Identifying potential dispersal corridors for Malayan tapirs (*Tapirus indicus*) in southern Thailand

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Abstract

The Malayan tapir (*Tapirus indicus*) is threatened by habitat loss and fragmentation, causing populations to become small and isolated. An assessment of dispersal corridor patterns is crucial for the survival of the species because it potentially facilitates species movement and gene flow. Our goal was to identify habitat patches and dispersal corridors for the Malayan tapir in southern Thailand. We first identified suitable habitat for tapirs as an evergreen forest patch with an area greater than 13 km^2 based on average home range size for tapirs. We then used electronic circuit theory analysis to assess potential dispersal corridors. We identified 78 suitable habitat forest patches and 18 potential dispersal corridors for tapirs across southern Thailand. Chumphon forest complex had the highest number of potential dispersal corridors. In addition, we found four potential dispersal corridors between Khlong Saeng-Khao Sok and Chumphon forest complexes. Our study highlights important potential suitable forest patches and dispersal corridors for the Malayan tapir within and between forest complexes. We suggest that dispersal corridor assessment can assist conservation efforts for the Malayan tapirs and other endangered mammals in the region.

Keywords: Circuit theory, conservation, corridors, habitat connectivity, malayan tapir

Introduction

The Malayan tapir (*Tapirus indicus*) is a globally endangered species (IUCN, 2016). It is also listed as an endangered species in the Wild Animal Reservation and Protection Act, B.E. 2535 of Thailand. Currently, the Malayan tapir abundances are approximately 343-367 individuals in southern Thailand distributed across five forest complexes (Kanchanasaka, 2015; Lynam, et al. 2012). However, the Malayan tapir has experienced a precipitous decline due to habitat loss and fragmentation. Small and isolated populations within a fragmented habitat have a higher of local extinction (Lindenmayer & Fischer, 2013). As such, the survival of Malayan tapirs in fragmented landscapes depends upon maintaining connectivity between isolated populations (Fahrig & Merriam, 1985; Noss et al., 1996; Taylor et al., 1993).

Habitat connectivity is defined as the degree to which a landscape facilitates individual movement between suitable habitat patches (Taylor et al., 1993). Habitat connectivity is crucial to assess for wildlife conservation planning. Habitat connectivity enhances gene flow among sub-populations, maintains a specie's home range, and increases the opportunity for adaptation in response to environmental changes (Brodie et al. 2015; McRae et al. 2008; Sulistyawan et al. 2017).

The goal of habitat connectivity is to preserve resilient habitat networks and design linkages of high-quality habitats (i.e., dispersal corridors) between remnant patches (Soule & Terborgh, 1999). Therefore, habitat connectivity can be achieved through a networking of dispersal corridors, which is a strip pathway that links habitat patches. Dispersal corridors have been successfully applied in conservation planning for species in many regions, such as deer (*Odocoileus hemionus*) in California and Arizona (Beier et al. 2006), jaguars (*Panthera onca*) in Mexico (de la Torre et al. 2017), and pandas (*Ailuropoda melanoleuca*) in China (Sulistyawan et al. 2017; Wang et al. 2014). Despite the advancements in theory and application, the evaluation of potential dispersal corridors in connectivity networks for Malayan tapirs has not yet been studied in Thailand which impedes conservation efforts (Lynam et al. 2012).

The goal of our study was to identify habitat patches and dispersal corridors for the Malayan tapir in southern Thailand. Our objectives were: (1) to identified suitable habitat patches, and (2) to assess potential dispersal corridors for the Malayan tapir.

Materials and Methods

Study area

Our study area was evergreen forest in southern Thailand (Figure 1). The total area of evergreen forest with an average patch size greater than 13 km^2 was approximately 14,186 km^2, covering 27 protected areas in five forest complexes: (1) Chumphon forest complex, (2) Khlong Saeng-Khao Sok forest complex, (3) Khao Luang forest complex, (4) Khao Banthad forest complex, and (5) Hala Bala forest complex.

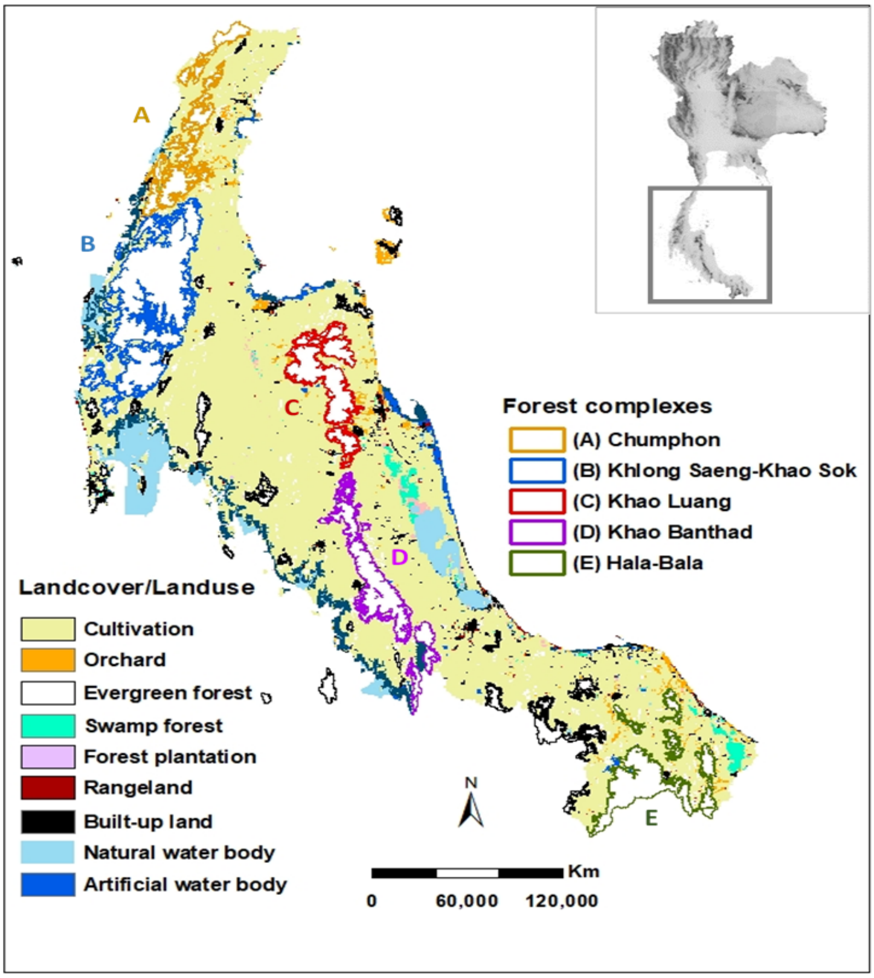

Figure 1 Study area in southern Thailand. Evergreen forests with an area greater than 13 km^2 are shown in dark green.

Assessing habitat connectivity for Malayan tapirs

To identify habitat patches for Malayan tapirs in southern Thailand, we considered suitable habitat patches for Malayan tapirs as evergreen forest with an area greater than 13 km^2 based on average home range size for tapirs in Thailand (Lynam et al. 2012; Williams & Petrides, 1980). In addition, tapirs prefer forest habitat with dense cover and often avoid human-made landscapes and anthropogenic activities (Clements et al. 2012). We classified suitable forest habitat using ArcGIS program version 10.2.1. Evergreen forest data were obtained from the land use and land cover map of Thailand for the year 2016 derived by the Land Development Department, Thailand.

To evaluate potential dispersal corridors for the Malayan tapir, we used Circuitscape software version 4.0 (McRae et al. 2008). Circuitscape applies electrical circuit theory and random walk theory to calculate pairwise resistances and create maps of current flowing between focal nodes (McRae et al. 2008). Circuitscape requires two inputs: (1) a resistance map (i.e., land use and land cover with a degree of movement resistance for Malayan tapirs); and (2) a focal node map (i.e., forest habitat). We prepared the resistance map by assigning resistance values to each land use and land cover raster, ranking from 1 to 100. We assigned lowest resistance values to forest habitat: evergreen forest. Higher resistance values were assigned to other natural habitats: swamp forest, rangeland, marsh and swamp, and natural water bodies. Highest resistance values were assigned to agricultural areas, such as forest plantation, and orchards. For complete barriers, we assigned them as no data areas (i.e., settlements, roads, perennial agricultural areas, and artificial water bodies). Circuitscape created current maps between pairs of forest patches using pairwise analysis and iterated all pairs into focal nodes (McRae, et al. 2013).

Results

We identified 78 potential suitable forest patches both inside and outside protected areas. The 39 out of 78 forest habitat patches (50% of the total patches) within protected areas covered 27 protected areas in five forest complexes with approximately an area of 10,586.40 km^2 (Table 1). In addition, we found large forest habitat patches in Khlong Saeng-Khao Sok forest complex and Khao Luang forest complex. In contrast, we found many small forest habitat patches in the Chumphon and Hala-Bala forest complexes.

The analysis also identified 18 potential dispersal corridors. Chumphon forest complex had the highest number of potential dispersal corridors. Khao Luang and Khao Banthad forest complexes had two dispersal corridors, while Khlong Saeng - Khao Sok forest complex had no corridors. In addition, we found four potential dispersal corridors between Khlong Saeng - Khao Sok and Chumphon forest complexes (Table 2). Our results showed that current flow density in Chumphon and Khao Saeng-Khao Sok forest complexes was the highest (Shades of blue), demonstrating these areas had a high percentage density of evergreen forest cover and were potential dispersal corridors (Figure 2).

Table 1 Suitable forest patches for the Malayan tapir in southern Thailand.

Forest complex	Number of patches	Mean Patch Size (km^2)
Chumphon	12	144.72
Hala-Bala	10	202.21
Khao Banthad	8	277.55
Khao Luang	4	459.57
Khlong Saeng – Khao Sok	5	798.04
Outside forest complex	39	92.30
Total	78	-

Table 2 Potential dispersal corridors for the Malayan tapir in southern Thailand.

Forest complex	Number of corridors
Chumphon	9
Hala-Bala	1
Khao Banthad	2
Khao Luang	2
Khlong Saeng - Khao Sok	0
Khlong Saeng - Khao Sok and Chumphon	4
Total	18

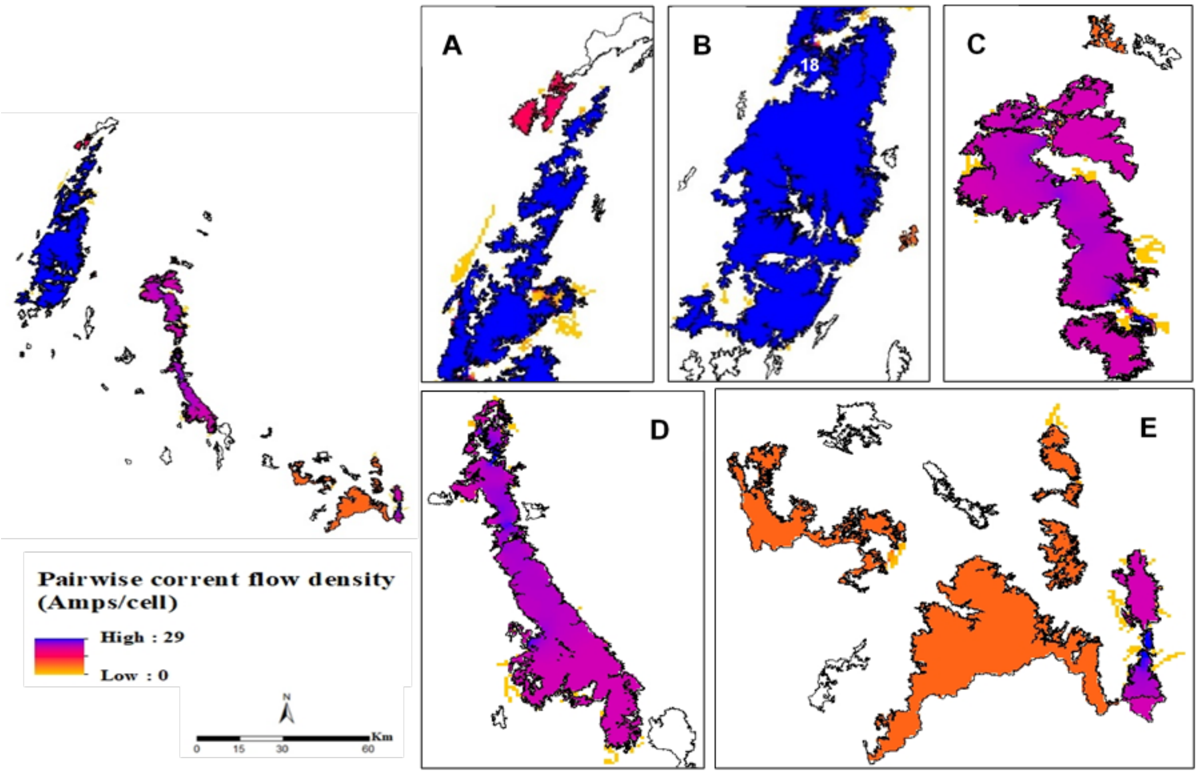

Figure 2 Pairwise current flow density (Amp/cell) among forest habitat patches in: (A) Chumphon forest complex; (B) Khlong Saeng-Khao Sok forest complex; (C) Khao Luang forest complex; (D) Khao Banthad forest complex; (E) Hala-Bala forest complex. Blue shades indicate areas with higher current density, indicating potential dispersal corridors. Areas where connectivity is most difficult, are shown in yellow.

Discussion

Our goal was to identify potential habitat patches and dispersal corridors for the Malayan tapir in southern Thailand. Our results showed that Chumphon and Hala-Bala complexes had the high numbers of forest habitat patches, indicating that forest habitat patches in those forest complexes are fragmented. Moreover, we found that forest complexes have several land use classes, such as perennial crop, artificial water body, orchard, and built-up area. To avoid human-made landscapes and anthropogenic activity, Malayan tapir populations are more likely to be separated and occupy small proportions of the available forest habitat patches (Clements et al. 2012). Furthermore, we found many forest habitat patches outside protected areas, indicating that habitat fragmentation has become severe outside the protected areas.

We found more potential dispersal corridors within the forest complex than between the forest complexes. Also, those corridors were located close to large forest habitat patches. Similarly, the study of habitat connectivity for Pumas (*Puma concolor*) in the southwestern United States (Arizona and New Mexico) demonstrates that maximum current flow corridors are more likely to be located within close proximity to high quality habitat (Dickson et al. 2013). We found no potential dispersal corridors in Khlong Saeng-Khao Sok forest complex because it has the largest evergreen forest patches size with the lowest number of forest habitat patches. We suggest that this forest complex had lower habitat fragmentation than other forest complexes.

Conclusions

We identified potential suitable habitat patches and dispersal corridors for Malayan tapirs in southern Thailand. Our results provide preliminary information to assist conservation planning and management for the Malayan tapir in Thailand. Specifically, evergreen forest patches are identified as priority areas for Malayan tapir conservation, which is currently threatened by habitat loss and fragmentation due to expansion of agricultural and settlement areas. Habitat connectivity and potential dispersal corridors are crucial to maintain the viability of Malayan tapirs and can help conservation management for other endangered species.

Acknowledgements

We would like to thank Walailak University and the Development and promotion of science and technology talents project (DPST) for funding. We are thankful to the Land Development Department (Thailand) for sharing the land use and land cover map of Thailand for the year 2016.

References

Beier, P., Majka, D., & Jenness, J. (2006). Conceptual steps for designing wildlife corridors. Corridor Design Arizona USA, 269, 23784-23789.

Brodie, J.F., Giordano, A.J., Dickson, B.G., Hebblewhite, M., Bernard, H., Mohd-Azlan, J., Anderson, J., & Ambu, L. (2015). Evaluating multispecies landscape connectivity in a threatened tropical mammal community. Conservation Biology, 29, 122-132.

Clements, G.R., Rayan, D.M., Aziz, S.A., Kawanishi, K., Traeholt, C., Magintan, D., Yazi, M.F.A., & Tingley, R. (2012). Predicting the distribution of the Asian tapir (Tapirus indicus) in Peninsular Malaysia using maximum entropy modelling. Integrative Zoology 7, 402-409.

de la Torre, J.A., Núñez, J.M., & Medellín, R.A. (2017). Habitat availability and connectivity for jaguars (Panthera onca) in the Southern Mayan Forest: Conservation priorities for a fragmented landscape. Biological Conservation, 206, 270-282.

Dickson, B.G., Roemer, G.W., McRae, B.H., & Rundall, J.M. (2013). Models of regional habitat quality and connectivity for Pumas (Puma concolor) in the Southwestern United States. PLoS One, 8(12), e81898.

Fahrig, L., & Merriam, G. (1985). Habitat patch connectivity and population survival. Ecology, 66, 1762-1768.

IUCN. (2016). The IUCN Red List of Threatened Species: Tapirus indicus, Malay Tapir. Version 2016-1. Retrieved from https://www.iucnredlist.org

Kanchanasaka, B. (2015). Habitat Use and Population of Tapirs in Thailand. Paper presented at the Wildlife Research Division, Wildlife Conservation Office, Department of National Parks,Wildlife and Plant Conservation, Bangkok.

Lindenmayer, D.B., & Fischer, J. (2013). Landscape modification and habitat fragmentation: a synthesis. Global Ecology and Biogeography, 16, 265-280.

Lynam, A.J., Tantipisanuh, N., Chutipong, W., Ngoprasert, D., Baker, M.C., Cutter, P., Kitamura, S., Steinmetz, R., Sukmasuang, R., & Thunhikorn, S. (2012). Comparative sensitivity to environmental variation and human disturbance of Asian tapirs (Tapirus indicus) and other wild ungulates in Thailand. Integrative Zoology, 7(4), 389-399.

McRae, B.H., Dickson, B.G., Keitt, T.H., & Shah, V.B. (2008). Using circuit theory to model connectivity in ecology, evolution, and conservation. Ecology, 89, 2712-2724.

Noss, R.F., Quigley, H.B., Hornocker, M.G., Merrill, T., & Paquet, P.C. (1996). Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology, 10, 949-963.

Soule, M.E., & Terborgh, J. (1999). Conserving nature at regional and continental scales: A scientific program for North America. Bioscience, 49, 809-817.

Sulistyawan, B.S., Eichelberger, B.A., Verweij, P., Boot, R.G.A., Hardian, O., Adzan, G., & Sukmantoro, W. (2017). Connecting the fragmented habitat of endangered mammals in the landscape of Riau-Jambi-Sumatera Barat (RIMBA), central Sumatra, Indonesia (connecting the fragmented habitat due to road development). Global Ecology and Conservation, 9, 116-130.

Taylor, P.D., Fahrig, L., Henein, K., & Merriam, G. (1993). Connectivity is a vital element of landscape structure. Oikos, 68, 571-573.

Wang, F., McShea, W.J., Wang, D., Li, S., Zhao, Q., Wang, H., & Lu, Z. (2014). Evaluating landscape options for corridor restoration between giant Panda reserves. PLoS One, 9(8), e105086.

Williams, K.D., & Petrides, G.A. (1980). Browse use, feeding behavior, and management of the Malayan Tapir. The Journal of Wildlife Management, 44(2), 489-494.