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Short Communication

Logging residues conserve small mammalian diversity in a Malaysian production forest

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ABSTRACT

The extraction of large trees by selective logging in tropical production forests often results in a reduction of natural fallen trees for a long period after logging has been completed. This causes a population decrease for various small mammals that exploit fallen trees to live. We expect that logging residues, which are unmerchantable upper parts of logged trees, will alleviate the negative effects of the reduced volume of naturally fallen trees immediately after logging. To examine this issue, we compared the activity of small mammals in forest floor habitats with and without logging residues in a Malaysian production forest using a camera trapping technique. We tested the hypothesis that the activity of small mammals would be higher on forest floors with logging residues when compared with those without them; our study affirmatively supported this hypothesis. Therefore, logging residues are expected to have positive roles in maintaining small mammal diversity at the ground level in production forests. Recently commercial use of logging residues has been promoted; however, removing all logging residues from a production forest would severely and negatively affect the diversity of ground-dwelling small mammals. In addition, for small mammals which essentially require fallen trees to survive, populations will shrink or in a worst case scenario, they would become extirpated from production forests if all logging debris is removed.

1. Introduction

The tropical rain forests of Southeast Asia have a hyper-diverse small mammalian fauna. For example, a hill dipterocarp forests in Temengor Forest Reserve, Perak, Peninsular Malaysia has 32 species of small mammals (Ratnam et al., 1995). Small mammals serve as an important group in the food webs of forest ecosystems by providing prey for other (often larger) mammals, reptiles and birds (Ghazoul and Sheil, 2010). They are also important seed herbivores as well as seed dispersers (Theimer, 2001). They bury seeds and nuts for future use and may contribute to seed dispersal when they fail to retrieve them (Forget and Vander Wall, 2001). Therefore, maintaining a rich small mammalian fauna is important for land managers who desire to support forest ecosystem health.

Although various studies have shown that commercially logged tropical forests retain a high conservation value (Putz et al., 2012); others have demonstrated that the diversity of mammals often deteriorated after commercial logging in Asian tropical forests including the diversity of small mammals (Meijaard et al., 2005; Burivalova et al., 2014). Some small mammals were found to rarely occur in logged forests and to react negatively to environmental variability in both a Canadian temperate forest (Henein et al., 1998) and a Kalimantan tropical rainforest (Wells et al., 2006). For example, populations of small mammals were smaller in a forest logged more than 50 years ago than an unlogged forest in a tropical rain forest in the Pasoh Forest Reserve (Yasuda, 1998).

The reduced availability of natural fallen trees in the logged forest, which are essential resources for some small mammals, may be one reason the populations of small mammals shrank. Fallen trees create spatially heterogeneity on the forest floor and provide small animals with many sheltering microsites where they can escape from predators (Bernard, 2004). Small mammals exploit such microsites in various ways; they eat insects and invertebrates that live in fallen trees (Maser and Trappe, 1984) and small mammals nest in the hollows in fallen trees (Maser and Trappe, 1984). The extraction of large trees by selective logging markedly alters the structure of a forest and results in a reduction in the number of natural fallen trees for a long period after logging (DeWalt et al., 2003).

Therefore, retaining adequate numbers of fallen trees after logging would be critically important to the conservation of small mammals in a production forest. One possible way to alleviate the negative effects of the reduced volume of fallen trees immediately after logging may be to exploit logging residues (the unmerchantable upper parts of

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logged trees and untargeted trees that fall during harvest by being struck by neighboring logged trees) instead of fallen trees. A study in a Canadian forest showed that managed habitat building by creating piles of woody debris in clear-cut forest after harvesting dramatically ameliorated forest-floor small mammalian diversity (Sullivian et al., 2012). We expect that logging residues may have the same function in upgrading small mammal diversity as do natural fallen trees but no study has been conducted in our area to examine this issue. Perhaps one may question whether smaller logging material and residues can be an adequate substitute of naturally fallen trees and can contribute to an increase in small mammal diversity. In addition, the use of logging residues has been discussed as a method that can be used to optimize the use of wood resources (Trockenbrodt et al., 2002). However, if logging residues significantly contribute to the biodiversity of small mammals in tropical forests, then the removal of those residues from forests may have a large negative effect on the diversity of small mammals.

The Malaysian government has no rules related to logging residues. If we want to decide how to treat logging residues, we first need to clarify their role in improving and conserving biodiversity. This paper analyzes the contribution of logging residues to small mammal diversity in a tropical production forest in the Temengor Forest Reserve, Perak, Malaysia. We compare the abundance and activity of small mammals on the forest floor in areas with and without logging residues. The underlying hypothesis is that the activity of small mammals is higher on forest floors with logging residues than those without it. By testing the hypothesis, we discuss the importance of logging residues in terms of biodiversity and the conservation of small mammals.

2. Materials and methods

2.1. Study sites

Our study site in the Temengor Forest Reserve in Perak, Peninsular Malaysia (5°24′–5°34′ N, 101°33′–101°39′ E) stands at 400–1000 m a.s.l. About 9000 ha of the 148,870 ha reserve has been selectively logged since 2001, using a sustainable forest management with a moderate intensity of timber harvesting (39–55 m^3 ha^{-1}) (PITC, 2010). The Temengor Forest Reserve has a typical tropical monsoon climate characterized by uniformly high temperatures and high humidity and often receives rain in excess of 3000 mm per year (PITC, 2010). The forest consists primarily of hilly dipterocarp forests with some bamboo-dominated patches (PITC, 2010). The reserve has a hyper diverse mammalian fauna including 101 species in 28 families in 10 orders (Ratnam et al., 1995). The fauna includes large mammals such as *Elephas maximus* and *Panthera tigris*. We conducted fieldwork in a 200-ha part of Block 5 of the reserve in August 2012 after trees had been selectively logged in 2010–2011. Many pieces of logging residue had been generated in the forest about 2 years prior to the current study.

2.2. Field methods

We used camera traps to quantify the species composition of small mammals (Hayes et al., 2006). The camera's (Fieldnote DS2, Marif Co. Ltd., Yamaguchi, Japan) sensors detect the infrared radiation (IR) from an animal's body. A few seconds after the sensor detects IR, the camera takes a picture, creating a few seconds of lag time between the IR detection and the camera being triggered. We baited the sites with peanuts and bananas which would encourage animals to remain in each camera's field of view to compensate for the time lag. We did not use logging residues left within 50 m from the nearest logging road because Yamada et al. (2014) revealed the distance from logging roads strongly affected the appearances of small mammals. We selected 17 sites with logging residues as sample sites and measured the diameters of each piece of residue at the base. One camera trap was set for 10 days at each sample site. As a control, for each of the above sites we set a camera trap for 10 days at 17 sites without logging residues which were about 25 m from each of the sites with logging residues.

Environmental attributes of each site were measured including the number of large trees >30 cm in diameter within a 5 m radius of each camera position, coverage of understory vegetation which classified into one of three grades (low [<30%], medium [30 to 70%], and high coverage [70%<]), canopy openness (%), distance from the nearest logging road (m), and slope angle (°). We used a digital camera (Coolpix 950, Nikon, Tokyo, Japan) with a fish-eye lens (FC-E8 fisheye lens, Nikon) mounted on a pole. A gimbal with a leveling device held the camera in a horizontal position. Photographs were taken only in periods of uniform, overcast sky to prevent reflections from affecting the measurements. We analyzed the digital images with an image-processing program (Hemi View 1.2, Delta-T Devices Ltd., Cambridge, UK) and calculated the percent of canopy openness (the percentage of open areas to entire sky view) using the program.

2.3. Species examined

Over a period of 340 camera days, we captured 4349 pictures of small mammals. Any series of conspecific appearances within 30 min were considered to be a single appearance following O'Brien et al. (2003); therefore, 726 appearances of small mammals were recorded including 12 genera in 5 families in 3 orders (Appendix 1). Photographic identification of small mammals to the correct species was impossible when the key characteristics needed for identification were not visible; as a result, we identified some animals to only the genus level. All individuals of *Maxomys*, *Callosciurus*, and *Sundasciurus* could only be one of two species each (Appendix 1); however, these conspecific species share similar life histories and occupy similar ecological niches (Francis, 2008). For the other genera, only one species was observed in each genus during our study (Appendix 1). We excluded *Ratufa bicolor* from the analysis because we captured only one picture of this mammal. Therefore, we examined data related to small mammals in a total of 11 genera. Briefly, among the 11 genera, we found two arboreal small mammals, that were squirrels in the genera *Callosciurus* and *Sundasciurus* while *Niviventer cremoriventer* and *Tupaia glis* are semi-arboreal; the other small mammals in the remaining seven genera were ground dwelling (Lim, 1970; Harrison, 1961; Francis, 2008, Appendix 1). The insectivorous species, *Hylomys suillus*, *Crocidura fuliginosa* and *Rhinosciurus laticaudatus* consume insects and other invertebrates while other species eat both fruits and insects (Lim, 1970; Harrison, 1961; Francis, 2008).

2.4. Analysis

Genus level diversity was measured by Shannon–Wiener H′ (Shannon, 1948) based on appearances. The number of genera captured, genus level diversity of small mammals, total appearances over all genera and an abundance of each genus were compared between sites with and without logging residues by using a non-parametric test because the criteria of normality was not satisfied. We selected camera trapping sites based on the presence of residues, some sites were congested and this would cause spatial autocorrelations of small mammal diversity as well as environmental variables. To minimize the effects of the spatial autocorrelations, we used the Wilcoxon signed-rank test based on the pair of the site with a logging residue and its control site (within 25 m from the site with a logging residue). Wilcoxon signed-rank test revealed no significant differences among the five environmental variables between the sites with and without logging residues (Appendix 2). Therefore, any significant differences in small mammal diversity must be attributed by the presence and absence of logging residues. All analyses were performed with Statistica 6.0 J.