DWNP for approving this study (ref. no- JPHL&TN (IP): 100-34/1.24 Jld 16 (50)) and for the database of Malayan tapir conflicts in Negeri Sembilan, which enabled us to perform the analysis.

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