

Road-networks, a practical indicator of human impacts on biodiversity in Tropical forests

T Hosaka^{1,3}, T Yamada², T Okuda²

¹Department of Tourism Sciences, Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University, 1-1 Minami-osawa, Hachioji, Tokyo, 1920397, Japan.

²Graduate School of Integrated Arts and Sciences, Hiroshima University, Higashi-Hiroshima, 739-8521, Japan

E-mail: hosaka-t@tmu.ac.jp

Abstract. Tropical forests sustain the most diverse plants and animals in the world, but are also being lost most rapidly. Rapid assessment and monitoring using remote sensing on biodiversity of tropical forests is needed to predict and evaluate biodiversity loss by human activities. Identification of reliable indicators of forest biodiversity and/or its loss is an urgent issue. In the present paper, we propose the density of road networks in tropical forests can be a good and practical indicator of human impacts on biodiversity in tropical forests through reviewing papers and introducing our preliminary survey in peninsular Malaysia. Many previous studies suggest a strong negative impact of forest roads on biodiversity in tropical rainforests since they changes microclimate, soil properties, drainage patterns, canopy openness and forest accessibility. Moreover, our preliminary survey also showed that even a narrow logging road (6 m wide) significantly lowered abundance of dung beetles (well-known bio-indicator in biodiversity survey in tropical forests) near the road. Since these road networks are readily to be detected with remote sensing approach such as aerial photographs and Lidar, regulation and monitoring of the road networks using remote sensing techniques is a key to slow down the rate of biodiversity loss due to forest degradation in tropical forests.

1. Introduction

Southeast Asia is one of the world's hotspots of imperiled biodiversity due to high rate of deforestation and forest degradation [1,2]. Strategies for biodiversity conservation in production forest are critically important since most of the remaining forest is classified as production forest and under selective logging [3].

The major ecological effects of selective logging often result from the network of logging roads, which includes changes in soil properties, drainage patterns, canopy openness and forest accessibility [4]. Wide range of forest specialists, such as small and large mammals, bats, birds, reptiles, amphibians and insects, are known to negatively respond to wider forest roads (< 30 m in width) [5]. Moreover, roads can act as a barrier for dispersal or gene flow of some animal groups such as ground beetles in Europe [6,7]. However, little information is available for narrower roads (< 10 m in width) such as logging roads in SE Asia.

Remote sensing techniques have an advantage in cost-effective monitoring of various forest features over large area. Logging road networks are accurately detectable with aerial photographs or Lidar [8,9]. Thus, if forest inhabitants negatively respond to logging roads, the density of logging roads can be a practical indicator to evaluate the level of human impacts on biodiversity.

In the present study, we examined responses of dung beetles to a logging road in a logged forest in Peninsular Malaysia. Dung beetles are one of the most cost-effective bio-indicators in biodiversity surveys in tropical forests [10]. They are also known to have some important ecological functions

³To whom any correspondence should be addressed.



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

such as nutrient cycling, bioturbation and secondary seed dispersal [11]. We focused on following questions; (1) Do logging roads have negative impact on abundance of dung beetles around the roads? and (2) Do logging roads have a barrier effect to movement of dung beetles?

2. Methods

2.1. Study site

The study site was in the Temengor Forest Reserve in Perak, peninsular Malaysia (5°24' N to 5°34' N, 101°33' E to 101°39' E, 400–1000 m asl). Fieldwork for this research was conducted in Block 5 (300 ha) in August 2011. This block was selectively logged in 2010–2011. Logging roads (5–8 m in width) were constructed in 2009. The logging roads were for wheeled trucks transporting timbers to a paved highway and were unpaved but graded and maintained for permanent use.

2.2. Abundance of dung beetles

We established 300 m × 100 m plot, which contains a logging road (6 m in width) and its surrounding forest (Figure 1). In the plot, we established sampling points at 25-m intervals in forests near the road and at 50-m intervals in forests far from the road.

Pit-fall traps with human dung (c. 10 g) as baits were used for sampling of dung beetles. The traps were set at each sampling point for 24 hr. Beetles were captured alive in the traps and sorted into genus. Since large-sized beetles are more vulnerable to disturbance but have disproportionately higher abilities in ecological functions [12], we focused on and counted the number of individuals in three large-sized genera, *Catharsius*, *Paragymnopleurus* and *Synapsis*.

2.3. Movement of dung beetles

Movement pattern of dung beetles were examined using mark-recapture experiment. Each captured beetle was sequentially numbered with a white marker on its elytra to distinguish individuals and released on the next day at the same point it had been captured. After 48–96 hr, we set the pitfall traps at each sampling point for 24 hr and captured beetles again. We recorded the sampling point of recaptured beetles and numbered for newly captured beetles. We repeated the same procedure five times during three weeks.

2.4. Data analysis

In order to examine the effect of logging road on abundance of large-sized dung beetles, the numbers of individuals per day × trap were compared between 'adjacent traps' (0–15 m from the logging road) and 'distant traps' (> 25 m from the logging road) using t-test for the three genera.

To examine whether the logging road acted as a barrier to movement of dung beetles, we drew movement pattern of dung beetles using the data from recapture experiment.

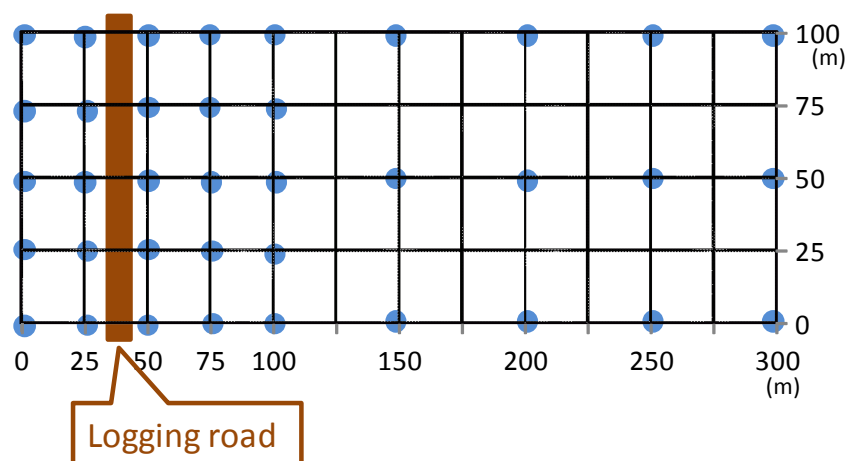


Figure 1. Plot design for sampling of dung beetles. Blue circle indicates sampling point at which pitfall traps were set.

3. Results

In total, 200 individuals of large-sized dung beetles were captured with the baited pit-fall traps, of which 119 were in genus *Catharsius*, 56 were in *Paragymnopleurus* and 25 were in *Synapsis*. The numbers of beetles captured were significantly different between ‘adjacent traps’ and ‘distant traps’ for all of the three large-sized genera, *Catharsius*, *Paragymnopleurus* and *Synapsis* (Figure 2). They were two to ten times larger at ‘distant traps’ than ‘adjacent traps’. The number of beetles in *Paragymnopleurus* and *Synapsis*, largest roller species in our site, were almost zero in adjacent traps.

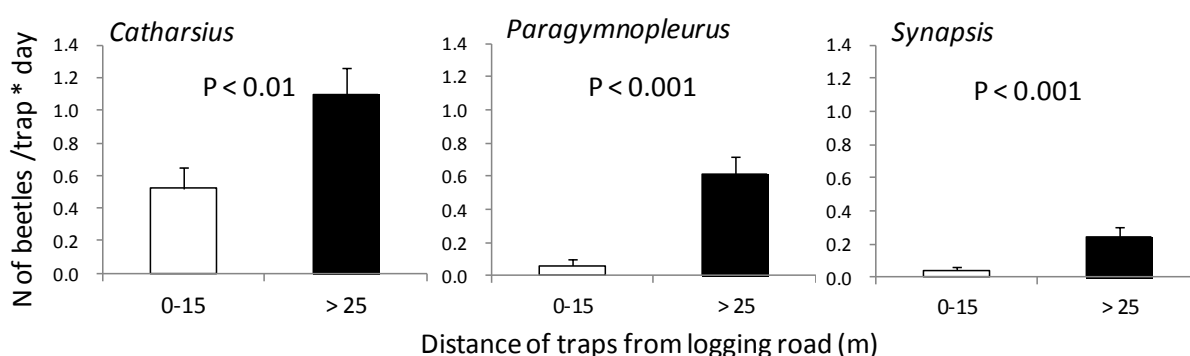


Figure 2. The number of beetles per trap * day in the genus *Catharsius* (left), *Paragymnopleurus* (middle) and *Synapsis* (right) captured with pit-fall traps located at 0-15 m (‘adjacent traps’, blank bar) and > 25 m (‘distant traps’, filled bar) from the logging road.

Total numbers of the large-sized dung beetles along the logging road were evenly depressed while those of further interior forests were largely fluctuated (Figure 3).

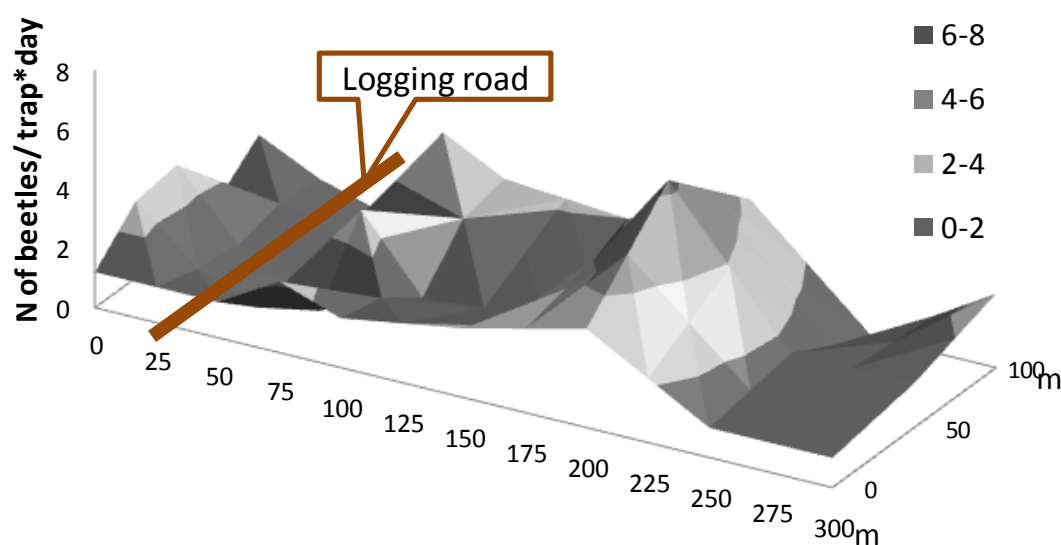


Figure 3. Spatial distribution pattern of dung beetle abundance (the total number of individuals per trap * day) in the plot.

Of 221 total captures, 20 were recaptures of the same individual: 6 were for *Catharsius*, 12 were for *Paragymnopleurus*, and two were for *Synopsis*. Two of the recaptured individuals were captured three times (one *Catharsius* and one *Paragymnopleurus*). 60% and 50% of individuals were recaptured at the initial location while 40% and 50% were at > 50 m apart from the initial position for *Catharsius* and *Paragymnopleurus*, respectively. The logging road was crossed three times by two individual beetles (one *Catharsius* and one *Paragymnopleurus*).

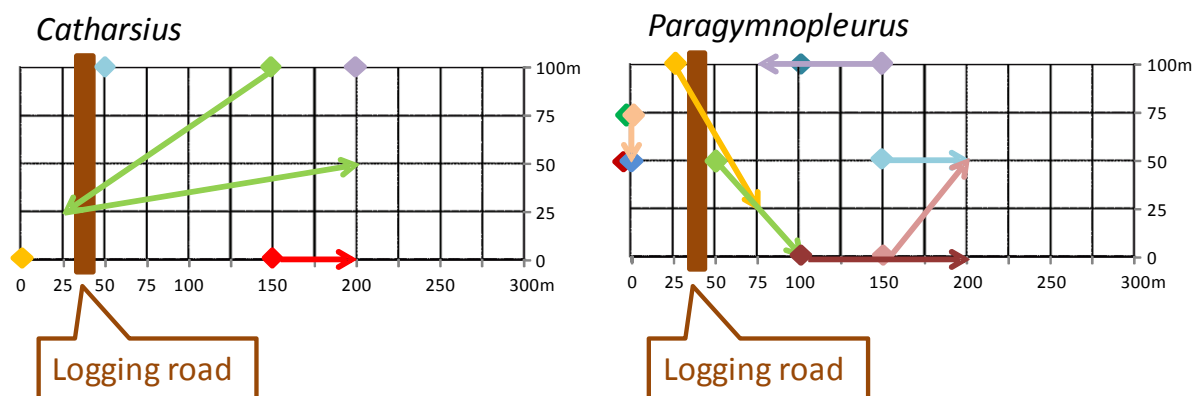


Figure 4. Dispersal pattern of the dung beetles in the genus *Catharsius* (left) and *Paragymnopleurus* (right) in the plot. Each colour indicates each individual. Arrows indicate the direction of movement.

4. Discussion

Our preliminary experiment shows that abundance of large-sized dung beetles was clearly depressed around the logging roads, suggesting that, even small in area of clearance, logging roads and its adjacent forests are not suitable habitat for the beetles. Lack of the large roller species may alter their ecological functions such as secondary seed dispersal.

On the other hand, the logging road did not obviously act as a barrier to movement of dung beetles. Although the number of recaptured beetles was too small to conclude, road crossing do not seem a rare event; among four individuals captured at traps adjacent to the logging road, two individuals crossed the road with one individual crossing twice. Therefore, dung beetles would not prefer forests adjacent to logging roads but they can fly over the area from one side to another.

Since many species in tropical rainforest understory adapted to humid, dark, stable microclimate [5], forests around logging roads would be unsuitable habitat also for many species other than dung beetles. However, most selective-logging operations in the tropics are still poorly planned and involve excessive road-building [5,13]. Fortunately, these road networks are readily to be detected with aerial photographs and Lidar [8, 9]. The density of logging roads would be a practical and reliable indicator of human impacts on biodiversity. Regulation and monitoring of the road networks using remote sensing techniques is a key to slow down the rate of biodiversity loss due to forest degradation in tropical forests.

Acknowledgments

We thank the Forest Research Institute Malaysia and Forest Department of Perak for permission to conduct our research in Temengor Forest Reserve. We are also grateful to Dr. M. Kon and Dr. T. Ochi for identification of dung beetles. The present study is a part of the project "Research on experimental studies for upgrading the REDD mechanism in ways that incorporate ecosystem services and values (D-1005)," which is financially supported by the Japanese Ministry of the Environment.

References

- [1] Sodhi N S, Koh L P, Brook B W and Ng P K L 2004 *Trends Ecol. Evol.* **19** 654-60
- [2] Gibson L, Lee T M, Koh L P, Brook B W, Gardner T A, Barlow J, Peres C A, Bradshaw C J A, Laurance W F, Lovejoy T E and Sodhi N S 2011 *Nature* **478** 378-83
- [3] Edwards D P, Larsen T H, Docherty T D S, Ansell F A, Hsu W W, Derhé A M, Hamer K C,

- Wilcove D S 2011 *Proc. R. Soc. B* **278** 82-90
- [4] Malcolm J R and Ray J C 2000 *Conserv. Biol.* **14** 1623-38
- [5] Laurance W F, Goosem M and Laurance S G W 2009 *Trends Ecol. Evol.* **24** 659-69
- [6] Keller I, Largiadér C R 2003 *Proc. R. Soc. B* **270** 417-23
- [7] Noordijk J, Prins D, De Jonge M, Vermeulen R. 2007 *Acta Entomol. Fenn.* **17** 276-83
- [8] Jusoff K, D'Souza G 1996 *ISPRS J. Photogramm. Remote Sens.* **51** 39-48
- [9] d'Oliveira M V N, Reutebuch S E, McGaughey R J and Andersen H-E 2012 *Remote Sens. Environ.* **124** 479-91
- [10] Gardner T A, Barlow J, Araujo I S, Ávila-Pires T C, Bonaldo A B, Costa J E, Esposito M C, Ferreira L V, Hawes J, Hernandez M I M, Hoogmoed M S, Leite R N, Lo-Man-Hung N F, Malcolm J R, Martins M B, Mestre L A M, Miranda-Santos R, Overal W L, Parry L, Peters S L, Ribeiro-Junior M A, da Silva M N F, Motta C S and Peres C A 2008 *Ecol. Lett.* **11** 139-50
- [11] Nichols E, Spector S, Louzada J, Larsen T., Amezcuita S, Favila M E and The Scarabaeinae Research Network 2008 *Biol. Conserv.* **141** 1461-74
- [12] Larsen T H, Williams N M and Kremen C 2005 *Ecol. Lett.* **8** 538-47
- [13] Putz F E, Dykstra D P and Heinrich R 2000 *Conserv. Biol.* **14** 951-56